Contents

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

S-8520/8521 Series

The S-8520/8521 Series consists of CMOS step-down switching regulator-controllers with PWM-control (S-8520) and PWM/PFM-switched control (S-8521). These devices contain a reference voltage source, oscillation circuit, error amplifier, and other components.

The S-8520 Series provides low-ripple power, high-efficiency, and excellent transient characteristics thanks to a PWM control circuit capable of varying the duty ratio linearly from 0% up to 100%. The series also contains an error amplifier circuit as well as a soft-start circuit that prevents overshoot at startup.

The S-8521 Series works with either PWM control or PFM control, and can switch from one to the other. It normally operates using PWM control with a duty ratio of 25% to 100%, but under a light load, it automatically switches to PFM control with a duty ratio of 25%. This series ensures high efficiency over a wide range of conditions, from standby mode to operation of peripheral equipment.

With the addition of an external Pch Power MOS FET or PNP transistor, a coil, capacitors, and a diode connected externally, these ICs can function as step-down switching regulators. They serve as ideal power supply units for portable devices when coupled with the SOT-23-5 minipackage, providing such outstanding features as low current consumption. Since this series can accommodate an input voltage of up to 16V, it is also suitable when operating via an AC adapter.

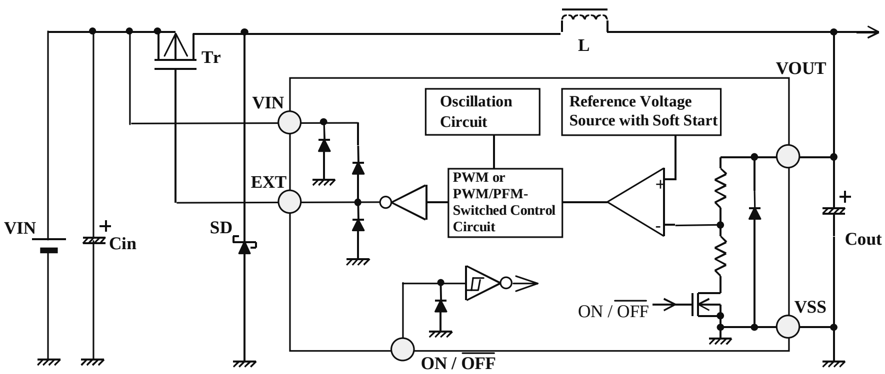
■ Features:

- Low current consumption:
  - In operation: 60 μA max. (A & B Series)
  - 21 μA max. (C & D Series)
  - When powered off: 0.5 μA max.
- Input voltage:
  - 2.5V to 16V (B & D Series)
  - 2.5V to 10V (A & C Series)
- Output voltage:
  - Selectable between 1.5V and 6.0V in steps of 0.1V.
- Duty ratio:
  - 0% to 100% PWM control (S-8520)
  - 25% to 100% PWM/PFM-switched control (S-8521)
- The only peripheral components that can be used with this IC are a Pch power MOS FET or PNP transistor, a coil, a diode, and capacitors. (If a PNP transistor is used, a base resistance and a capacitor will also be required.)
- Oscillation frequency: 180 kHz type. (A & B Series), 60 kHz type. (C & D Series), or 300 kHz type. (version under development).
- Soft-start function: 8 msec type. (A & B Series) or 12 msec type (C & D Series).
- With power-off function.
- With a built-in overload protection circuit. Overload detection time: 4 msec type. (A Series) or 14 msec type. (C Series).

■ Applications:

- On-board power supplies of battery devices for portable telephones, electronic notebooks, PDAs, and the like.
- Power supplies for audio equipment, including portable CD players and headphone stereo equipment.
- Fixed voltage power supply for cameras, video equipment and communications equipment.
- Power supplies for microcomputers.
- Conversion from four NiH or NiCd cells or two lithium-ion cells to 3.3V/3V.
- Conversion of AC adapter input to 5V/3V.

■ Block Diagram:



Note: The diode inside the IC is a parasitic diode.

Figure 1. Block Diagram

■ Selection Guide:

1. Product Name

S - 852 X X XX MC - XXX - T2

- T2: Tape specifications.
- XXX: Product name abbreviation.
- MC: Package name abbreviation.
- XX: Output voltage x 10
- X (second): Product type:
  - A: Oscillation frequency of 180 kHz, with overload protection circuit.
  - B: Oscillation frequency of 180 kHz, without overload protection circuit.
  - C: Oscillation frequency of 60 kHz, with overload protection circuit.
  - D: Oscillation frequency of 60 kHz, without overload protection circuit.
  - E: Oscillation frequency of 300 kHz, with overload protection circuit (currently under development).
  - F: Oscillation frequency of 300 kHz, without overload protection circuit (currently under development).
- X (first): Control system
  - 0: PWM control
  - 1: PWM/PFM-switched control

2. Product List (As of Mar. 9, 1998)

A & B Series (Oscillation Frequency of 180 kHz)

Item Output Voltage (V)	S-8520AXXMC Series	S-8521AXXMC Series	S-8520BXXMC Series	S-8521BXXMC Series
2.5	S-8520A25MC-AVK-T2	S-8521A25MC-AXK-T2	S-8520B25MC-ARK-T2	S-8521B25MC-ATK-T2
3.0	S-8520A30MC-AVP-T2	S-8521A30MC-AXP-T2	S-8520B30MC-ARP-T2	S-8521B30MC-ATP-T2
3.3	S-8520A33MC-AVS-T2	S-8521A33MC-AXS-T2	S-8520B33MC-ARS-T2	S-8521B33MC-ATS-T2
5.0	S-8520A50MC-AWJ-T2	S-8521A50MC-AYJ-T2	S-8520B50MC-ASJ-T2	S-8521B50MC-AUJ-T2

C & D Series (Oscillation Frequency of 60 kHz)

Item Output Voltage (V)	S-8520CXXMC Series	S-8521CXXMC Series	S-8520DXXMC Series	S-8521DXXMC Series
2.5	S-8520C25MC-BRK-T2	S-8521C25MC-BTK-T2	S-8520D25MC-BVK-T2	S-8521D25MC-BXK-T2
3.0	S-8520C30MC-BRP-T2	S-8521C30MC-BTP-T2	S-8520D30MC-BVP-T2	S-8521D30MC-BXP-T2
3.3	S-8520C33MC-BRS-T2	S-8521C33MC-BTS-T2	S-8520D33MC-BVS-T2	S-8521D33MC-BXS-T2
5.0	S-8520C50MC-BSJ-T2	S-8521C50MC-BUJ-T2	S-8520D50MC-BWJ-T2	S-8521D50MC-BYJ-T2

Product samples of the different versions of the series listed above are currently being prepared. Please contact the SII Sales Department regarding the availability of samples. Also contact SII Sales Department if you desire an output voltage other than those noted above.

■ Pin Assignment:

SOT-23-5
Top view

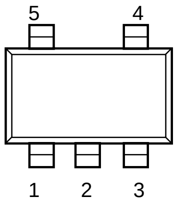


Figure 2

Terminal No.	Terminal Name	Function
1	ON/$\overline{\text{OFF}}$	Power-off terminal H: Normal operation (Step-down operation) L: Step-down operation stopped (All circuits deactivated)
2	V_{SS}	GND terminal
3	V_{OUT}	Output voltage monitoring terminal
4	EXT	Connection terminal for external transistor
5	V_{IN}	IC power supply terminal

■ Absolute Maximum Ratings:

Note: Although this IC incorporates an electrostatic protection circuit, the user is urged to avoid subjecting it to an extremely high static electricity or static voltage in excess of the performance of the said protection circuit.

(Ta = 25 °C, unless otherwise specified)

Item	Symbol	Ratings	Unit
V_{IN} terminal voltage	VIN *1	V_{SS} -0.3 to V_{SS}+12 or 18	V
V_{OUT} terminal voltage	VOUT	V_{SS} -0. 3 to V_{IN}+0.3	V
ON/$\overline{\text{OFF}}$ terminal voltage	ON/OFF *1	V_{SS} -0.3 to V_{SS}+12 or 18	V
EXT terminal voltage	VEXT	V_{SS} -0.3 to V_{IN}+0.3	V
EXT terminal current	IEXT	±50	mA
Power dissipation	PD	150	mW
Operating temperature range	TOPR	-40 to +85	°C
Storage temperature range	TSTG	-40 to +125	°C

*1: VSS+12V for S-8520/21A/C; VSS+18V for S-8520/21B/D

■ Electrical Characteristics:

1. S-8520/21 A & B Series

(Ta = 25 °C, unless otherwise specified)

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Units	Measurement Circuit
Output voltage	VOUT			VOUT X 0.976	VOUT	VOUT X1.024	V	3
Input voltage	VIN		S-8520/21A Series	2.5	–	10.0	V	2
			S-8520/21B Series	2.5	–	16.0		
Current Consumption 1	ISS1	Vout = Output voltage x 1.2		–	35	60	μA	2
Current Consumption during power off	ISSS	Power-off Pin = 0V		–	–	0.5	μA	2
EXT Pin Output Current	IEXTH	VEXT = VIN-0.4V	S-8520/21X15 – 24	-2.3	-4.5	–	mA	–
			S-8520/21X25 – 34	-3.7	-7.0	–		
			S-8520/21X35 – 44	-5.3	-9.3	–		
			S-8520/21X45 – 54	-6.7	-11.3	–		
			S-8520/21X55 – 60	-8.0	-13.3	–		
	IEXTL	VEXT = 0.4V	S-8520/21X15 – 24	+4.3	+8.4	–		
			S-8520/21X25 – 34	+7.0	+13.2	–		
			S-8520/21X35 – 44	+9.9	+17.5	–		
			S-8520/21X45 – 54	+12.6	+21.4	–		
			S-8520/21X55 – 60	+15.0	+25.1	–		
Line Regulation	ΔVOUT1	Vin = Output voltage x1.2 to x1.4 *3		–	30	60	mV	3
Load regulation	ΔVOUT2	Load current =10uA to IOUT(See below) x1.25		–	30	60	mV	3
Output Voltage Temperature Coefficient	ΔVOUT /ΔTa	Ta= - 40 °C to 85 °C		–	±VOUT x 5E-5	–	V/°C	3
Oscillation Frequency	fosc	Measure waveform at EXT pin	VOUT ≥ 2.5V	153	180	207	kHz	3
			VOUT ≤ 2.4V	144	180	216		
PWM/PFM-control switch Duty Ratio *1	PFMDuty	Measure waveform at EXT pin under no load.		15	25	40	%	3
Power-Off Terminal Input Voltage	VSH	Evaluate oscillation at EXT pin		1.8	–	–	V	2
	VSL	Evaluate oscillation stop at EXT pin		–	–	0.3		
Power-Off Terminal Input Leakage Current	ISH			–	–	0.1	μA	1
	ISL			–	–	-0.1	μA	1
Soft-Start Time	TSS			4.0	8.0	16.0	ms	3
Overload Detection Time *2	TPRO	Duration from the time Vout is reduced to 0V to the time the EXT terminal obtains Vin.		2.0	4.0	8.0	ms	2
Efficiency	EFFI			–	93	–	%	3

Conditions:

The recommended components are connected to the IC, unless otherwise indicated. Vin = Vout x 1.2 [V], Iout = 120 [mA] (Vin = 2.5V, if Vout ≤2.0V.)

Peripheral components:

- Coil : Sumida Electric Co.,Ltd. CD54 (47 μH).
- Diode : Matsushita Electronics Corporation MA720 (Schottky type).
- Capacitor : Matsushita Electronics Corporation TE (16V, 22 μF tantalum type).
- Transistor : Toshiba 2SA1213Y.
- Base resistance (Rb) : 0.68KΩ
- Base capacitor (Cb) : 2200 pF (Ceramic type)

The power-off terminal is connected to VIN.

Notes:

The output voltage indicated above represents a typical output voltage set up. These specifications apply in common to both S-8520 and S-8521, unless otherwise noted.

*1: Applicable to the S-8521A Series and S-8521B Series.
*2: Applicable to the S-8520A Series and S-8521A Series.
*3: Vin = 2.5V to 2.94V, if Vout ≤2.0V.

2. S-8520/21 C & D Series

(Ta = 25 °C, unless otherwise specified)

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Units	Measurement Circuit
Output voltage	VOUT			VOUT X 0.976	VOUT	VOUT X 1.024	V	4
Input voltage	VIN		S-8520/21C Series	2.5	–	10.0	V	2
			S-8520/21D Series	2.5	–	16.0		
Current Consumption 1	ISS1	Vout = Output voltage x 1.2		–	10	21	μA	2
Current Consumption during Power-Off	ISSS	Power-off Pin = 0V		–	–	0.5	μA	2
EXT Pin Output Current	IEXTH	VEXT = VIN-0.4V	S-8520/21X15 – 24	-2.3	-4.5	–	mA	–
			S-8520/21X25 – 34	-3.7	-7.0	–		
			S-8520/21X35 – 44	-5.3	-9.3	–		
			S-8520/21X45 – 54	-6.7	-11.3	–		
			S-8520/21X55 – 60	-8.0	-13.3	–		
	IEXTL	VEXT = 0.4V	S-8520/21X15 – 24	+4.3	+8.4	–		
			S-8520/21X25 – 34	+7.0	+13.2	–		
			S-8520/21X35 – 44	+9.9	+17.5	–		
			S-8520/21X45 – 54	+12.6	+21.4	–		
			S-8520/21X55 – 60	+15.0	+25.1	–		
Line Regulation	ΔVOUT1	Vin = Output voltage x1.2 to x1.4 *3		–	30	60	mV	3
Load regulation	ΔVOUT2	Load current =10uA to IOUT(See below) x1.25		–	30	60	mV	3
Output Voltage Temperature Coefficient	ΔVOUT /ΔTa	Ta= - 40 °C to 85 °C		–	± VOUT x 5E-5	–	V/°C	3
Oscillation Frequency	fosc	Measure waveform at EXT pin	VOUT ≥ 2.5V	48	60	72	kHz	3
			VOUT ≤ 2.4V	45	60	75		
PWM/PFM-control switch Duty Ratio *1	PFMDuty	Measure waveform at EXT pin under no load.		15	25	40	%	3
Power-Off Terminal Input Voltage	VSH	Evaluate oscillation at EXT pin		1.8	–	–	V	2
	VSL	Evaluate oscillation stop at EXT pin		–	–	0.3		
Power-Off Terminal Input Leakage Current	ISH			–	–	0.1	μA	1
	ISL			–	–	-0.1	μA	1
Soft-Start Time	TSS			6.0	12.0	24.0	ms	3
Overload Detection Time *2	TPRO	Duration from the time Vout is reduced to 0V to the time the EXT terminal obtains Vin.		7.0	14.0	28.0	ms	2
Efficiency	EFFI			–	93	–	%	3

Conditions:

The recommended components are connected to the IC, unless otherwise indicated. Vin = Vout x 1.2 [V], Iout = 120 [mA] (Vin = 2.5V, if Vout ≤2.0V.)

Peripheral components:

Coil	: Sumida Electric Co.,Ltd. CD54 (47 μH).
Diode	: Matsushita Electronics Corporation MA720 (Schottky type).
Capacitor	: Matsushita Electronics Corporation TE (16V, 22 μF tantalum type).
Transistor	: Toshiba 2SA1213Y.
Base resistance (Rb)	: 0.68KΩ
Base capacitor (Cb)	: 2200 pF (Ceramic type)

The power-off terminal is connected to VIN.

Notes:

The output voltage indicated above represents a typical output voltage set up. These specifications apply in common to both S-8520 and S-8521, unless otherwise noted.

*1: Applicable to the S-8521C Series and S-8521D Series.

*2: Applicable to the S-8520C Series and S-8521C Series.

*3: Vin = 2.5V to 2.94V, if Vout ≤2.0V.

■ Measurement Circuits:

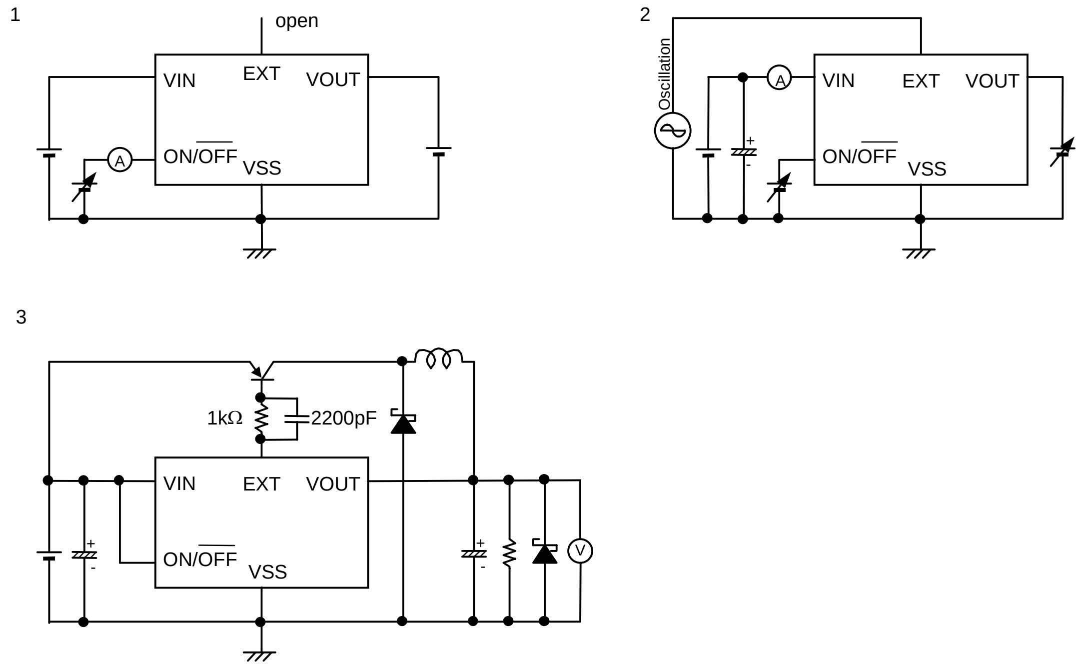


Figure 3

■ Operation:

1. Step-Down DC-DC Converter

1.1 PWM Control (S-8520 Series)

The S-8520 Series consists of DC/DC converters that employ a pulse-width modulation (PWM) system. This series is characterized by its low current consumption. In conventional PFM system DC/DC converters, pulses are skipped when they are operated with a low output load current, causing variations in the ripple frequency of the output voltage and an increase in the ripple voltage. Both of these effects constitute inherent drawbacks to those converters.

In converters of the S-8520 Series, the pulse width varies in a range from 0% to 100%, according to the load current, and yet ripple voltage produced by the switching can easily be removed through a filter because the switching frequency remains constant. Therefore, these converters provide a low-ripple power over broad ranges of input voltage and load current.

1.2 PWM/PFM-Switched Control (S-8521 Series)

The S-8521 Series consists of DC/DC converters capable of automatically switching the pulse-wide modulation system (PWM) over to the pulse-frequency modulation system (PFM), and vice versa, according to the load current. This series of converters features low current consumption.

In a region of high output load currents, the S-8521 Series converters function with PWM control, where the pulse-width duty varies from 25% to 100%. This function helps keep the ripple power low.

For certain low output load currents, the converters are switched over to PFM control, whereby pulses having their pulse-width duty fixed at 25% are skipped depending on the quantity of the load current, and are output to a switching transistor. This causes the oscillation circuit to produce intermittent oscillation. As a result, current consumption is reduced and efficiency losses are prevented under low loads. Especially for output load currents in the region of 100 μA, these DC/DC converters can operate at extremely high efficiency.

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

This terminal deactivates or activates the step-down operation.When the power-off terminal is set to "L", the Vin voltage appears through the EXT terminal, prodding the switching transistor to go off. All the internal circuits stop working, and substantial savings in current consumption are thus achieved.

The power-off terminal is configured as shown in Figure 4. Since pull-up or pull-down is not performed internally, please avoid operating the terminal in a floating state. Also, try to refrain from applying a voltage of 0.3V to 1.8V to the terminal, lest the current consumption increase. When this power-off terminal is not used, leave it coupled to the VIN terminal.

Power-Off Terminal	CR Oscillation Circuit	Output Voltage
“H”	Activated	Set value
“L”	Deactivated	V_{SS}

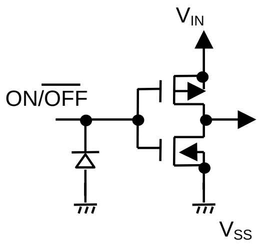


Figure 4

3. Soft-Start Function

The S-8520/21 Series comes with a built-in soft-start circuit. This circuit enables the output voltage to rise gradually over the specified soft-start time, when the power is switched on or when the power-off terminal remains at the "H" level. This prevents the output voltage from overshooting.

However, the soft-start function of this IC is not able to perfectly prevent a rush current from flowing to the load (see Figure 5). Since this rush current depends on the input voltage and load conditions, we recommend that you evaluate it by testing performance with the actual equipment.

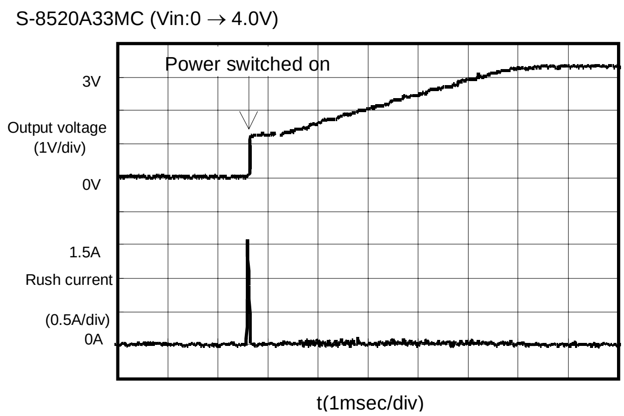


Figure 5. Waveforms of Output Voltage and Rush Current at Soft-Start

4. Overload Protection Circuit (A & C Series)

The S-8520/21A and S-8520/21C Series come with a built-in overload protection circuit.

If the output voltage falls because of an overload, the maximum duty state (100%) will continue. If this 100% duty state lasts longer than the prescribed overload detection time (TPRO), the overload protection circuit will hold the EXT terminal at "H," thereby protecting the switching transistor and inductor. When the overload protection circuit is functioning, the reference voltage circuit will be activated by means of a soft-start in the IC, and the reference voltage will rise slowly from 0V. The reference voltage and the feedback voltage obtained by dividing the output voltage are compared to each other. So long as the reference voltage is lower, the EXT terminal will be held at "H" to keep the oscillation inactive. If the reference voltage keeps rising and exceeds the feedback voltage, the oscillation will resume.

If the load is heavy when the oscillation is restarted, and the EXT terminal holds the "L" level longer than the specified overload detection time (TPRO), the overload protection circuit will operate again, and the IC will enter intermittent operation mode, in which it repeats the actions described above. Once the overload state is eliminated, the IC resumes normal operation.

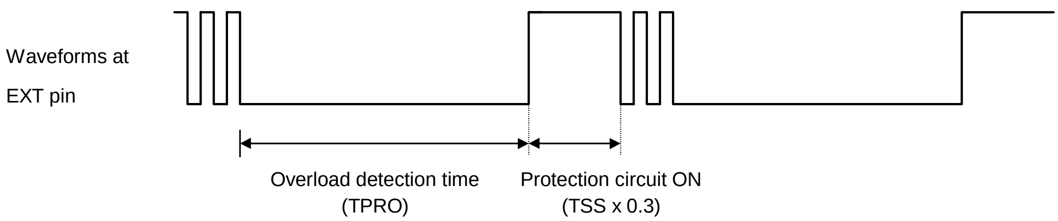


Figure 6. Waveforms Appearing at EXT Pin As the Overload Protection Circuit Operates

5. 100% Duty Cycle

The S-8520/21 Series operates with a maximum duty cycle of 100%. When a B Series or C Series product not provided with an overload protection circuit is used, the switching transistor can be kept ON to supply current to the load continually, even in cases where the input voltage falls below the preset output voltage value. The output voltage delivered under these circumstances is one that results from subtracting, from the input voltage, the voltage drop caused by the DC resistance of the inductance and the on-resistance of the switching transistor.

If an A Series or C Series product provided with an overload protection circuit is used, this protection circuit will function when the 100% duty state has lasted longer than the preset overload detection time (TPRO), causing the IC to enter intermittent operation mode. Under these conditions, the IC will not be able to supply current to the load continually, unlike the case described in the preceding paragraph.

■ Selection of Series Products and Associated External Components

1. Method for selecting series products

The S-8520/21 Series is classified into 8 types, according to the way the control systems (PWM and PWM/PFM-Switched), the different oscillation frequencies, and the inclusion or exclusion of an overload protection circuit are combined one with another. Please select the type that best suits your needs by taking advantage of the features of each type described below.

①Control systems:

Two different control systems are available: PWM control system (S-8520 Series) and PWM/PFM-switched control system (S-8521 Series).

If particular importance is attached to the operation efficiency while the load is on standby — for example, in an application where the load current heavily varies from that in standby state as the load starts operating — a high efficiency will be obtained in standby mode by selecting the PWM/PFM-switched control system (S-8521 Series).

Moreover, for applications where switching noise poses a serious problem, the PWM control system (S-8520 Series), in which the switching frequency does not vary with the load current, is preferable because it can eliminate ripple voltages easily using a filter.

②Oscillation frequencies:

Two oscillation frequencies--180 kHz (A & B Series) and 60 kHz (C & D Series)--are available.

Because of their high oscillation frequency and low-ripple voltage the A & B Series offer excellent transient response characteristics. The products in these series allow the use of small-sized inductors since the peak current remains smaller in the same load current than with products of the other series. In addition, they can also be used with small output capacitors. These outstanding features make the A & B Series ideal products for downsizing the associated equipment.

On the other hand, the C & D Series, having a lower oscillation frequency, are characterized by a small self-consumption of current and excellent efficiency under light loads. In particular, the D Series, which employs a PWM/PFM-switched control system, enables the operation efficiency to be improved drastically when the output load current is approximately 100 μA. (See Reference Data.)

③Overload protection circuit:

Products can be chosen either with an overload protection circuit (A & C Series) or without one (B & D Series).

Products with an overload protection circuit (A & C Series) enter intermittent operation mode when the overload protection circuit operates to accommodate overloads or load short-circuiting. This protects the switching elements and inductors. Nonetheless, in an application where the load needs to be fed continually with a current by taking advantage of the 100% duty cycle state, even if the input voltage falls below the output voltage value, a B or D Series product will have to be used. Choose whichever product best handles the conditions of your application.

In making the selection, please keep in mind that the upper limit of the operating voltage range is either 10V (A & C Series) or 16V (B & D Series), depending on whether the product comes with an overload protection circuit built in.

The table below provides a rough guide for selecting a product type depending on the requirements of the application. Choose the product that gives you the largest number of circles (O).

	S-8520						S-8521					
	A	B	C	D	(E)	(F)	A	B	C	D	(E)	(F)
An overload protection circuit is required	☆		☆		☆		☆		☆		☆	
The input voltage range exceeds 10V		☆		☆		☆		☆		☆		☆
The efficiency under light loads is an important factor							○	○	○	○		
To be operated with a medium load current (200 mA class)	○	○			○	○			○	○		
To be operated with a high load current (1 A class)	○	○			○	○	○	○			○	○
It is important to have a low-ripple voltage	○	○			◎	◎	○	○			◎	◎
Importance is attached to the downsizing of external components	○	○			◎	◎	○	○			◎	◎

The symbol "☆" denotes an indispensable condition, while the symbol "○" indicates that the corresponding series has superiority in that aspect. The symbol "◎" indicates particularly high superiority.
The E and F Series (versions with an oscillation frequency of 300 kHz) are currently under development.

2. Inductor

The inductance value greatly affects the maximum output current Iout and the efficiency η.

As the L-value is reduced gradually, the peak current Ipk increases, to finally reach the maximum output current Iout when the L-value has fallen to a certain point. If the L-value is made even smaller, Iout will begin decreasing because the current drive capacity of the switching transistor becomes insufficient.

Conversely, as the L-value is augmented, the loss due to Ipk in the switching transistor will decrease until the efficiency is maximized at a certain L-value. If the L-value is made even larger, the loss due to the series resistance of the coil will increase to the detriment of the efficiency.

If the L-value is increased in an S-8520/21 Series product, the output voltage may turn unstable in some cases, depending on the conditions of the input voltage, output voltage, and the load current. Perform thorough evaluations under the conditions of actual service and decide on an optimum L-value.

In many applications, selecting a value of 47μH will allow a S-8520/21 Series product to yield its best characteristics in a well balanced manner.

When choosing an inductor, pay attention to its allowable current, since a current applied in excess of the allowable value will

cause the inductor to produce magnetic saturation, leading to a marked decline in efficiency.

Therefore, select an inductor in which the peak current Ipk will not surpass its allowable current at any moment. The peak current

Ipk is represented by the following equation in continuous operation mode:

$$I_{PK} = IOUT + \frac{(VOUT + VF) \times (VIN - VOUT)}{2 \times fosc \times L \times (VIN + VF)}$$

Where fosc is the oscillation frequency, L the inductance value of the coil, and VF the forward voltage of the diode.

3. Diode

The diode to be externally coupled to the IC should be a type that meets the following conditions:

- Its forward voltage is low (Schottky barrier diode recommended).
- Its switching speed is high (50 ns max.).
- Its reverse direction voltage is higher than VIN.
- Its current rating is higher than Ipk.

4. Capacitors (Cin, Cout)

The capacitor inserted on the input side (Cin) serves to lower the power impedance and to average the input current for better efficiency. Select the Cin-value according to the impedance of the power supplied. As a rough rule of thumb, you should use a value of 47μF to 100μF, although the actual value will depend on the impedance of the power in use and the load current value.

For the output side capacitor (Cout), select one of large capacitance with low ESR (Equivalent Series Resistance) for smoothing the ripple voltage. However, notice that a capacitor with extremely low ESR (say, below 0.3Ω), such as a ceramic capacitor, could make the output voltage unstable, depending on the input voltage and load current conditions. Instead, a tantalum electrolytic capacitor is recommended. A capacitance value from 47μF to 100μF can serve as a rough yardstick for this selection.

5. External Switching Transistor

The S-8520/21 Series can be operated with an external switching transistor of the enhancement (Pch) MOS FET type or bipolar (PNP) type.

5.1 Enhancement MOS FET type

The EXT terminal of the S-8520/21 Series is capable of directly driving a Pch power MOS FET with a gate capacity of some 1000 pF.

When a Pch power MOS FET is chosen, because it has a higher switching speed than a PNP type bipolar transistor and because power losses due to the presence of a base current are avoided, efficiency will be 2% to 3% higher than when other types of transistor are employed.

The important parameters to be kept in mind in selecting a Pch power MOS FET include the threshold voltage, breakdown voltage between gate and source, breakdown voltage between drain and source, total gate capacity, on-resistance, and the current rating.

The EXT terminal swings from voltage VIN over to voltage Vss. If the input voltage is low, a MOS FET with a low threshold voltage has to be used so that the MOS FET will come on as required. If, conversely, the input voltage is high, select a MOS FET whose gate-source breakdown voltage is higher than the input voltage by at least several volts.

Immediately after the power is turned on, or when the power is turned off (that is, when the step-down operation is terminated), the input voltage will be imposed across the drain and the source of the MOS FET. Therefore, the transistor needs to have a 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 increase, when the total gate capacity becomes larger and the input voltage rises higher. Therefore the gate capacity affects the efficiency of power in a low load current region. If the efficiency under light loads is a matter of particular concern, select a MOS FET with a small total gate capacity.

In regions where the load current is high, the efficiency is affected by power losses caused due to the on-resistance of the MOS FET. Therefore, if the efficiency under heavy loads is particularly important for your application, choose a MOS FET with as low an on-resistance as possible.

As for the current rating, select a MOS FET whose maximum continuous drain current rating is higher than the peak current Ipk.

For reference purpose, some efficiency data has been included in this document. For applications with an input voltage range of 10V or less, data was obtained by using TM6201 of Toyoda Automatic Loom Works, Ltd. IRF7606, a standard of International Rectifier, was used for applications with an input voltage range over 10V. Refer to "Reference Data."

5.2 Bipolar PNP type

Figure 7 shows a sample circuit diagram using Toshiba 2SA1213-Y for the bipolar transistor (PNP). The driving capacity for increasing the output current by means of a bipolar transistor is determined by the hFE-value and the Rb-value of that bipolar transistor.

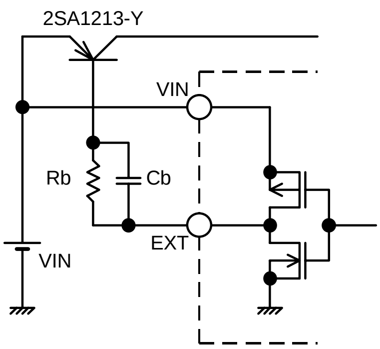


Figure 7

The Rb-value is given by the following equation:

$$Rb = \frac{VIN-0.7}{Ib} - \frac{0.4}{|IEXTL|}$$

Find the necessary base current Ib using the hFE - value of bipolar transistor by the equation, Ib = Ipk/hFE, and select a smaller RB-value.

A small Rb-value will certainly contribute to increasing the output current, but it will also adversely affect the efficiency. Moreover, in practice, a current may flow as the pulses or a voltage drop may take place due to the wiring resistance or some other reason. Determine an optimum value through experimentation.

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

Select a Cb-value by using the following equation as a guide:

$$Cb \leq \frac{1}{2\pi \, x Rb \, x \, f_{OSC} \, x \, 0.7}$$

■ Standard Circuits:(1) Using a bipolar transistor:

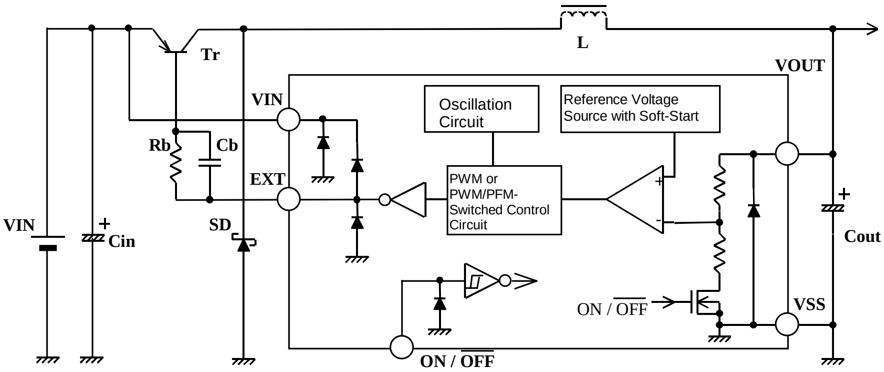


Figure 8

(2) Using a Pch MOS-FET transistor

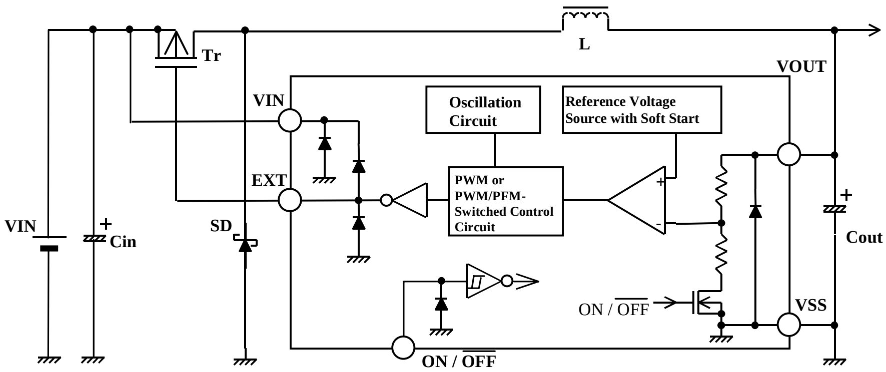


Figure 9

■ Precautions:

- Install the external capacitors, diode, coil, and other peripheral components as close to the IC as possible, and secure grounding at a single location.
- Any switching regulator intrinsically produces a ripple voltage and spike noise, which are largely dictated by the coil and capacitors in use. When designing a circuit, first test them on actual equipment.
- The overload protection circuit of this IC performs the protective function by detecting the maximum duty time (100%). In choosing the components, make sure that overcurrents generated by short-circuits in the load, etc., will not surpass the allowable dissipation of the switching transistor and inductor.
- Make sure that dissipation of the switching transistor will not surpass the allowable dissipation of the package. (especially at the time of high temperature)

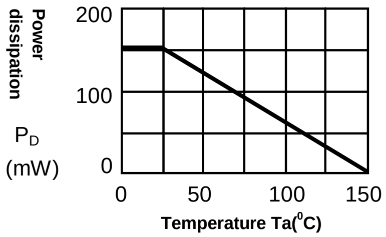


Figure 10. Power dissipation of an SOT-23-5 Package (When Not Mounted)

- Seiko Instruments Inc. shall not be responsible for any patent infringement by products including the S-8520/8521 Series in connection with the method of using the S-8520/8521 Series in such products, the product specifications or the country of destination thereof.

■ Application Circuits:

1. External adjustment of output voltage

The S-8520/21 Series allows you to adjust the output voltage or to set the output voltage to a value over the preset output voltage range (6V) of the products of this series, when external resistances RA, RB, and capacitor CC are added, as illustrated in Figure 11. Moreover, a temperature gradient can be obtained by inserting a thermistor or other element in series with RA and RB.

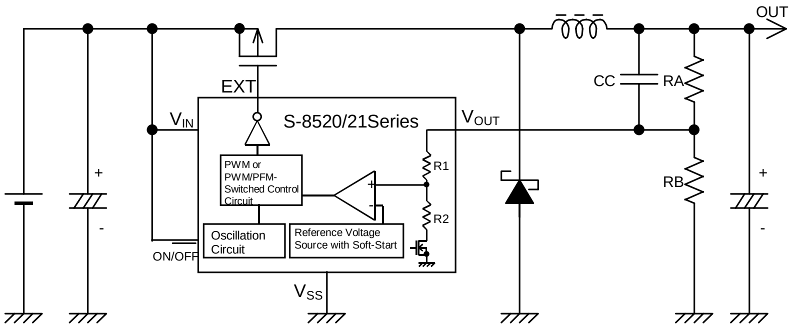


Figure 11

The S-8520 and 21 Series have an internal impedance of R1 and R2 between the V_{OUT} and the V_{SS} terminal, as shown in Figure 11.

Therefore, the output voltage (OUT) is determined by the output voltage value VOUT of the S-8520/21 Series, and the ratio of the parallel resistance value of external resistance RB and internal resistances R1 + R2 of the IC, to external resistance RA. The output voltage is expressed by the following equation:

OUT = VOUT + VOUT × RA ÷ (RB // (R1 + R2)) (Note: // denotes a combined resistance in parallel.)

The voltage accuracy of the output OUT set by resistances RA and RB is not only affected by the IC's output voltage accuracy (VOUT ±2.4%), but also by the absolute precision of external resistances RA and RB in use and the absolute value deviations of internal resistances R1 and R2 in the IC.

Let us designate the maximum deviations of the absolute value of external resistances RA and RB by Ramax and Rbmax, respectively, the minimum deviations by Ramin and Rbmin, respectively, and the maximum and minimum deviations of the absolute value of internal resistances R1 and R2 in the IC by (R1+R2)max and (R1+R2)min, respectively. Then, the minimum deviation value OUTmin and the maximum deviation value OUTmax of the output voltage OUT are expressed by the following equations:

OUTmin = VOUT × 0.976 + VOUT × 0.976 × Ramin ÷ (Rbmax // (R1 + R2)max)

OUTmax = VOUT × 1.024 + VOUT × 1.024 × Ramax ÷ (Rbmin // (R1 + R2)min)

The voltage accuracy of the output OUT cannot be made higher than the output voltage accuracy (VOUT ± 2.4%) of the IC itself, without adjusting the external resistances RA and RB involved. The closer the voltage value of the output OUT and the output voltage value (VOUT) of the IC are brought to one other, the more the output voltage remains immune to deviations in the absolute accuracy of externally connected resistances RA and RB and the absolute value of internal resistances R1 and R2 in the IC.

In particular, to suppress the influence of deviations in internal resistances R1 and R2 in the IC, a major contributor to deviations in the output OUT, the external resistances RA and RB must be limited to a much smaller value than that of internal resistances R1 and R2 in the IC.

On the other hand, a reactive current flows through external resistances RA and RB. This reactive current must be reduced to a negligible value with respect to the load current in the actual use of the IC so that the efficiency characteristics will not be degraded. This requires that the value of external resistance RA and RB be made sufficiently large.

However, too large a value (more than 1MΩ) for the external resistances RA and RB would make the IC vulnerable to external noise. Check the influence of this value on actual equipment.

There is a tradeoff between the voltage accuracy of the output OUT and the reactive current. This should be taken into consideration based on the requirements of the intended application.

Deviations in the absolute value of internal resistances R1 and R2 in the IC vary with the output voltage of the S-8520/21 Series, and are broadly classified as follows:

- Output voltage 1.5V to 2.0V → 5.16MΩ to 28.9MΩ
- Output voltage 2.1V to 2.5V → 4.44MΩ to 27.0MΩ
- Output voltage 2.6V to 3.3V → 3.60MΩ to 23.3MΩ
- Output voltage 3.4V to 4.9V → 2.44MΩ to 19.5MΩ
- Output voltage 5.0V to 6.0V → 2.45MΩ to 15.6MΩ

When a value of R1+R2 given by the equation indicated below is taken in calculating the voltage value of the output OUT, a median voltage deviation will be obtained for the output OUT.

R1 + R2 = 2 ÷ (1 ÷ maximum deviation in absolute value of internal resistances R1 and R2 in IC + 1 ÷ minimum deviation in absolute value of internal resistances R1 and R2 of IC)

Moreover, add a capacitor CC in parallel to the external resistance RA in order to avoid output oscillations and other types of instability. (See Figure 11.)

Make sure that CC is larger than the value given by the following equation:

$$CC\ (F) \geq 1 \div (2 \times \pi \times RA\ (\Omega) \times 7.5\text{kHz})$$

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

SII is equipped with a tool that allows you to automatically calculate the necessary resistance values of RA and RB from the required voltage accuracy of the output OUT. SII will be pleased to assist its customers in determining the RA and RB values. Should such assistance be desired, please inquire at:

SII Components Sales Dept.

Telephone: 043-211-1196 (Direct)

Fax: 043-211-8032

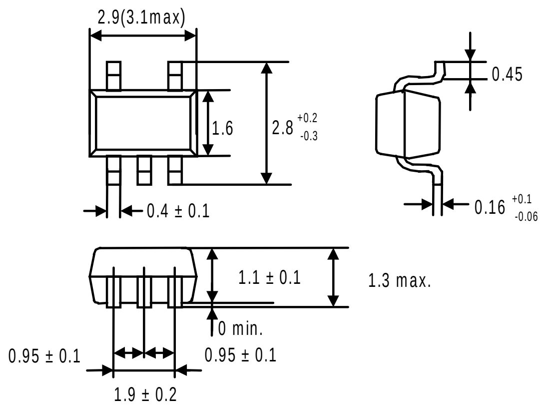
- Moreover, SII also has ample information on which peripheral components are suitable for use with this IC and data concerning the deviations in the IC's characteristics. We are ready to help our customers with the design of application circuits.

  Please contact the SII Components Sales Dept. at:

  Telephone: 043-211-1196 (Direct)

  Fax: 043-211-8032

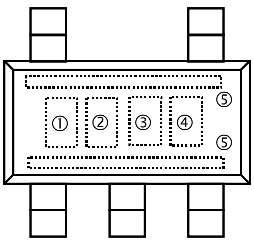
■ Outlines and Dimensions:



Unit: mm

Figure 12

■ Marking:



① ~ ③ Product No. (Abbreviations)

④ ~ ⑤ Lot No.

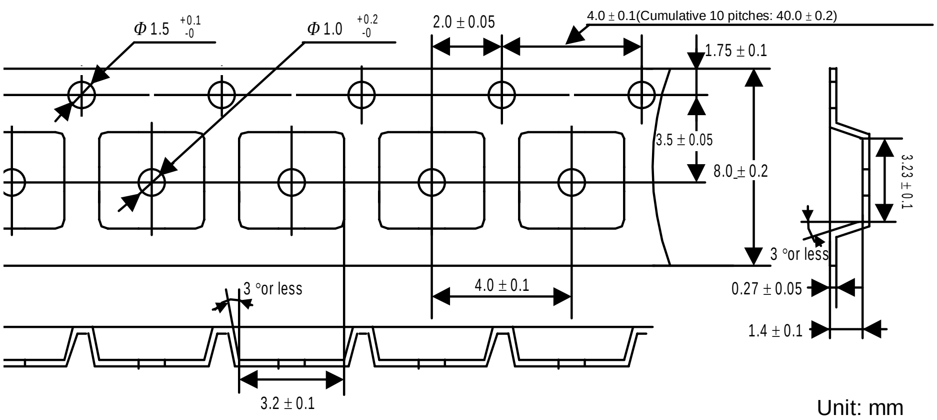
④ : Alphabet

⑤ : A dot marked on either side

Figure 13

■ Taping:

1. Tape specifications



Unit: mm

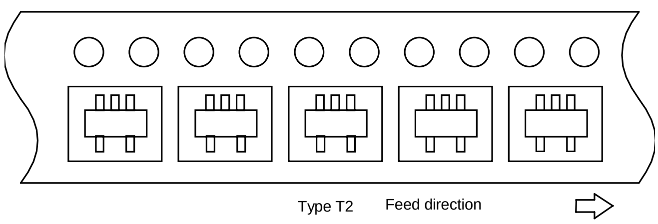
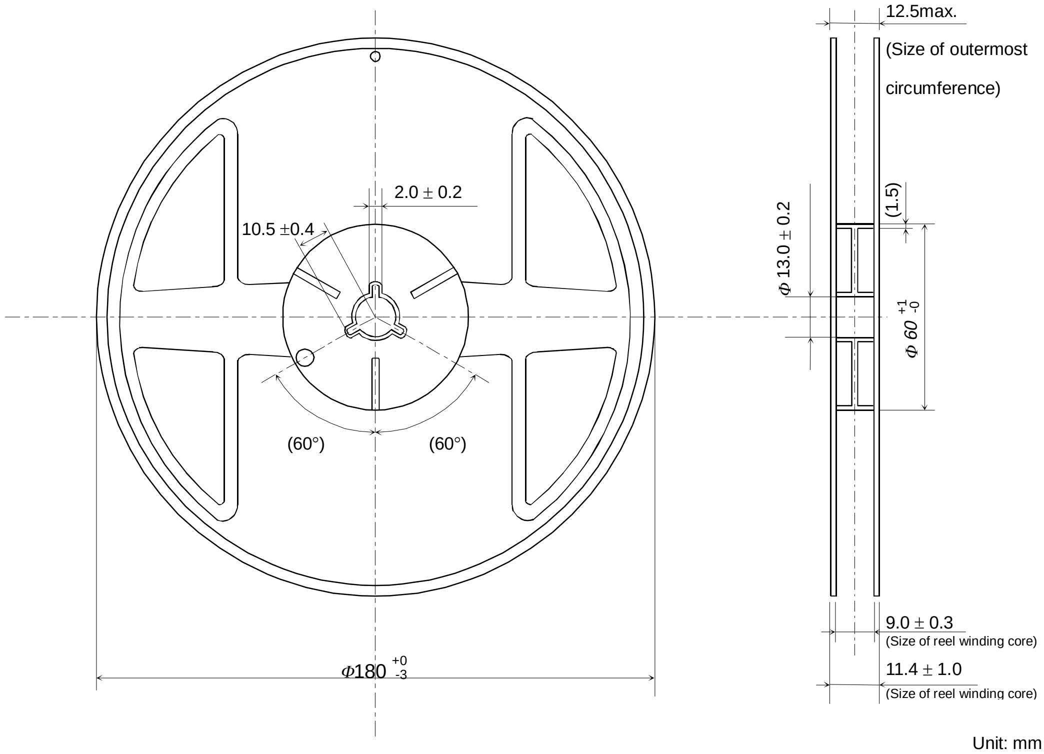


Figure 14

2.Reel specifications

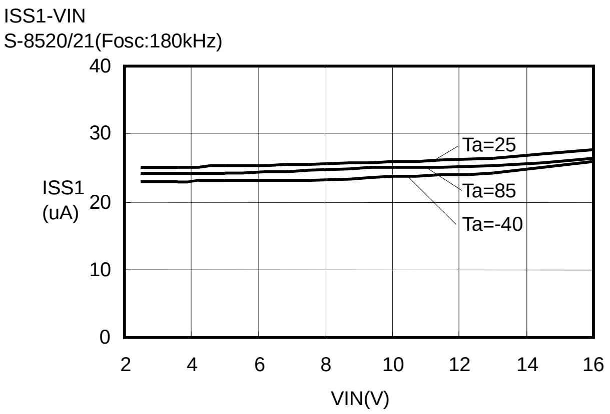
One reel holds 3000 ICs.

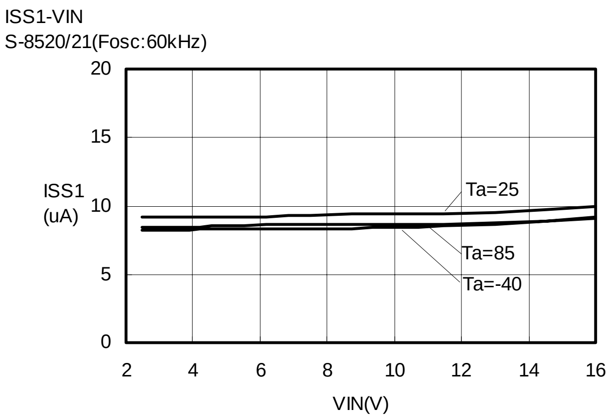


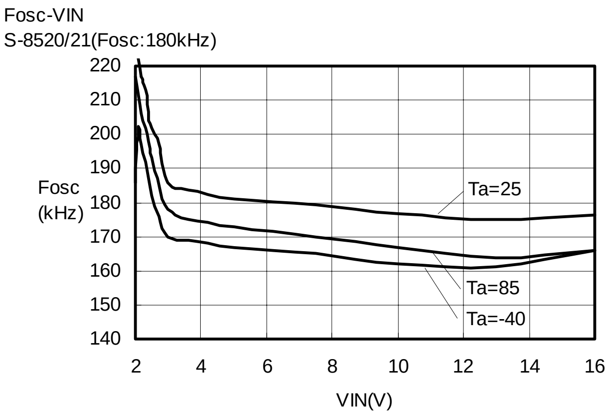
Unit: mm

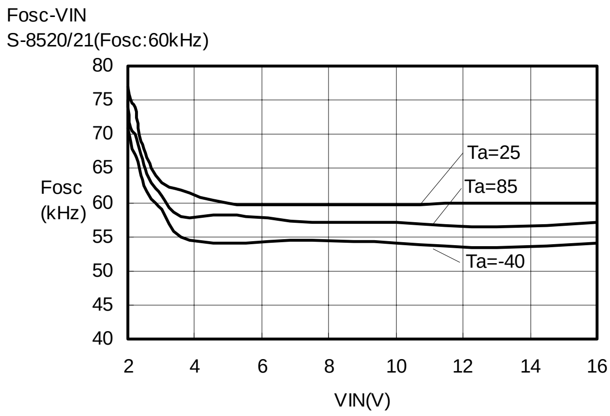
Figure 15

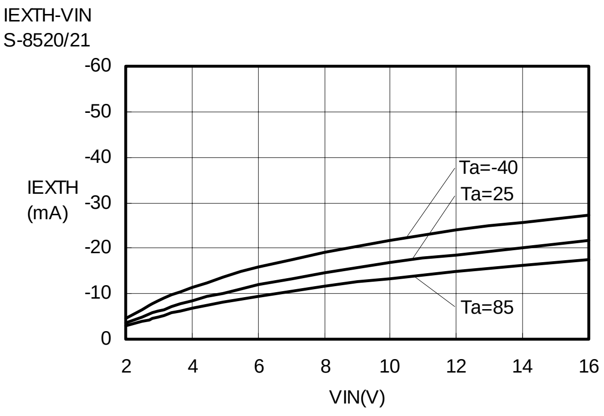
■ Characteristics of Major Items (All data represents typical values):

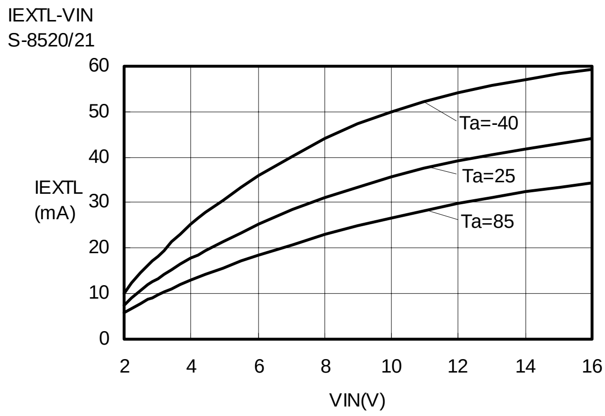


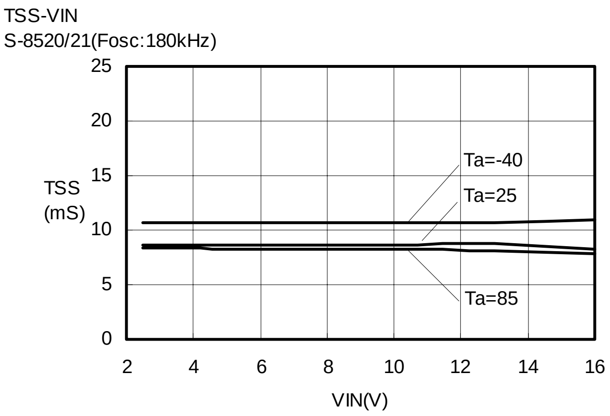


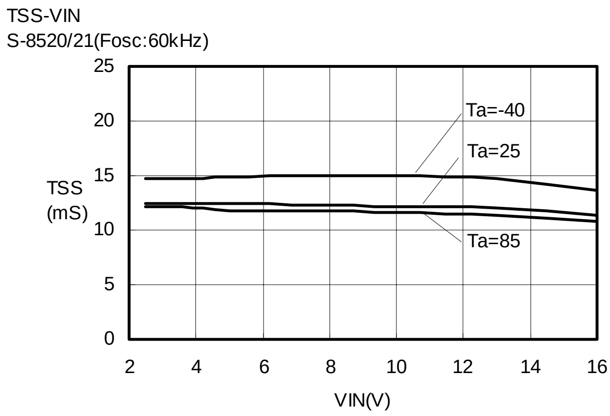




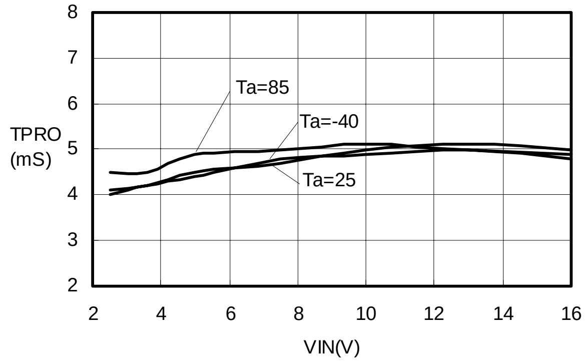




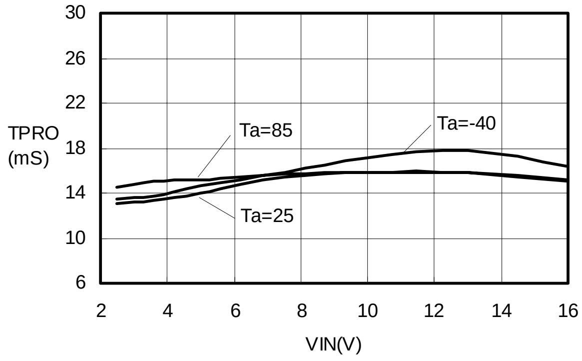




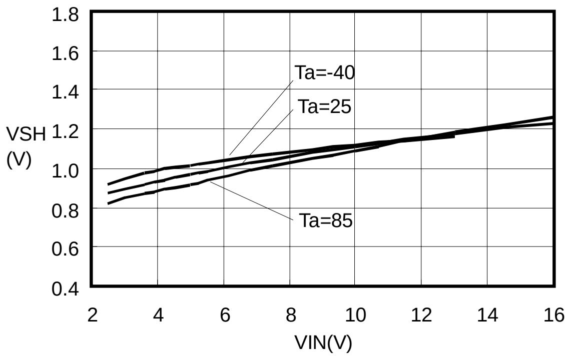
TPRO-VIN
S-8520/21(Fosc:180kHz)



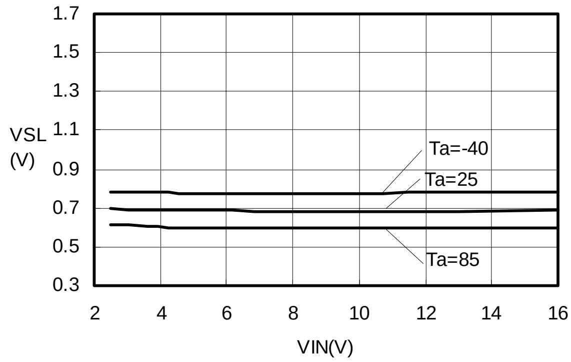
TPRO-VIN
S-8520/21(Fosc:60kHz)



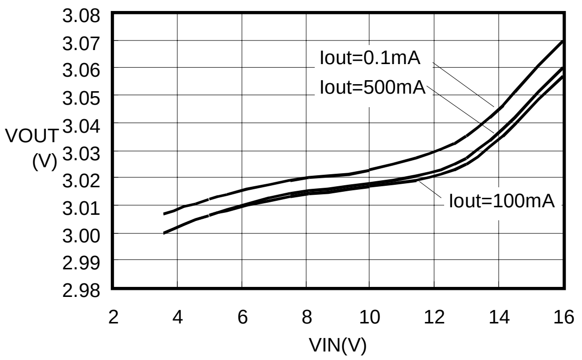
VSH-VIN
S-8520/21



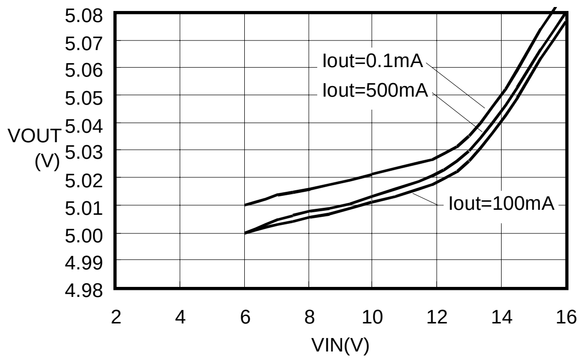
VSL-VIN
S-8520/21



VOUT-VIN
S-8521B30MC (Ta=25°C)



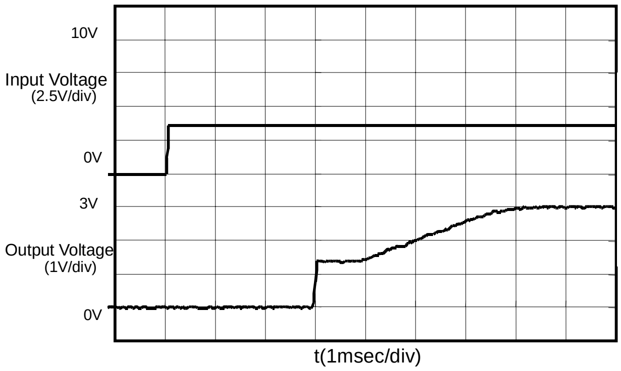
VOUT-VIN
S-8521B50MC (Ta=25°C)



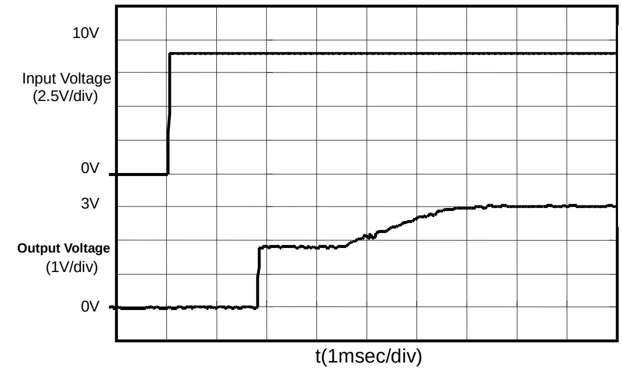
■ Transient Response Characteristics:

1. Power-On (Vin: 0V→3.6V, 0V→9.0V Iout: No-load)

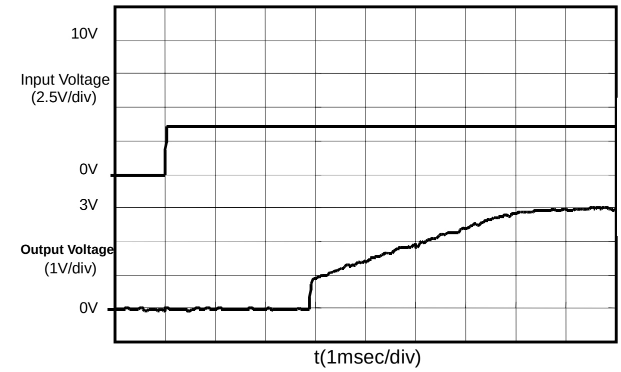
S-8520A30MC (Vin:0 → 3.6V)



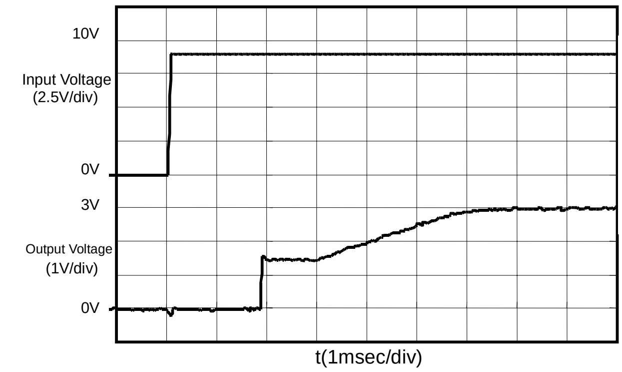
S-8520A30MC (Vin:0 → 9.0V)



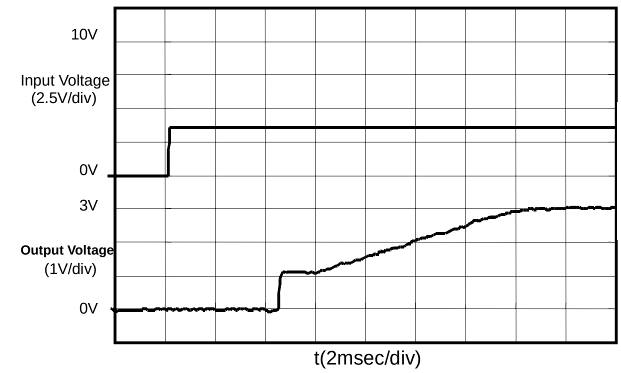
S-8521A30MC (Vin:0 → 3.6V)



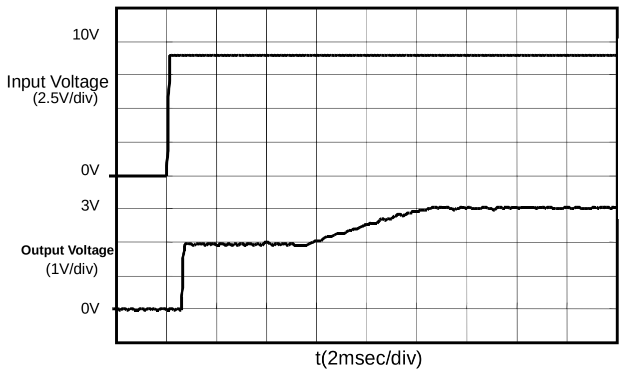
S-8521A30MC (Vin:0 → 9.0V)



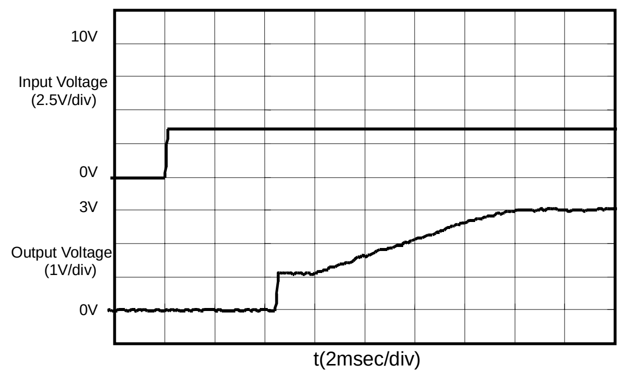
S-8520C30MC (Vin:0 → 3.6V)



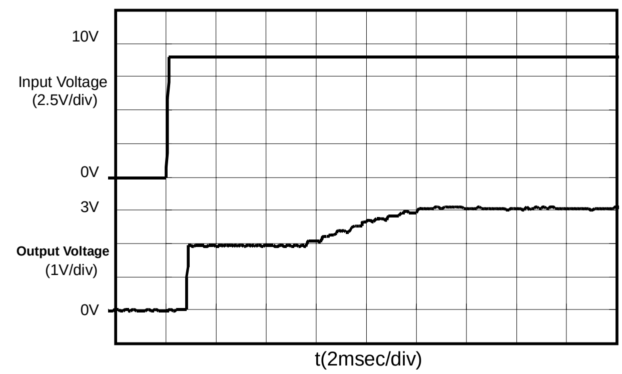
S-8520C30MC (Vin:0 → 9.0V)



S-8521C30MC (Vin:0 → 3.6V)

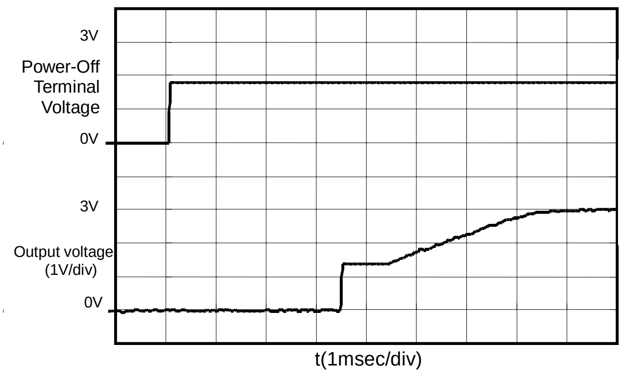


S-8521C30MC (Vin:0 → 9.0V)

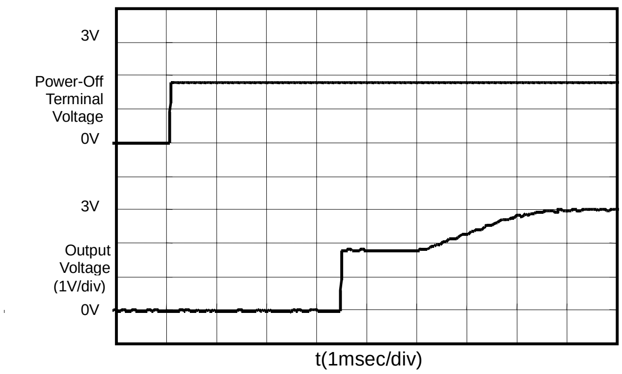


2. Power-Off Terminal Response (ON/$\overline{\text{OFF}}$: 0V→1.8V Iout : No-load)

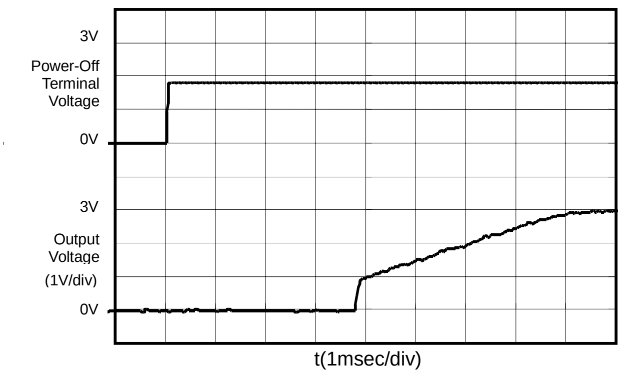
S-8520A30MC (Vin:3.6V)



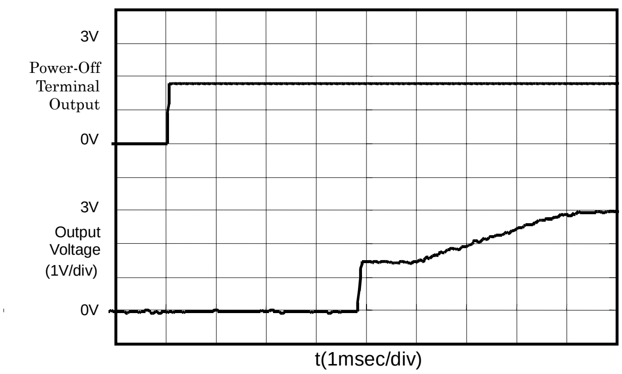
S-8520A30MC (Vin:9.0V)



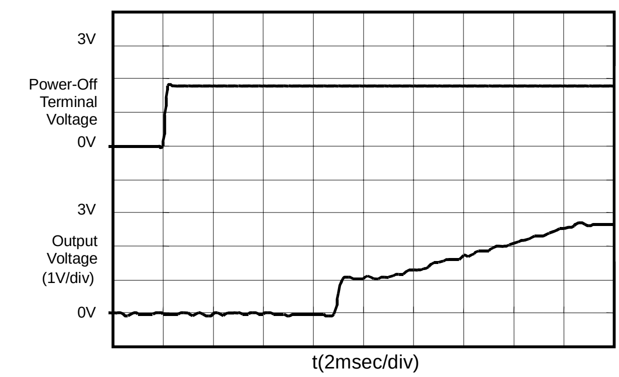
S-8521A30MC (Vin:3.6V)



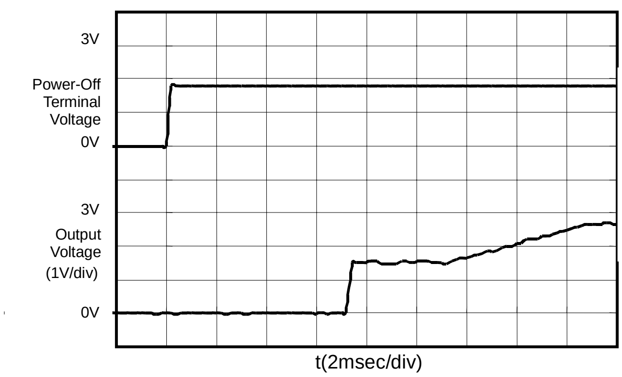
S-8521A30MC (Vin:9.0V)



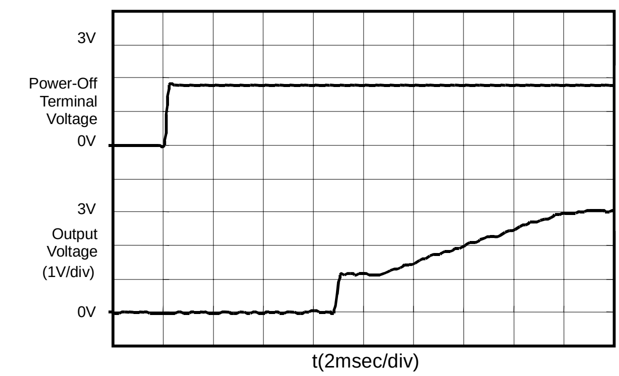
S-8520C30MC (Vin:3.6V)



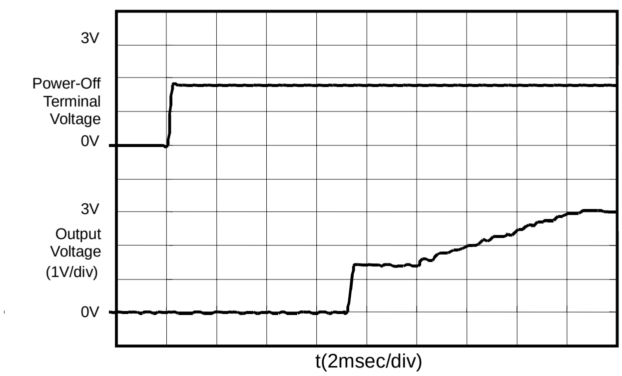
S-8520C30MC (Vin:9.0V)



S-8521C30MC (Vin:3.6V)

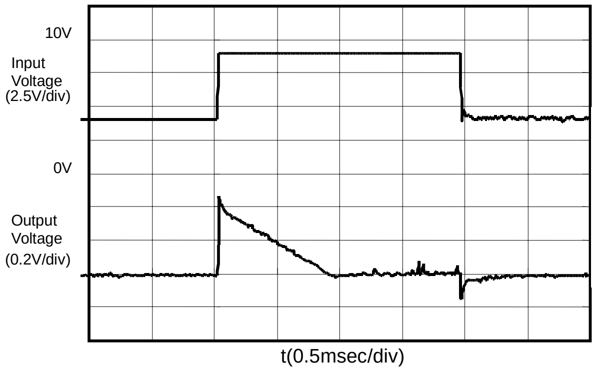


S-8521C30MC (Vin:9.0V)

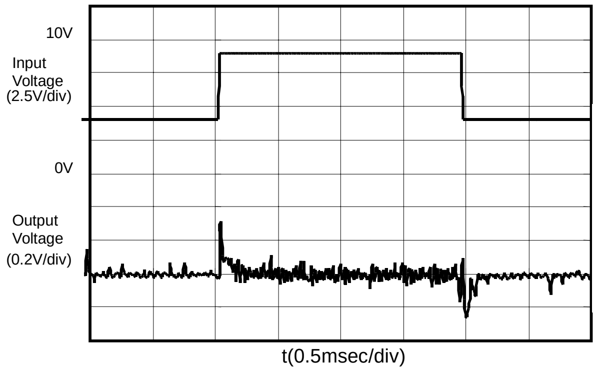


3. Supply Voltage Variation (Vin: 4V→9V, 9V→4V)

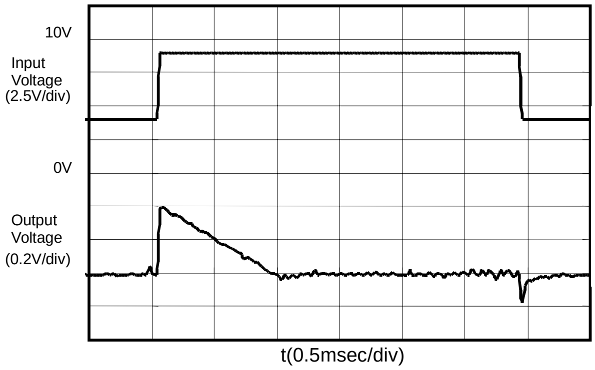
S-8520A30MC (Iout:10mA)



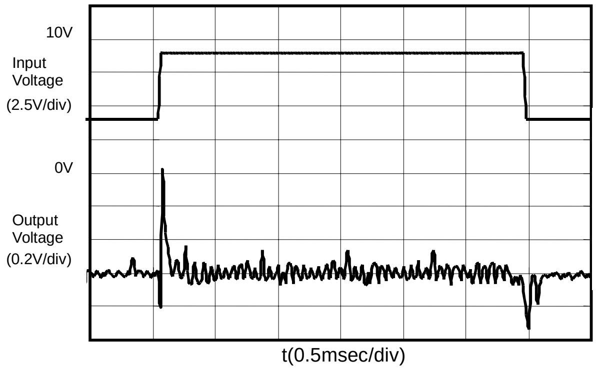
S-8520A30MC (Iout:500mA)



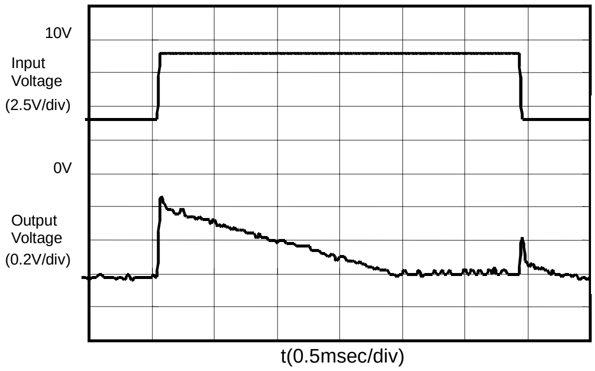
S-8521A30MC (Iout:10mA)



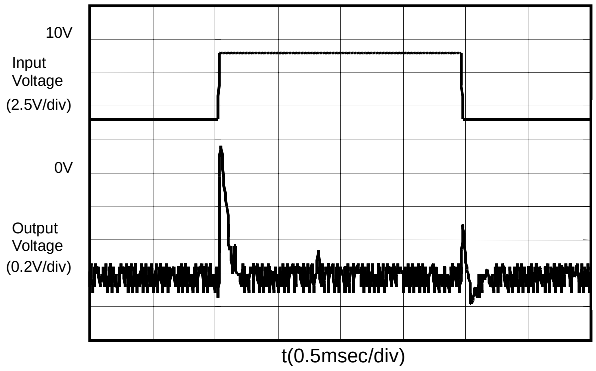
S-8521A30MC (Iout:500mA)



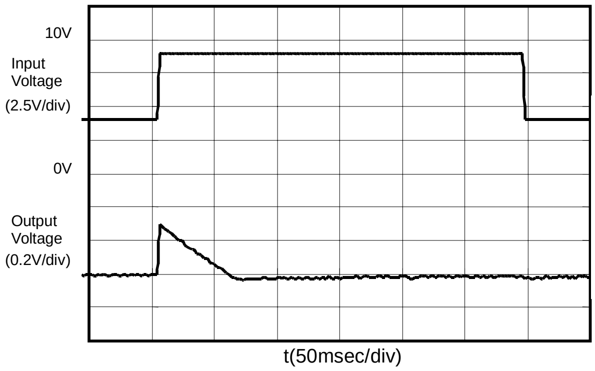
S-8520C30MC (Iout:10mA)



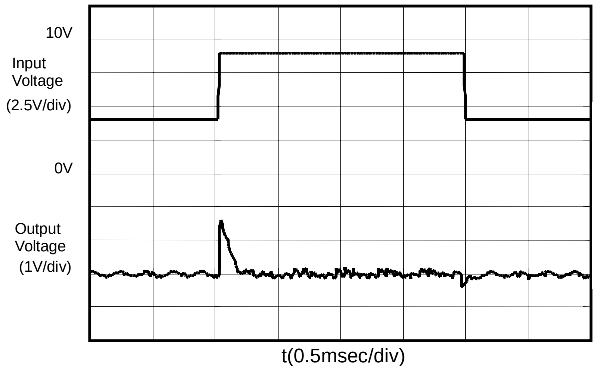
S-8520C30MC (Iout:500mA)



S-8521C30MC (Iout:10mA)

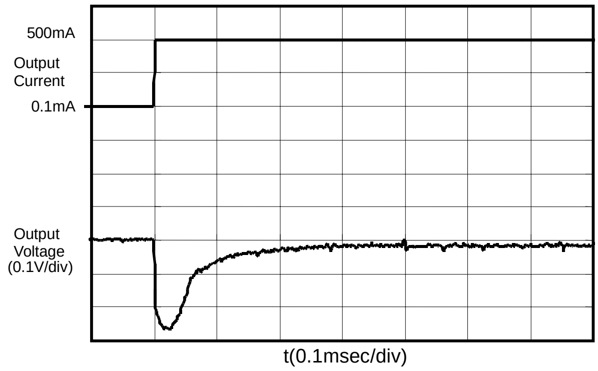


S-8521C30MC (Iout:500mA)

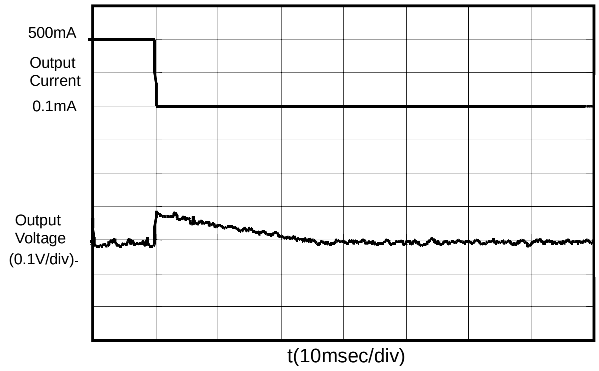


4. Load Variation (Vin: 3.6V Iout: 0.1mA→500mA, 500mA→0.1mA)

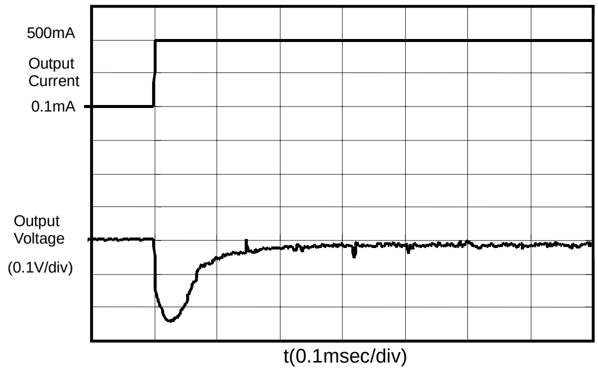
S-8520A30MC (Vin:3.6V)



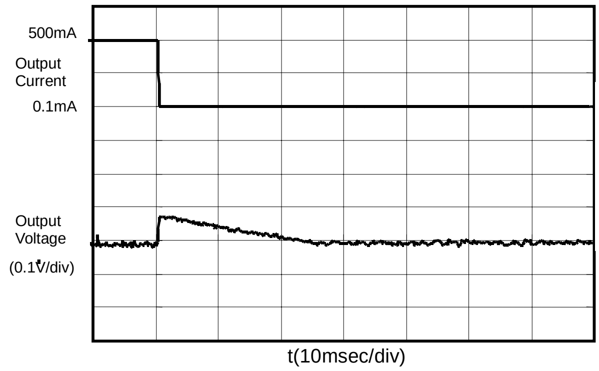
S-8520A30MC (Vin:3.6V)



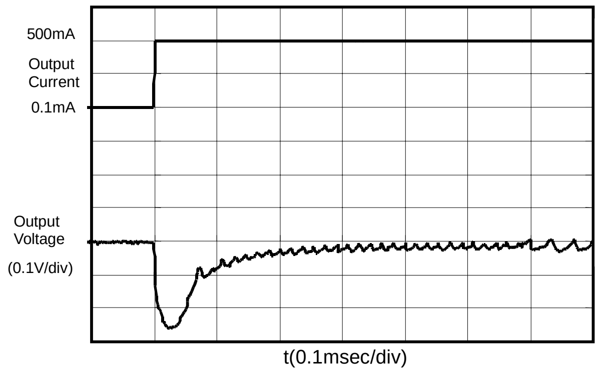
S-8521A30MC (Vin:3.6V)



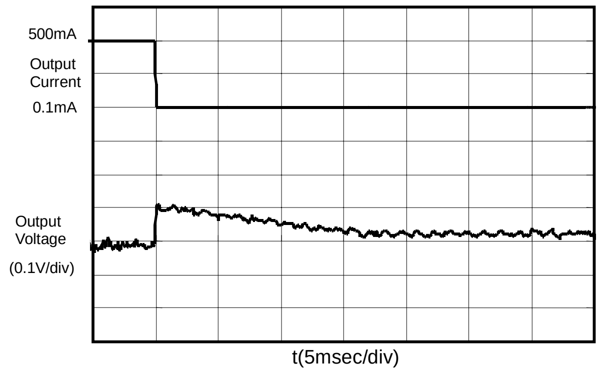
S-8521A30MC (Vin:3.6V)



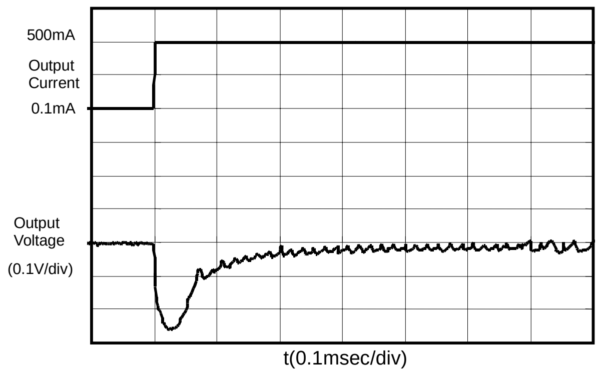
S-8520C30MC (Vin:3.6V)



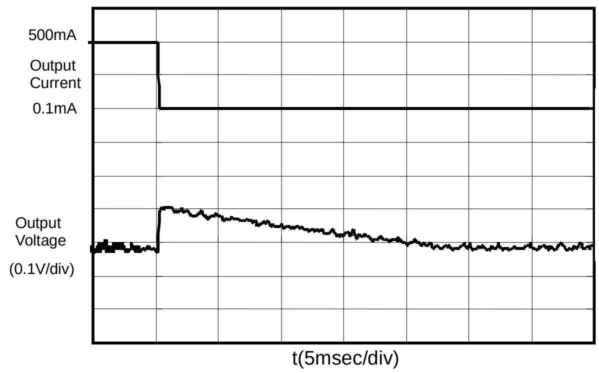
S-8520C30MC (Vin:3.6V)



S-8521C30MC (Vin:3.6V)



S-8521C30MC (Vin:3.6V)



■ Reference Data:

This reference data is intended to help you select peripheral components to be externally connected to the IC. Therefore, this information provides recommendations on external components selected with a view to accommodating a wide variety of IC applications. Characteristic data is duly indicated in the table below.

Table 1

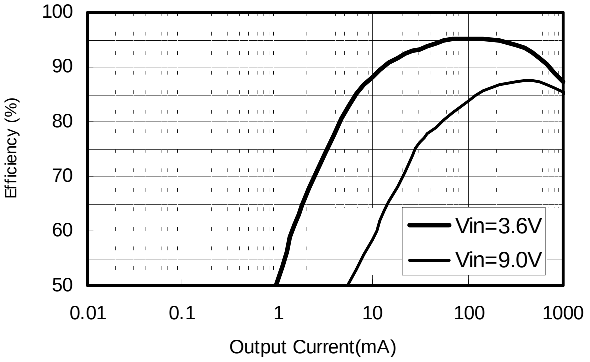
No.	Product Name	Output Voltage	Inductor	Transistor	Diode	Output Capacitor	Application
(1)	S-8520B30MC	3.0V	CD105/47uH	TM6201	MA737	47uF	Load current 1A max., input voltage 10V max.
(2)	S-8521B30MC	↑	↑	↑	↑	↑	Load current 1A max., input voltage 10V max. Equipment standby mode involved.
(3)	↑	↑	↑	IRF7606	↑	↑	Load current 1A max., input voltage 16V max. Equipment standby mode involved.
(4)	S-8521D30MC	↑	CD54/47uF	TM6201	MA720	47uFx2	Load current 0.5A max., input voltage 10V max. Equipment standby mode involved.
(5)	↑	↑	↑	IRF7606	↑	↑	Load current 0.5A max., input voltage 16V max. Equipment standby mode involved.
(6)	S-8520B50MC	5.0V	↑	TM6201	↑	47uF	Load current 0.5A max., input voltage 10V max.
(7)	S-8521B50MC	↑	↑	↑	↑	↑	Load current 0.5A max., input voltage 10V max. Equipment standby mode involved.
(8)	S-8521D50MC	↑	↑	↑	↑	47uFx2	Load current 0.5A max., input voltage 10V max. Equipment standby mode involved.

Table 2

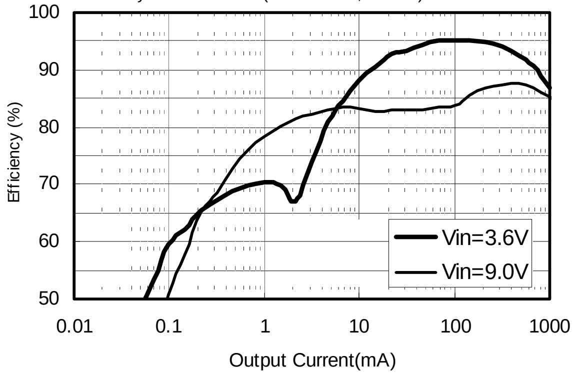
Component	Product Name	Manufacturer's Name	L-Value	DC Resistance	Max. Allowable Current	Dia.	Height
Inductor	CD54	Sumida Electric Co., Ltd.	47uH	0.37Ω	0.72A	5.8mm	4.5mm
	CD105	↑	47uH	0.17Ω	1.28A	10.0mm	5.4mm
Diode	MA720	Matsushita Electronics Corporation	Forward current 500mA (When VF = 0.55V)				
	MA737	↑	Forward current 1.5A (When VF = 0.5V)				
Output Capacity	F93	Nichicon					
	TE	Matsushita Electronics Corporation					
External Transistor	TM6201	Toyoda Automatic Loom Works, Ltd.	VGS 12V max. , ID -2A max. , Vth -0.7V min. , Ciss 320pF typ. Ron 0.25Ωmax.(Vgs=-4.5V)				
	IRF7606	International Rectifier	VGS 20V max. , ID -2.4A max. , Vth -1V min. Ciss 470pF typ. Ron 0.15Ωmax.(Vgs=-4.5V)				
	2SA1213-Y	Toshiba Corporation					

1. Efficiency Characteristics

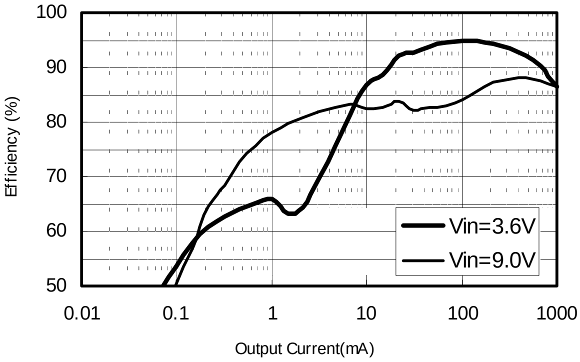
(1) S-8520B30MC
Output Current-Efficiency Characteristics (CD105/47uH,TM6201)



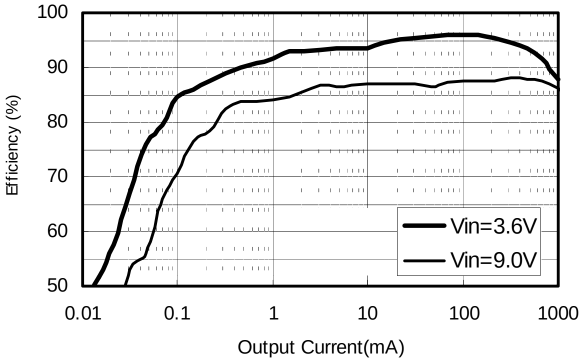
(2) S-8521B30MC
Output Current-Efficiency Characteristics (CD105/47uH,TM6201)



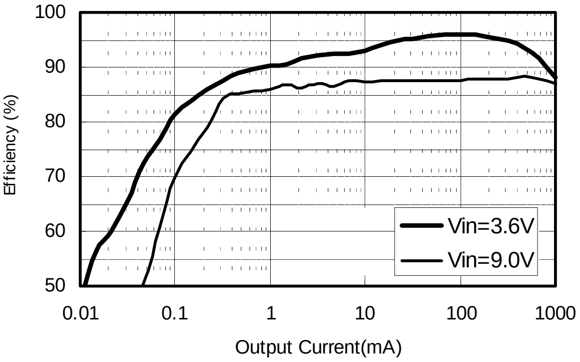
(3) S-8521B30MC
Output Current-Efficiency Characteristics (CD105/47uH,IRF7606)



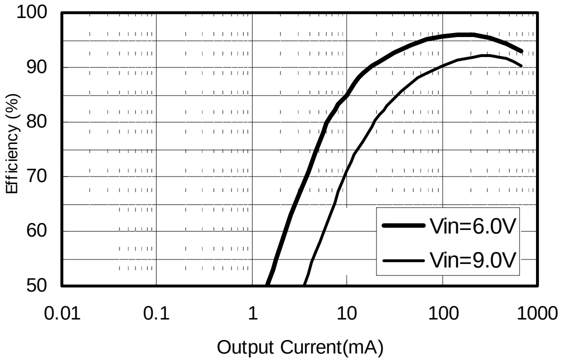
(4) S-8521D30MC
Output Current-Efficiency Characteristics (CD54/47uH,TM6201)



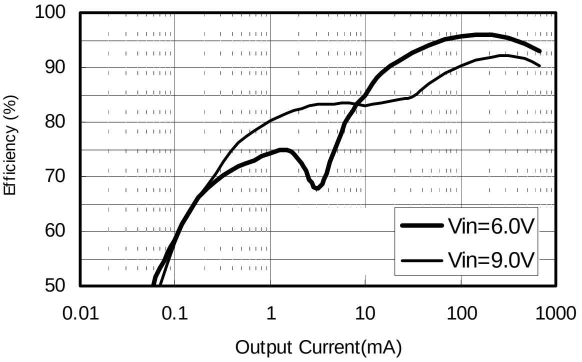
(5) S-8521D30MC
Output Current-Efficiency Characteristics (CD54/47uH,IRF7606)



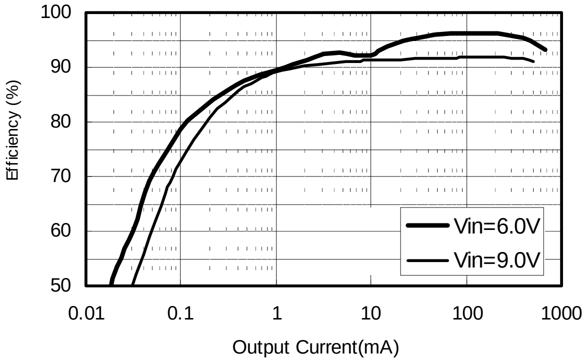
(6) S-8520B50MC
Output Current-Efficiency Characteristics (CD54/47uH,TM6201)



(7) S-8521B50MC
Output Current-Efficiency Characteristics (CD54/47uH,TM6201)

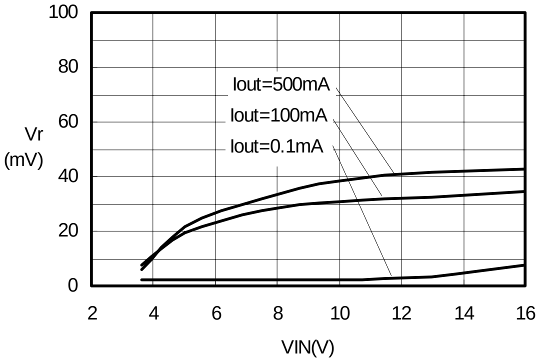


(8) S-8521D50MC
Output Current-Efficiency Characteristics (CD54/47uH,TM6201)

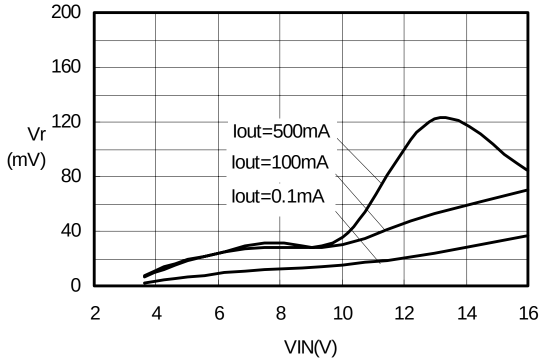


2. Ripple Voltage Characteristics (L:CD105/47uF,Tr:2SA1213,SBD:MA720)

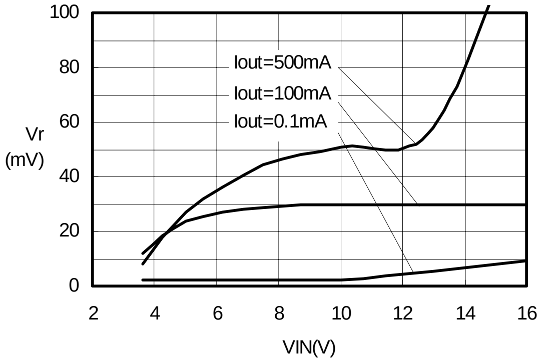
(9) Ripple voltage-VIN
S-8520B30MC(Cout:22uFx2)



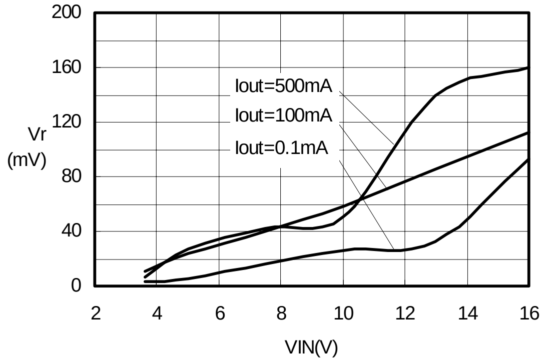
(10) Ripple voltage-VIN
S-8521B30MC(Cout:22uFx2)



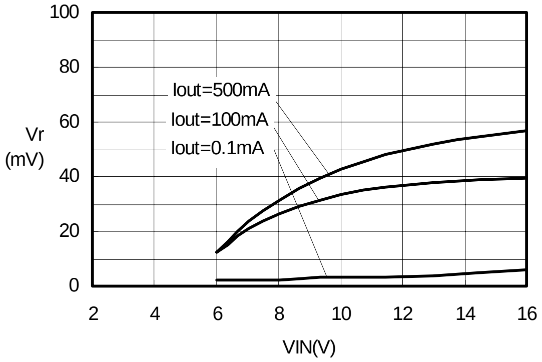
(11) Ripple voltage-VIN
S-8520D30MC(Cout:47uFx2)



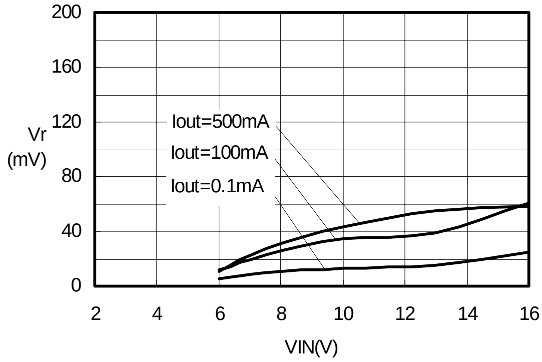
(12) Ripple voltage-VIN
S-8521D30MC(Cout:47uFx2)



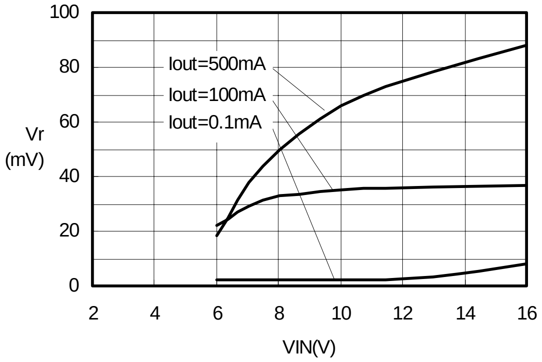
(13) Ripple voltage-VIN
S-8520B50MC(Cout:22uFx2)



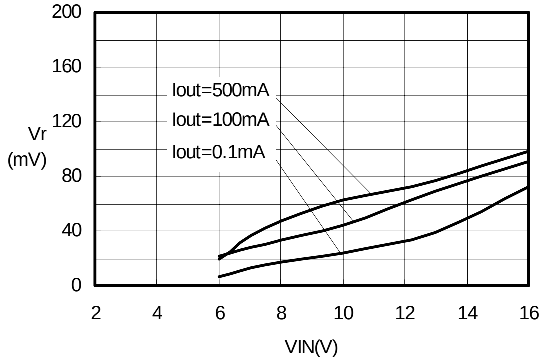
(14) Ripple voltage-VIN
S-8521B50MC(Cout:22uFx2)



(15) Ripple voltage-VIN
S-8520D50MC(Cout:47uFx2)



(16) Ripple voltage-VIN
S-8521D50MC(Cout:47uFx2)



Collection of Product FAQs

Author: Tachibana Midori Date: 98/11/12 (Thursday) 10:17 (Modified:)

<Information level>

A: Public (Printing O.K.)

Index: B: Technical

<Product>

Division name: 01 IC

Category 1: 11 Power Supply

Category 2: 4. Switching Regulators

Cal No.: S-8520/21

Related documents:

Question:

Why does the efficiency under a low load differ significantly between the 180-KHz type and the 60-KHz type?

Answer:

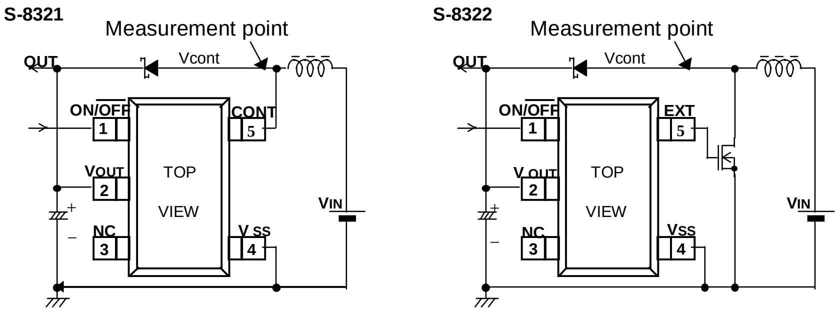
The efficiency characteristics graph in the reference data (Rev. 6. 1, p. 24) on the data sheet indicates that there is a difference of a significant % in the efficiency characteristics between the 180-KHz type (S-8520/1AB) and the 60-KHz type (S-8520/1CD) at a low load (up to 10 mA).

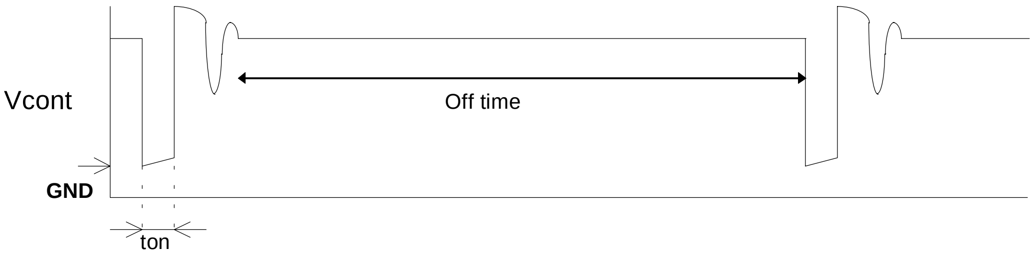
This is due to the fact that the energy obtained from switching in the PFM operation is greater for the 60-KHz type than for the 180-KHz type.

In general, PFM control provides higher efficiency under a low load than does PWM control.

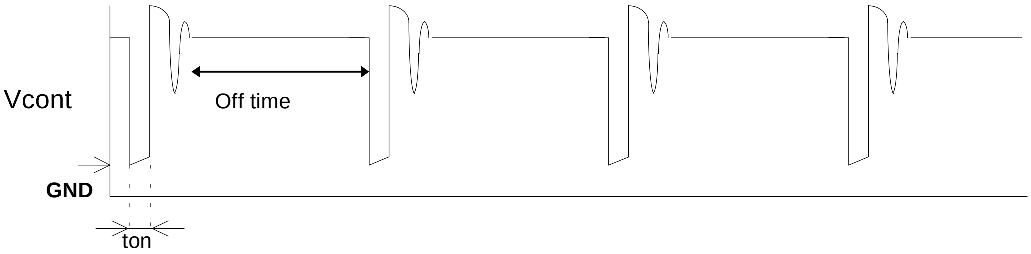
As shown by the Vcont waveforms below for the 60-KHz type and the 180-KHz type, the ton duration is shorter in the 180-KHz type. Therefore, the energy obtained from switching is smaller and the off time decreases, as with PWM control, resulting in reduced efficiency under a low load.

However, note that rippling of the output voltage is greater in the 60-KHz type.





60-KHz type (S-8520/1CD)



180-KHz type (S-8520/1AB)

<Remarks>

FAQ No.: 11S8520003

Collection of Product FAQs

Author: Tachibana Midori Date: 98/11/12 (Thursday), 10:17 (Modified:)

<Information level>

A: Public (Printing O.K.)

Index: B (Technical)

<Product>

Division name: 01 IC

Category 1: 11 Power Supply

Category 2: 4. Switching Regulators

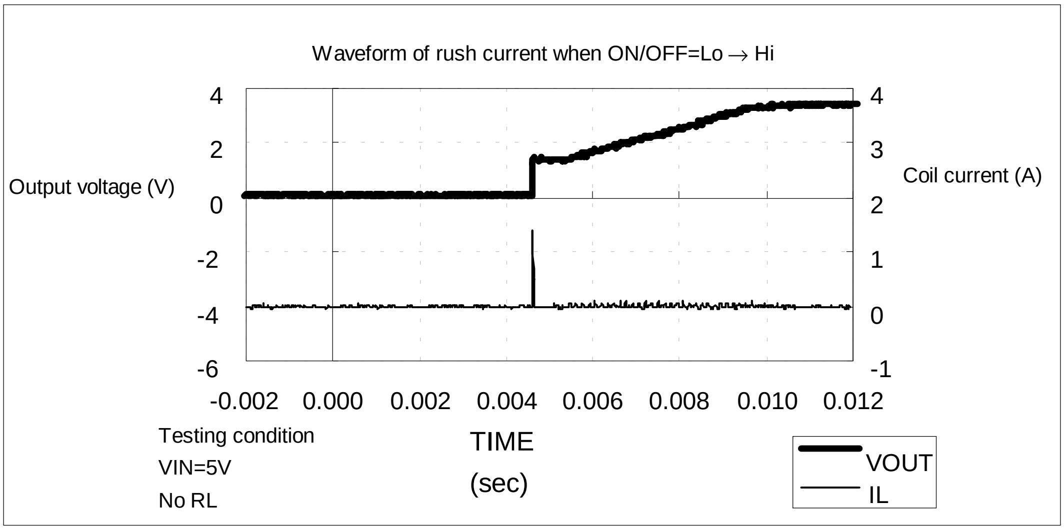
Cal No.: S-8520/21

Related documents:

Question:

At start-up, a large rush current flows from the input power source VIN. What countermeasures against this do you recommend?

Answer:

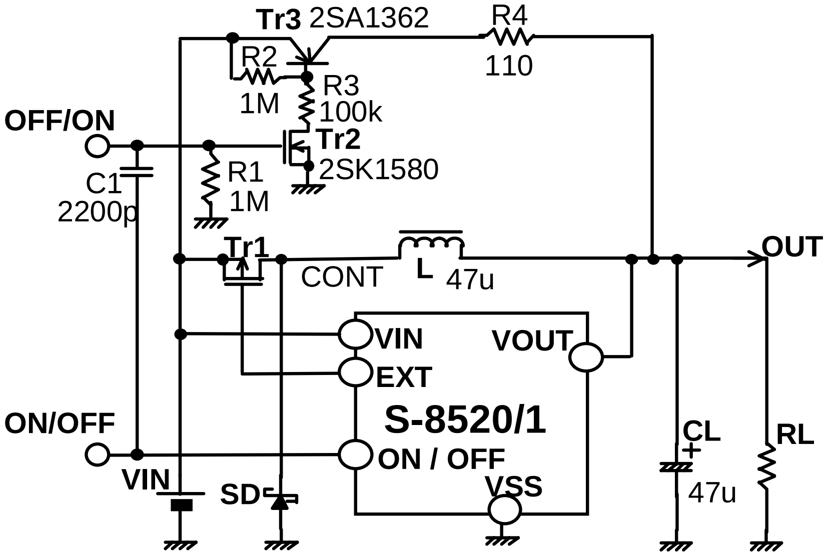


Conditions: S-8520B33, VIN=5V, No RL, Cout=47 μF

This shows the performance of IC. This IC includes a soft start-up circuit to ensure that the VREF voltage in the IC rises slowly from 0V to the base voltage. As a result, the output voltage rises slowly, suppressing the rush current at start-up.

However, the moment the voltage begins to drop, the VREF voltage and VOUT terminal voltage become 0V, making it impossible to control the output voltage normally. Increases in the output voltage need to be suppressed until the VREF voltage rises to a certain level. Then, as the VREF reaches certain voltage level, the output voltage rises instantaneously, causing a rush current.

One countermeasure for this is to add Tr's 2 and 3, R1~4, and C1, as shown in the figure below.



The basic concept of this countermeasure is that the same effect as with the soft start-up is obtained by charging CL from VIN via resistance R4, while ON/OFF keeps Tr1 in the UVLO circuit off coercively by Lo → Hi. Using C1 and R1, set a time constant for the desired off-time in the UVLO circuit (if possible, use the microcomputer to set the time constant by creating a delay time of the same period), and also, set the gradient of the voltage increase R4, so that a soft start-up is obtained.

Turn on Tr3 by turning on the small signal Tr2 for set amount of time, and charge CL by applying a (VIN-VOUT)/R4 current to OUT. The rush current will then be reduced.

<Remarks>

FAQ No.: 11S8520001