VFM STEP-UP DC/DC CONVERTER WITH VOLTAGE REGULATOR AND DETECTOR

RS5RJ SERIES

APPLICATION MANUAL

NO.EA-024-0006

VFM STEP-UP DC/DC CONVERTER WITH VOLTAGE REGULATOR AND DETECTOR

RS5RJ SERIES

OUTLINE

The RS5RJ series are step-up DC/DC converter ICs equipped with a voltage regulator (VR) and a voltage detector (VD) by CMOS process. Each of these step-up DC/DC converter ICs consists of a VFM DC/DC converter, a linear regulator and a voltage detector. These ICs are output-voltage-fixed type regulators which function as a linear regulator when input voltage is high, and as step-up DC/DC converter + linear regulator when input voltage is low, by using an inductor, a diode and a capacitor as external parts for the ICs.

Since a voltage detector is built in these ICs, the potentials such as the output voltage of DC/DC converters can be monitored.

In addition, these step-up DC/DC converter ICs are suitable for battery-powered and hand-held instruments because internal circuits can be turned off by the chip enable function so that the standby current can be minimized.

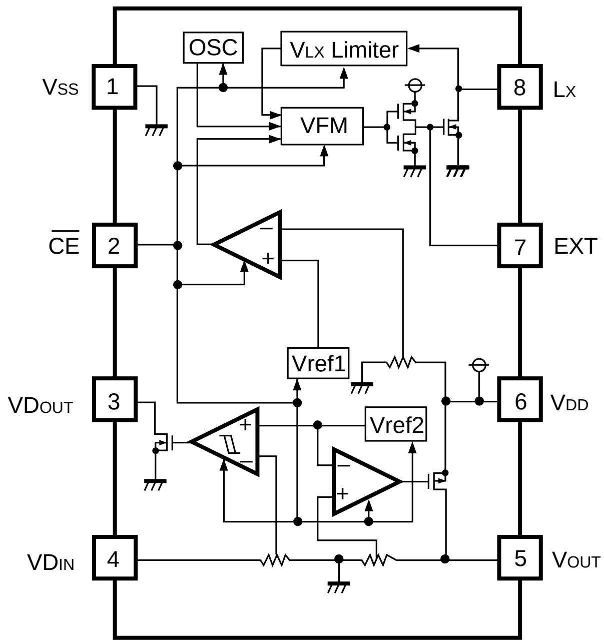
FEATURES

- Low Supply Current ············ TYP. 15µA (RS5RJ3624A : V_{IN}=3.0V,at no load)
- Standby Mode ············ Istandby=MAX. 1.0µA (RS5RJ××××A)
  Istandby=MAX. 10.0µA (RS5RJ××××B)
- Low Voltage Operation Possible ············ Operating Voltage V_{IN}=1.2V to 10V
- High Output Voltage Accuracy ············ Fixed Output Voltage Accuracy±2.5%
- High Detector Threshold Accuracy ············ ±2.5%
- Output Voltage can be set at User's request (refer to Selection Guide).
- Voltage close to battery's voltage can be output because these ICs are of a step-up / step-down type (Ex. a fixed voltage of 3V can be output by a 3V battery).
- Built-in Protection Circuits for Lx Driver
- Pin for External Driver is equipped, and a large current output can be obtained.
- Small Package ············ 8pin SOP

APPLICATIONS

- Power source for cameras, camcorders, and hand-held audio equipment.
- Power source for small OA apparatus such as note type personal computers,and word processors.
- Power source for hand-held communication appliances such as pagers,cordless telephones, and cellular phones.

BLOCK DIAGRAM



SELECTION GUIDE

In the RS5RJ Series, the output voltage, the detector threshold, the version symbols, and the taping type for the ICs can be selected at the user's request.

The selection can be made by designating the part number as shown below:

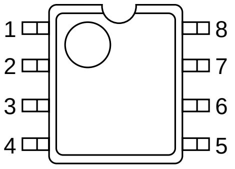
RS5RJ××××× – ×× ← Part Number
↑ ↑ ↑ ↑
a b c d

Code	Contens
a	Setting Output Voltage (V_{OUT}): Stepwise setting with a step of 0.6V in the range of 1.5V to 6.0V is possible.
b	Setting Detector Threshold Voltage ($-V_{DET}$): Stepwise setting with a step of 0.1V in the range of 1.2V to 5.0V is possible.
c	Designation of Version Symbols: A: Operation of all the internal circuits is stopped by setting $\overline{CE}$ pin at V_{DD} level. B: Operation of only Step-up DC/DC converter is stopped by setting $\overline{CE}$ pin atV_{DD} level.
d	Designation of Taping Type: Ex. 8pin SOP : T1, T2 (refer to Taping Specification) “T2” is prescribed as a standard.

For example, the product with Output Voltage 5.0V, Detector Threshold 4.5V, Version A, and Taping Type T1, is designated by Part Number RS5RJ5045A-T1.

PIN CONFIGURATION

• **8pin SOP**



PIN DESCRIPTION

Pin No.	Symbol	Pin Description
1	V_{SS}	Ground Pin
2	$\overline{CE}$	Chip Enable Pin
3	VD_{OUT}	Voltage Detector Output Pin.Nch Open Drain Output
4	VD_{IN}	Detection Input Pin of Voltage Detector
5	V_{OUT}	Output Pin for Regulator
6	V_{DD}	Step-up Output. Power Supply Pin
7	EXT	External Transistor Drive Pin
8	L_X	External Inductor Drive Pin.

ABSOLUTE MAXIMUM RATINGS

Topt=25°C,Vss=0V

Symbol	Item			Rating	Unit
V_{DD}	Supply Voltage			–0.3 to +12	V
V_{LX}	Output Voltage	Lx Pin Voltage		Vss–0.3 to +12	V
V_{EXT}		EXT Pin Voltage		Vss–0.3 to V_{DD}+0.3	V
V_{OUT}		V_{OUT} Pin Voltage		Vss–0.3 to V_{DD}+0.3	V
VD_{OUT}		VD_{OUT} Pin Voltage		Vss–0.3 to +12	V
V_{CE}	Input Voltage	$\overline{CE}$ Pin Voltage		Vss–0.3 to V_{DD}+0.3	V
VD_{IN}		VD_{IN} Pin Voltage	A Version	Vss–0.3 to V_{DD}+0.3	V
			B Version	Vss–0.3 to +12	
I_{LX}	Inductor Drive Output Current	Lx Pin Current		250	mA
I_{EXT}		EXT Pin Current		50	mA
P_D	Power Dissipation			300	mW
Topt	Operating Temperature Range			–30 to +80	°C
Tstg	Storage Temperature Range			–55 to +125	°C
Tsolder	Lead Temperature (Soldering)			260°C, 10s	

ABSOLUTE MAXIMUM RATINGS

Absolute Maximum ratings are threshold limit values that must not be exceeded even for an instant under any conditions. Moreover, such values for any two items must not be reached simultaneously. Operation above these absolute maximum ratings may cause degradation or permanent damage to the device. These are stress ratings only and do not necessarily imply functional operation below these limits.

ELECTRICAL CHARACTERISTICS

• RS5RJ3624A,B

Topt=25°C

Symbol	Item	Conditions	MIN.	TYP.	MAX.	Unit	Note
V_{IN}	Operation Input Voltage	No load	1.2		10	V	
V_{DD}	Step-up Output Voltage	No load	3.99	4.1	4.21	V	
Voscst	Oscillator Start-up Voltage	No load		0.9	1.2	V	
Vhold	Hold-on Voltage	I_{OUT}=1mA	0.7			V	
fosc	MaximumOscillator Frequency		80	100	120	kHz	
Maxdty	Oscillator Duty Cycle		65	80	90	%	
V_{OL1}	Lx Output Voltage	I_{OL}=50mA			0.5	V	
I_{OH1}	Lx Leakage Current			0.01	10	µA	
V_{LXlim}	Lx Voltage Limit	Lx Pin On		0.9		V	
V_{OH}	EXT Output Pch ON Voltage	I_{EXT}=–3mA,V_{DD}=4.1V	3.6			V	
V_{OL2}	EXT Output Nch ON Voltage	I_{EXT}=5mA,V_{DD}=4.1V			0.5	V	
V_{OUT}	Output Voltage	I_{RL}=–5mA	3.51	3.6	3.69	V	
V_{DIF}	Dropout Voltage	I_{RL}=–30mA		0.3		V	
$\Delta V_{OUT}/\Delta I_{OUT}$	Load Regulation	–30mA≤I_{RL}≤0mA			100	mV	
$-V_{DET}$	Detector Threshold		2.34	2.4	2.46	V	
V_{HYS}	Detector Threshold Hysteresis		60	120	240	mV	
V_{OL3}	VD_{OUT} ON Voltage	I_{OL}=5mA			0.5	V	
I_{OH2}	VD_{OUT} Leakage Current			0.01	5	µA	
I_{VDINH}	VD_{IN} “H” Input Current	VD_{IN}=V_{DD}			5	µA	
I_{VDINL}	VD_{IN} “L” Input Current	VD_{IN}=Vss	–0.5		0.5	µA	
V_{CEH}	$\overline{CE}$ “H” Input Voltage		V_{DD}–0.3		V_{DD}	V	
V_{CEL}	$\overline{CE}$ “L” Input Voltage		0		0.2V_{DD}	V	
I_{CEH}	$\overline{CE}$ “H” Input Current	$\overline{CE}$=V_{DD}	–0.5		0.5	µA	
I_{CEL}	$\overline{CE}$ “L” Input Current	$\overline{CE}$=Vss	–0.5		0.5	µA	
I_{DD}	Supply Current	V_{IN}=3V, L=100µH, C=22µF, $\overline{CE}$=Vss, No load		15	30	µA	
Istandby	Standby Current	V_{IN}=3V, L=100µH, C=22µF, $\overline{CE}$=V_{DD}, No load			1.0	µA	Note1
					10.0	µA	Note2

(Note 1) Standby current of Version A
(Note 2) Standby current of Version B
Please refer to Basic Circuit for Test Circuit.

• RS5RJ5045A,B

Topt=25°C

Symbol	Item	Conditions	MIN.	TYP.	MAX.	Unit	Note
V_{IN}	Operation Input Voltage	No load	1.2		10	V	
V_{DD}	Step-up Output Voltage	No load	5.36	5.5	5.64	V	
Voscst	Oscillator Start-up Voltage	No load		0.9	1.2	V	
Vhold	Hold-on Voltage	I_{OUT}=1mA	0.7			V	
fosc	MaximumOscillator Frequency		80	100	120	kHz	
Maxdty	Oscillator Duty Cycle		65	80	90	%	
V_{OL1}	Lx Output Voltage	I_{OL}=50mA			0.5	V	
I_{OH1}	Lx Leakage Current			0.01	10	µA	
V_{LXlim}	Lx Voltage Limit	Lx Pin On		0.9		V	
V_{OH}	EXT Output Pch ON Voltage	I_{EXT}=−3mA,V_{DD}=5.5V	5.0			V	
V_{OL2}	EXT Output Nch ON Voltage	I_{EXT}=5mA,V_{DD}=5.5V			0.5	V	
V_{OUT}	Output Voltage	I_{RL}=−5mA	4.87	5.0	5.13	V	
V_{DIF}	Dropout Voltage	I_{RL}=−30mA		0.3		V	
$\Delta V_{OUT}/\Delta I_{OUT}$	Load Regulation	−30mA≤I_{RL}≤0mA			100	mV	
$-V_{DET}$	Detector Threshold		4.38	4.5	4.62	V	
V_{HYS}	Detector Threshold Hysteresis		112	225	450	mV	
V_{OL3}	VD_{OUT} ON Voltage	I_{OL}=5mA			0.5	V	
I_{OH2}	VD_{OUT} Leakage Current			0.01	5	µA	
I_{VDINH}	VD_{IN} "H" Input Current	VD_{IN}=V_{DD}			5	µA	
I_{VDINL}	VD_{IN} "L" Input Current	VD_{IN}=Vss	−0.5		0.5	µA	
V_{CEH}	$\overline{CE}$ "H" Input Voltage		V_{DD}−0.3		V_{DD}	V	
V_{CEL}	$\overline{CE}$ "L" Input Voltage		0		0.2V_{DD}	V	
I_{CEH}	$\overline{CE}$ "H" Input Current	$\overline{CE}$=V_{DD}	−0.5		0.5	µA	
I_{CEL}	$\overline{CE}$ "L" Input Current	$\overline{CE}$=Vss	−0.5		0.5	µA	
I_{DD}	Supply Current	V_{IN}=4V, L=100µH, C=22µF, $\overline{CE}$=Vss, No load		20	40	µA	
Istandby	Standby Current	V_{IN}=4V, L=100µH, C=22µF, $\overline{CE}$=V_{DD}, No load			1.0	µA	Note1
					10.0	µA	Note2

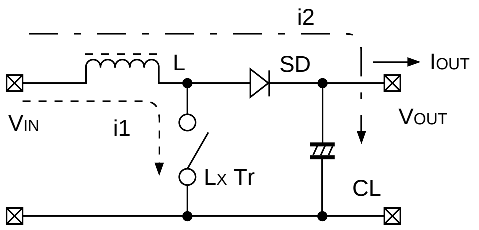
(Note 1) Standby current of Version A
(Note 2) Standby current of Version B
Please refer to Basic Circuit for Test Circuit.

OPERATION OF STEP-UP DC/DC CONVERTER

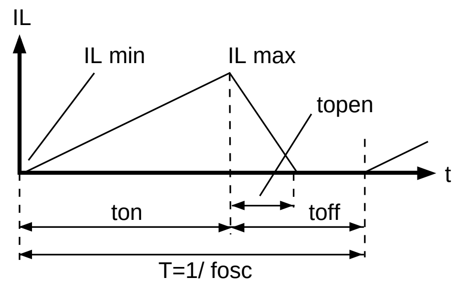
Step-up DC/DC Converter charges energy in the inductor when Lx Transistor (LxTr) is ON, and discharges the energy with the addition of the energy from Input Power Source thereto when LxTr is off, so that a higher output voltage than the input voltage is obtained.

The operation will be explained with reference to the following diagrams:

< Basic Circuits >



< Current through L >



Step.1 : LxTr is turned on and current IL (= i1) flows, so that energy is charged in L. At this moment, IL(=i1) is increased from ILmin (= 0) to reach ILmax in proportion to the on-time period (ton) of LxTr.

Step.2 : When LxTr is turned off, Schottky diode (SD) is turned on in order that L maintains IL at ILmax, so that current IL (= i2) is released.

Step.3 : IL (=i2) is gradually decreased, and in the case of discontinuous mode, IL reaches ILmin (=0) after a time period of topen, so that SD is turned off.

In the case of the VFM control system, with the on-time period (ton) maintained constant, the output voltage is maintained constant by controlling the oscillator frequency (fosc).

OPERATION

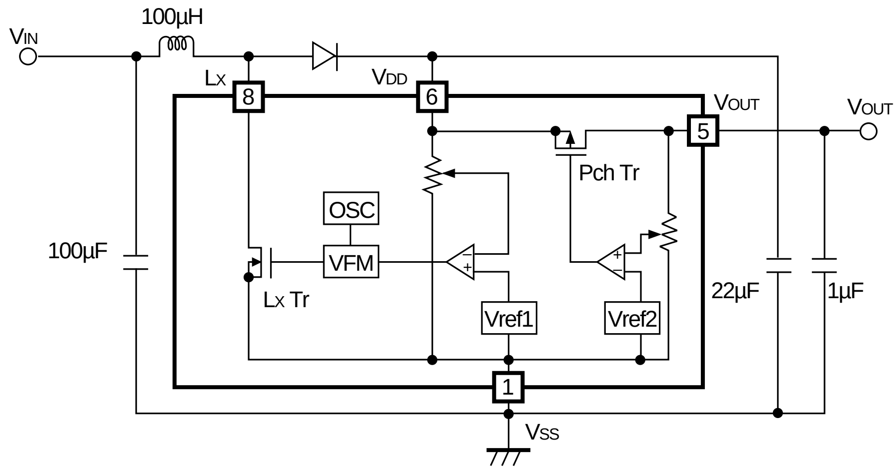


FIG. A Diagram of RS5RJ including external circuits

1. V_{DD} Output Voltage

V_{DD} output voltage is shown in Fig. B.

(1) In the case of V_{IN}–Vf≥V_{DD}0:

In Area B, LxTr is maintained in an OFF state, so that V_{IN}–Vf (V) is output as it is from V_{DD} pin without step-up operation.

(2) In the case of V_{IN}–Vf <V_{DD}0:

In Area A, this IC functions as Step-up DC/DC converter. The step-up operation will now be explained with reference to FIG. A. The step-up operation is an operation for regulating the V_{DD} output voltage by comparing Vref1 and the V_{DD} output voltage by error amplifier circuits and subjecting LxTr to on-time control by VFM circuits (i.e., by controlling the step-up operation).

2. V_{OUT} Output Voltage

A constant voltage is output from V_{OUT} pin, with above-mentioned the V_{DD} output voltage being subjected to a step-down operation by a linear regulator. This step-down operation will now be explained with reference to FIG. A. The step-down operation is an operation for regulating the V_{DD} output voltage by Pch Tr by comparing Vref2 and the V_{DD} output voltage.

V_{IN}	: Input Voltage
V_{DD}0	: V_{DD} Set Voltage
V_{OUT}0	: V_{OUT} Set Voltage
Vf	: ON Voltage of Diode

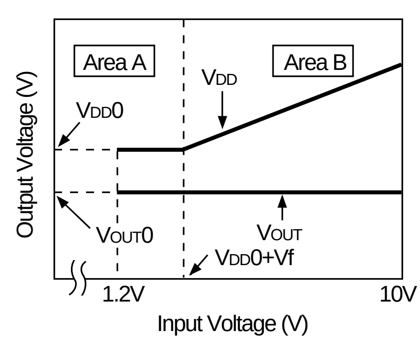
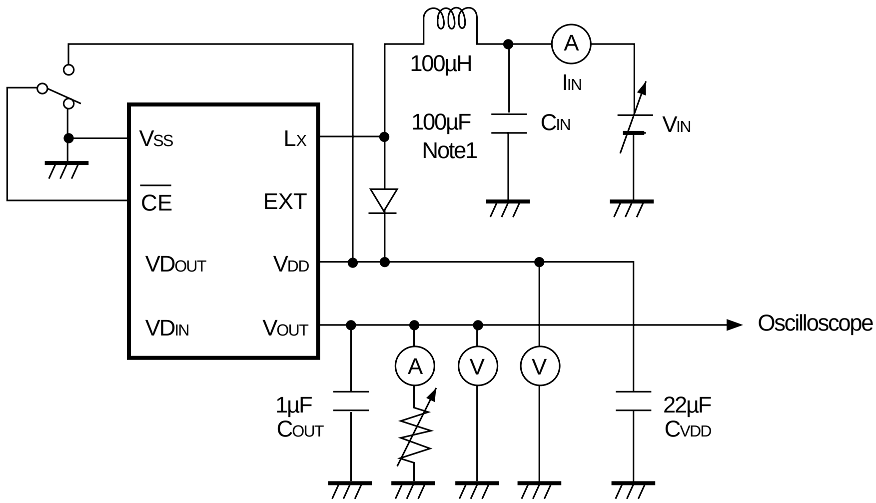
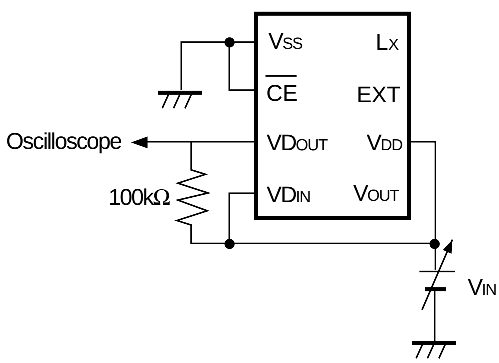


FIG. B Output Voltage vs. Input Voltage characteristic

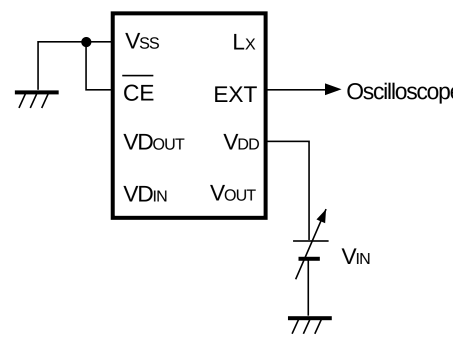
TEST CIRCUITS



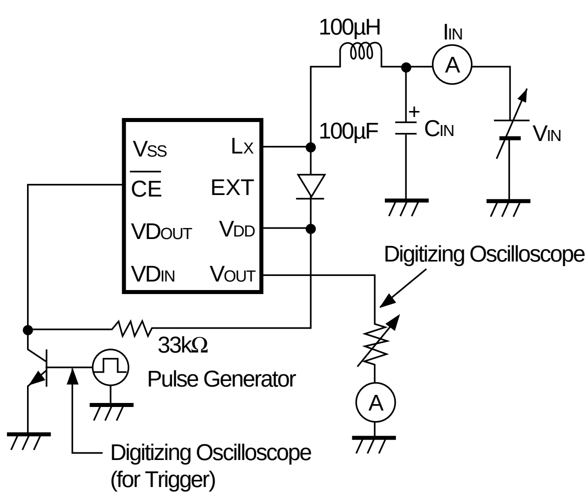
Test Circuit 1



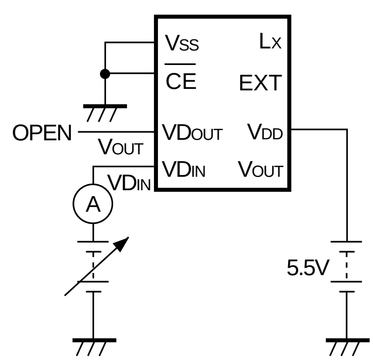
Test Circuit 2



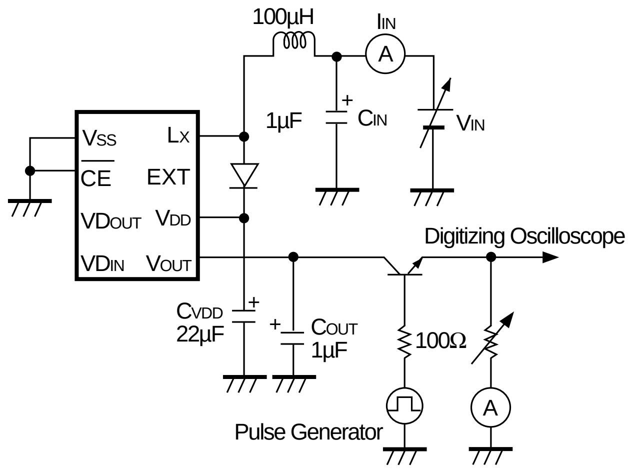
Test Circuit 3



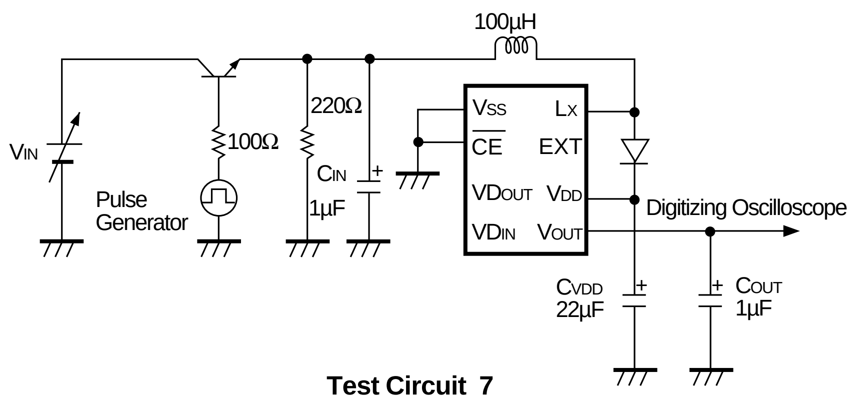
Test Circuit 4



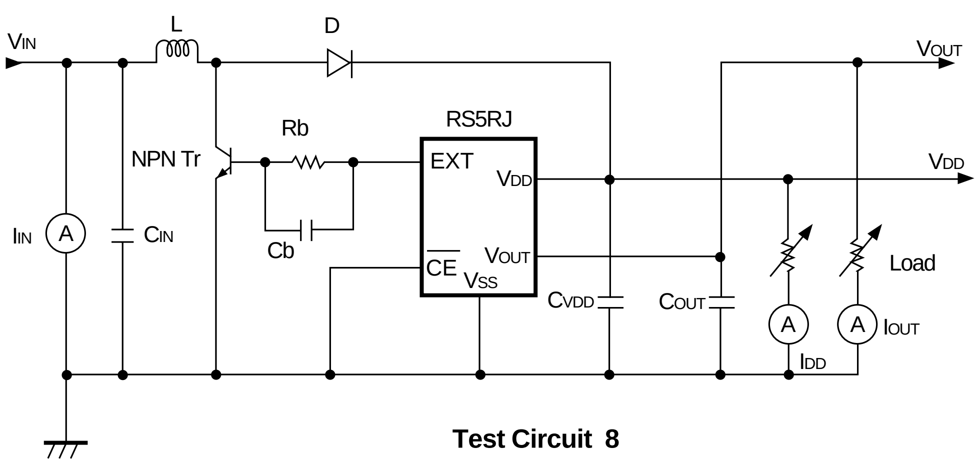
Test Circuit 5



Test Circuit 6



Test Circuit 7



Test Circuit 8

L	:47µH(SUMIDA ELECTRIC CD105)	Cb	:0.01µF
D	:Schottky Diode (HITACHI HRP22)	CVDD	:220µF(Aluminum electroltic Type)
CIN	:220µF(Aluminum electrolytic Type)	COUT	:1µF(Tantalum Type)
Rb	:220Ω		

By use of these test circuits,the typical characteristics were obtained as shown in the following pages:

Test Circuit 1: Typical Characteristics 1) 2) 3) 4) 5) 9) 10) 13) 14) 16)
(Typical Characteristics 13) and 14) were measured by replacing the capacitor shown in Note1 with a 1μF Capacitor)

Test Circuit 2: Typical Characteristics 11) 12)

Test Circuit 3: Typical Characteristics 7) 8)
Efficiency η is shown by the following formula:
$\eta = (V_{OUT} \times I_{OUT}) / (V_{IN} \times I_{IN})$

Test Circuit 4: Typical Characteristics 6)

Test Circuit 5: Typical Characteristics 15)

Test Circuit 6: Typical Characteristics 17)

Test Circuit 7: Typical Characteristics 18)

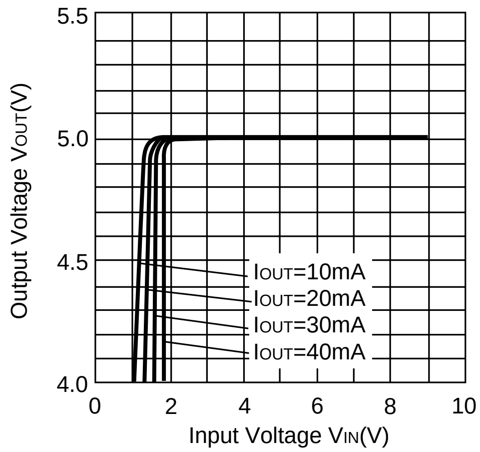
Test Circuit 8: Typical Characteristics 19) 20)

In this IC, input current at no load is defined as supply current.($\overline{CE}=V_{SS}$).
And when $\overline{CE}=V_{DD}$, the input current (no load) is defined as standby current.

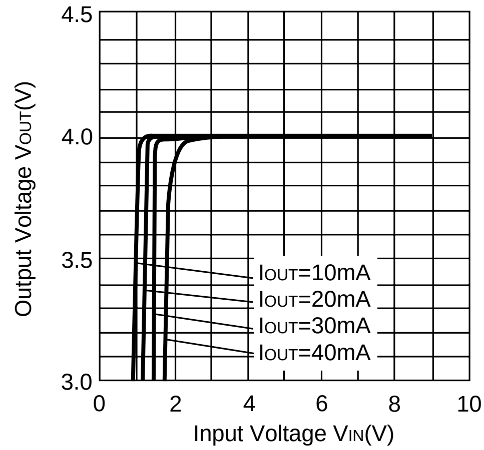
TYPICAL CHARACTERISTICS

1) Output Voltage vs. Input Voltage (Topt=25˚C)

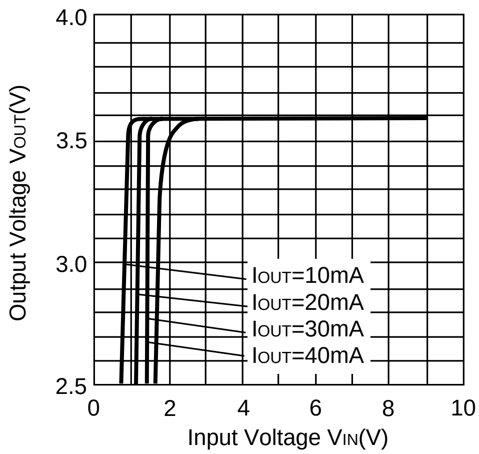
RS5RJ5045A



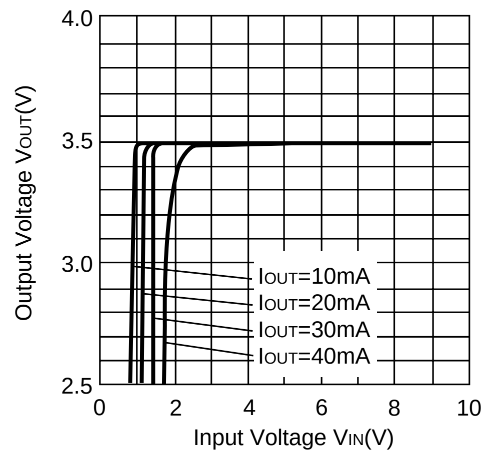
RS5RJ4036A



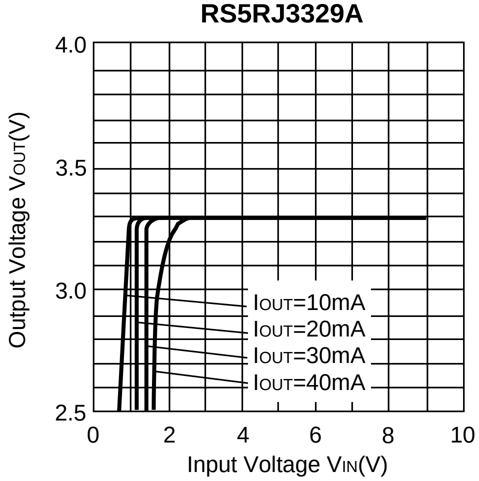
RS5RJ3624A



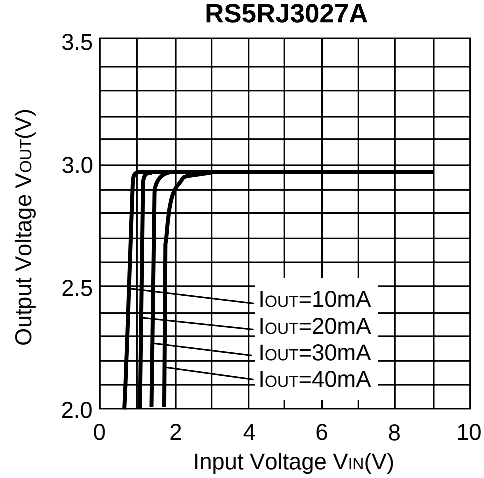
RS5RJ3531A



RS5RJ3329A

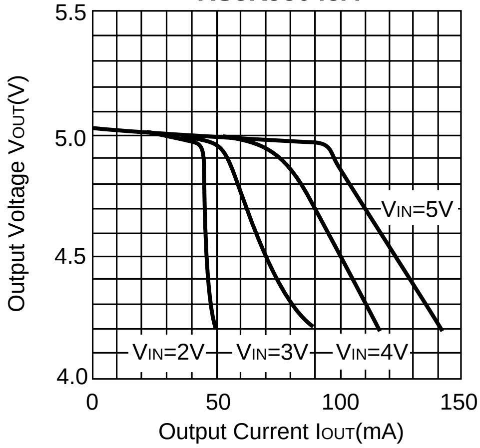


RS5RJ3027A

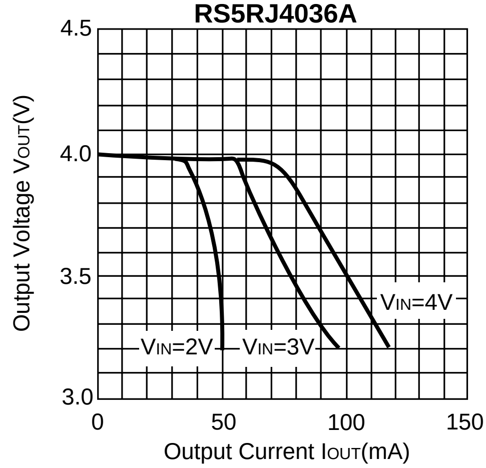


2) Output Voltage vs. Output Current (Topt=25°C)

RS5RJ5045A



RS5RJ4036A



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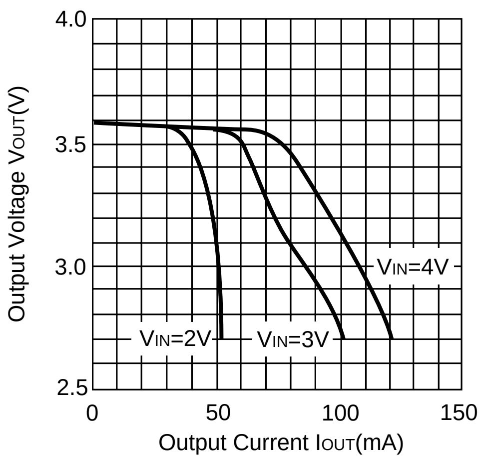
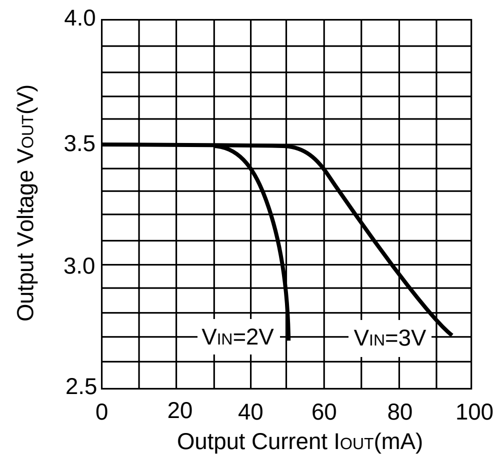


RS5RJ3531A



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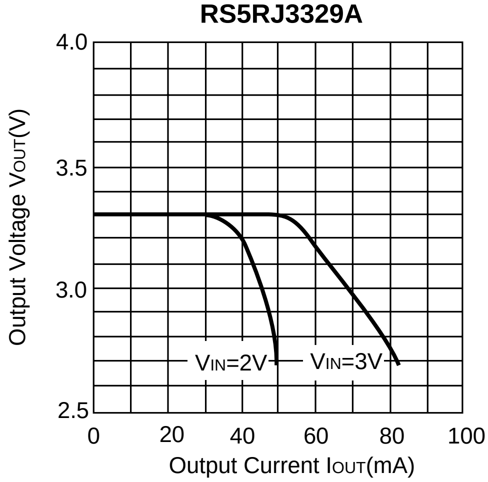
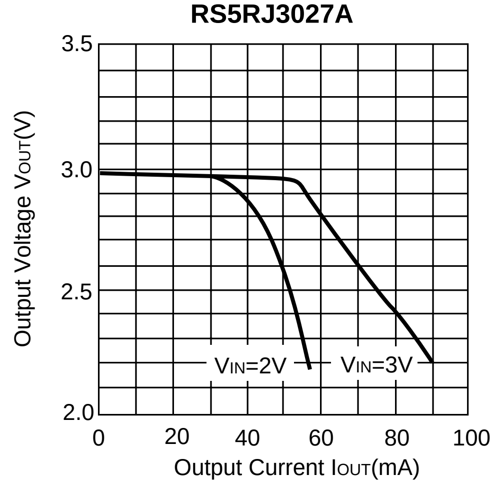
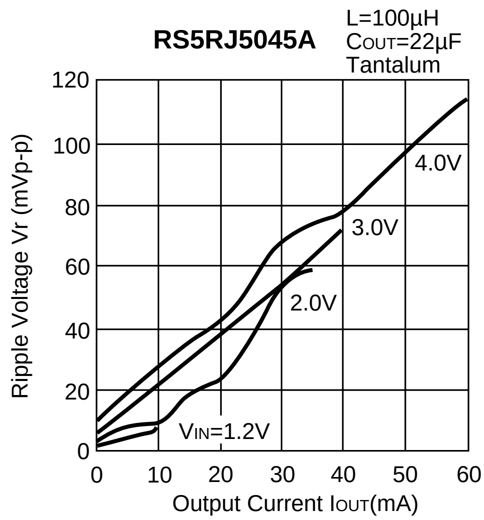
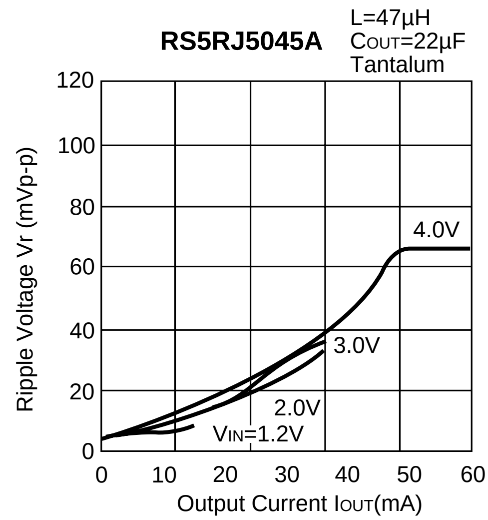


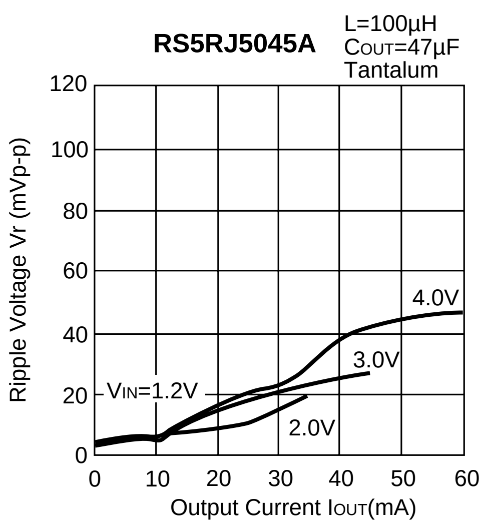
RS5RJ3027A

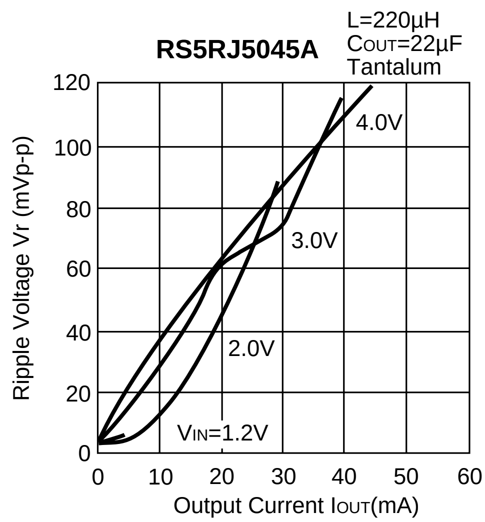


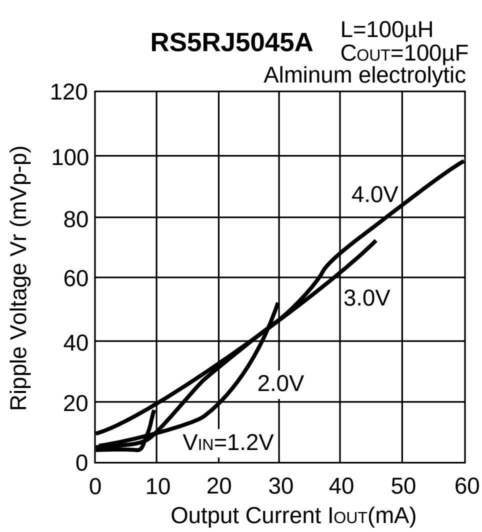
3) Ripple Voltage vs. Output Current (Topt=25˚C)





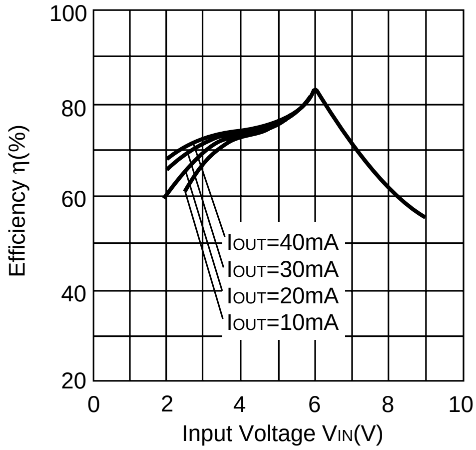




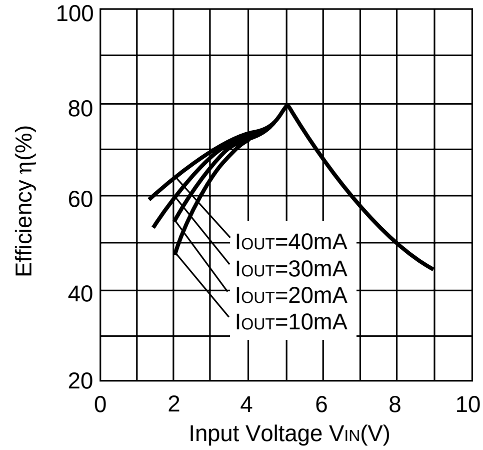


4) Efficiency vs. Input Voltage (Topt=25°C)

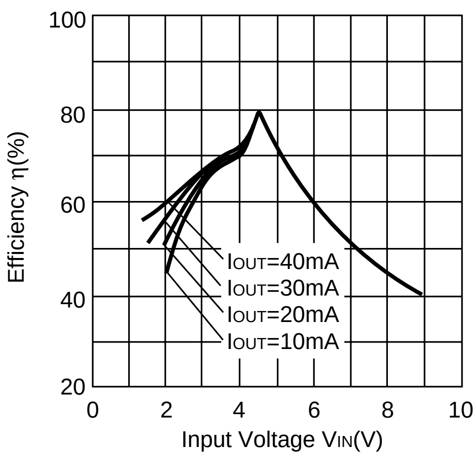
RS5RJ5045A



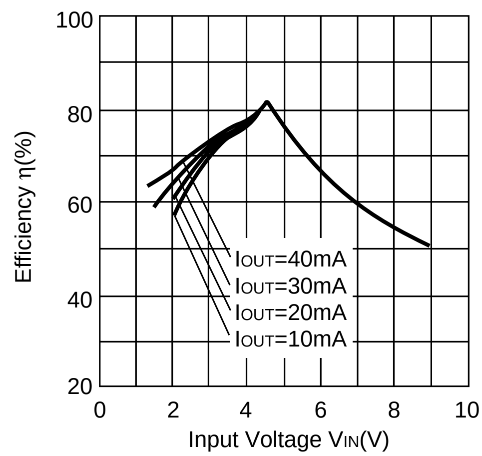
RS5RJ4036A



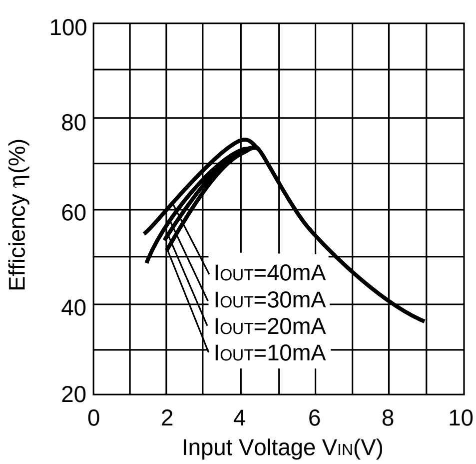
RS5RJ3624A



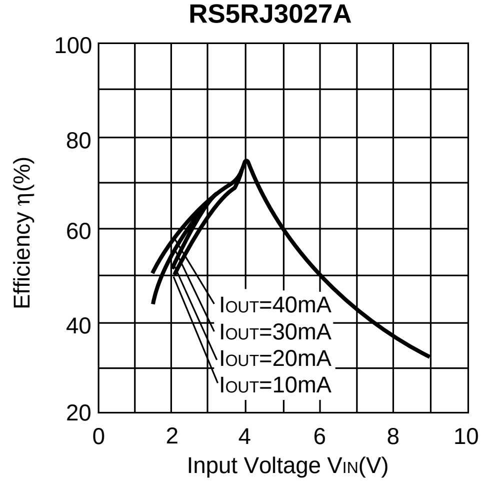
RS5RJ3531A



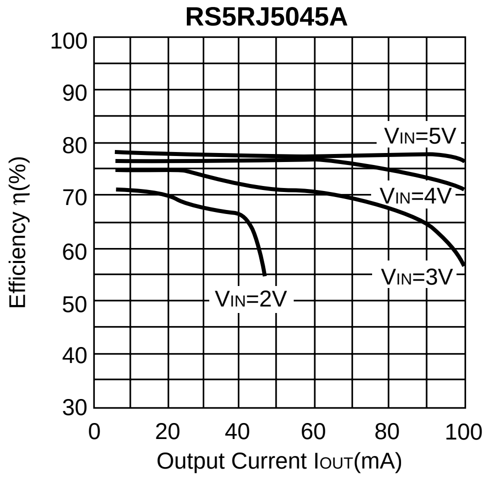
RS5RJ3329A

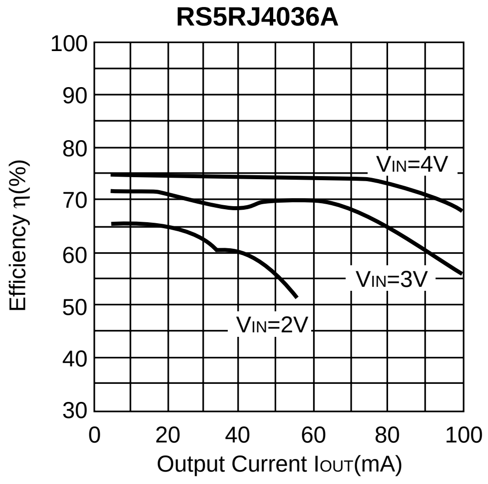


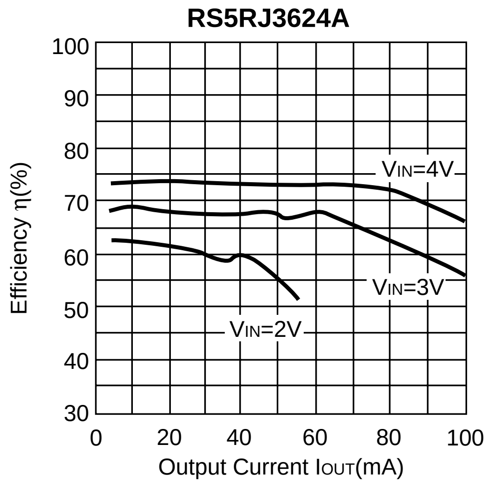
RS5RJ3027A

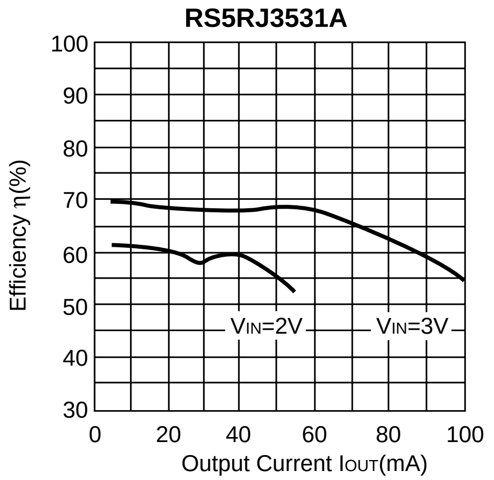


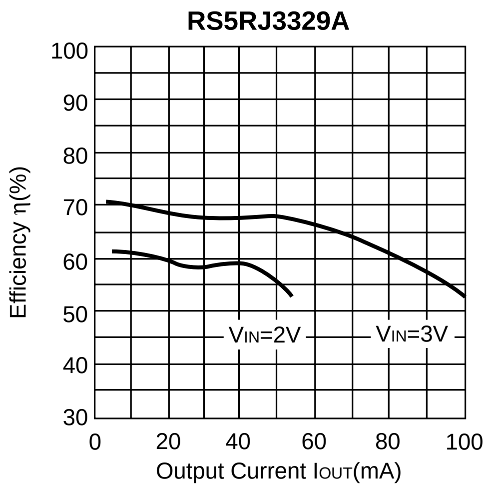
5) Efficiency vs. Output Voltage (Topt=25°C)

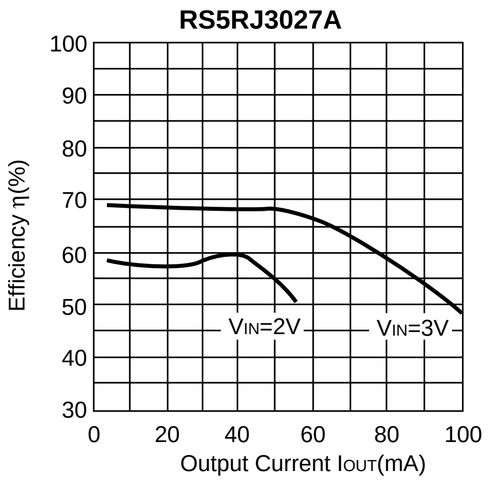




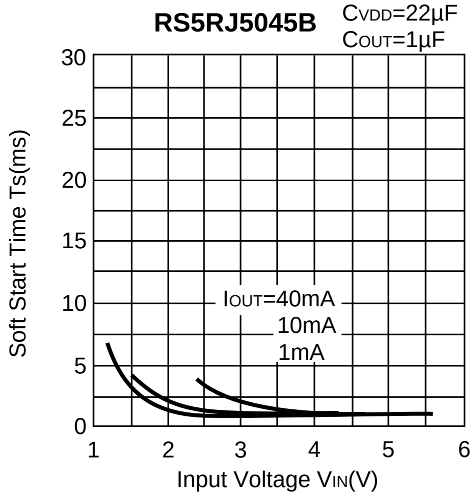


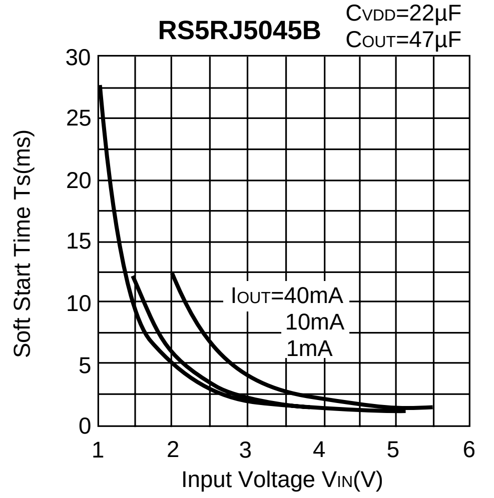


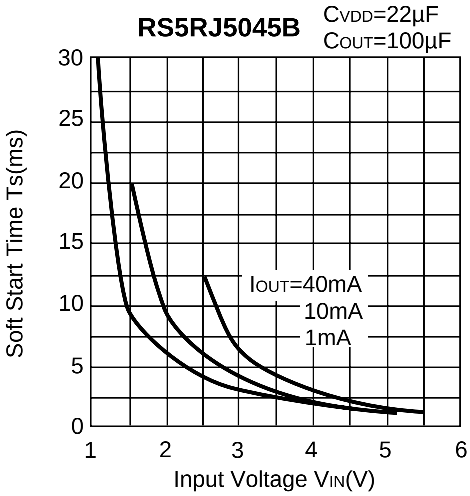




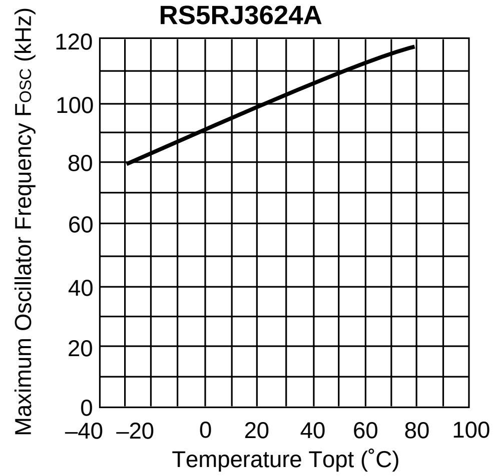
6) Soft Start Time vs. Input Voltage



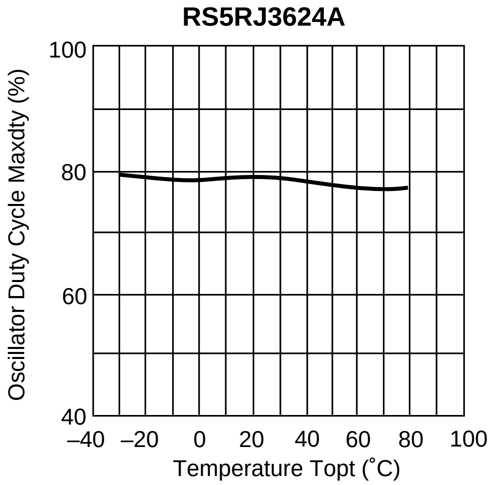




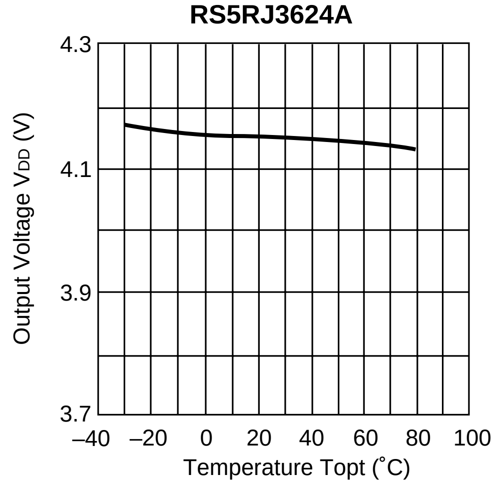
7) Maximum Oscillator Frequency vs. Temperature



8) Oscillator Duty Cycle vs.Temperature

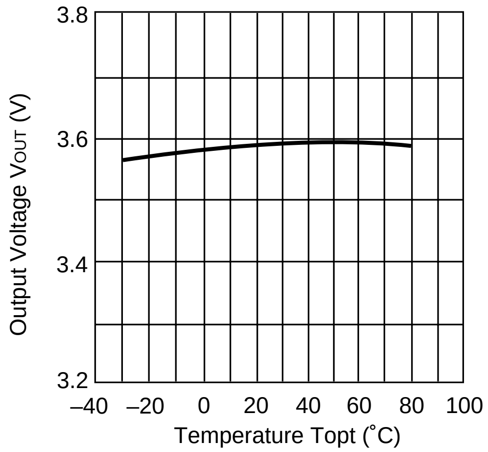


9) Output Voltage (VDD) vs.Temperature



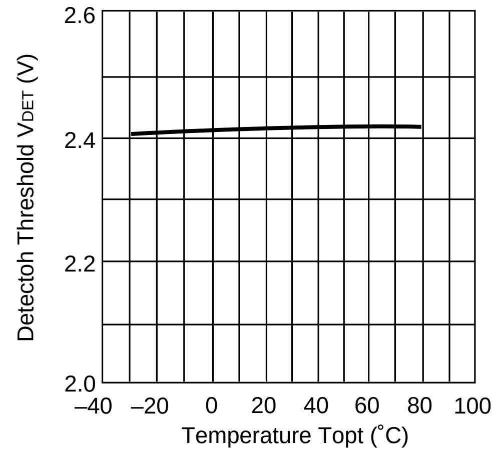
10) Output Voltage vs. Temperature

RS5RJ3624A



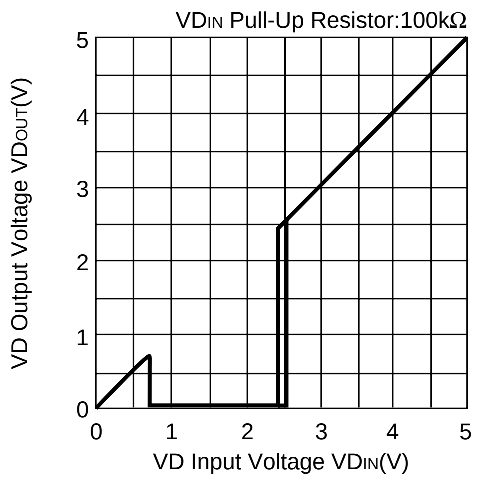
11) Detector Threshold vs. Temperature

RS5RJ3624A



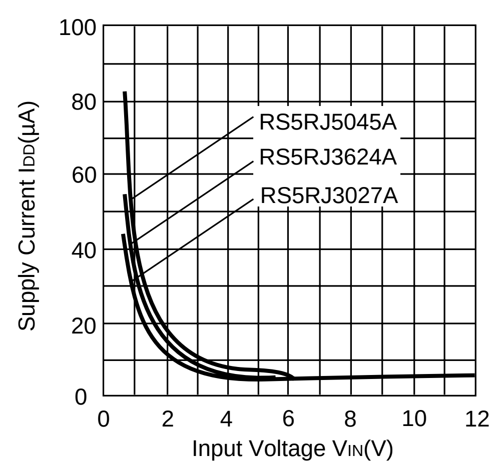
12) VD Output Voltage vs. VD Input Voltage

RS5RJ3624A



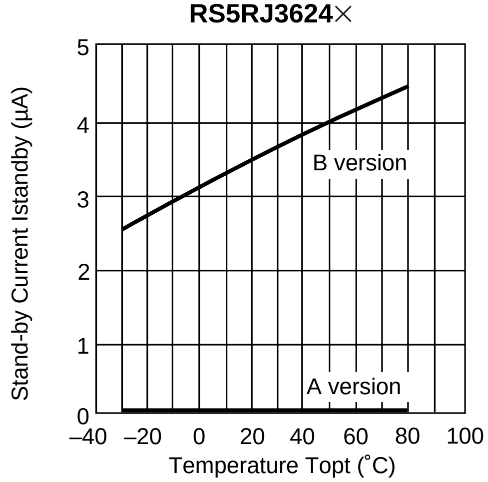
13) Supply Current vs. Input Voltage

RS5RJ××××A



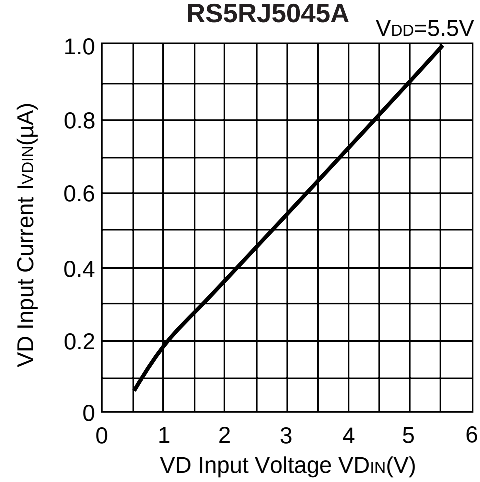
14) Stand-by Current vs.Temperature

RS5RJ3624×

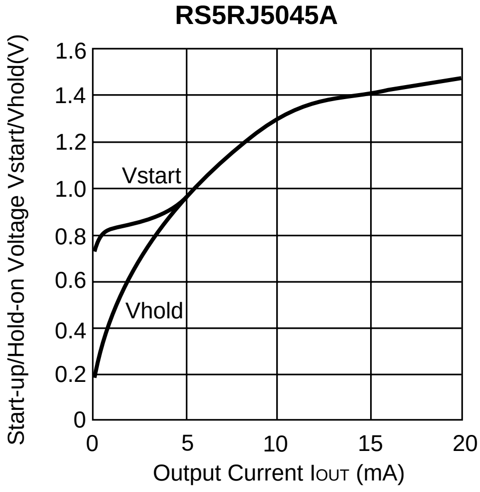


15) VD Input Current vs. VD Input Voltage

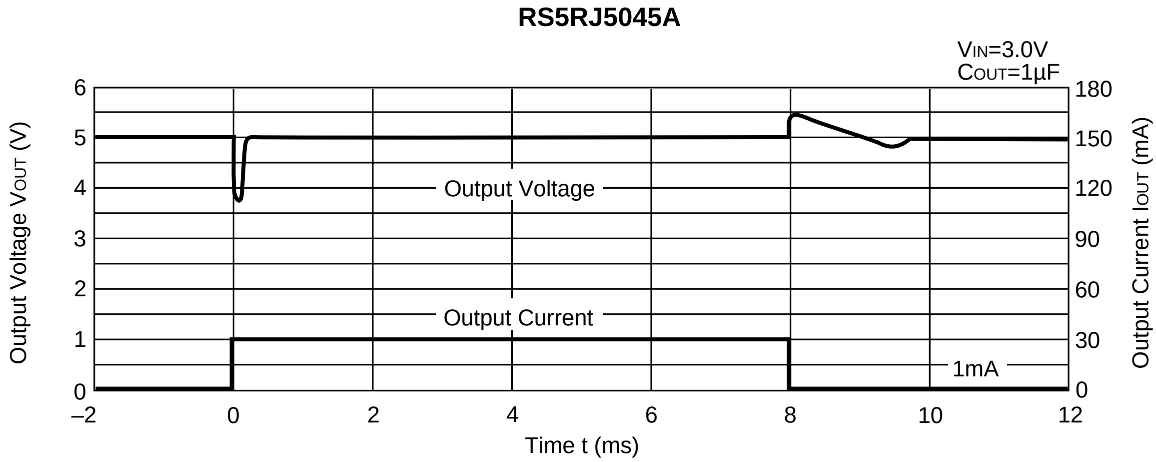
RS5RJ5045A

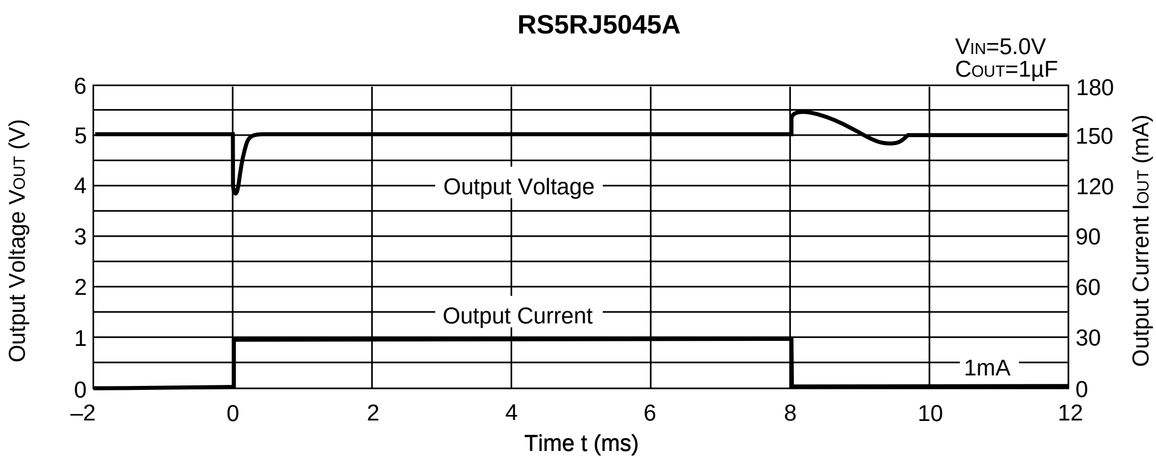


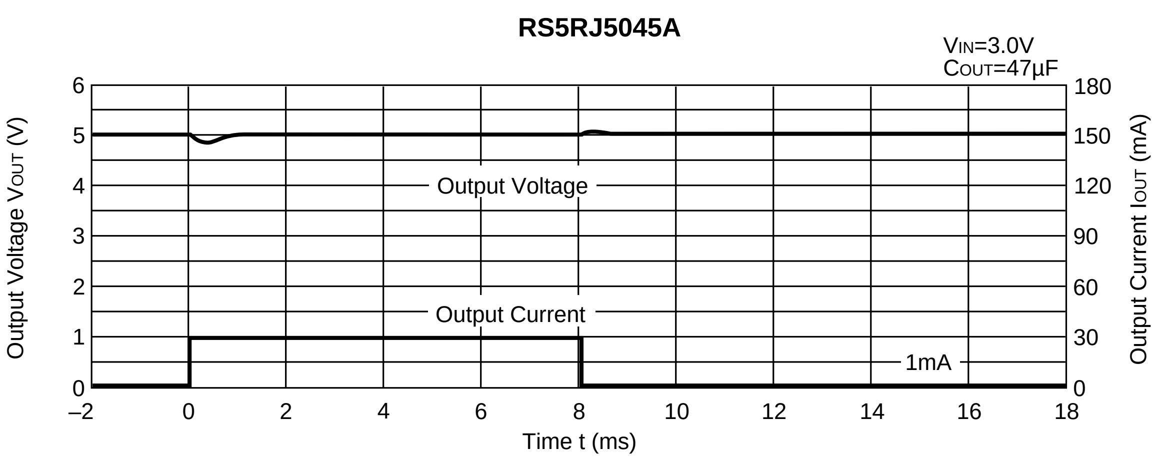
16) Start-up/Hold-on Voltage vs. Output Current



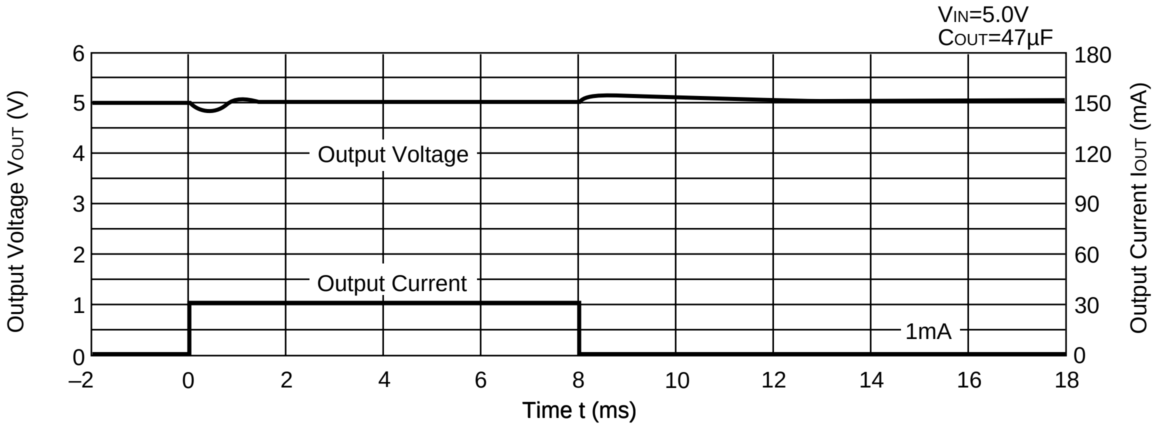
17) Load Transient Response



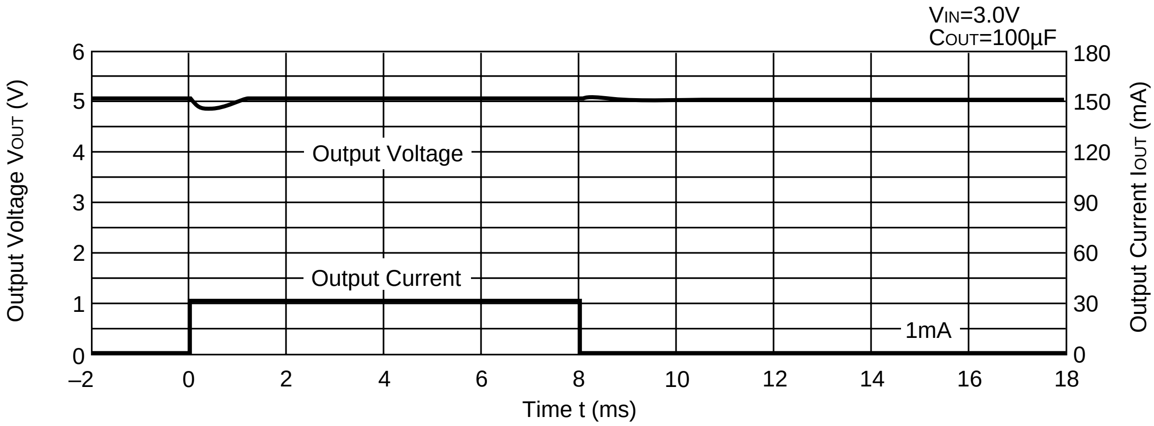




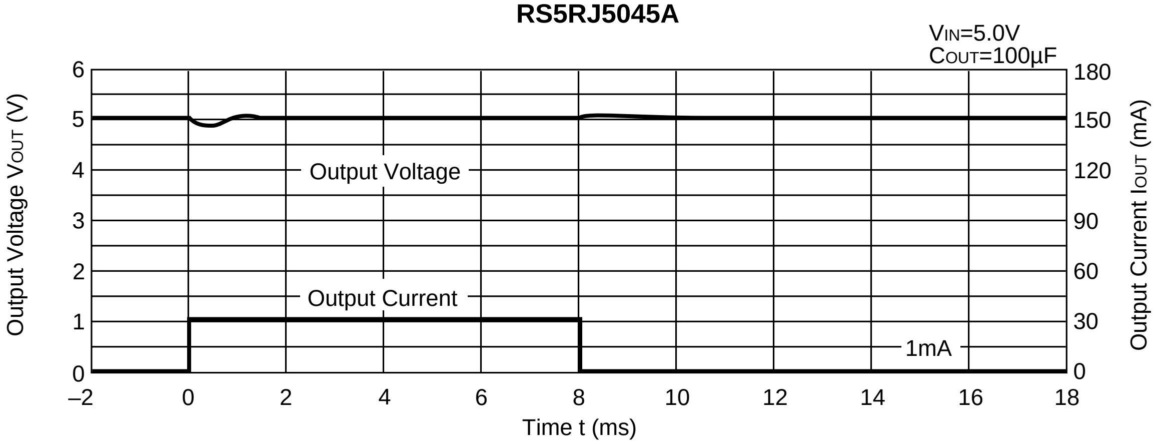
RS5RJ5045A



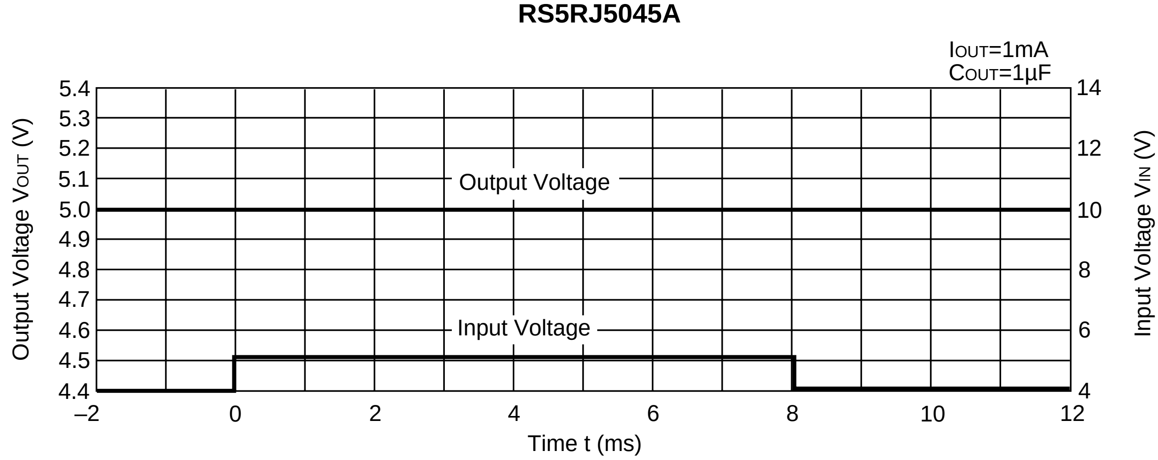
RS5RJ5045A

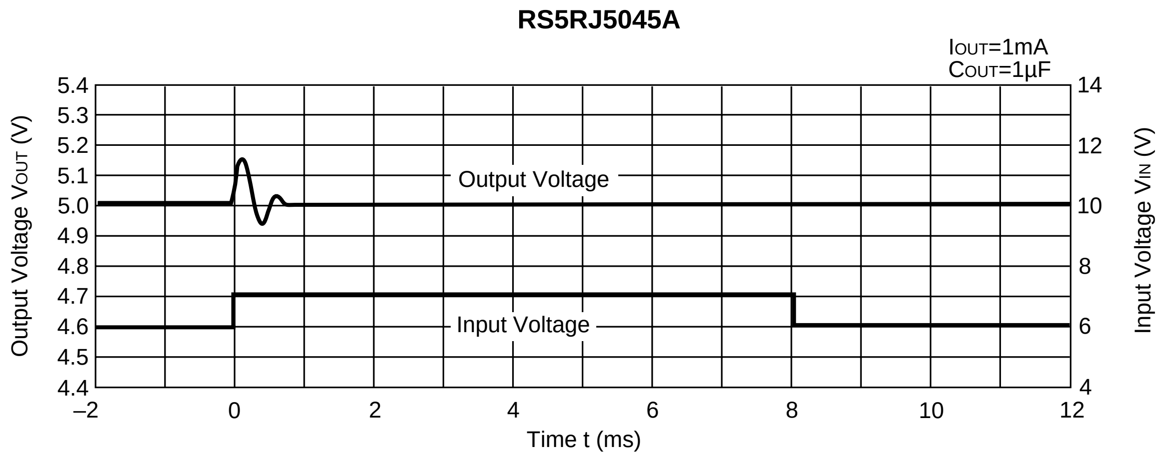


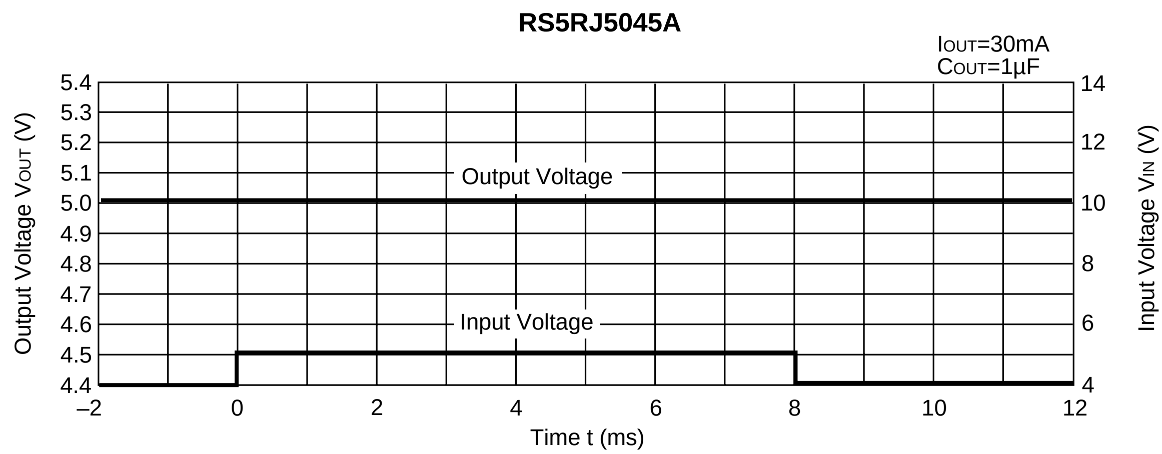
RS5RJ5045A



18) Line Transient Response

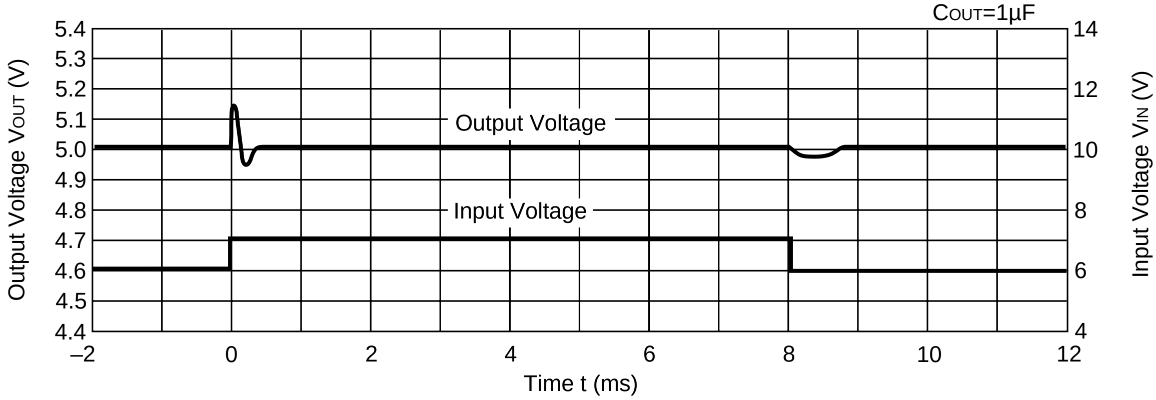






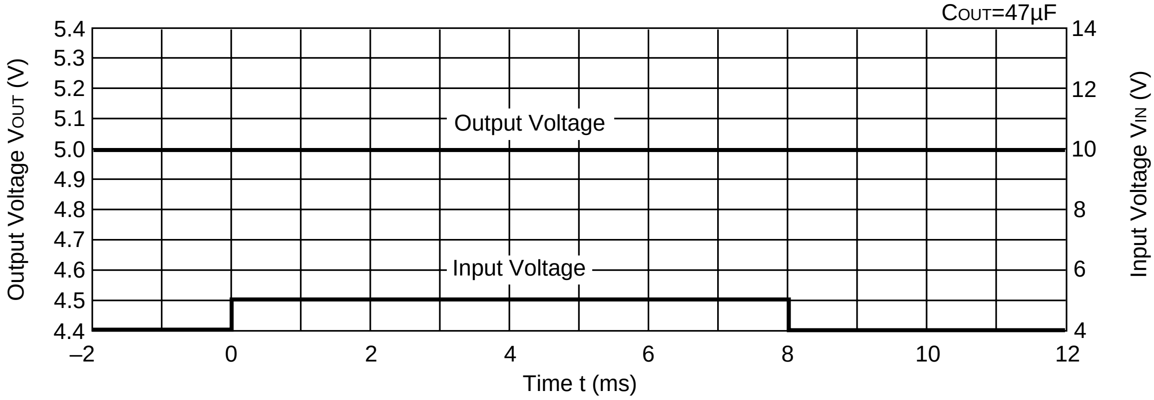
RS5RJ5045A

I_{OUT}=30mA
C_{OUT}=1µF



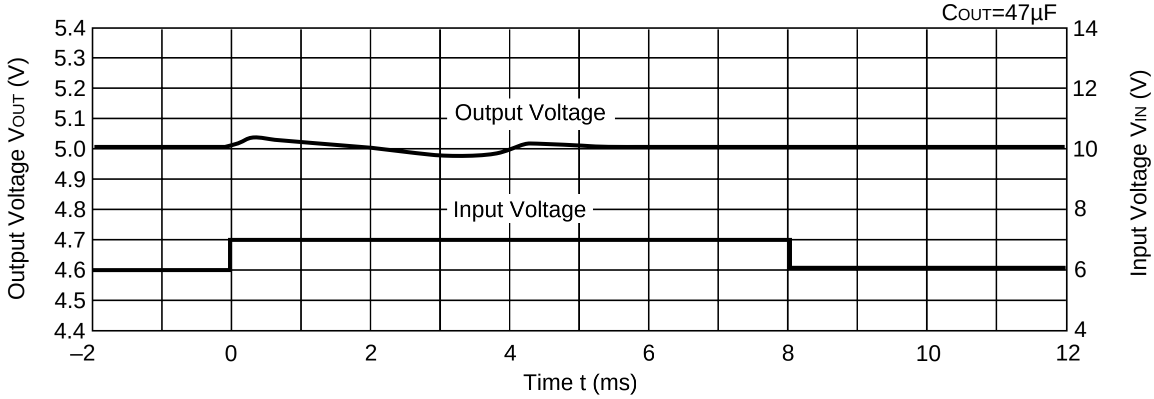
RS5RJ5045A

I_{OUT}=1mA
C_{OUT}=47µF



RS5RJ5045A

I_{OUT}=1mA
C_{OUT}=47µF



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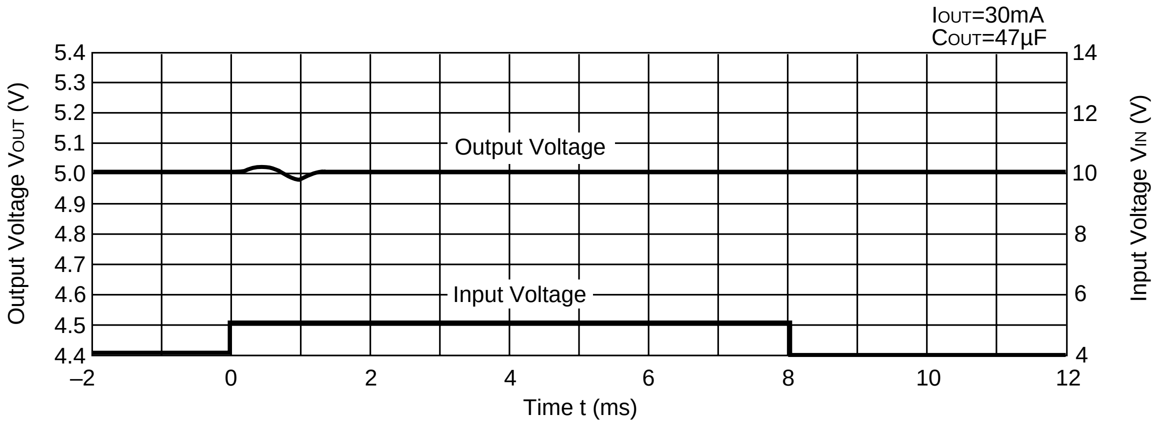

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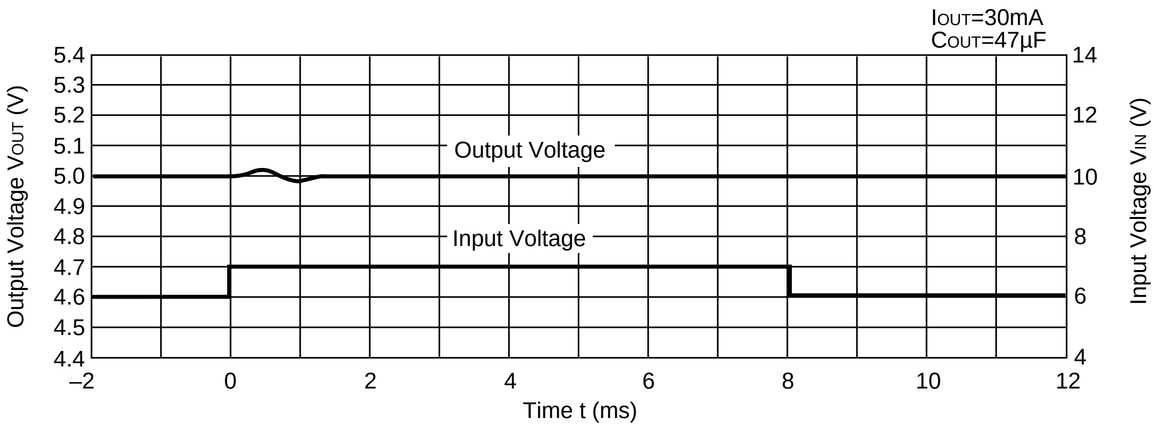
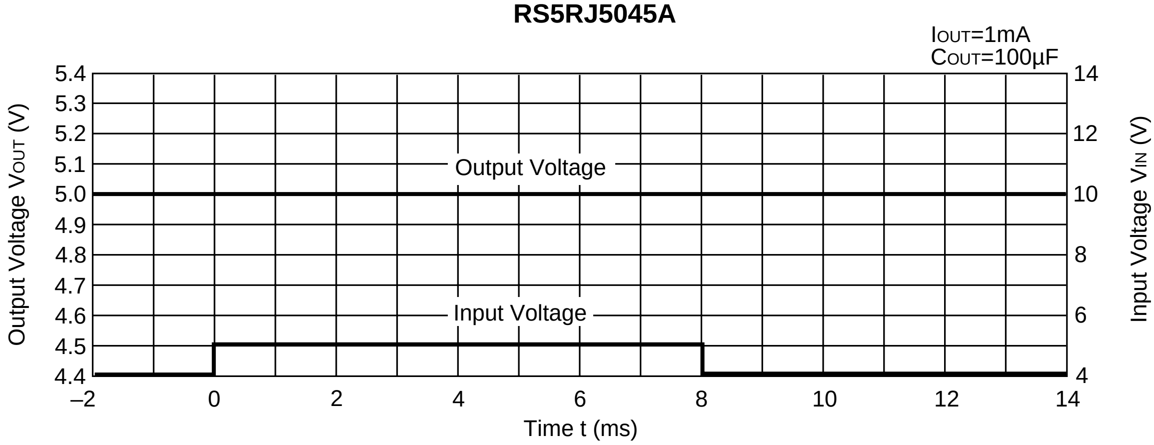
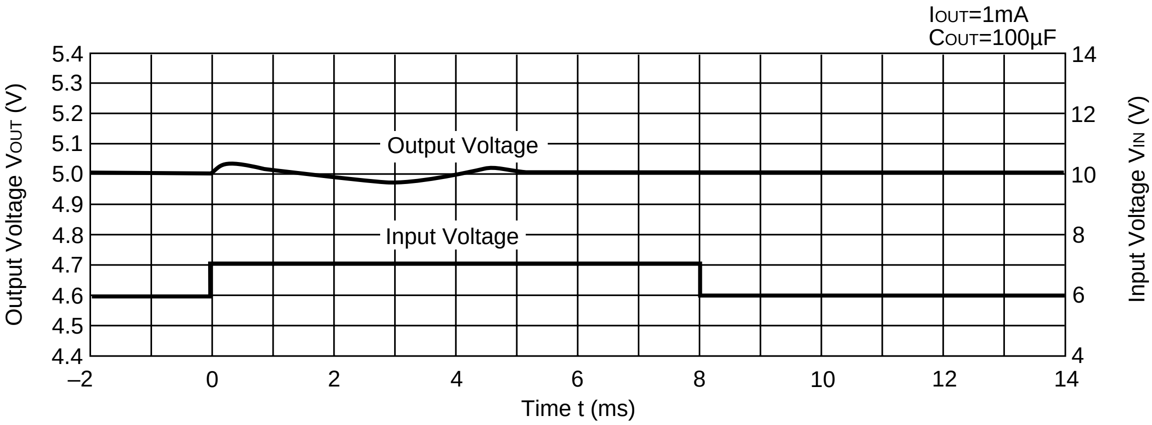


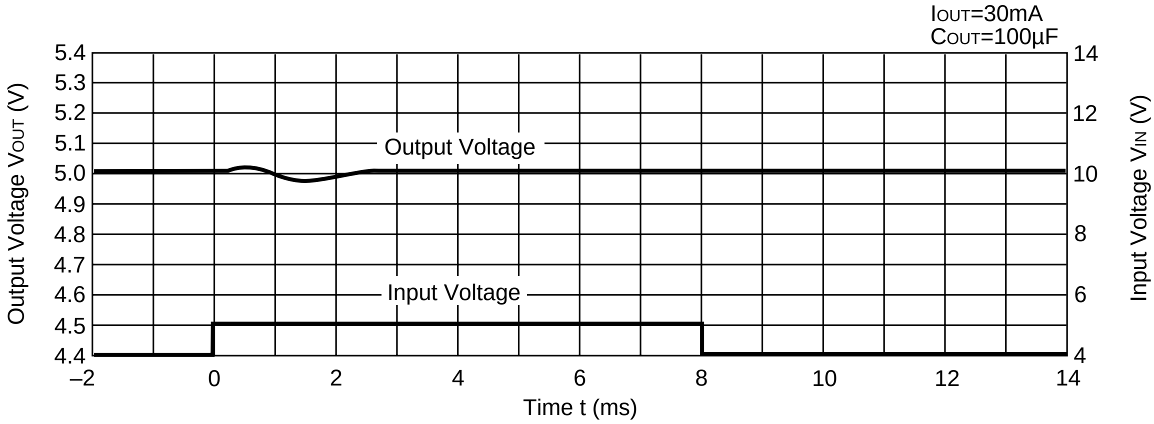
RS5RJ5045A



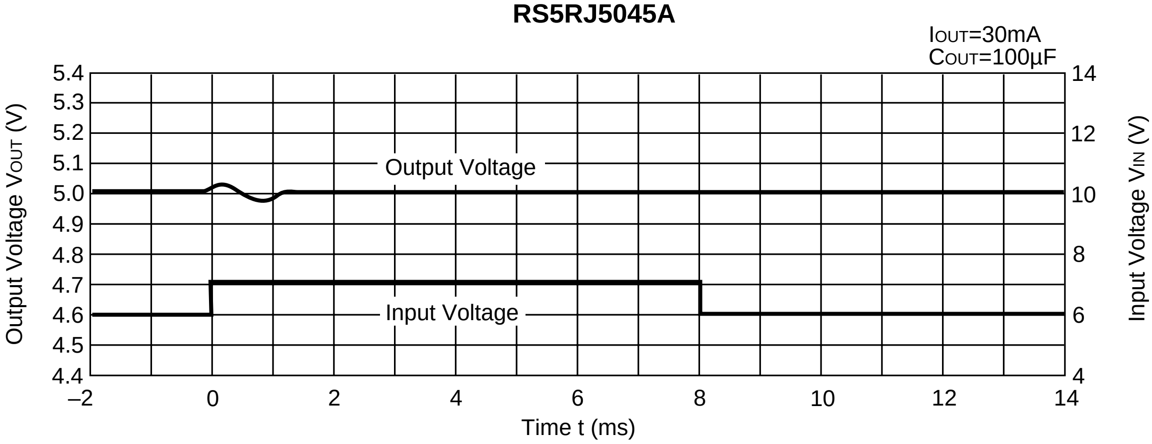
RS5RJ5045A



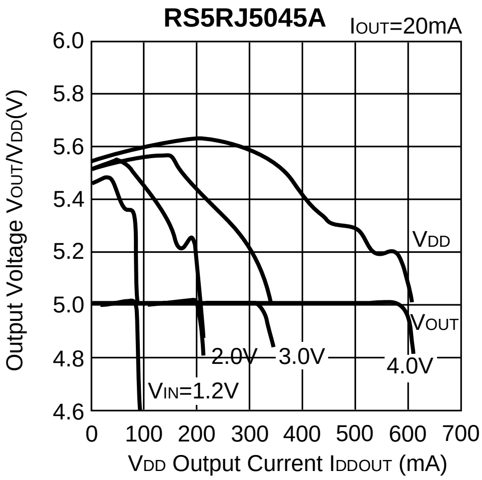
RS5RJ5045A

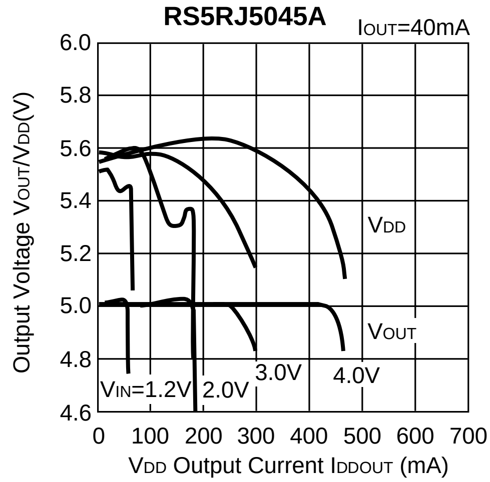


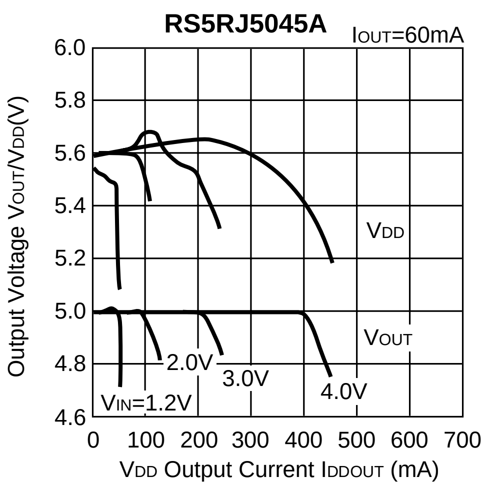
RS5RJ5045A



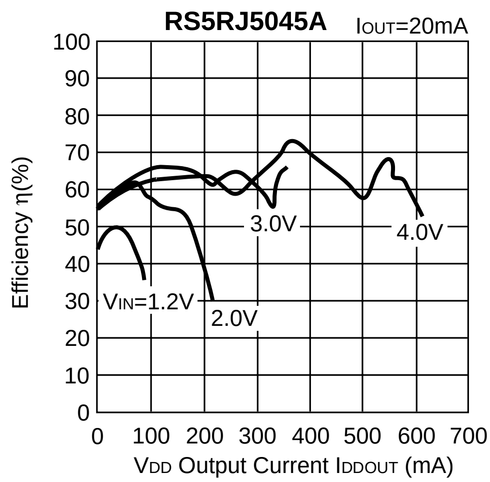
19) Output Voltage vs. V_{DD} Output Currrent

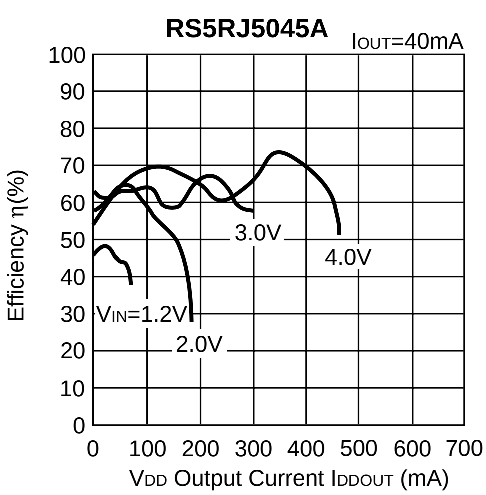


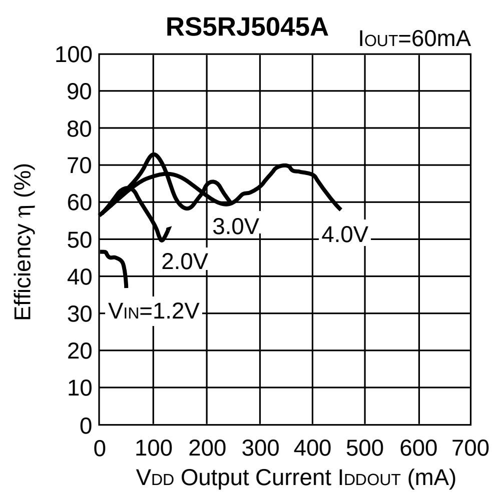




20) Output Current Efficiency vs. V_{DD} Output Current

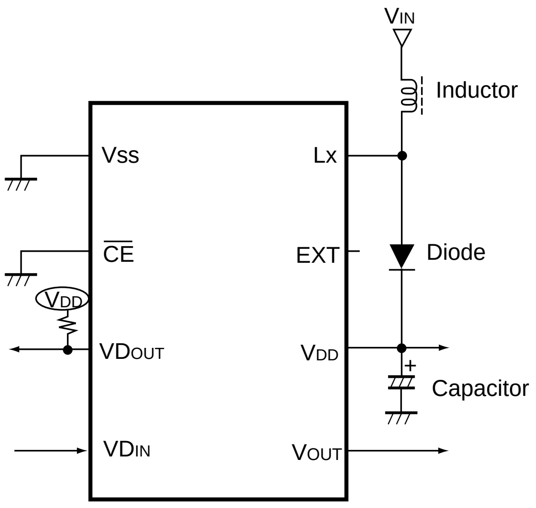






(NOTE) Efficiency η at Typical Characteristics 20) is shown by the following formula: $\eta = \frac{(V_{DD} \times I_{DDOUT}) + (V_{OUT} \times I_{OUT})}{V_{IN} \times I_{IN}} \times 100$

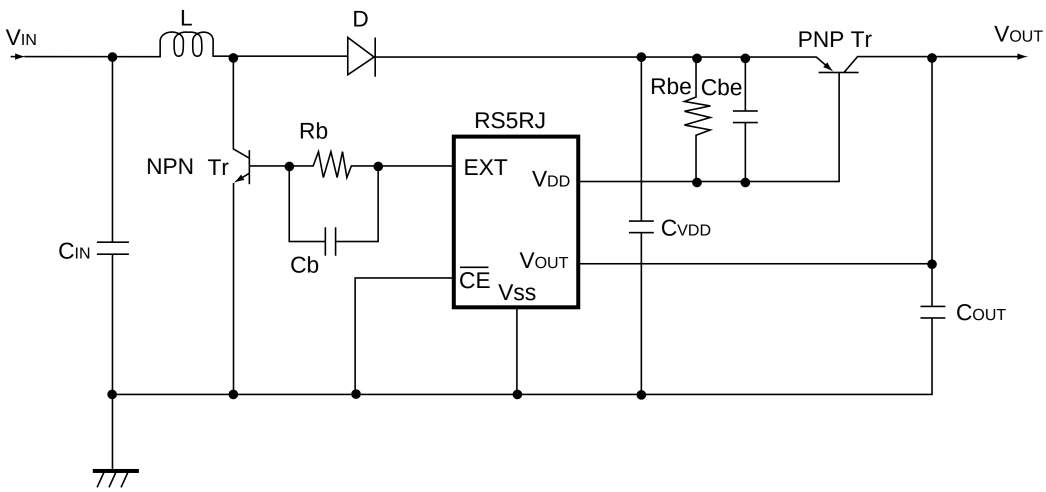
BASIC CIRCUIT



Examples of Parts : Inductor : RCR-664D (100μH) ; Sumida Electric Co., Ltd.
Diode : MA721 (Schottky type) ; Matsushita Electronics Corporation
Capacitor : 22μF (Tantalum type)

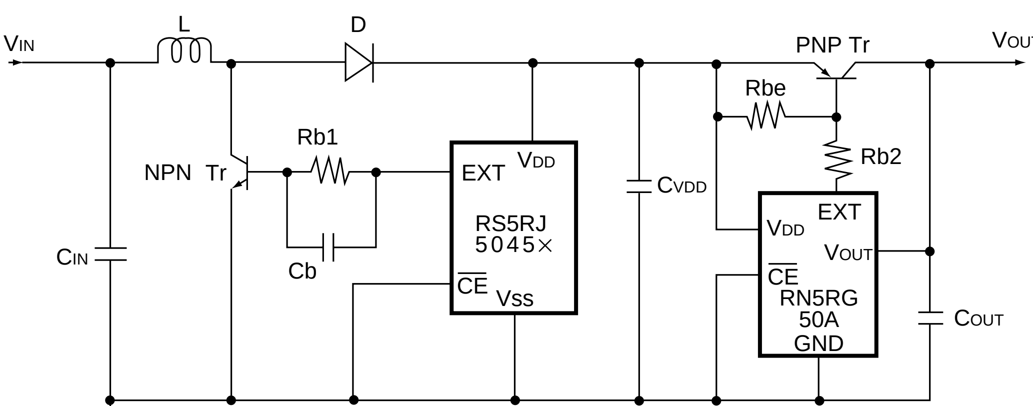
TYPICAL APPLICATIONS

• Current Boost Circuit 1



Examples of Components				
L	: 47µH(SUMIDA ELECTRIC CD105)		CD	:0.01µF
D	: Schottky Diode (HITACHI HRP22)		Cbe	:0.1µF(RS5RJ5045×, RS5RJ4036×, RS5RJ3624×)
CIN	: 220µF(Aluminum electrolytic Type)			100pF(RS5RJ3531×, RS5RJ3329×, RS5RJ3027×)
CVDD	: 100µF(Tantalum type)/ 220µF(Aluminum electroltic Type)		NPN Tr	:2SD1628
COUT	: 47µF(Tantalum Type)		PNP Tr	:2SA1213
			Rb	:220Ω
			Rbe	:12Ω

• Current Boost Circuit 2 (High Efficiiency Circuit)



(NOTE) High efficiency current boost circuit,using RS5RJ5045× with RN5RG50A(RICOH Voltage Regulator).

Examples of Components				
L	: 47µH(SUMIDA ELECTRIC CD105)		CD	: 0.01µF
D	: Schottky Diode (HITACHI HRP22)		NPN Tr	: 2SD1628
CIN	: 33µF(Tantalum type)/ : 220µF(Aluminum electrolytic Type)		PNP Tr	: 2SA1213
CVDD	: 33µF(Tantalum type)/ 220µF(Aluminum electroltic Type)		Rb1	: 220Ω
COUT	: 47µF(Tantalum Type)		Rb2	: 330Ω
			Rbe	: 10kΩ

APPLICATION HINTS

When using these ICs, be sure to take care of the following points:

- Set external components as close as possible to the IC and minimize the connection between the components and the IC. In particular, when an external component is connected to V_{OUT} Pin, make minimum connection with the capacitor.
- Make sufficient grounding. A large current flows through V_{SS} Pin by switching. When the impedance of the V_{SS} connection is high, the potential within the IC is varied by the switching current. This may result in unstable operation of the IC.
- Use capacitor with a capacity of 10µF or more, and with good high frequency characteristics such as tantalum capacitor. We recommend the use of a capacitor with an allowable voltage which is at least three times the output set voltage. This is because there may be the case where a spike-shaped high voltage is generated by the inductor when Lx transistor is turned off.
- Take the utmost care when choosing a inductor. Namely, choose such an inductor that has sufficiently small d.c. resistance and large allowable current, and hardly reaches magnetic saturation. When the inductance value of the inductor is small, there may be the case where I_{LX} exceeds the absolute maximum ratings at the maximum load. Use an inductor with an appropriate inductance.
- Use a diode of a Schottky type with high switching speed, and also take care of the rated current.

The performance of power source circuits using these ICs largely depends upon the peripheral components. Take the utmost care in the selection of the peripheral components. In particular, design the peripheral circuits in such a manner that the values such as voltage, current and power of each component, PCB patterns and the IC do not exceed their respective rated values.