PWM STEP-UP DC/DC CONVERTER

RH5RH××1A/××2B/××3B SERIES

APPLICATION MANUAL

NO.EA-023-0006

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OUTLINE

The RH5RH××1A/××2B/××3B Series are PWM Step-up DC/DC converter ICs by CMOS process.

The RH5RH××1A IC consists of an oscillator, a PWM control circuit, a driver transistor (Lx switch), a reference voltage unit, an error amplifier, a phase compensation circuit, resistors for voltage detection, a soft-start circuit, and an Lx switch protection circuit. A low ripple, high efficiency step-up DC/DC converter can be constructed of this RH5RH××1A IC with only three external components, that is, an inductor, a diode and a capacitor.

These RH5RH××1A/××2B/××3B ICs can achieve ultra-low supply current (no load) –TYP. 15µA –by a newly developed PWM control circuit, equivalent to the low supply current of a VFM (chopper) Step-up DC/DC converter.

Furthermore, these ICs can hold down the supply current to TYP. 2µA by stopping the operation of the oscillator when the input voltage > (the output voltage set value + the dropout voltage by the diode and the inductor).

These RH5RH××1A/××2B/××3B Series ICs are recommendable to the user who desires a low ripple PWM DC/DC converter, but cannot adopt a conventional PWM DC/DC converter because of its too large supply current.

The RH5RH××2B/××3B Series ICs use the same chip as that employed in the RH5RH××1A IC and are provided with a drive pin (EXT) for an external transistor. Because of the use of the drive pin (EXT), an external transistor with a low saturation voltage can be used so that a large current can be caused to flow through the inductor and accordingly a large output current can be obtained. Therefore, these RH5RH××2B/××3B Series ICs are recommendable to the user who need a current as large as several tens mA to several hundreds mA.

The RH5RH××3B IC also includes an internal chip enable circuit so that it is possible to set the standby supply current at MAX. 0.5µA.

These RH5RH××1A/××2B/××3B ICs are suitable for use with battery-powered instruments with low noise and low supply current.

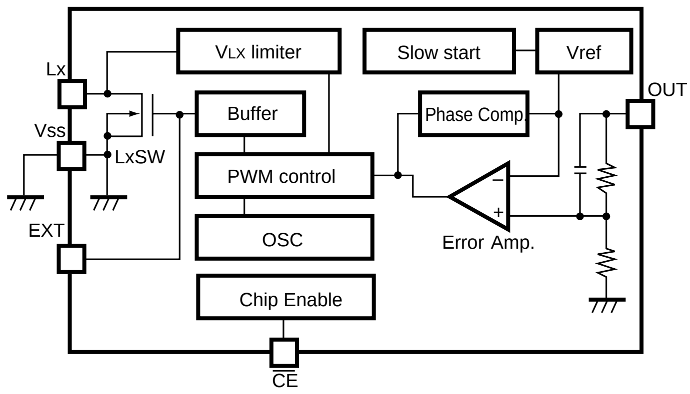
FEATURES

- Small Number of External Components ··········Only an inductor, a diode and a capacitor (RH5RH××1A)
- Low Supply Current ··········TYP. 15µA (RH5RH301A)
- Low Ripple and Low Noise
- Low Start-up Voltage (when the output current is 1mA) ··········MAX. 0.9V
- High Output Voltage Accuracy ··········±2.5%
- High Efficiency ··········TYP. 85%
- Low Temperature-Drift Coefficient of Output Voltage ··········TYP. ±50 ppm/°C
- Soft-Start ··········MIN. 500µs
- Small Packages ··········SOT-89 (RH5RH××1A, RH5RH××2B),
  SOT-89-5 (RH5RH××3B)

APPLICATIONS

- Power source for battery-powered equipment.
- Power source for cameras, camcorders, VCRs, PDAs, electronic data banks,and hand-held communication equipment.
- Power source for instruments which require low noise and low supply current, such as hand-held audio equipment.
- Power source for appliances which require higher cell voltage than that of batteries used in the appliances.

BLOCK DIAGRAM



Error Amp. (Error Amplifier) has a DC gain of 80dB, and Phase Comp. (Phase Compensation Circuit) provides the frequency characteristics including the 1st pole (fp=0.25Hz) and the zero point (fz=2.5kHz). Furthermore, another zero point (fz=1.0kHz) is also obtained by the resistors and a capacitor connected to the OUT pin.

(Note) Lx Pin ············only for RH5RH××1A and RH5RH××3B
EXT Pin ·········only for RH5RH××2B and RH5RH××3B
$\overline{\text{CE}}$ Pin ···········only for RH5RH××3B

SELECTION GUIDE

In RH5RH Series, the output voltage, the driver, 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 :

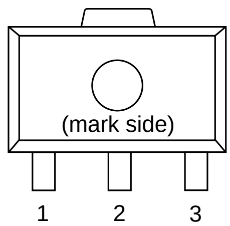
RH5RH$\underbrace{\times\times}_{a}\underbrace{\times\times}_{b}$ – $\underbrace{\times\times}_{c}$ ← Part Number

Code	Description
a	Setting Output Voltage (VOUT): Stepwise setting with a step of 0.1V in the range of 2.7V to 7.5V is possible.
b	Designation of Driver: 1A: Internal Lx Tr. Driver (Oscillator Frequency 50kHz) 2B: External Tr. Driver (Oscillator Frequency 100kHz) 3B: Internal Tr./External Tr. (selectively available) (Oscillator Frequency 100kHz, with chip enable function)
c	Designation of Taping Type : Ex. SOT-89 : T1, T2 SOT-89-5 : T1, T2 (refer to Taping Specifications) “T1” is prescribed as a standard.

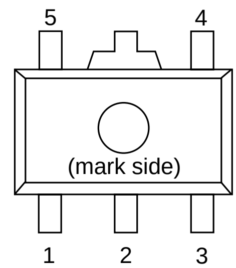
For example, the product with Output Voltage 5.0V, the External Driver (the Oscillator Frequency 100kHz) and Taping Type T1, is designated by Part Number RH5RH502B-T1.

PIN CONFIGURATION

• **SOT-89**



• **SOT-89-5**



PIN DESCRIPTION

Pin No.			Symbol	Description
××1B	××2B	××3B		
1	1	5	V_{SS}	Ground Pin
2	2	2	OUT	Step-up Output Pin, Power Supply (for device itself)
3	—	4	Lx	Switching Pin (Nch Open Drain)
—	3	3	EXT	External Tr. Drive Pin (CMOS Output)
—	—	1	$\overline{CE}$	Chip Enable Pin (Active Low)

ABSOLUTE MAXIMUM RATINGS

Vss=0V

Symbol	Item	Rating	Unit	Note
V_{OUT}	Output Pin Voltage	+12	V	
V_{LX}	Lx Pin Voltage	+12	V	Note1
V_{EXT}	EXT Pin Voltage	– 0.3 to V_{OUT}+0.3	V	Note2
V_{CE}	$\overline{CE}$ Pin Voltage	–0.3 to V_{OUT}+0.3	V	Note3
I_{LX}	Lx Pin Output Current	250	mA	Note1
I_{EXT}	EXT Pin Current	±50	mA	Note2
P_D	Power Dissipation	500	mW	
Topt	Operating Temperature Range	–30 to +80	°C	
Tstg	Storage Temperature Range	–55 to +125	°C	
Tsolder	Lead Temperature(Soldering)	260°C,10s		

(Note 1) Applicable to RH5RH××1A and RH5RH××3B. (Note 2) Applicable to RH5RH××2B and RH5RH××3B.
(Note 3) Applicable to RH5RH××3B.

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

• RH5RH301A

V_{OUT}=3.0V

Symbol	Item	Conditions	MIN.	TYP.	MAX.	Unit	Note
V_{OUT}	Output Voltage		2.925	3.000	3.075	V	
V_{IN}	Input Voltage				8	V	
Vstart	Start-up Voltage	I_{OUT}=1mA,V_{IN} : 0→2V		0.8	0.9	V	
Vhold	Hold-on Voltage	I_{OUT}=1mA,V_{IN} : 2→0V	0.7			V	
I_{DD1}	Supply Current 1	To be measured at OUT Pin (excluding Switching Current)		15	25	µA	
I_{DD2}	Supply Current 2	To be measured at OUT Pin (excluding Switching Current) V_{IN}=3.5V		2	5	µA	
I_{LX}	Lx Switching Current	V_{LX}=0.4V	60			mA	
I_{LXleak}	Lx Leakage Current	V_{LX}=6V,V_{IN}=3.5V			0.5	µA	
fosc	Oscillator Frequency		40	50	60	kHz	
Maxdty	Oscillator Maximum Duty Cycle	on (V_{LX} “L”) side	70	80	90	%	
η	Efficiency		70	85		%	
tstart	Soft-Start Time	Time required for the rising of V_{OUT} up to 3V.	0.5	2.0		ms	Note1
V_{LXlim}	V_{LX} Voltage Limit	Lx Switch ON	0.65	0.8	1.0	V	Note2

Unless otherwise provided, V_{IN}=1.8V, V_{SS}=0V, I_{OUT}=10mA, Topt=25°C, and use External Circuit of Typical Application (FIG. 1).

(Note 1) Soft-Start Circuit is operated in the following sequence :
(1) V_{IN} is applied.
(2) The voltage (Vref) of the reference voltage unit is maintained at 0V for about 200µs after the application of V_{IN}.
(3) The output of Error Amp. is raised to “H” level during the maintenance of the voltage (Vref) of the reference voltage unit.
(4) After the rise of Vref, the output of Internal Error Amp. is gradually decreased to an appropriate value by the function of Internal Phase Compensation Circuit, and the Output Voltage is gradually increased in accordance with the gradual decrease of the output of Internal Error Amp.

(Note 2) I_{LX} is gradually increased after Lx Switch is turned ON. In accordance with the increase of I_{LX}, V_{LX} is also increased. When V_{LX} reaches V_{LXlim}, Lx Switch is turned OFF by an Lx Switch Protection Circuit.

• RH5RH501A

V_{OUT}=5.0V

Symbol	Item	Conditions	MIN.	TYP.	MAX.	Unit	Note
V_{OUT}	Output Voltage		4.875	5.000	5.125	V	
V_{IN}	Input Voltage				8	V	
Vstart	Start-up Voltage	Iout=1mA,Vin:0→2V		0.8	0.9	V	
Vhold	Hold-on Voltage	Iout=1mA,Vin:2→0V	0.7			V	
I_{DD1}	Supply Current 1	To be measured at OUT Pin (excluding Switching Current)		30	45	μA	
I_{DD2}	Supply Current 2	To be measured at OUT Pin (excluding Switching Current) V_{IN}=5.5V		2	5	μA	
I_{LX}	Lx Switching Current	V_{LX}=0.4V	80			mA	
I_{LXleak}	Lx Leakage Current	V_{LX}=6V,V_{IN}=5.5V			0.5	μA	
fosc	Oscillator Frequency		40	50	60	kHz	
Maxdty	Oscillator Maximum Duty Cycle	on (V_{LX} “L”) side	70	80	90	%	
η	Efficiency		70	85		%	
tstart	Soft-Start Time	Time required for the rising of V_{OUT} up to 5V.	0.5	2.0		ms	Note1
V_{LXlim}	V_{LX} Voltage Limit	Lx Switch ON	0.65	0.8	1.0	V	Note2

Unless otherwise provided, V_{IN}=3V, Vss=0V, I_{OUT}=10mA, Topt=25°C, and use External Circuit of Typical Application (FIG. 1).

(Note 1) Soft-Start Circuit is operated in the following sequence :
(1) V_{IN} is applied.
(2) The voltage (Vref) of the reference voltage unit is maintained at 0V for about 200μs after the application of V_{IN}.
(3) The output of Error Amp. is raised to “H” level during the maintenance of the voltage (Vref) of the reference voltage unit.
(4) After the rise of Vref, the output of Internal Error Amp. is gradually decreased to an appropriate value by the function of Internal Phase Compensation Circuit, and the Output Voltage is gradually increased in accordance with the gradual decrease of the output of Internal Error Amp.

(Note 2) I_{LX} is gradually increased after Lx Switch is turned ON. In accordance with the increase of I_{LX}, V_{LX} is also increased. When V_{LX} reaches V_{LXlim}, Lx Switch is turned OFF by an Lx Switch Protection Circuit.

• RH5RH302B

V_{OUT}=3.0V

Symbol	Item	Conditions	MIN.	TYP.	MAX.	Unit	Note
V_{OUT}	Output Voltage		2.925	3.000	3.075	V	
V_{IN}	Input Voltage				8	V	
Vstart	Oscillator Start-up Voltage	EXT no load,V_{OUT} :0→2V		0.7	0.8	V	
I_{DD1}	Supply Current 1	EXT no load,V_{OUT}=2.88V		30	50	µA	
I_{DD2}	Supply Current 2	EXT no load,V_{OUT}=3.5V		2	5	µA	
I_{EXTH}	EXT "H" Output Current	V_{EXT}=V_{OUT}–0.4V			–1.5	mA	
I_{EXTL}	EXT "L" Output Current	V_{EXT}=0.4V	1.5			mA	
fosc	Oscillator Frequency		80	100	120	kHz	
Maxdty	Oscillator Maximum Duty Cycle	V_{EXT} "H" side	70	80	90	%	
tstart	Soft-Start Time	Time required for the rising of V_{OUT} up to 3V	0.5	2.0		ms	Note1

Unless otherwise provided, V_{IN}=1.8V, Vss=0V, I_{OUT}=10mA, Topt=25°C, and use External Circuit of Typical Application (FIG. 2).

• RH5RH502B

V_{OUT}=5.0V

Symbol	Item	Conditions	MIN.	TYP.	MAX.	Unit	Note
V_{OUT}	Output Voltage		4.875	5.000	5.125	V	
V_{IN}	Input Voltage				8	V	
Vstart	Oscillator Start-up Voltage	EXT no load,V_{OUT} :0→2V		0.7	0.8	V	
I_{DD1}	Supply Current 1	EXT no load,V_{OUT}=4.8V		60	90	µA	
I_{DD2}	Supply Current 2	EXT no load,V_{OUT}=5.5V		2	5	µA	
I_{EXTH}	EXT "H" Output Current	V_{EXT}=V_{OUT}–0.4V			–2	mA	
I_{EXTL}	EXT "L" Output Current	V_{EXT}=0.4V	2			mA	
fosc	Oscillator Frequency		80	100	120	kHz	
Maxdty	Oscillator Maximum Duty Cycle	V_{EXT} "H" side	70	80	90	%	
tstart	Soft-Start Time	Time required for the rising of V_{OUT} up to 5V	0.5	2.0		ms	Note1

Unless otherwise provided, V_{IN}=3V, Vss=0V, I_{OUT}=10mA, Topt=25°C and use External Circuit of Typical Application (FIG. 2).

(Note 1) refer to page 5 (Note 1)

• **RH5RH303B**

V_{OUT}=3.0V

Symbol	Item	Conditions	MIN.	TYP.	MAX.	Unit	Note
V_{OUT}	Output Voltage		2.925	3.000	3.075	V	
V_{IN}	Input Voltage				8	V	
Vstart	Start-up Voltage	I_{OUT}=1mA,V_{IN} : 0→2V		0.8	0.9	V	
Vhold	Hold-on Voltage	I_{OUT}=1mA,V_{IN} : 2→0V	0.7			V	
η	Efficiency		70	85		%	
I_{DD1}	Supply Current 1	To be measured at OUT pin		30	50	µA	
I_{DD2}	Supply Current 2	To be measured at OUT pin V_{IN}=3.5V		2	5	µA	
I_{LX}	Lx Switching Current	V_{LX}=0.4V	60			mA	
I_{LXleak}	Lx Leakage Current	V_{LX}=6V,V_{IN}=3.5V			0.5	µA	
I_{EXTH}	EXT "H" Output Current	V_{EXT}=V_{OUT}–0.4V			–1.5	mA	
I_{EXTL}	EXT "L" Output Current	V_{EXT}=0.4V	1.5			mA	
V_{CEH1}	$\overline{CE}$ "H" Level 1	V_{OUT}≥1.5V	V_{OUT}–0.4			V	
V_{CEL1}	$\overline{CE}$ "L" Level 1	V_{OUT}≥1.5V			0.4	V	
V_{CEH2}	$\overline{CE}$ "H" Level 2	0.8V≤V_{OUT}<1.5V	V_{OUT}–0.1			V	
V_{CEL2}	$\overline{CE}$ "L" Level 2	0.8V≤V_{OUT}<1.5V			0.1	V	
I_{CEH}	$\overline{CE}$ "H" Input Current	$\overline{CE}$=3V			0.5	µA	
I_{CEL}	$\overline{CE}$ "L" Input Current	$\overline{CE}$=0V	–0.5			µA	
fosc	Oscillator Frequency		80	100	120	kHz	
Maxdty	Oscillator Maximum Duty Cycle	on (V_{LX} "L")side	70	80	90	%	
tstart	Soft-Start Time	Time required for the rising of V_{OUT} up to 3V.	0.5	2.0		ms	Note1
V_{LXlim}	V_{LX} Voltage Limit	Lx Switch ON	0.65	0.8	1.0	V	Note2

Unless otherwise provided, V_{IN}=1.8V, V_{SS}=0V, I_{OUT}=10mA, Topt=25°C, and use External Circuit of Typical Application (FIG. 3).

(Note 1) Soft-Start Circuit is operated in the following sequence :

(1) V_{IN} is applied.

(2) The voltage (Vref) of the reference voltage unit is maintained at 0V for about 200µs after the application of V_{IN}.

(3) The output of Error Amp. is raised to "H" level during the maintenance of the voltage (Vref) of the reference voltage unit.

(4) After the rise of Vref, the output of Internal Error Amp. is gradually decreased to an appropriate value by the function of Internal Phase Com pensation Circuit, and the Output Voltage is gradually increased in accordance with the gradual decrease of the output of Internal Error Amp.

(Note 2) I_{LX} is gradually increased after Lx Switch is turned ON. In accordance with the increase of I_{LX}, V_{LX} is also increased. When V_{LX} reaches V_{LXlim}, Lx Switch is turned OFF by an Lx Switch Protection Circuit.

• **RH5RH503B**

V_{OUT}=5.0V

Symbol	Item	Conditions	MIN.	TYP.	MAX.	Unit	Note
V_{OUT}	Output Voltage		4.875	5.000	5.125	V	
V_{IN}	Input Voltage				8	V	
Vstart	Start-up Voltage	I_{OUT}=1mA,V_{IN} : 0→2V		0.8	0.9	V	
Vhold	Hold-on Voltage	I_{OUT}=1mA,V_{IN} : 2→0V	0.7			V	
η	Efficiency		70	85		%	
I_{DD1}	Supply Current 1	To be measured at OUT pin		60	90	µA	
I_{DD2}	Supply Current 2	To be measured at OUT pin V_{IN}=5.5V		2	5	µA	
I_{LX}	Lx Switching Current	V_{LX}=0.4V	80			mA	
I_{LXleak}	Lx Leakage Current	V_{LX}=6V,V_{IN}=5.5V			0.5	µA	
I_{EXTH}	EXT "H" Output Current	V_{EXT}=V_{OUT}–0.4V			–2.0	mA	
I_{EXTL}	EXT "L" Output Current	V_{EXT}=0.4V	2.0			mA	
V_{CEH1}	$\overline{CE}$ "H" Level 1	V_{OUT}≥1.5V	V_{OUT}–0.4			V	
V_{CEL1}	$\overline{CE}$ "L" Level 1	V_{OUT}≥1.5V			0.4	V	
V_{CEH2}	$\overline{CE}$ "H" Level 2	0.8V≤V_{OUT}<1.5V	V_{OUT}–0.1			V	
V_{CEL2}	$\overline{CE}$ "L" Level 2	0.8V≤V_{OUT}<1.5V			0.1	V	
I_{CEH}	$\overline{CE}$ "H" Input Current	$\overline{CE}$=5V			0.5	µA	
I_{CEL}	$\overline{CE}$ "L" Input Current	$\overline{CE}$=0V	–0.5			µA	
fosc	Oscillator Frequency		80	100	120	kHz	
Maxdty	Oscillator Maximum Duty Cycle	on (V_{LX} "L")side	70	80	90	%	
tstart	Soft-Start Time	Time required for the rising of V_{OUT} up to 5V.	0.5	2.0		ms	Note1
V_{LXlim}	V_{LX} Voltage Limit	Lx Switch ON	0.65	0.8	1.0	V	Note2

Unless otherwise provided, V_{IN}=3V, V_{SS}=0V, I_{OUT}=10mA, Topt=25°C, and use External Circuit of Typical Application (FIG. 3).

(Note 1) Soft-Start Circuit is operated in the following sequence :
(1) V_{IN} is applied.
(2) The voltage (Vref) of the reference voltage unit is maintained at 0V for about 200µs after the application of V_{IN}.
(3) The output of Error Amp. is raised to "H" level during the maintenance of the voltage (Vref) of the reference voltage unit.
(4) After the rise of Vref, the output of Internal Error Amp. is gradually decreased to an appropriate value by the function of Internal Phase Com pensation Circuit, and the Output Voltage is gradually increased in accordance with the gradual decrease of the output of Internal Error Amp.

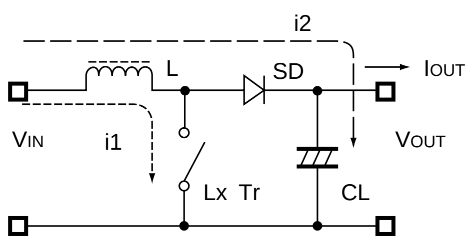
(Note 2) I_{LX} is gradually increased after Lx Switch is turned ON. In accordance with the increase of I_{LX}, V_{LX} is also increased. When V_{LX} reaches V_{LX}lim, Lx Switch is turned OFF by an Lx Switch Protection Circuit.

OPERATION OF STEP-UP DC/DC CONVERTER

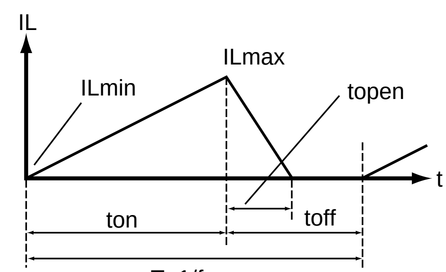
Step-up DC/DC Converter charges energy in the inductor when Lx Transistor (LxTr) is on, and discharges the energy with the addition of the energy from Input Power Source thereto, so that a higher output voltage than the input voltage is obtained.

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. However, in the case of a continuous mode which will be mentioned later,the time period (toff) runs out before IL reaches ILmin (=0), so that LxTr is turned ON in the next cycle, and SD is turned OFF. In this case, ILmin does not reach zero, and IL (=i1) increases from ILmin (> 0).

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

• Discontinuous Conduction Mode and Continuous Conduction Mode

In the above two diagrams, the maximum value (ILmax) and the minimum value (ILmin) of the current which flows through the inductor are the same as those when LxTr is ON and also when LxTr is OFF.

The difference between ILmax and ILmin, which is represented by ΔI, is :

$$\Delta I = IL_{max} - IL_{min} = V_{IN} \cdot ton/L = (V_{OUT} - V_{IN}) \cdot topen/L \quad \cdots\cdots \text{Equation 1}$$

wherein $T = 1/fosc = ton + toff$

$duty\ (\%) = ton/T \cdot 100 = ton \cdot fosc \cdot 100$

$topen \leq toff$

In Equation 1, $V_{IN} \cdot ton/L$ and $(V_{OUT} - V_{IN}) \cdot topen/L$ are respectively show the change in the current at ON, and the change in the current at OFF.

When the output current (I_{OUT}) is relatively small, topen<toff as illustrated in the above diagram. In this case, the energy charged in the inductor during the time period of ton is discharged in its entirely during the time period of toff, so that ILmin becomes zero (ILmin=0). When I_{OUT} is gradually increased, topen eventually becomes equal to toff (topen=toff), and when I_{OUT} is further increased. ILmin becomes larger than zero (ILmin>0). The former mode is referred to as the discontinuous mode and the latter mode is referred to as the continuous mode.

In the continuous mode, when Equation 1 is solved for ton and the solution is tonc,

$$tonc = T \cdot (1 - V_{IN}/V_{OUT}) \quad \text{Equation 2}$$

When ton<tonc, the mode is the discontinuous mode, and when ton=tonc, the mode is the continuous mode.

• Output Current in Discontinuous Mode

In the discontinuous mode, when LxTr is on, the energy P_{ON} charged in the inductor is provided by Equation 3 as follows :

$$P_{ON} = \int_0^{ton} V_{IN} \cdot IL(t)\,dt = \int_0^{ton} (V_{IN}^2 \cdot t/L)\,dt$$
$$= V_{IN}^2 \cdot ton^2/(2 \cdot L) \quad \text{Equation 3}$$

In the case of the step-up DC/DC converter, the energy is also supplied from the input power source at the time of OFF.

$$\text{Thus, } P_{OFF} = \int_0^{topen} V_{IN} \cdot IL(t)\,dt = \int_0^{topen} ((V_{OUT} - V_{IN}) \cdot t/L)dt$$
$$= V_{IN} \cdot (V_{OUT} - V_{IN}) \cdot topen^2/(2 \cdot L)$$

Here, $topen = V_{IN} \cdot ton/(V_{OUT} - V_{IN})$ from Equation 1, and when this is substituted into the above equation.

$$= V_{IN}^3 \cdot ton^2/(2 \cdot L \cdot (V_{OUT} - V_{IN})) \quad \text{Equation 4}$$

Input power is ($P_{ON}+P_{OFF}$)/T. When this is converted in its entirely to the output.

$$P_{IN} = (P_{ON} + P_{OFF})/T = V_{OUT} \cdot I_{OUT} = P_{OUT} \quad \text{Equation 5}$$

Equation 6 can be obtained as follows by solving Equation 5 for I_{OUT} by substituting Equations 3 and 4 into Equation 5 :

$$I_{OUT} = V_{IN}^2 \cdot ton^2/(2 \cdot L \cdot T \cdot (V_{OUT} - V_{IN})) \quad \text{Equation 6}$$

The peak current which flows through L · LxTr · SD is

$$ILmax = V_{IN} \cdot ton/L \quad \text{Equation 7}$$

Therefore it is necessary that the setting of the input/output conditions and the selection of peripheral components should be made with ILmax taken into consideration.

• Output Current in Continuous Conduction Mode

When the operation enters into the continuous conduction mode by increasing the I_{OUT}, ILmin becomes equal to Iconst (> 0), and this current always flows through the inductor. Therefore, V_{IN} · Iconst is added to P_{IN} in Equation 5.

Thus, $P_{IN}=V_{IN} \cdot \text{Iconst}+(P_{ON}+P_{OFF})/T=V_{OUT} \cdot I_{OUT}=P_{OUT}$

When the above Equation is solved for I_{OUT},

$I_{OUT}=V_{IN}^2 \cdot \text{tonc}^2/(2 \cdot L \cdot T \cdot (V_{OUT}-V_{IN}))+V_{IN} \cdot \text{Iconst}/V_{OUT}$ ············Equation 8

The peak current which flows through L · LxTr · SD is

$ILmax=V_{IN} \cdot \text{ton}/L+\text{Iconst}$ ············Equation 9

From Equations 6 and 9, the larger the value of L, the smaller the load current at which the operation enters into the continuous mode, and the smaller the difference between ILmax and ILmin, and the smaller the value of ILmax.

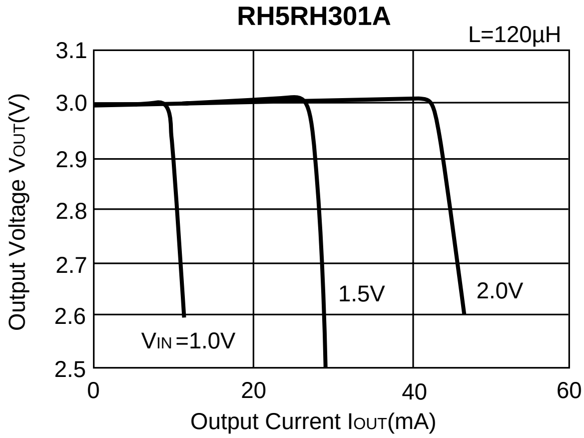
Therefore, when the load current is the same, the larger the value of L, the easier the selection of peripheral components with a small allowable current becomes, and the smaller the ripple of the peripheral components can be made. In this case, however, it must be noted from Equation 6 that I_{OUT} becomes small when the allowable current of the inductor is small or when V_{IN} is so small that the operation cannot enter into the continuous mode.

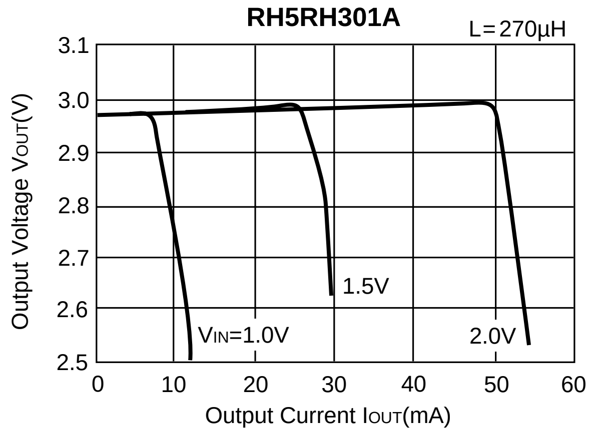
HINTS

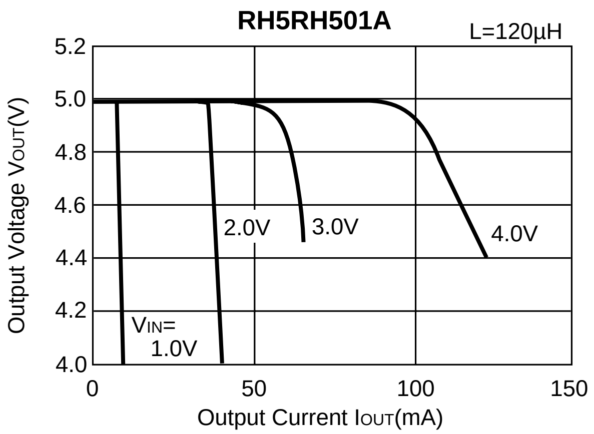
The above explanation is directed to the calculation in an ideal case where there is no energy loss caused by the resistance in the external components and LxSW. In an actual case, the maximum output current will be 50 to 80% of the above calculated maximum output current. In particular, care must be taken because V_{IN} is decreased in an amount corresponding to the voltage drop caused by LxSW when IL is large or V_{IN} is low. Furthermore, it is required that with respect to V_{OUT}, Vf of the diode (about 0.3V in the case of a Schottky type diode) be taken into consideration.

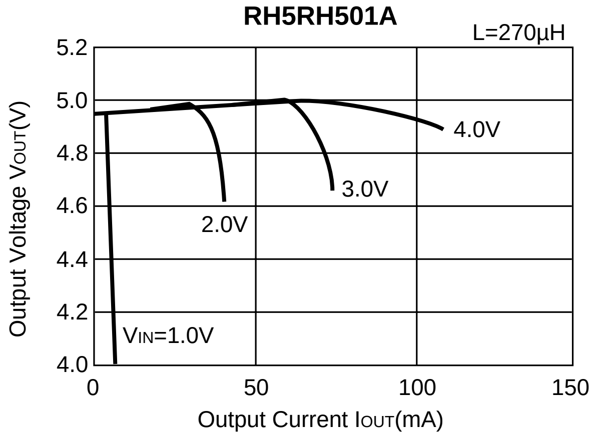
TYPICAL CHARACTERISTICS

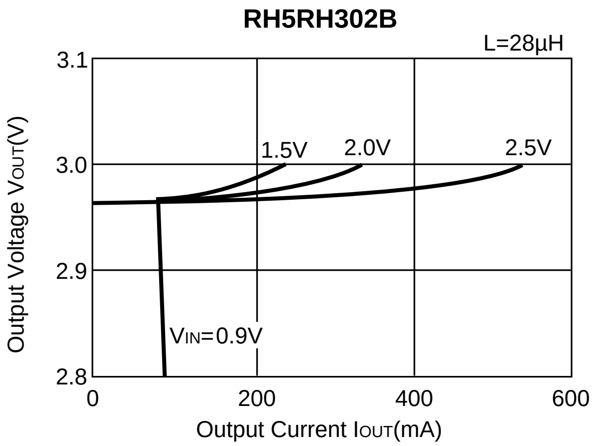
1) Output Voltage vs. Output Current

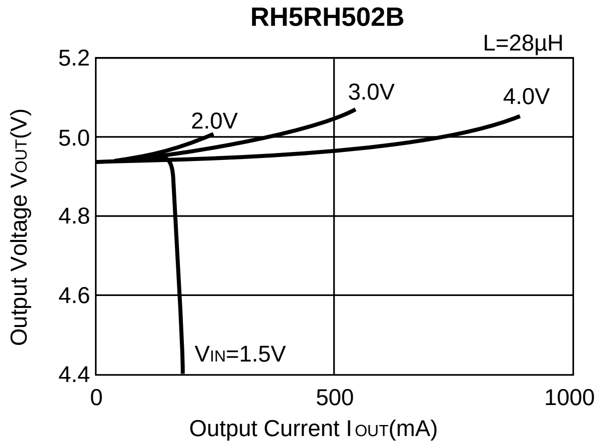






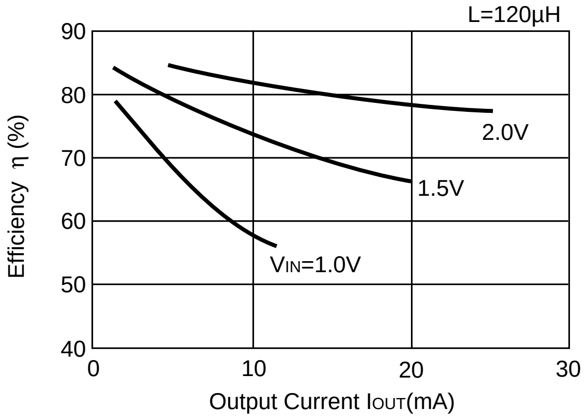




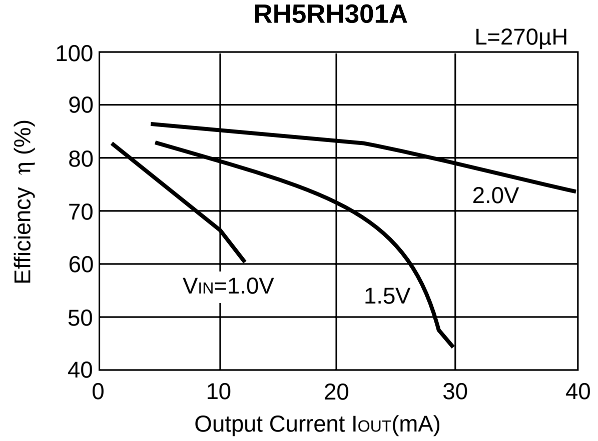


2) Efficiency vs. Output Current

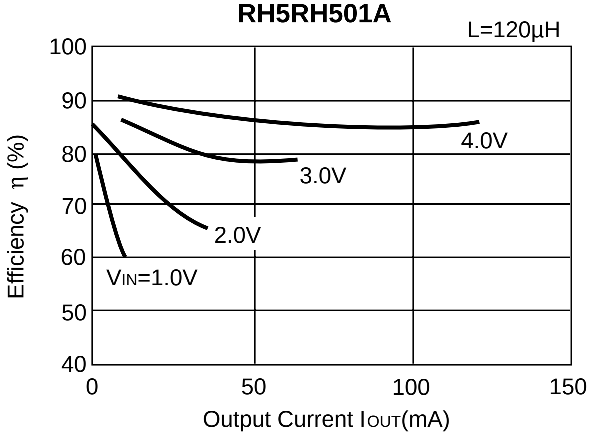
RH5RH301A



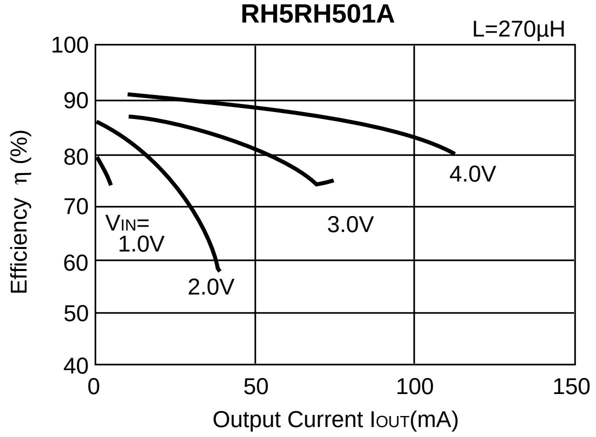
RH5RH301A



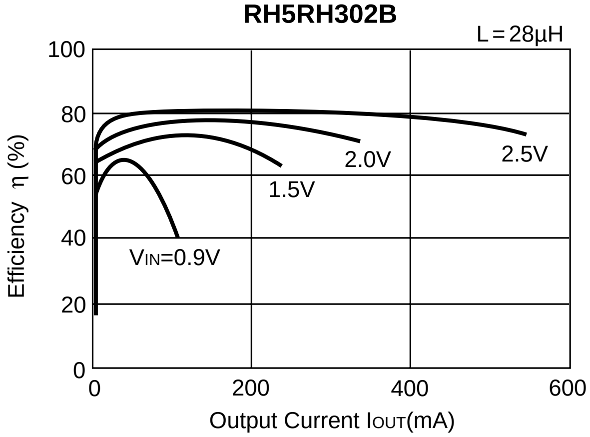
RH5RH501A



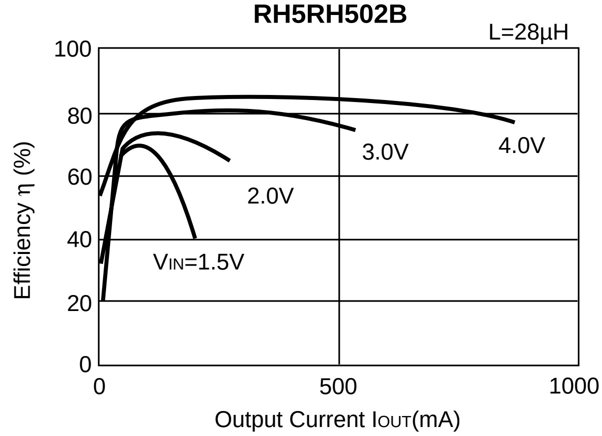
RH5RH501A



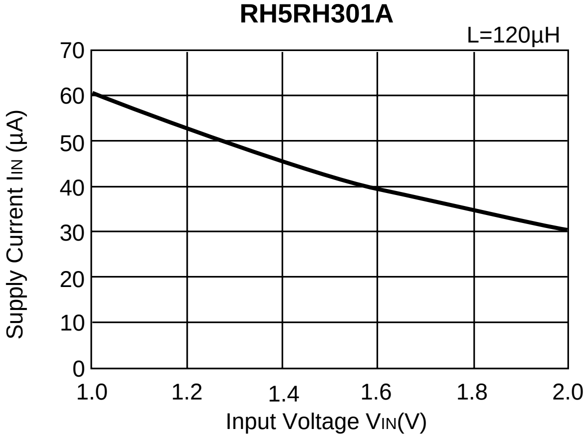
RH5RH302B

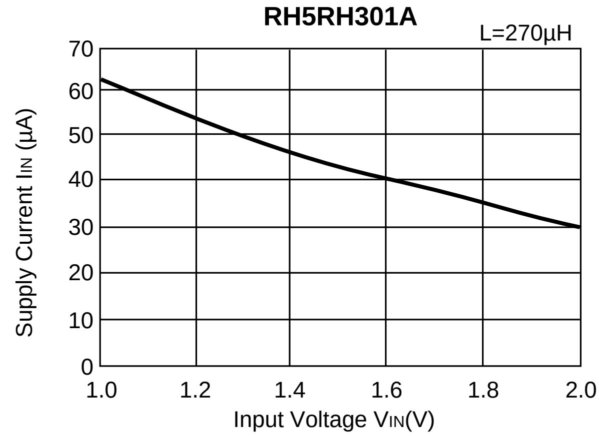


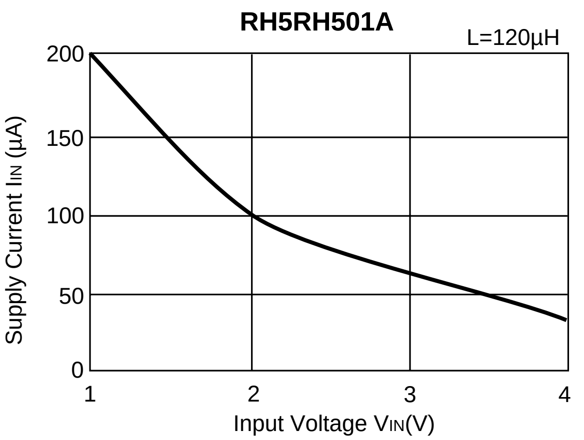
RH5RH502B

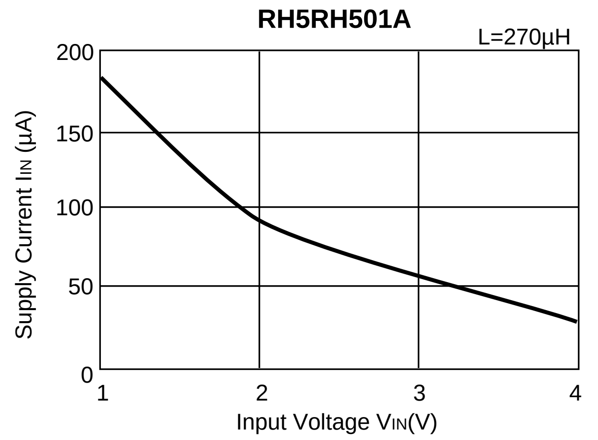


3) Supply Curret (No Load) vs. Input Voltage

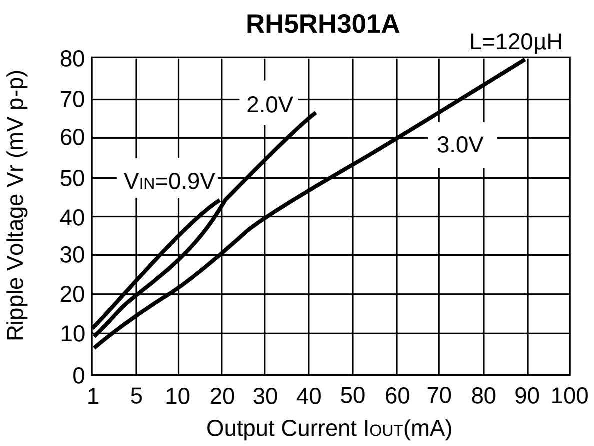


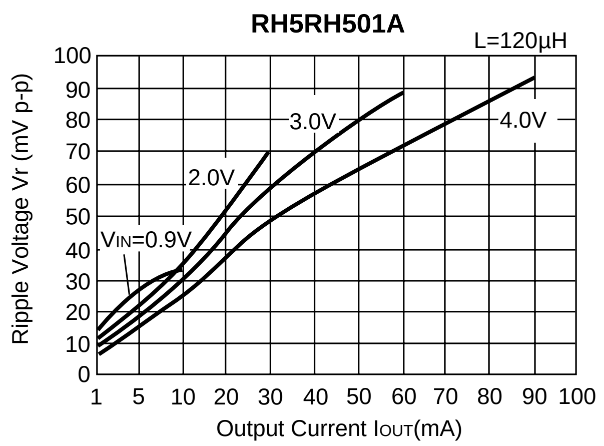


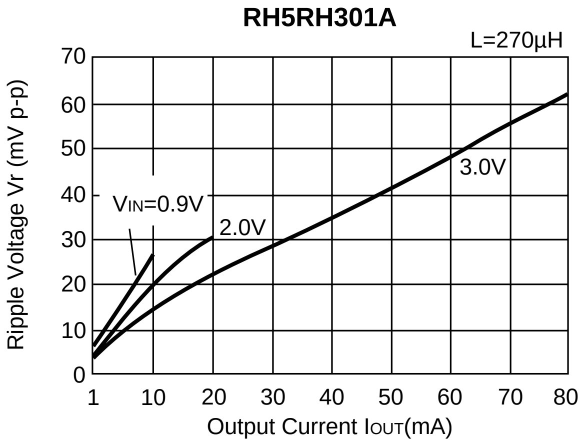


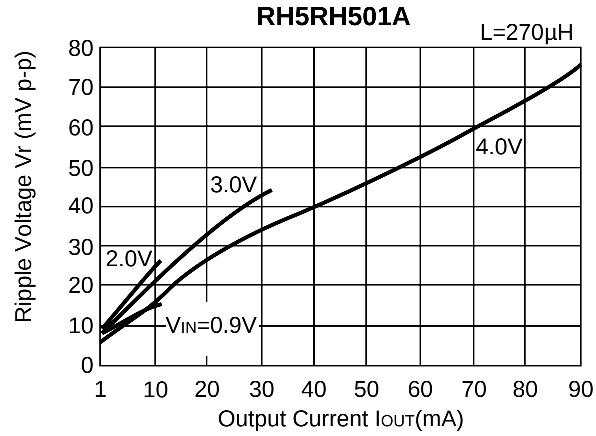


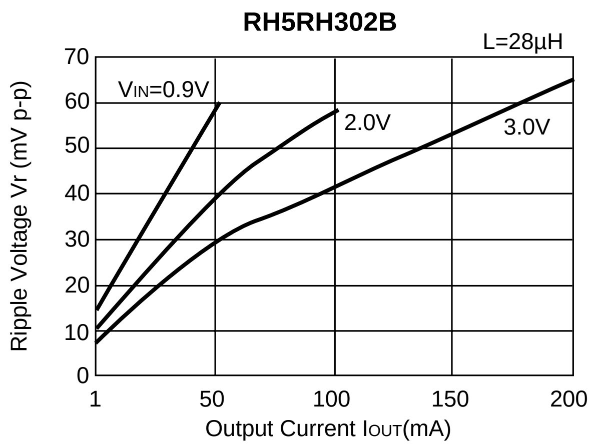
4) Output Current vs.Ripple Voltage

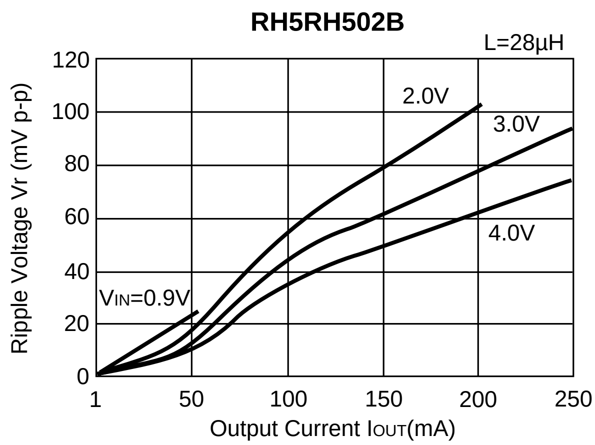




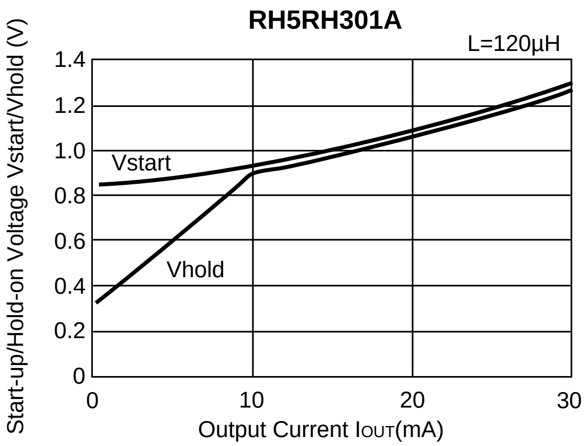


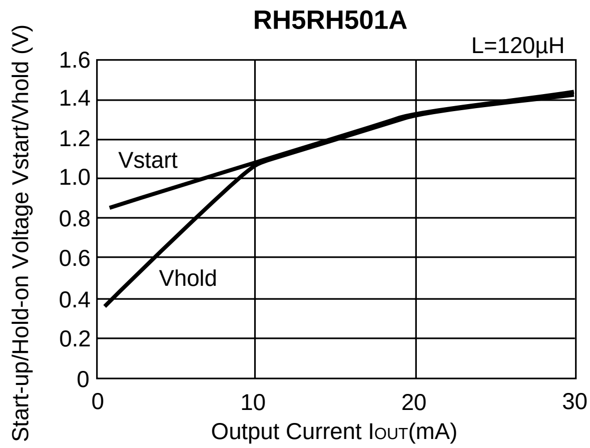


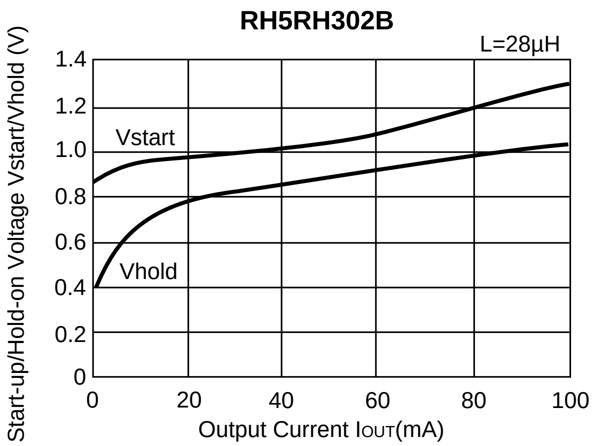


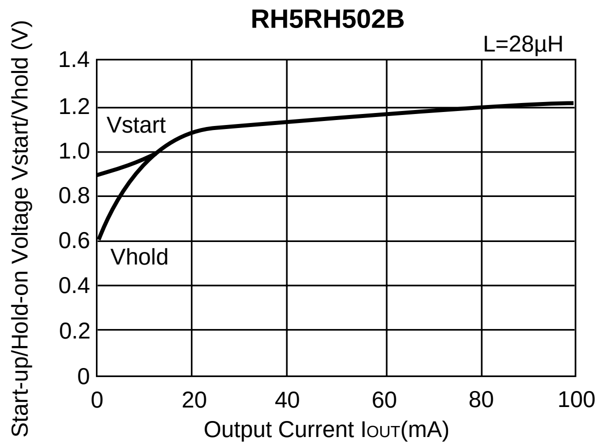


5) Start-up/Hold-on Voltage vs. Output Current (Topt=25°C)

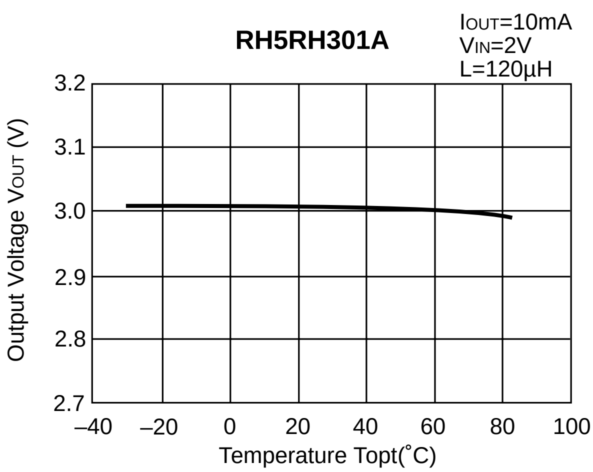


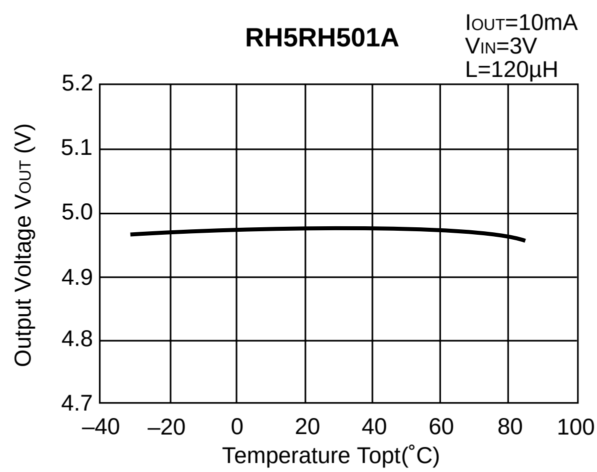


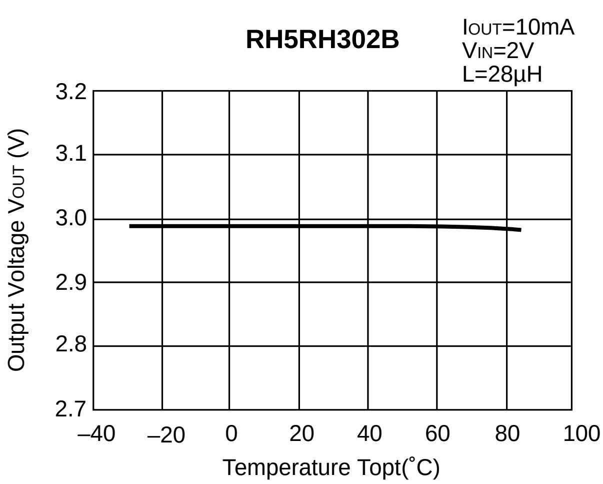


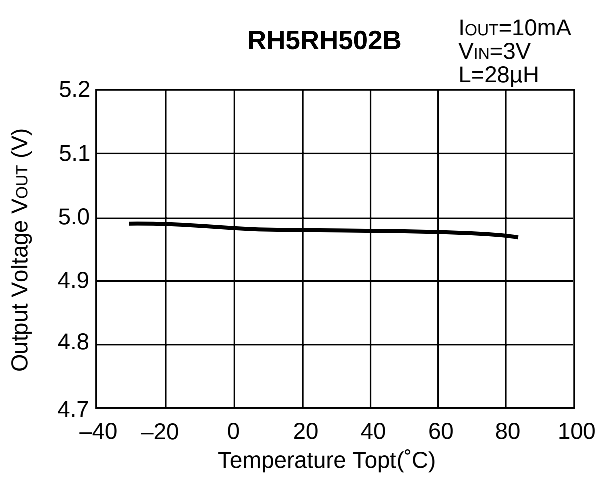


6) Output Voltage vs.Temperature



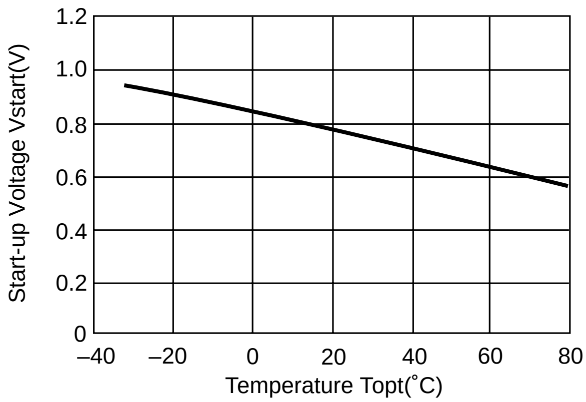






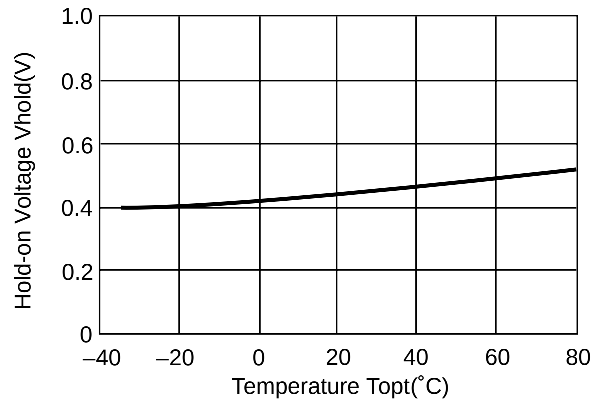
7) Start-up Voltage vs. Temperature

RH5RH501A



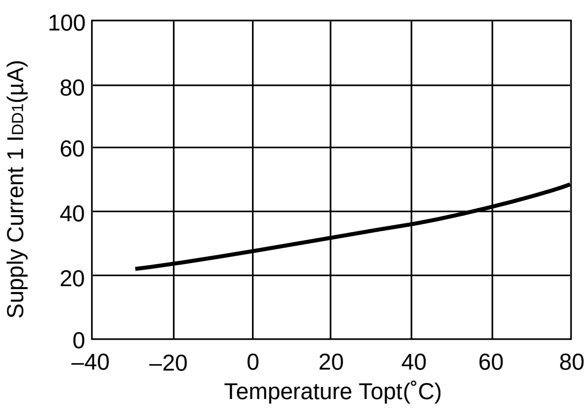
8) Hold-on Voltage vs. Temperature

RH5RH501A



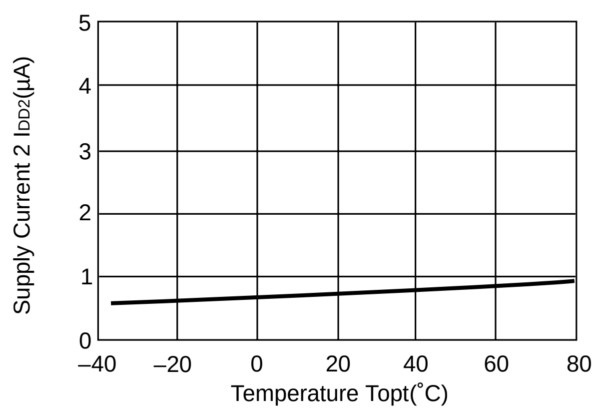
9) Supply Current 1 vs.Temperature

RH5RH501A



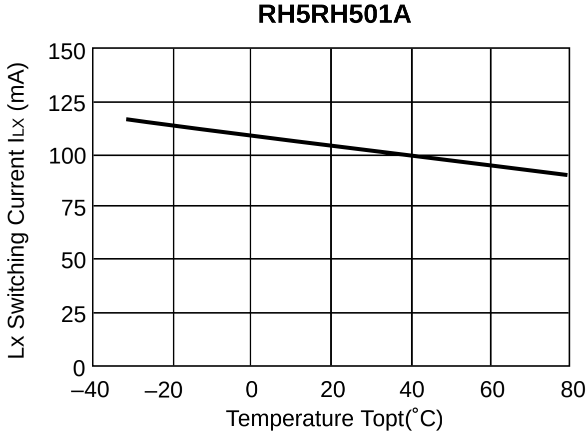
10) Supply Current 2 vs.Temperature

RH5RH501A



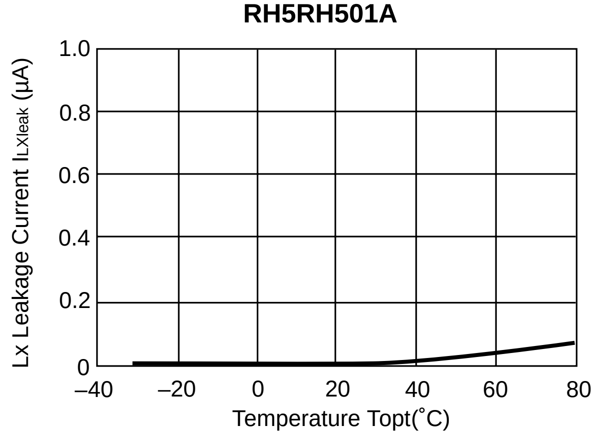
11) Lx Switching Current vs.Temperature

RH5RH501A

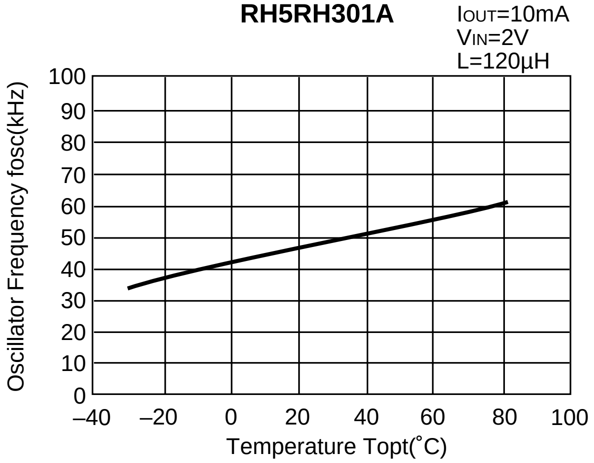


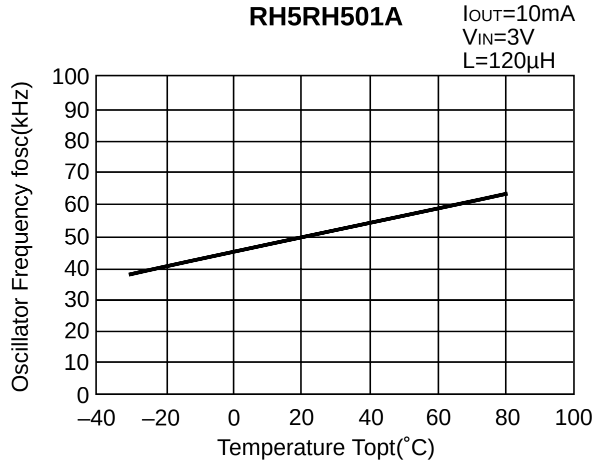
12) Lx Leakage Current vs.Temperature

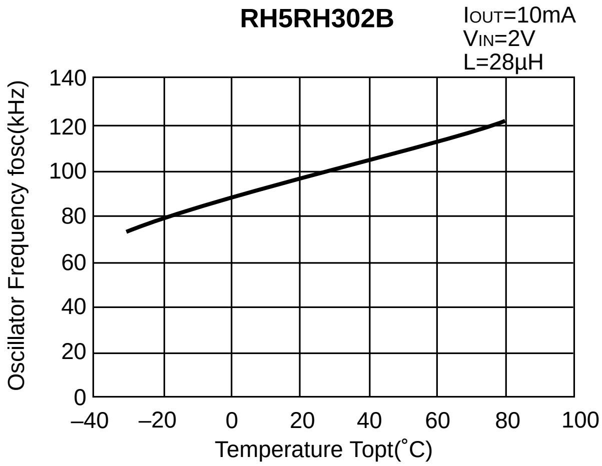
RH5RH501A

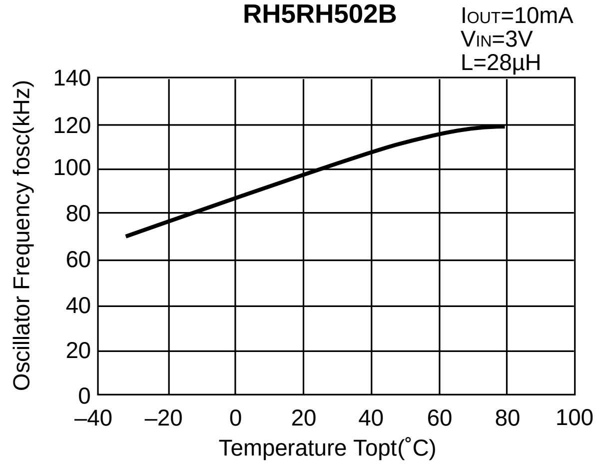


13) Oscillator Frequency vs. Temperature

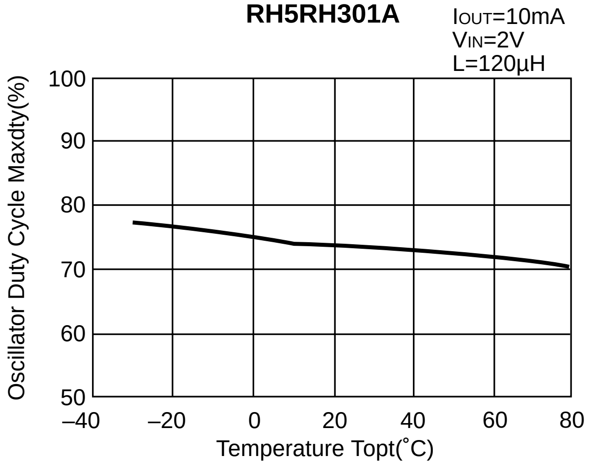


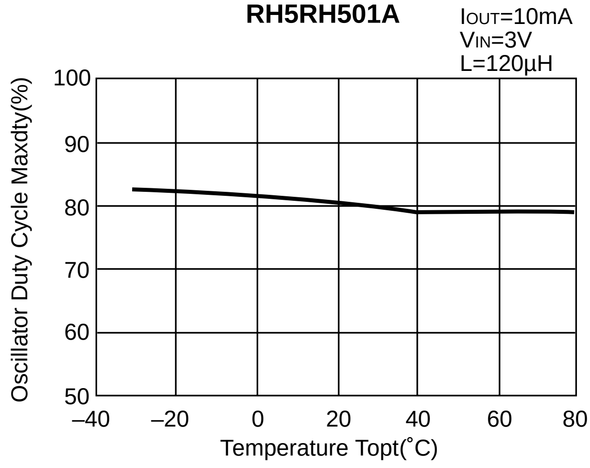






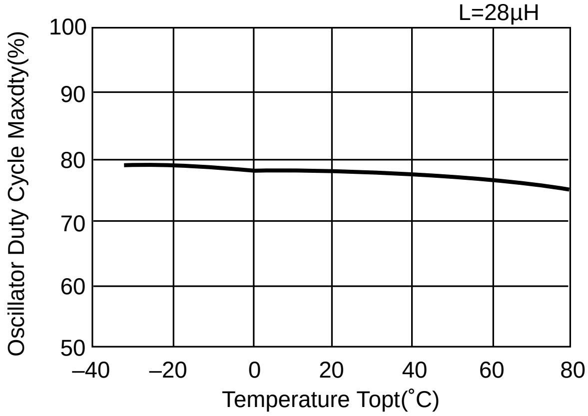
14) Oscillator Duty Cycle vs. Temperature





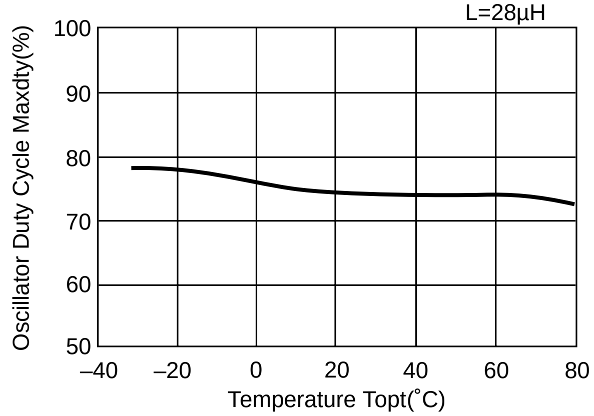
RH5RH302B

I_{OUT}=10mA
V_{IN}=2V
L=28μH



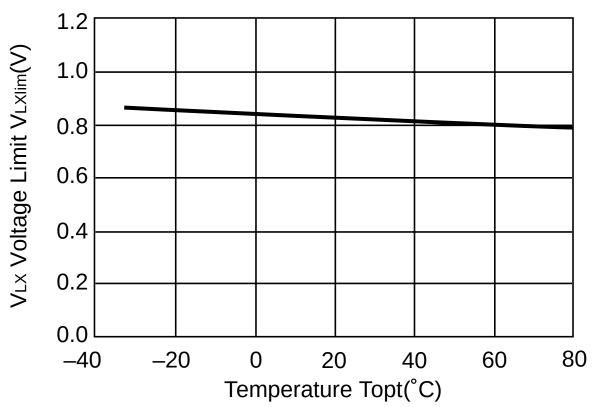
RH5RH502B

I_{OUT}=10mA
V_{IN}=3V
L=28μH



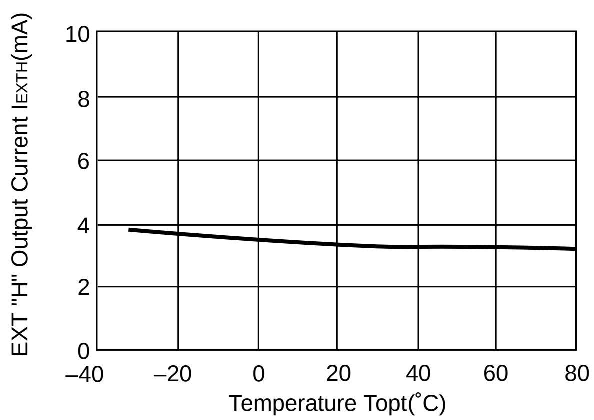
15) V_{LX} Voltage Limit vs. Temperature

RH5RH501A



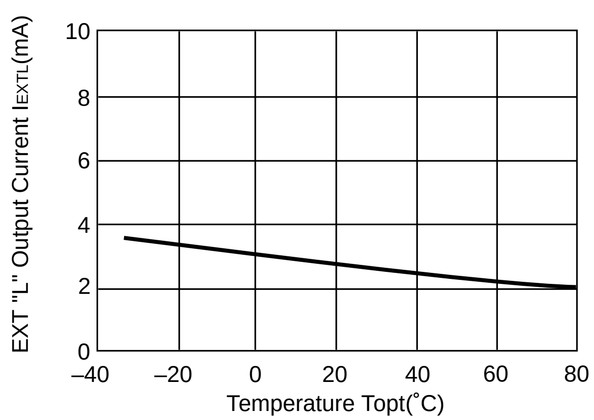
16) EXT “H” Output Current vs. Temperature

RH5RH501A



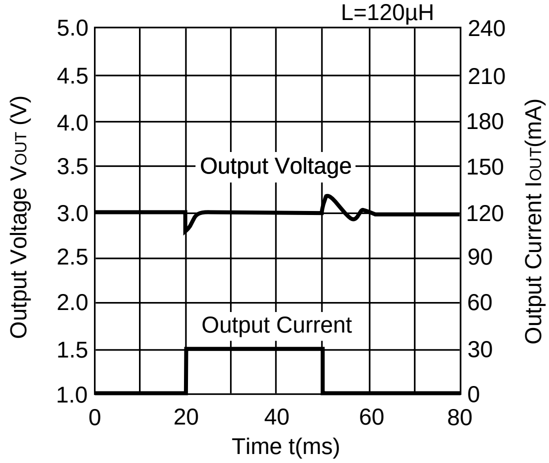
17) EXT “L” Output Current vs. Temperature

RH5RH501A

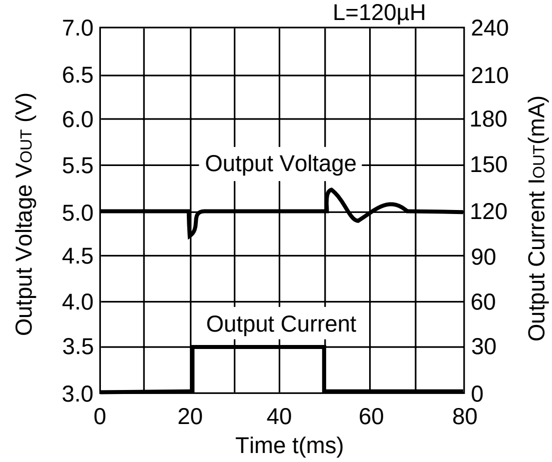


18) Load Transient Response

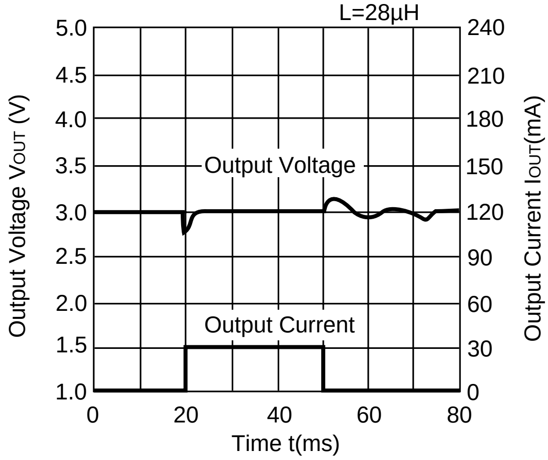
RH5RH301A I_{OUT}=1mA-30mA
V_{IN}=2V
L=120µH



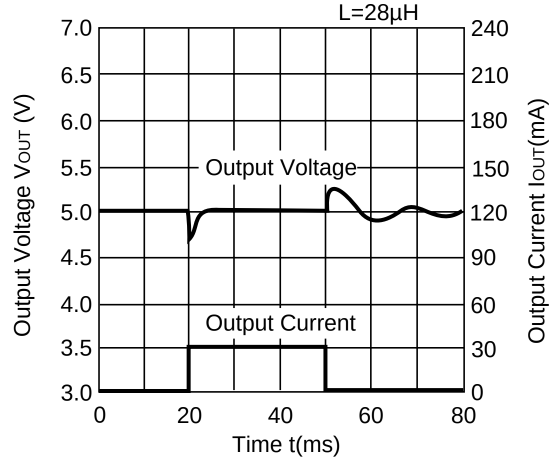
RH5RH501A I_{OUT}=1mA-30mA
V_{IN}=3V
L=120µH



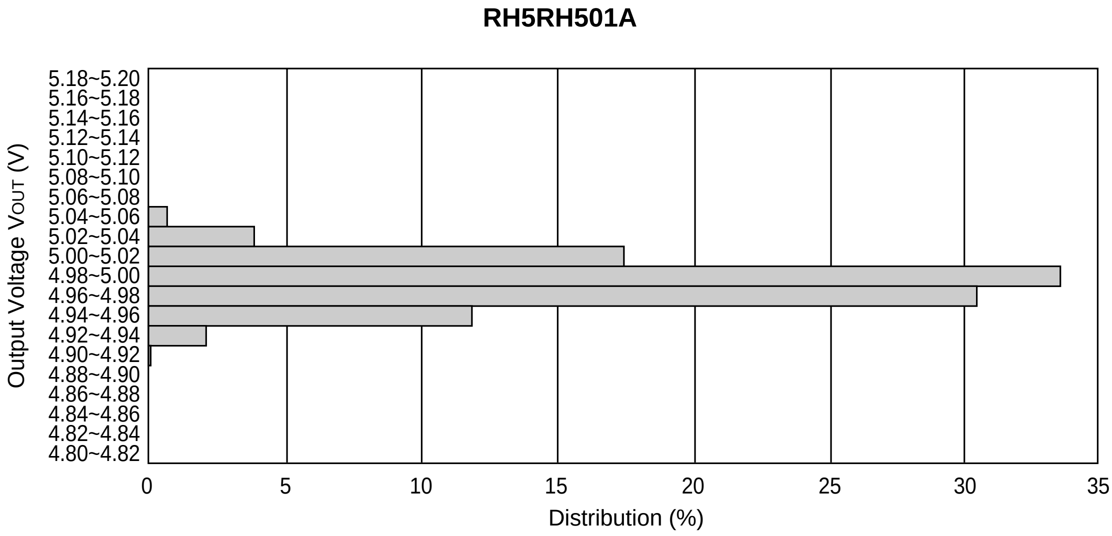
RH5RH302B I_{OUT}=1mA-30mA
V_{IN}=2V
L=28µH



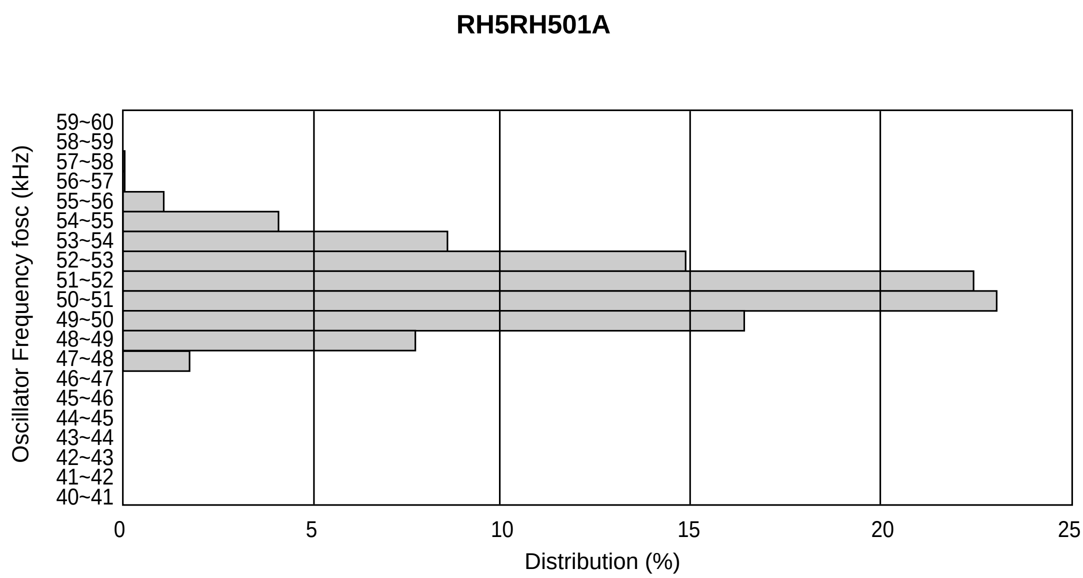
RH5RH502B I_{OUT}=1mA-30mA
V_{IN}=3V
L=28µH



19) Distribution of Output Voltage

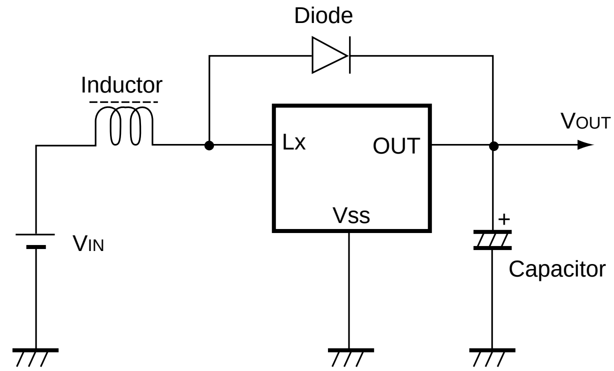


20) Distribution of Oscillator Frequency



TYPICAL APPLICATIONS

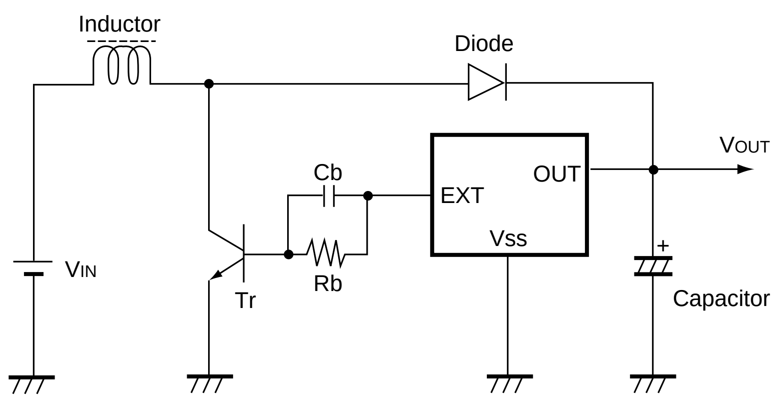
• **RH5RH××1A**



Components	Inductor (L)	: 120µH (Sumida Electric Co., Ltd.)
	Diode (D)	: MA721 (Matsushita Electronics Corporation, Schottky Type)
	Capacitor (C_L)	: 22µF (Tantalum Type)

FIG. 1

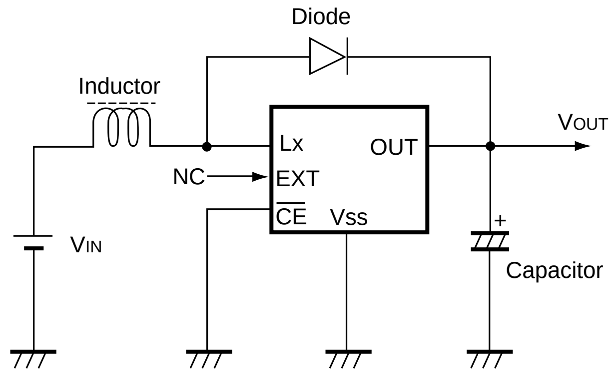
• **RH5RH××2B**



Components	Inductor (L)	: 28µH (Troidal Core)
	Diode (D)	: HRP22 (Hitachi, Schottky Type)
	Capacitor (C_L)	: 100µF (Tantalum Type)
	Transistor (Tr)	: 2SD1628G
	Base Resistor (Rb)	: 300Ω
	Base Capacitor (Cb)	: 0.01µF

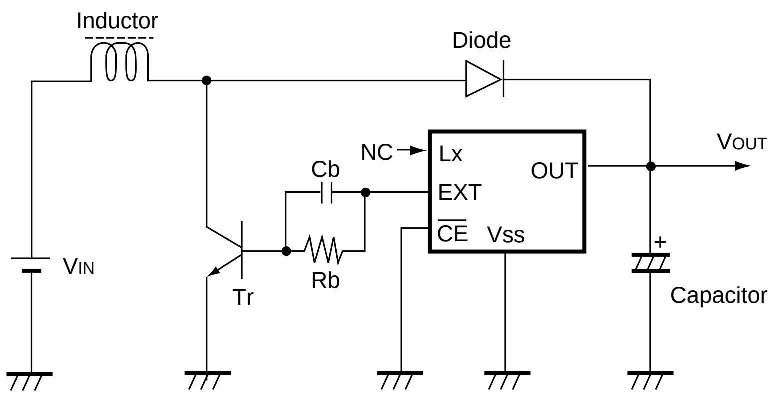
FIG. 2

• **RH5RH××3B**



Components	Inductor (L)	: 120μH (Sumida Electric Co., Ltd.)
	Diode (D)	: MA721 (Matsushita Electronics Corporation, Schottky Type)
	Capacitor (CL)	: 22μF (Tantalum Type)

FIG. 3



Components	Inductor (L)	: 28μH (Troidal Core)
	Diode (D)	: HRP22 (Hitachi, Schottky Type)
	Capacitor (CL)	: 100μF (Tantalum Type)
	Transistor (Tr)	: 2SD1628G
	Base Resistor (Rb)	: 300Ω
	Base Capacitor (Cb)	: 0.01μF

FIG. 4

• $\overline{\text{CE}}$ pin Drive Circuit

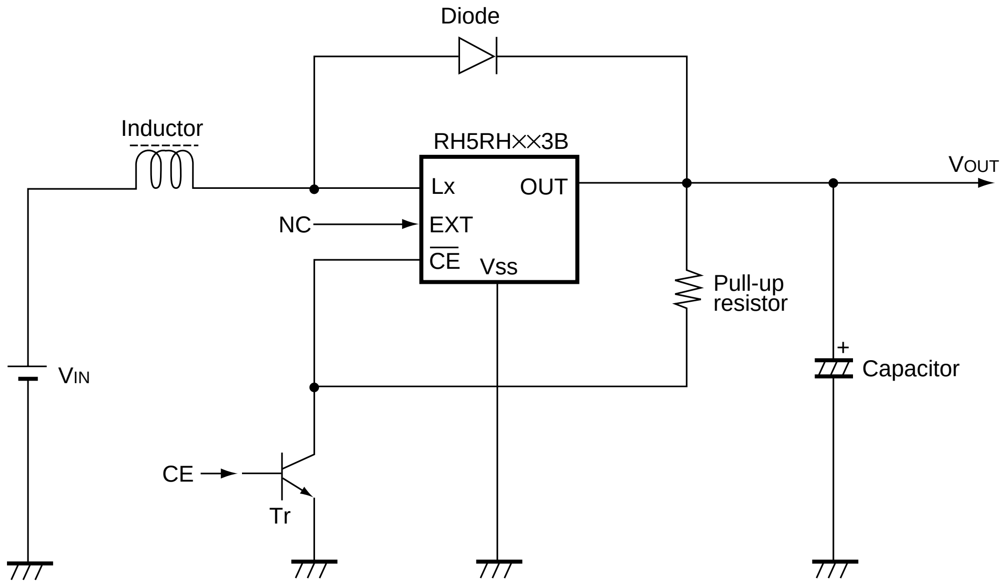
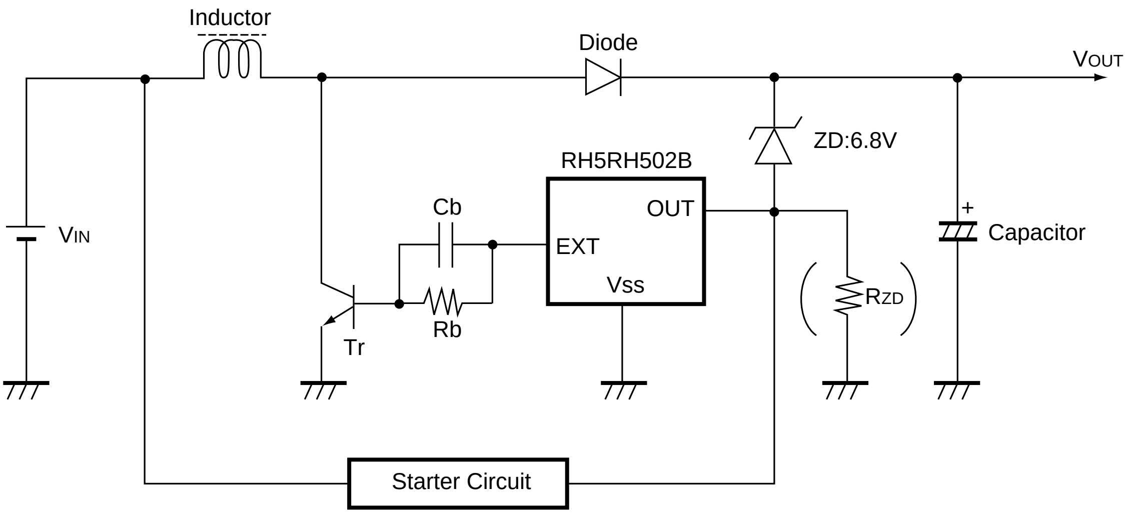


FIG. 5

APPLICATION CIRCUITS

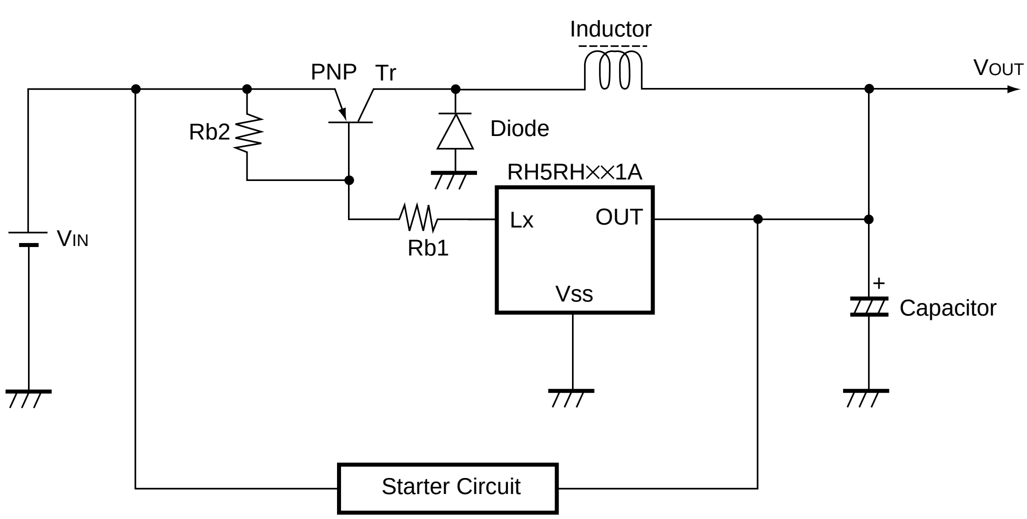
• 12V Step-up Circuit



(Note) When the Output Current is small or the Output Voltage is unstable,use the Rzd for flowing the bias current through the Zener diode ZD.

FIG. 6

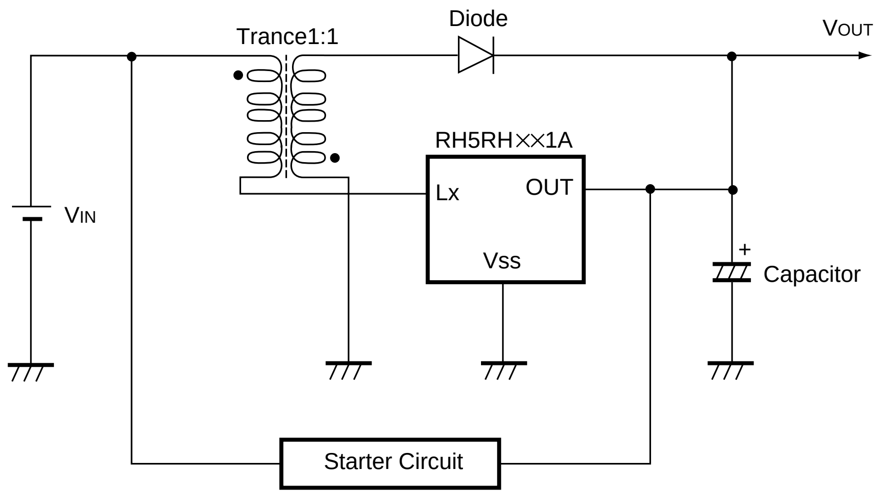
• Step-down Circuit



(Note) When the Lx pin Voltage is over the rating at the time PNP Tr is OFF,use a RH5RH××2B and drive the PNP Tr. by the external NPN Tr.

FIG. 7

• Step-up/Step-down Circuit with Flyback

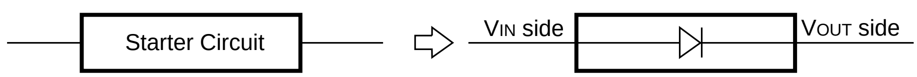


(Note) Use a RH5RH××2B,depend on the Output Current.

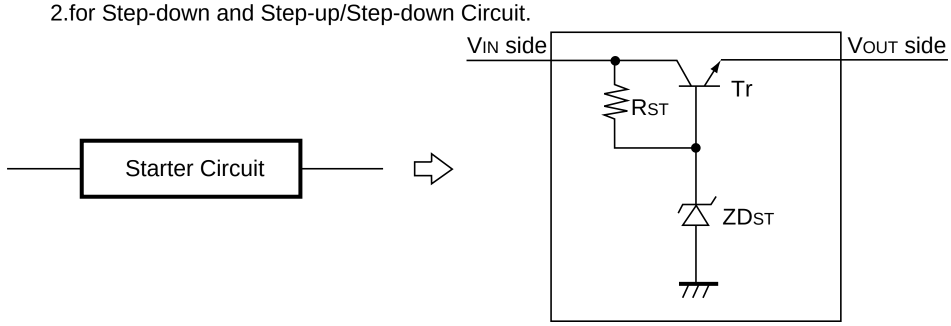
FIG. 8

⁎The Starter Circuit is necessary for all above circuits.

1.for Step-up Circuit.



2.for Step-down and Step-up/Step-down Circuit.



ZDst 2.5V≤/ZDst≤Designation of Output Voltage
Rst Input Bias Current of ZDst and Tr.
(several kΩ to several hundreds kΩ)