HA17431VPJ/PJ/PAJ/FPJ/FPAJ/PNAJ/UPA, HA17432UPA

Shunt Regulator

REJ03D0892-0100
Rev.1.00
Apr 03, 2007

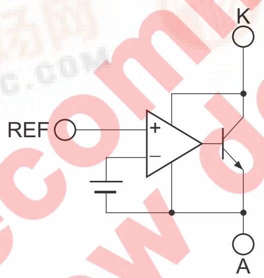
Description

The HA17431 series is temperature-compensated variable shunt regulators. The main application of these products is in voltage regulators that provide a variable output voltage. The on-chip high-precision reference voltage source can provide ±1% accuracy in the V versions, which have a V_{KA} max of 16 volts.

Features

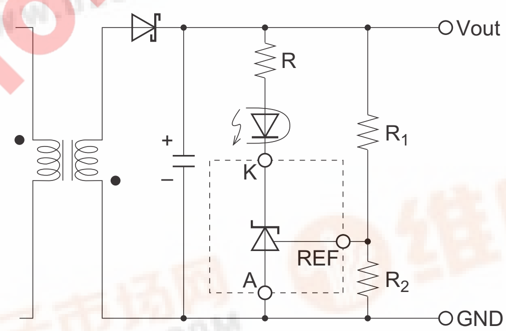
- The V versions provide 2.500 V ±1% at Ta = 25°C
- The reference voltage has a low temperature coefficient
- The UPAKV miniature packages are optimal for use on high mounting density circuit boards

Block Diagram



Application Circuit Example

Switching power supply secondary-side error amplification circuit

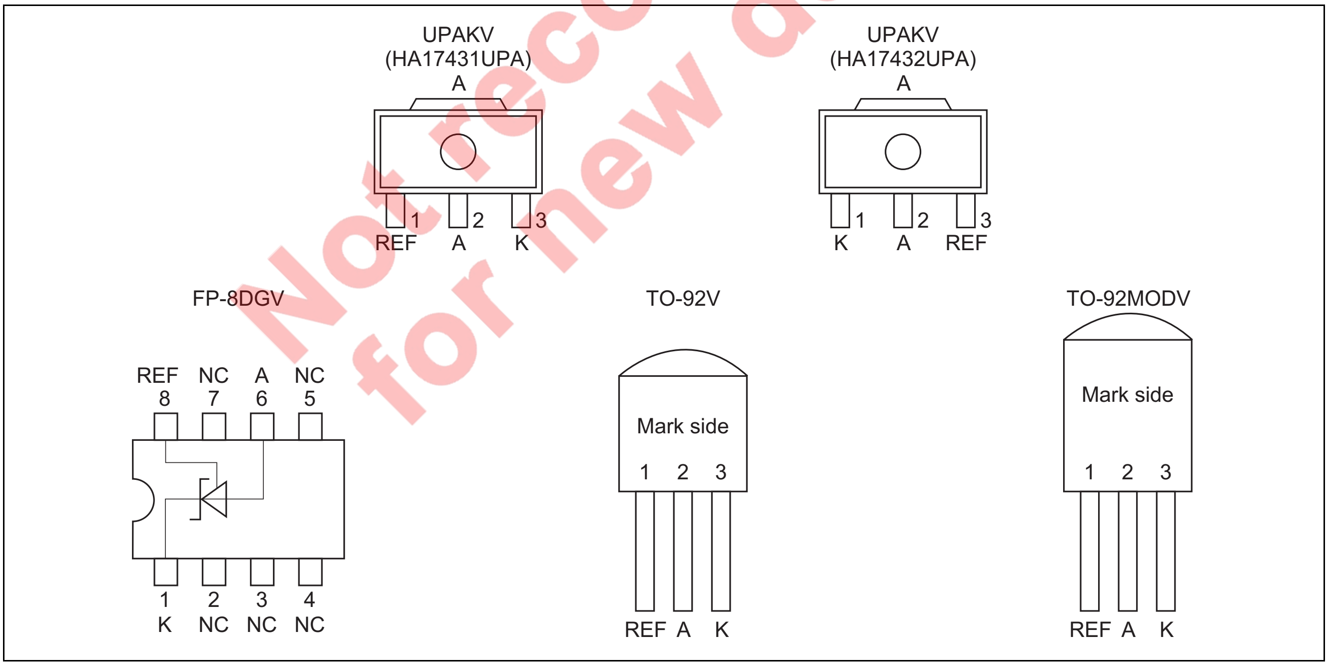


HA17431 Series

Ordering Information

Item		Reference voltage (at 25°C)			Package Code (Package Name)	Operating Temperature Range
		Normal Version ±4% 2.395V to 2.495V to 2.595V	A Version ±2.2% 2.440V to 2.495V to 2.550V	V Version ±1% 2.475V to 2.500V to 2.525V		
Car use	HA17431FPAJ		O		PRSP0008DE-B (FP-8DGV)	–40 to +85°C
	HA17431FPJ	O			PRSP0008DE-B (FP-8DGV)	
	HA17431PAJ		O		PRSS0003DC-A (TO-92MODV)	
	HA17431PJ	O			PRSS0003DC-A (TO-92MODV)	
	HA17431PNAJ		O		PRSS0003DA-A (TO-92V)	
	HA17431VPJ			O	PRSS0003DA-A (TO-92V)	
Industrial use	HA17431UPA		O		PLZZ0004CA-A (UPAKV)	–20 to +85°C
	HA17432UPA		O		PLZZ0004CA-A (UPAKV)	

Pin Arrangement



Absolute Maximum Ratings

(Ta = 25°C)

Item	Symbol	Ratings			Unit	Notes
		HA17431VPJ	HA17431UPA	HA17432UPA		
Cathode voltage	V_{KA}	16	40	40	V	1
Continuous cathode current	I_K	–50 to +50	–100 to +150	–100 to +150	mA	
Reference input current	Iref	–0.05 to +10	–0.05 to +10	–0.05 to +10	mA	
Power dissipation	P_T	500 *2	800 *5	800 *5	mW	2, 5
Operating temperature range	Topr	–40 to +85	–20 to +85	–20 to +85	°C	
Storage temperature	Tstg	–55 to +150	–55 to +150	–55 to +150	°C	

Item	Symbol	Ratings			Unit	Notes
		HA17431PNAJ	HA17431PJ/PAJ	HA17431FPJ/FPAJ		
Cathode voltage	V_{KA}	40	40	40	V	1
Continuous cathode current	I_K	–100 to +150	–100 to +150	–100 to +150	mA	
Reference input current	Iref	–0.05 to +10	–0.05 to +10	–0.05 to +10	mA	
Power dissipation	P_T	500 *2	800 *3	500 *4	mW	2, 3, 4
Operating temperature range	Topr	–40 to +85	–40 to +85	–40 to +85	°C	
Storage temperature	Tstg	–55 to +150	–55 to +150	–55 to +125	°C	

Notes:
1. Voltages are referenced to anode.
2. Ta ≤ 25°C. If Ta > 25°C, derate by 4.0 mW/°C.
3. Ta ≤ 25°C. If Ta > 25°C, derate by 6.4 mW/°C.
4. 50 mm × 50 mm × 1.5mmt glass epoxy board (5% wiring density), Ta ≤ 25°C. If Ta > 25°C, derate by 5 mW/°C.
5. 15 mm × 25 mm × 0.7mmt alumina ceramic board,Ta ≤ 25°C. If Ta > 25°C, derate by 6.4 mW/°C.

Electrical Characteristics

HA17431VPJ

(Ta = 25°C, I_K = 10 mA)

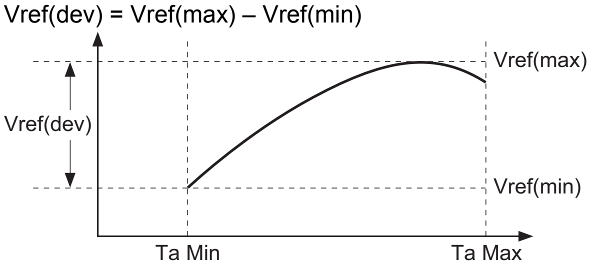
Item	Symbol	Min	Typ	Max	Unit	Test Conditions	Notes
Reference voltage	Vref	2.475	2.500	2.525	V	V_{KA} = Vref	
Reference voltage temperature deviation	Vref(dev)	—	10	—	mV	V_{KA} = Vref, Ta = –20°C to +85°C	1
Reference voltage temperature coefficient	ΔVref/ΔTa	—	±30	—	ppm/°C	V_{KA} = Vref, 0°C to 50°C gradient	
Reference voltage regulation	ΔVref/ΔV_{KA}	—	2.0	3.7	mV/V	V_{KA} = Vref to 16 V	
Reference input current	Iref	—	2	6	μA	R_1 = 10 kΩ, R_2 = ∞	
Reference current temperature deviation	Iref(dev)	—	0.5	—	μA	R_1 = 10 kΩ, R_2 = ∞, Ta = –20°C to +85°C	
Minimum cathode current	Imin	—	0.4	1.0	mA	V_{KA} = Vref	2
Off state cathode current	Ioff	—	0.001	1.0	μA	V_{KA} = 16 V, Vref = 0 V	
Dynamic impedance	Z_{KA}	—	0.2	0.5	Ω	V_{KA} = Vref, I_K = 1 mA to 50 mA	

HA17431PJ/PAJ/FPJ/FPAJ/PNAJ/UPA, HA17432UPA

(Ta = 25°C, I_K = 10 mA)

Item	Symbol	Min	Typ	Max	Unit	Test Conditions		Notes
Reference voltage	Vref	2.440	2.495	2.550	V	V_{KA} = Vref		A
		2.395	2.495	2.595				Normal
Reference voltage temperature deviation	Vref(dev)	—	11	(30)	mV	V_{KA} = Vref	Ta = –20°C to +85°C	1, 3, 4
		—	5	(17)			Ta = 0°C to +70°C	1, 3, 5
Reference voltage regulation	ΔVref/ΔV_{KA}	—	1.4	3.7	mV/V	V_{KA} = Vref to 10 V		
		—	1	2.2		V_{KA} = 10 V to 40 V		
Reference input current	Iref	—	3.8	6	μA	R_1 = 10 kΩ, R_2 = ∞		
Reference current temperature deviation	Iref(dev)	—	0.5	(2.5)	μA	R_1 = 10 kΩ, R_2 = ∞, Ta = 0°C to +70°C		3
Minimum cathode current	Imin	—	0.4	1.0	mA	V_{KA} = Vref		2
Off state cathode current	Ioff	—	0.001	1.0	μA	V_{KA} = 40 V, Vref = 0 V		
Dynamic impedance	Z_{KA}	—	0.2	0.5	Ω	V_{KA} = Vref, I_K = 1 mA to 100 mA		

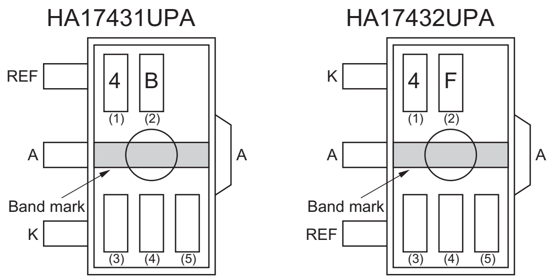
Notes: 1. Vref(dev) = Vref(max) – Vref(min)



2. Imin is given by the cathode current at Vref = $Vref_{(IK=10mA)}$ – 15 mV.
3. The maximum value is a design value (not measured).
4. HA17431PJ/PAJ/FPJ/FPAJ/PNAJ
5. HA17431UPA, HA17432UPA

UPAKV Marking Patterns

The marking patterns shown below are used on UPAKV products. Note that the product code and mark pattern are different. The pattern is laser-printed.



Notes: 1. Boxes (1) to (5) in the figures show the position of the letters or numerals, and are not actually marked on the package.

2. The letters (1) and (2) show the product specific mark pattern.

Product	(1)	(2)
HA17431UPA	4	B
HA17432UPA	4	F

3. The letter (3) shows the production year code (the last digit of the year).

4. The letter (4) shows the production month code (see table below).

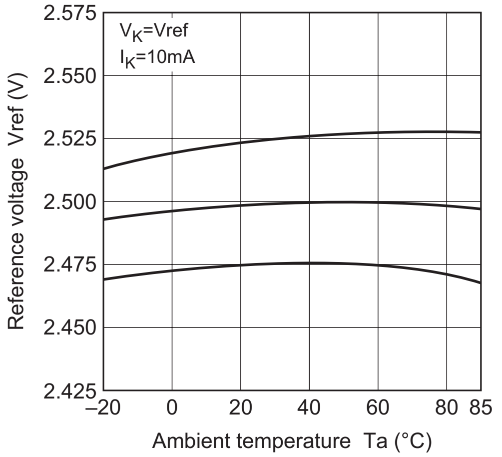
Production month	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Marked code	A	B	C	D	E	F	G	H	J	K	L	M

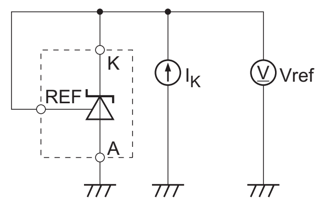
5. The letter (5) shows manufacturing code.

Characteristics Curves

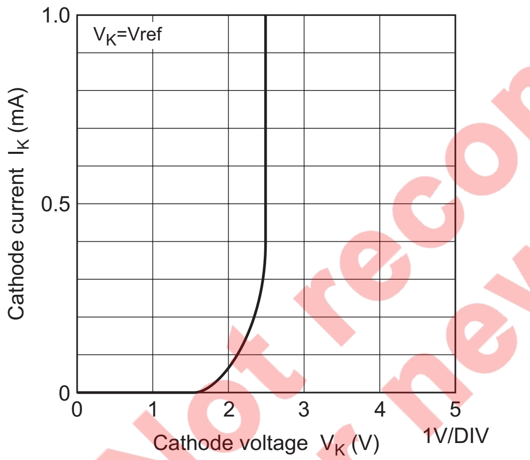
HA17431VPJ

Reference Voltage Temperature Characteristics

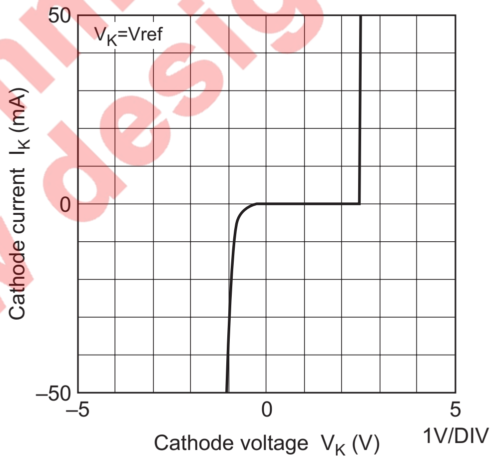


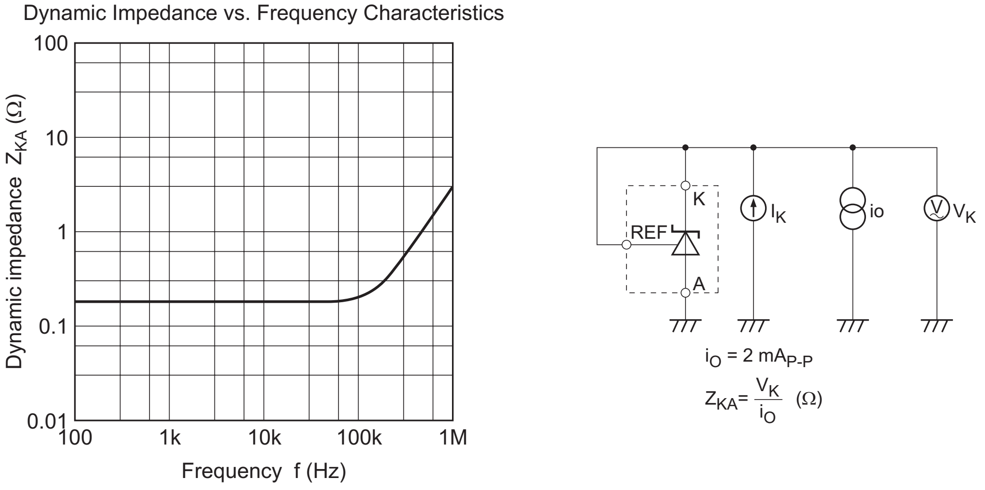


Cathode Current vs. Cathode Voltage Characteristics 1

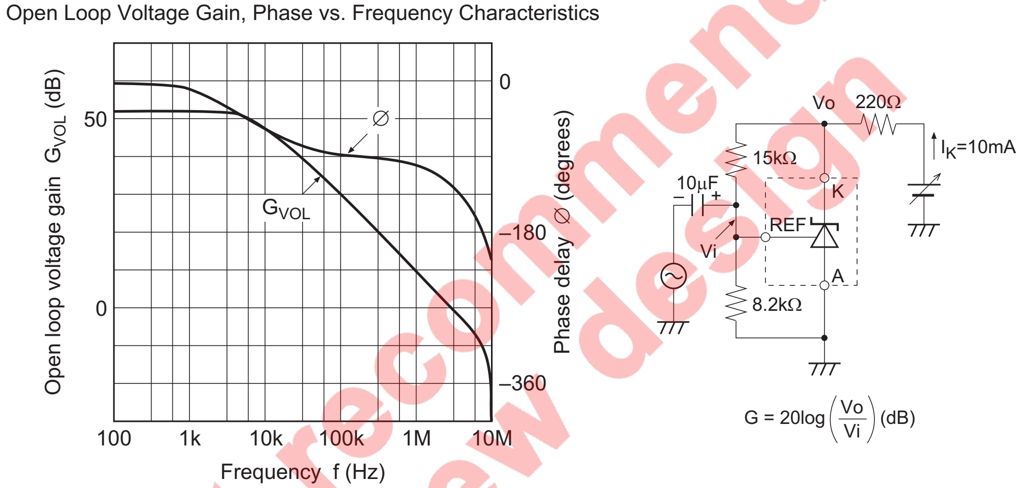


Cathode Current vs. Cathode Voltage Characteristics 2





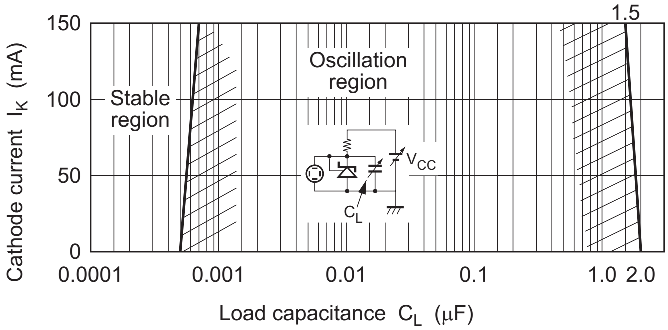
Dynamic Impedance vs. Frequency Characteristics
Dynamic impedance Z_{KA} (Ω)
100
10
1
0.1
0.01
100
1k
10k
100k
1M
Frequency f (Hz)
K
REF
A
I_K
io
V_K
i_O = 2 mA_{P-P}
$Z_{KA} = \frac{V_K}{i_O}$ (Ω)



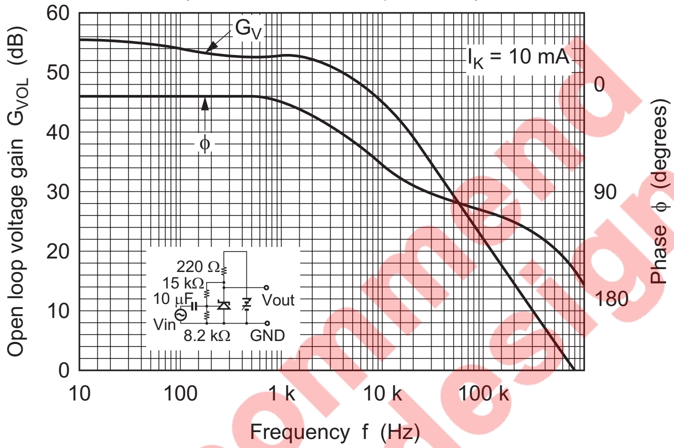
Open Loop Voltage Gain, Phase vs. Frequency Characteristics
Open loop voltage gain G_{VOL} (dB)
50
0
Phase delay ∅ (degrees)
0
–180
–360
∅
G_{VOL}
100
1k
10k
100k
1M
10M
Frequency f (Hz)
Vo
220Ω
I_K=10mA
15kΩ
10μF
K
REF
Vi
A
8.2kΩ
$G = 20\log\left(\frac{Vo}{Vi}\right)$ (dB)

HA17431PJ/PAJ/FPAJ/PNAJ/UPA, HA17432UPA

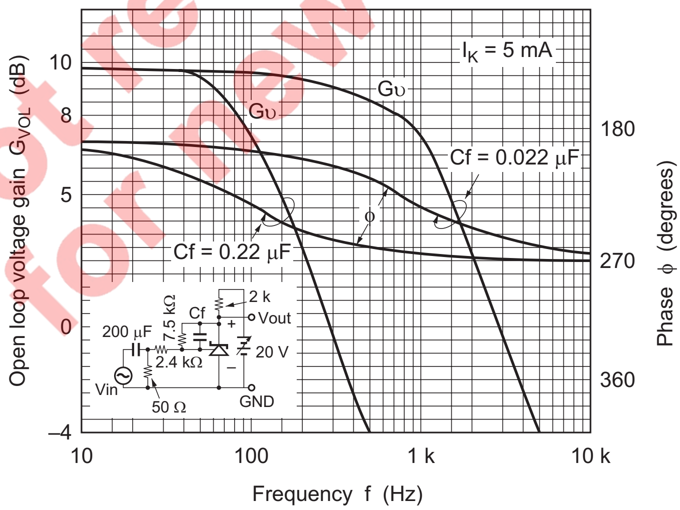
Oscillation Stability vs. Load Capacitance between Anode and Cathode



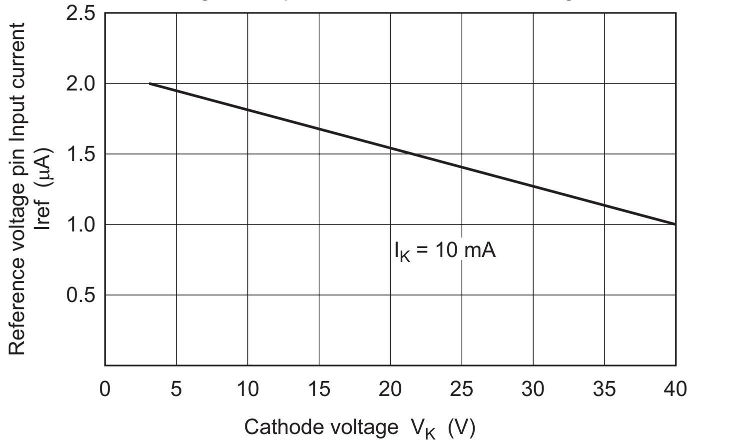
Open Loop Voltage Gain, Phase vs. Frequency Characteristics (1)
(With no feedback capacitance)



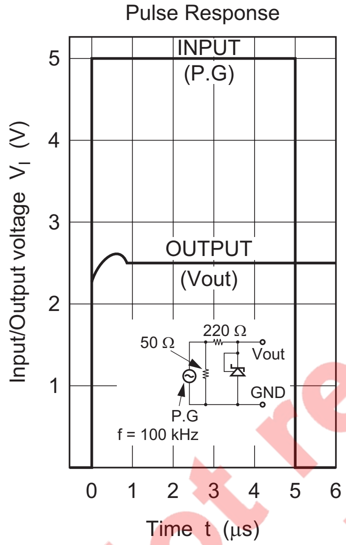
Open Loop Voltage Gain, Phase vs. Frequency Characteristics (2)
(When a feedback capacitance (Cf) is provided)



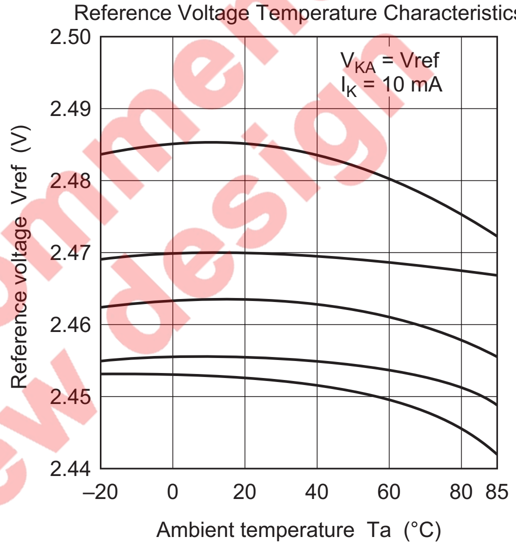
Reference Voltage Pin Input Current vs. Cathode Voltage Characteristics



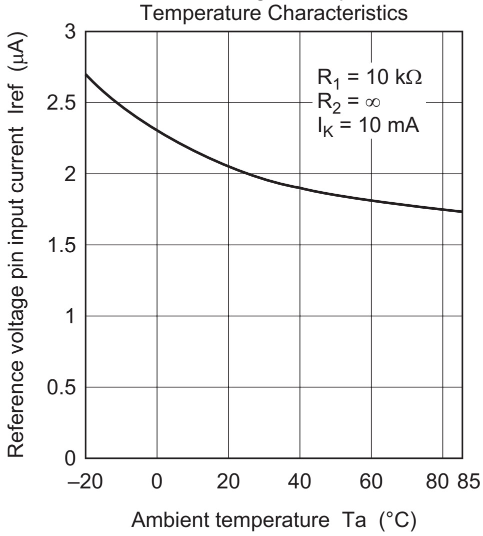
Pulse Response



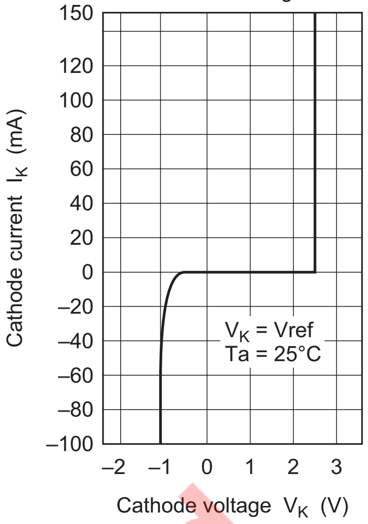
Reference Voltage Temperature Characteristics



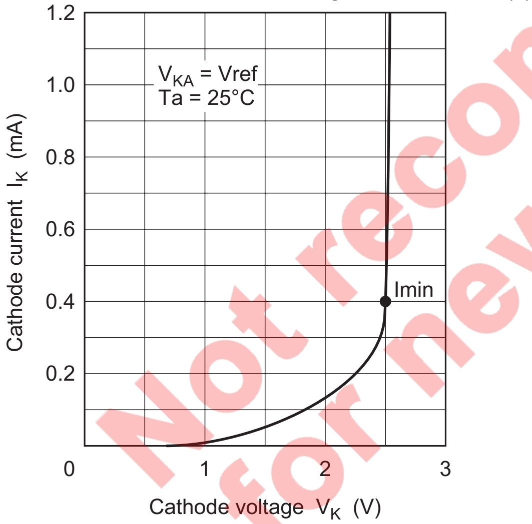
Reference Voltage Pin Input Current Temperature Characteristics



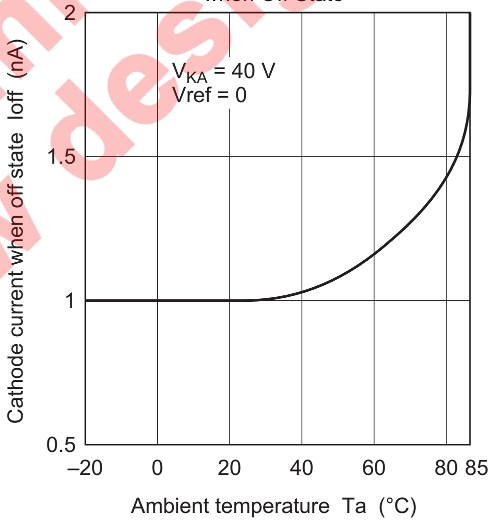
Cathode Current vs. Cathode Voltage Characteristics (1)



Cathode Current vs. Cathode Voltage Characteristics (2)



Cathode Current Temperature Characteristics when Off State



Application Examples

As shown in the figure on the right, this IC operates as an inverting amplifier, with the REF pin as input pin. The open-loop voltage gain is given by the reciprocal of “reference voltage deviation by cathode voltage change” in the electrical specifications, and is approximately 50 to 60 dB. The REF pin has a high input impedance, with an input current Iref of 3.8 μA Typ (V version: Iref = 2 μA Typ). The output impedance of the output pin K (cathode) is defined as dynamic impedance Z_{KA}, and Z_{KA} is low (0.2 Ω) over a wide cathode current range. A (anode) is used at the minimum potential, such as ground.

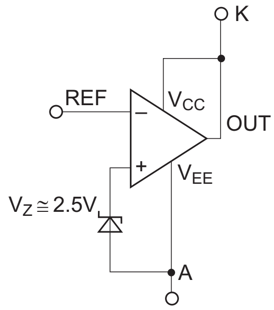
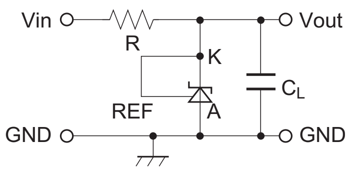
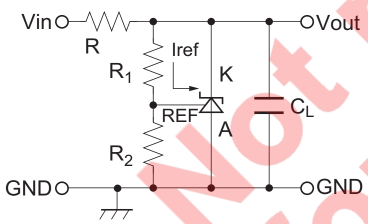
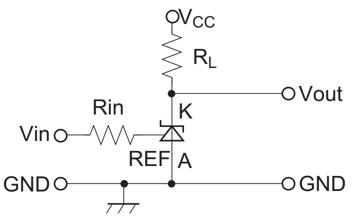
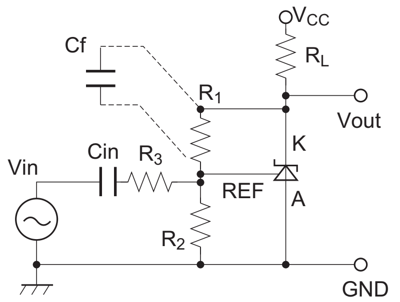


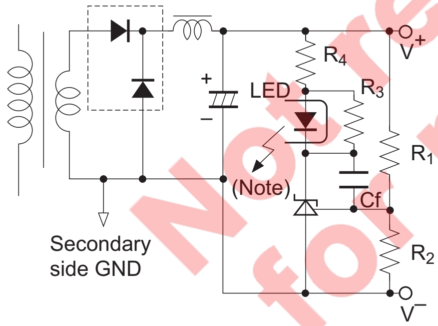
Figure 1 Operation Diagram

Application Hints

No.	Application Example	Description
1	Reference voltage generation circuit 	This is the simplest reference voltage circuit. The value of the resistance R is set so that cathode current $I_K \geq 1$ mA. Output is fixed at Vout ≅ 2.5 V. The external capacitor C_L ($C_L \geq 3.3$ μF) is used to prevent oscillation in normal applications.
2	Variable output shunt regulator circuit 	This is circuit 1 above with variable output provided. Here, $\text{Vout} \cong 2.5\text{ V} \times \frac{(R_1 + R_2)}{R_2}$ Since the reference input current Iref = 3.8 μA Typ (V version: Iref = 2 μA Typ) flows through R_1, resistance values are chosen to allow the resultant voltage drop to be ignored.

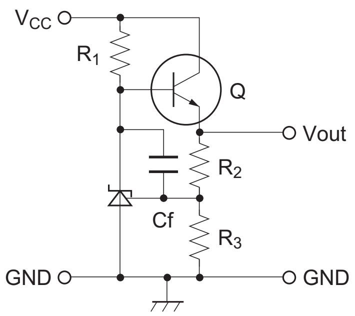
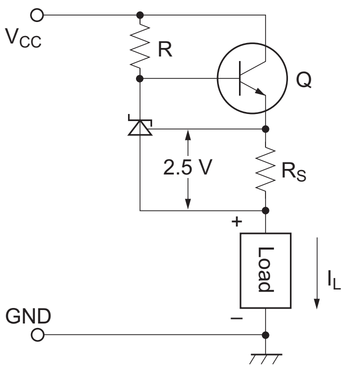
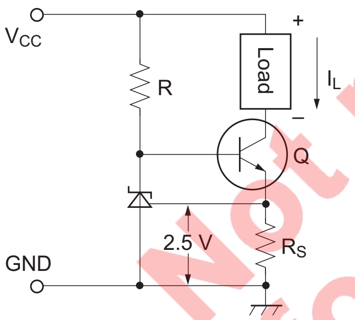
Application Hints (cont.)

<table>
<tr><th>No.</th><th>Application Example</th><th>Description</th></tr>
<tr><td>3</td><td>Single power supply inverting comparator circuit

</td><td>This is an inverting type comparator with an input threshold voltage of approximately 2.5 V. Rin is the REF pin protection resistance, with a value of several kΩ to several tens of kΩ.
R_L is the load resistance, selected so that the cathode current $I_K \geq 1$ mA when Vout is low.
<table>
<tr><th>Condition</th><th>Vin</th><th>Vout</th><th>IC</th></tr>
<tr><td>C1</td><td>Less then 2.5 V</td><td>V_{CC} (V_{OH})</td><td>OFF</td></tr>
<tr><td>C2</td><td>2.5 V or more</td><td>Approx. 2 V (V_{OL})</td><td>ON</td></tr>
</table></td></tr>
<tr><td>4</td><td>AC amplifier circuit


Gain $G = \frac{R_1}{R_2 \,//\, R_3}$ (DC gain)
Cutoff frequency $fc = \frac{1}{2\pi\, Cf\, (R_1 \,//\, R_2 \,//\, R_3)}$</td><td>This is an AC amplifier with voltage gain $G = -R_1 / (R_2//R_3)$. The input is cut by capacitance Cin, so that the REF pin is driven by the AC input signal, centered on 2.5 V_{DC}.
R_2 also functions as a resistance that determines the DC cathode potential when there is no input, but if the input level is low and there is no risk of Vout clipping to V_{CC}, this can be omitted.
To change the frequency characteristic, Cf should be connected as indicated by the dotted line.</td></tr>
<tr><td>5</td><td>Switching power supply error amplification circuit


Note: LED : Light emitting diode in photocoupler
R3 : Bypass resistor to feed IK(>Imin) when LED current vanishes
R4 : LED protection resistance</td><td>This circuit performs control on the secondary side of a transformer, and is often used with a switching power supply that employs a photocoupler for offlining.
The output voltage (between V+ and V–) is given by the following formula:
$Vout \cong 2.5\ V \times \frac{(R_1 + R_2)}{R_2}$
In this circuit, the gain with respect to the Vout error is as follows:
$G = \frac{R_2}{(R_1 + R_2)} \times$ [HA17431 open loop gain] $\times$ [photocoupler total gain]
As stated earlier, the HA17431 open-loop gain is 50 to 60 dB.</td></tr>
</table>

Application Hints (cont.)

No.	Application Example	Description
6	Constant voltage regulator circuit 	This is a 3-pin regulator with a discrete configuration, in which the output voltage $Vout = 2.5\ V \times \frac{(R_2 + R_3)}{R_3}$ R_1 is a bias resistance for supplying the HA17431 cathode current and the output transistor Q base current.
7	Discharge type constant current circuit 	This circuit supplies a constant current of $I_L \cong \frac{2.5\ V}{R_S}$ [A] into the load. Caution is required since the HA17431 cathode current is also superimposed on I_L. The requirement in this circuit is that the cathode current must be greater than Imin = 1 mA. The I_L setting therefore must be on the order of several mA or more.
8	Induction type constant current circuit 	In this circuit, the load is connected on the collector side of transistor Q in circuit 7 above. In this case, the load floats from GND, but the HA17431 cathode current is not superimposed on I_L, so that I_L can be kept small (1 mA or less is possible). The constant current value is the same as for circuit 7 above: $I_L \cong \frac{2.5\ V}{R_S}$ [A]

Design Guide for AC-DC SMPS (Switching Mode Power Supply)

1. Use of Shunt Regulator in Transformer Secondary Side Control
   This example is applicable to both forward transformers and flyback transformers. A shunt regulator is used on the secondary side as an error amplifier, and feedback to the primary side is provided via a photocoupler.

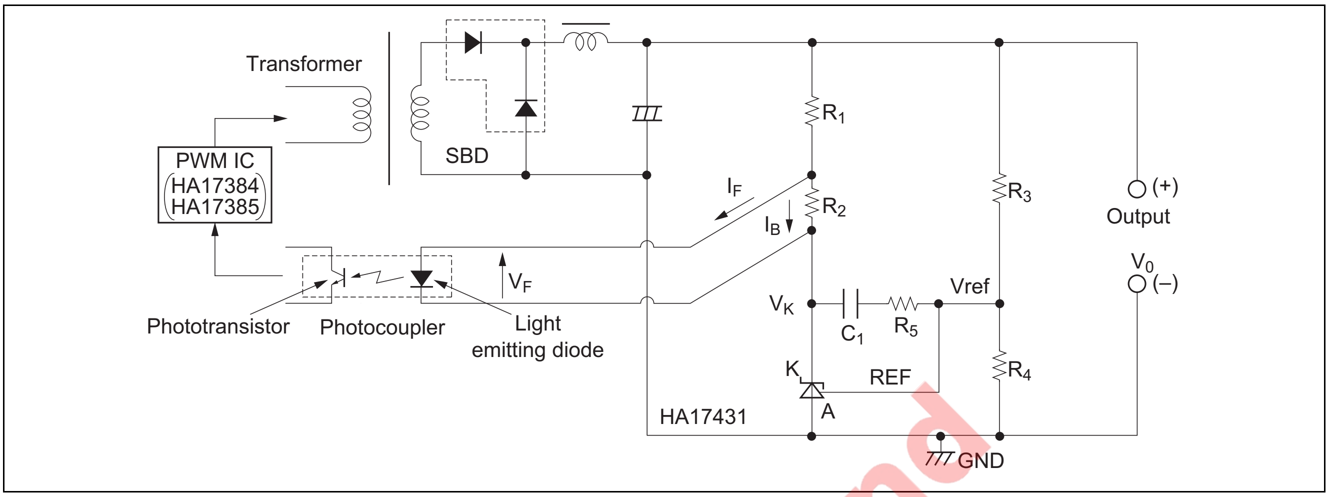


Figure 2 Typical Shunt Regulator/Error Amplifier

2. Determination of External Constants for the Shunt Regulator
   A. DC characteristic determination
   In figure 2, R_1 and R_2 are protection resistor for the light emitting diode in the photocoupler, and R_2 is a bypass resistor to feed I_K minimum, and these are determined as shown below. The photocoupler specification should be obtained separately from the manufacturer. Using the parameters in figure 2, the following formulas are obtained:

$$R_1 = \frac{V_0 - V_F - V_K}{I_F + I_B}, \quad R_2 = \frac{V_F}{I_B}$$

   V_K is the HA17431 operating voltage, and is set at around 3 V, taking into account a margin for fluctuation. R_2 is the current shunt resistance for the light emitting diode, in which a bias current I_B of around 1/5 I_F flows.
   Next, the output voltage can be determined by R3 and R4, and the following formula is obtained:

$$V_0 = \frac{R_3 + R_4}{R_4} \times \text{Vref}, \text{Vref} = 2.5 \text{ V Typ}$$

   The absolute values of R_3 and R_4 are determined by the HA17431 reference input current Iref and the AC characteristics described in the next section. The Iref value is around 3.8 μA Typ. (V version: 2 μA Typ)
   B. AC characteristic determination
   This refers to the determination of the gain frequency characteristic of the shunt regulator as an error amplifier. Taking the configuration in figure 2, the error amplifier characteristic is as shown in figure 3.

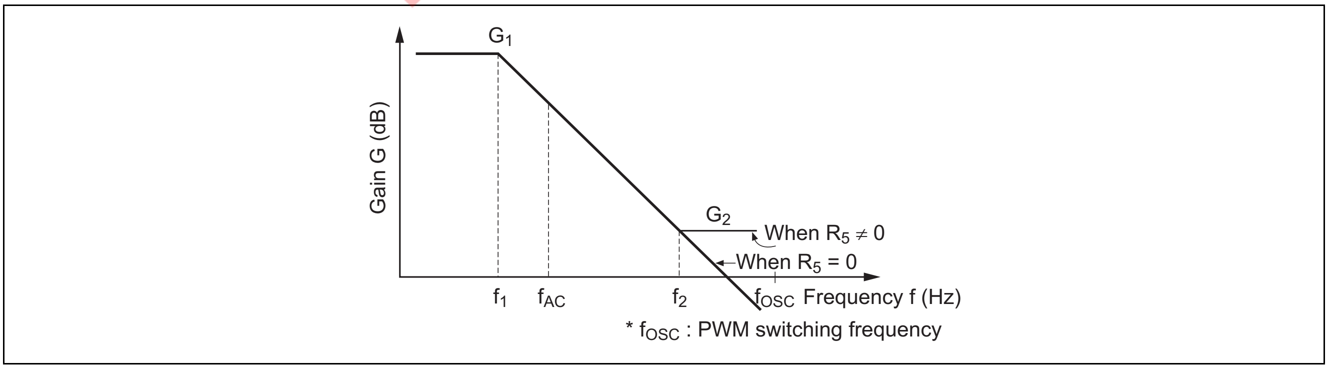


Figure 3 HA17431 Error Amplification Characteristic

In Figure 3, the following formulas are obtained:

Gain

$G_1 = G_0 \approx$ 50 dB to 60 dB (determined by shunt regulator)

$$G_2 = \frac{R_5}{R_3}$$

Corner frequencies

$f_1 = 1/(2\pi\ C_1\ G_0\ R_3)$

$f_2 = 1/(2\pi\ C_1\ R_5)$

G_0 is the shunt regulator open-loop gain; this is given by the reciprocal of the reference voltage fluctuation $\Delta Vref/\Delta V_{KA}$, and is approximately 50 dB.

3. Practical Example

Consider the example of a photocoupler, with an internal light emitting diode V_F = 1.05 V and I_F = 2.5 mA, power supply output voltage V_2 = 5 V, and bias resistance R_2 current of approximately 1/5 I_F at 0.5 mA. If the shunt regulator V_K = 3 V, the following values are found.

$$R_1 = \frac{5V - 1.05V - 3V}{2.5mA + 0.5mA} = 316(\Omega)\ (330\Omega \text{ from E24 series})$$

$$R_2 = \frac{1.05V}{0.5mA} = 2.1(k\Omega)\ (2.2k\Omega \text{ from E24 series})$$

Next, assume that $R_3 = R_4$ = 10 kΩ. This gives a 5 V output. If R_5 = 3.3 kΩ and C_1 = 0.022 μF, the following values are found.

G_2 = 3.3 kΩ / 10 kΩ = 0.33 times (–10 dB)

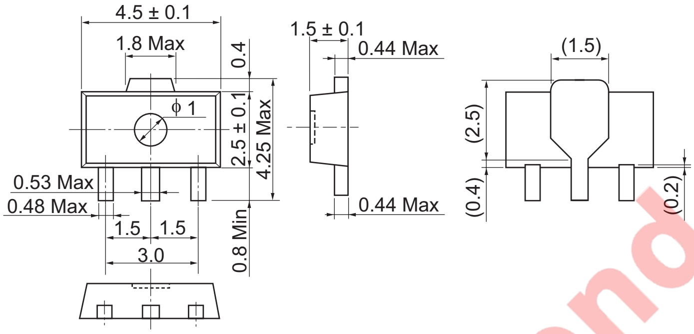
$f_1 = 1 / (2 \times \pi \times 0.022\ \mu F \times 316 \times 10\ k\Omega) = 2.3$ (Hz)

$f_2 = 1 / (2 \times \pi \times 0.022\ \mu F \times 3.3\ k\Omega) = 2.2$ (kHz)

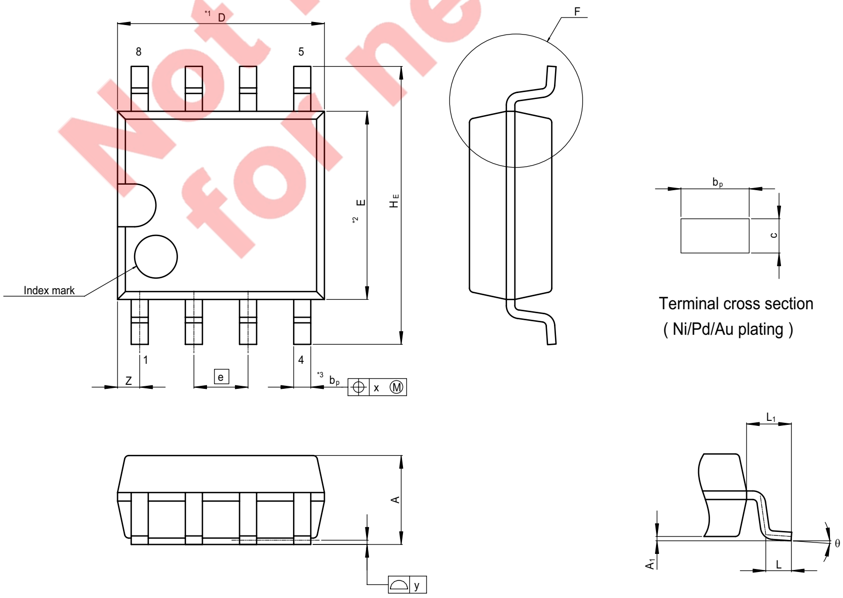
Package Dimensions

Package Name	JEITA Package Code	RENESAS Code	Previous Code	MASS[Typ.]
UPAK	SC-62	PLZZ0004CA-A	UPAK / UPAKV	0.050g

Unit: mm



JEITA Package Code	RENESAS Code	Previous Code	MASS[Typ.]
P-SOP8-4.4x4.85-1.27	PRSP0008DE-B	FP-8DGV	0.1g

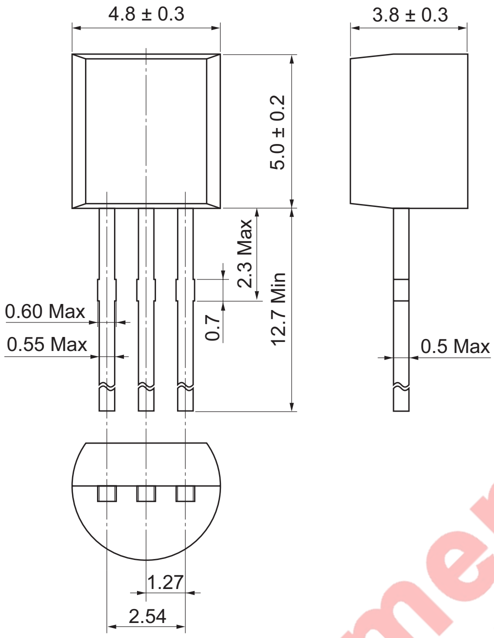


NOTE)
1. DIMENSIONS"*1 (Nom)"AND"*2" DO NOT INCLUDE MOLD FLASH.
2. DIMENSION"*3"DOES NOT INCLUDE TRIM OFFSET.

Reference Symbol	Dimension in Millimeters		
	Min	Nom	Max
D	—	4.85	5.25
E	—	4.4	—
A_2	—	—	—
A_1	0.00	0.1	0.20
A	—	—	2.03
b_p	0.35	0.4	0.45
b_1	—	—	—
c	0.15	0.20	0.25
c_1	—	—	—
θ	0°	—	8°
H_E	6.35	6.5	6.75
e	—	1.27	—
x	—	—	0.12
y	—	—	0.15
Z	—	—	0.75
L	0.42	0.60	0.85
L_1	—	1.05	—

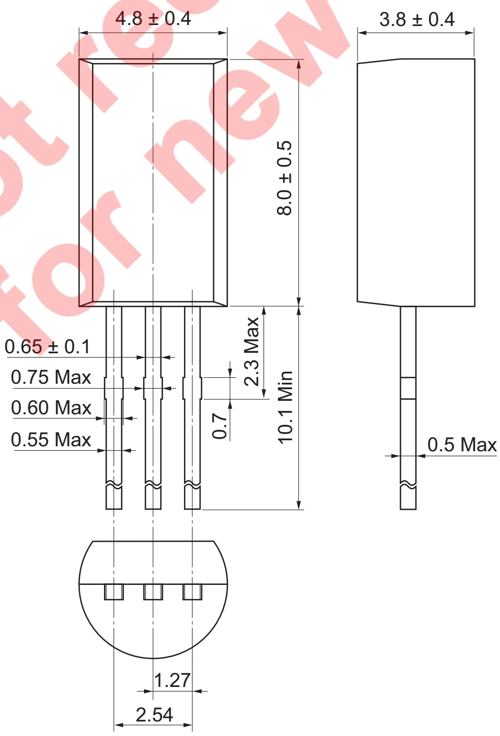
Package Name	JEITA Package Code	RENESAS Code	Previous Code	MASS[Typ.]
TO-92(1)	SC-43A	PRSS0003DA-A	TO-92(1) / TO-92(1)V	0.25g

Unit: mm



Package Name	JEITA Package Code	RENESAS Code	Previous Code	MASS[Typ.]
TO-92 Mod	SC-51	PRSS0003DC-A	TO-92 Mod / TO-92 ModV	0.35g

Unit: mm



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Refer to "**http://www.renesas.com/en/network**" for the latest and detailed information.

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