



APPLICATION NOTE

# HA17431 Series

Shunt Regulators



**HITACHI**

2nd Edition  
ADE-504-004A (Z)

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# Contents

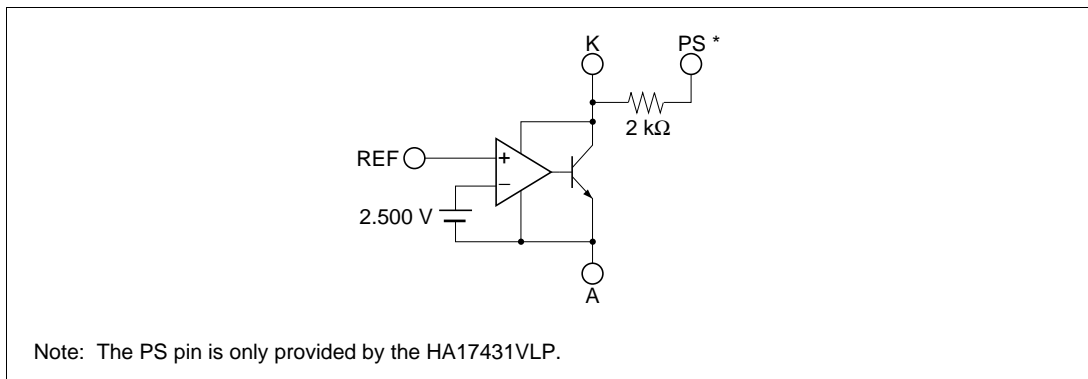
Section 1	Outline .....	1
1.1	Features .....	1
1.2	Selection Guide .....	2
1.3	Pin Arrangement by Product .....	3
Section 2	Specifications .....	4
2.1	Absolute Maximum Ratings .....	4
2.2	Electrical Characteristics .....	6
Section 3	Characteristics Curves .....	8
Section 4	Outline Dimensions .....	13
Section 5	MPAK-5 and UPAK Marking Patterns .....	14
Section 6	Ordering Information .....	16
Section 7	Application Examples .....	17
7.1	Application Hints .....	18
7.2	Design Guide for AC-DC SMPS (Switching Mode Power Supply) .....	21
7.2.1	Use of Shunt Regulator in Transformer Secondary Side Control .....	21
7.2.2	Determination of External Constants for the Shunt Regulator .....	21
7.2.3	Practical Example .....	23
7.3	Circuit Example AC-DC SMPS .....	24

## Section 1 Outline

The HA17431 series is a family of voltage referenced shunt regulators. The main application of these products is in voltage regulators that provide a variable output voltage. The HA17431 series products are provided in a wide range of packages; TO-92 and TO-92MOD insertion mounting packages and MPAK-5, UPAK, and FP-8D surface mounting packages are available. The on-chip high-precision reference voltage source can provide  $\pm 1\%$  accuracy in the V versions, which have a  $V_{KA}$  max of 16 volts. The HA17431VLP, which is provided in the MPAK-5 package, is designed for use in switching mode power supplies. It provides a built-in photocoupler bypass resistor for the PS pin, and an error amplifier can be easily constructed on the supply side.

### 1.1 Features

- The V versions provide  $2.500\text{ V} \pm 1\%$  at  $T_a = 25^\circ\text{C}$
- The HA17431VLP includes a photocoupler bypass resistor ( $2\text{ k}\Omega$ )
- The reference voltage has a low temperature coefficient
- The MPAK-5 and UPAK miniature packages are optimal for use on high mounting density circuit boards
- A wide operating temperature range ( $-40$  to  $+85^\circ\text{C}$ ) is provided by the TO-92, TO-92MOD, and FP-8D package versions

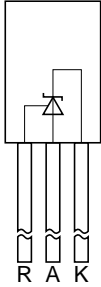
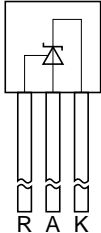
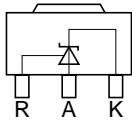
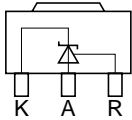
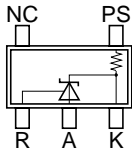
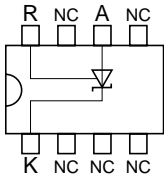


**Figure 1.1 Block Diagram**

## 1.2 Selection Guide

HA17431						
Item		V Version	A Version	Normal Version	Package	Temp. Range
Reference voltage	Accuracy	±1% (at 25°C)	±2.2%	±4%		
	Max	2.525 V	2.550 V	2.595 V		
	Typ	2.500 V	2.495 V	2.495 V		
	Min	2.475 V	2.440 V	2.395 V		
Cathode voltage		16 V max	40 V max	40 V max		
Cathode current		50 mA max	150 mA max	150 mA max		
Wide temperature use		HA17431VPJ	HA17431PNAJ		TO-92	-40 to +85°C
			HA17431PAJ		TO-92MOD	
				HA17431PJ	TO-92MOD	
			HA17431FPAJ		FP-8D	
				HA17431FPJ	FP-8D	
Industrial use		HA17431VLP			MPAK-5	-20 to +85°C
		HA17431VP	HA17431PNA		TO-92	
			HA17431UPA		UPAK	
			HA17432UPA		UPAK	
			HA17431PA		TO-92MOD	
				HA17431P	TO-92MOD	
			HA17431FPA		FP-8D	
				HA17431FP	FP-8D	
Commercial use			HA17431UA		UPAK	
			HA17432UA		UPAK	

### 1.3 Pin Arrangement by Product

Product Name	Package	Pin Arrangement
HA17431PA	TO-92MOD	
HA17431VP (2.5 V series) HA17431PNA	TO-92	
HA17431UA HA17431UPA	UPAK	
HA17432UA HA17432UPA	UPAK	
HA17431VLP (2.5 V series)	MPAK-5	
HA17431FPA	SOP-8	

## Section 2 Specifications

### 2.1 Absolute Maximum Ratings (Ta = 25°C)

Item	Symbol	HA17431VLP	HA17431VP	HA17431VPJ	Unit	Notes
Cathode voltage	$V_{KA}$	16	16	16	V	1
PS term. voltage	$V_{PS}$	$V_{KA}$ to 16	—	—	V	1, 2, 3
Continuous cathode current	$I_K$	-50 to +50	-50 to +50	-50 to +50	mA	
Reference input current	$I_{ref}$	-0.05 to +10	-0.05 to +10	-0.05 to +10	mA	
Power dissipation	$P_T$	150* <sup>4</sup>	500* <sup>5</sup>	500* <sup>5</sup>	mW	4, 5
Operating temperature range	$T_{opr}$	-20 to +85	-20 to +85	-40 to +85	°C	
Storage temperature	$T_{stg}$	-55 to +150	-55 to +150	-55 to +150	°C	

Item	Symbol	HA17431P/PA	HA17431FP/FPA	HA17431UA/UPA	Unit	Notes
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	$I_{ref}$	-0.05 to +10	-0.05 to +10	-0.05 to +10	mA	
Power dissipation	$P_T$	800* <sup>6</sup>	500* <sup>7</sup>	800* <sup>8</sup>	mW	6, 7, 8
Operating temperature range	$T_{opr}$	-20 to +85	-20 to +85	-20 to +85	°C	
Storage temperature	$T_{stg}$	-55 to +150	-55 to +125	-55 to +150	°C	

Item	Symbol	HA17431PJ/PAJ	HA17431FPJ/FPAJ	Unit	Notes
Cathode voltage	$V_{KA}$	40	40	V	1
Continuous cathode current	$I_K$	-100 to +150	-100 to +150	mA	
Reference input current	$I_{ref}$	-0.05 to +10	-0.05 to +10	mA	
Power dissipation	$P_T$	800* <sup>6</sup>	500* <sup>7</sup>	mW	6, 7
Operating temperature range	$T_{opr}$	-40 to +85	-40 to +85	°C	
Storage temperature	$T_{stg}$	-55 to +150	-55 to +125	°C	

Item	Symbol	HA17432UA/UPA	HA17431PNA	HA17431PNAJ	Unit	Notes
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	$I_{ref}$	-0.05 to +10	-0.05 to +10	-0.05 to +10	mA	
Power dissipation	$P_T$	800* <sup>6</sup>	500* <sup>5</sup>	500* <sup>5</sup>	mW	5, 6
Operating temperature range	$T_{opr}$	-20 to +85	-20 to +85	-40 to +85	°C	
Storage temperature	$T_{stg}$	-55 to +150	-55 to +150	-55 to +150	°C	

- Notes:
1. Voltages are referenced to anode.
  2. The PS pin is only provided by the HA17431VLP.
  3. The PS pin voltage must not fall below the cathode voltage. If the PS pin is not used, the PS pin is recommended to be connected with the cathode.
  4.  $T_a \leq 25^\circ\text{C}$ . If  $T_a > 25^\circ\text{C}$ , derate by 1.2 mW/°C.
  5.  $T_a \leq 25^\circ\text{C}$ . If  $T_a > 25^\circ\text{C}$ , derate by 4.0 mW/°C.
  6.  $T_a \leq 25^\circ\text{C}$ . If  $T_a > 25^\circ\text{C}$ , derate by 6.4 mW/°C.
  7. 50 mm × 50 mm × t 1.5 mm glass epoxy board,  $T_a \leq 25^\circ\text{C}$ . If  $T_a > 25^\circ\text{C}$ , derate by 5 mW/°C.
  8. 15 mm × 25 mm × t 0.7 mm alumina ceramic board,  $T_a \leq 25^\circ\text{C}$ . If  $T_a > 25^\circ\text{C}$ , derate by 6.4 mW/°C.



## 2.2 Electrical Characteristics

HA17431VLP/VP/VPJ (Ta = 25°C, I<sub>K</sub> = 10 mA)

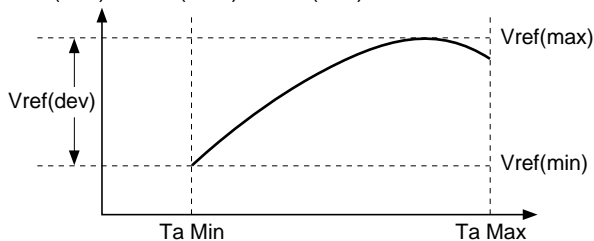
Item	Symbol	Min	Typ	Max	Unit	Test Conditions	Notes
Reference voltage	V <sub>ref</sub>	2.475	2.500	2.525	V	V <sub>KA</sub> = V <sub>ref</sub>	
Reference voltage temperature deviation	V <sub>ref</sub> (dev)	—	10	—	mV	V <sub>KA</sub> = V <sub>ref</sub> Ta = -20°C to +85°C	1
Reference voltage temperature coefficient	ΔV <sub>ref</sub> /ΔTa	—	±30	—	ppm/°C	V <sub>KA</sub> = V <sub>ref</sub> 0°C to 50°C gradient	
Reference voltage regulation	ΔV <sub>ref</sub> /ΔV <sub>KA</sub>	—	2.0	3.7	mV/V	V <sub>KA</sub> = V <sub>ref</sub> to 16 V	
Reference input current	I <sub>ref</sub>	—	2	6	μA	R1 = 10 kΩ, R2 = ∞	
Reference current temperature deviation	I <sub>ref</sub> (dev)	—	0.5	—	μA	R1 = 10 kΩ, R2 = ∞ Ta = -20°C to +85°C	
Minimum cathode current	I <sub>min</sub>	—	0.4	1.0	mA	V <sub>KA</sub> = V <sub>ref</sub>	2
Off state cathode current	I <sub>off</sub>	—	0.001	1.0	μA	V <sub>KA</sub> = 16 V, V <sub>ref</sub> = 0 V	
Dynamic impedance	Z <sub>KA</sub>	—	0.2	0.5	Ω	V <sub>KA</sub> = V <sub>ref</sub> I <sub>K</sub> = 1 mA to 50 mA	
Bypass resistance	R <sub>PS</sub>	1.6	2.0	2.4	kΩ	I <sub>PS</sub> = 1 mA	3
Bypass resistance temperature coefficient	ΔR <sub>PS</sub> /ΔTa	—	+2000	—	ppm/°C	I <sub>PS</sub> = 1 mA 0°C to 50°C gradient	3

**HA17431PJ/PAJ/FPJ/FPAJ/P/PA/UA/UPA/FP/FPA/PNA/PNAJ, HA17432UA/UPA**

( $T_a = 25^\circ\text{C}$ ,  $I_K = 10\text{ mA}$ )

Item	Symbol	Min	Typ	Max	Unit	Test Conditions	Notes
Reference voltage	Vref	2.440	2.495	2.550	V	$V_{KA} = V_{ref}$	A
		2.395	2.495	2.595			Normal
Reference voltage temperature deviation	Vref(dev)	—	11	(30)	mV	$V_{KA} = V_{ref}$ $T_a = -20^\circ\text{C}$ to $+85^\circ\text{C}$	1, 4
		—	5	(17)		$T_a = 0^\circ\text{C}$ to $+70^\circ\text{C}$	1, 4
Reference voltage regulation	$\Delta V_{ref}/\Delta V_{KA}$	—	1.4	3.7	mV/V	$V_{KA} = V_{ref}$ to 10 V $V_{KA} = 10\text{ V}$ to 40 V	
Reference input current	Iref	—	3.8	6	$\mu\text{A}$	$R1 = 10\text{ k}\Omega$ , $R2 = \infty$	
Reference current temperature deviation	Iref(dev)	—	0.5	(2.5)	$\mu\text{A}$	$R1 = 10\text{ k}\Omega$ , $R2 = \infty$ $T_a = 0^\circ\text{C}$ to $70^\circ\text{C}$	4
Minimum cathode current	Imin	—	0.4	1.0	mA	$V_{KA} = V_{ref}$	2
Off state cathode current	Ioff	—	0.001	1.0	$\mu\text{A}$	$V_{KA} = 40\text{ V}$ , $V_{ref} = 0\text{ V}$	
Dynamic impedance	$Z_{KA}$	—	0.2	0.5	$\Omega$	$V_{KA} = V_{ref}$ $I_K = 1\text{ mA}$ to $100\text{ mA}$	

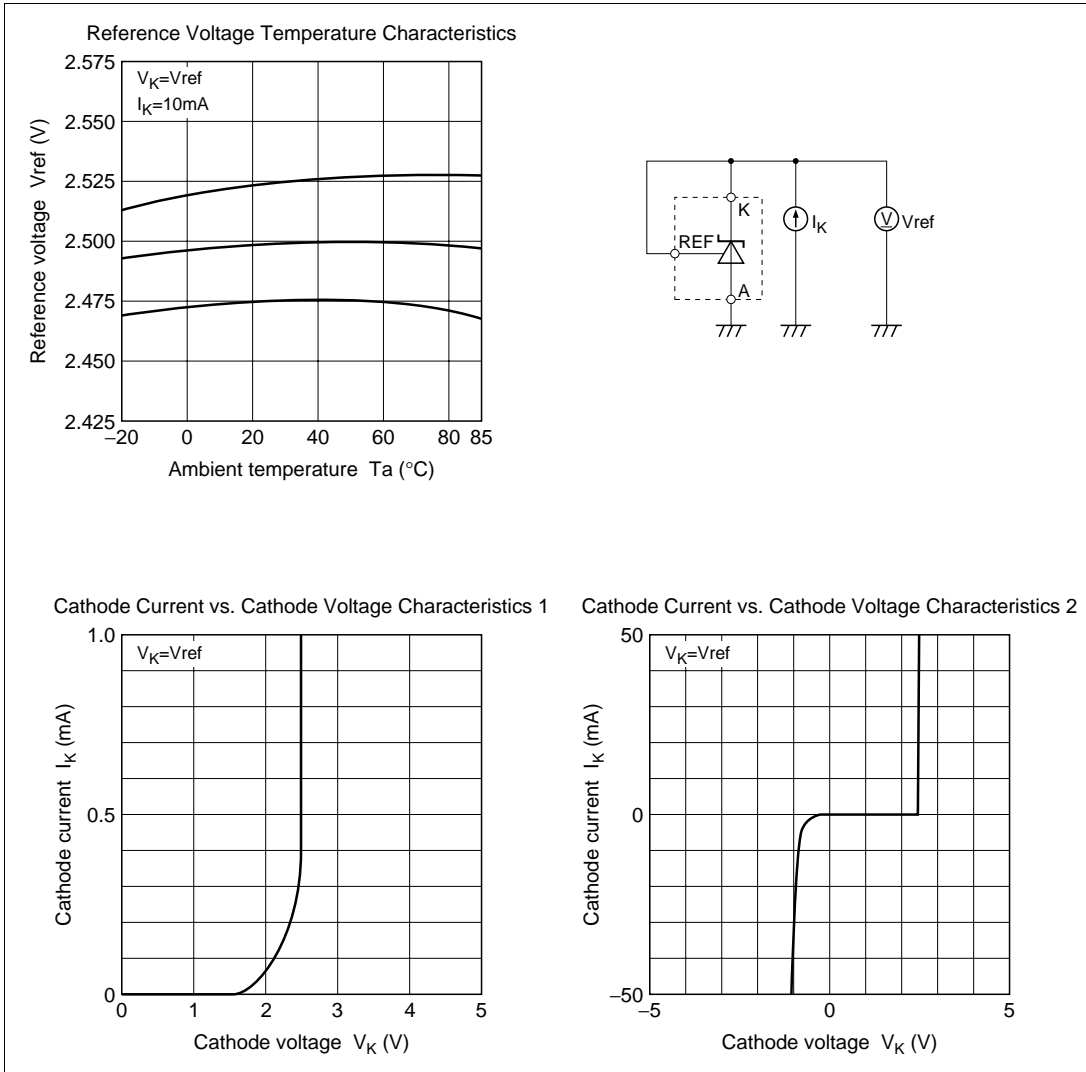
Notes: 1.  $V_{ref}(\text{dev}) = V_{ref}(\text{max}) - V_{ref}(\text{min})$



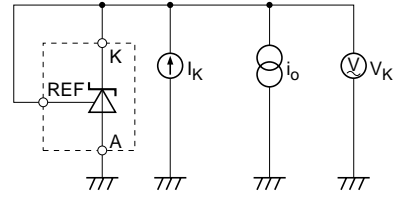
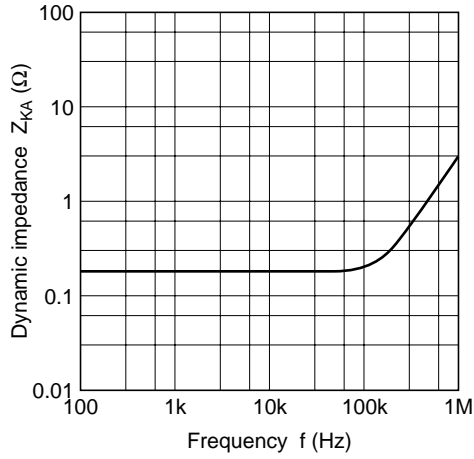
2. Imin is given by the cathode current at  $V_{ref} = V_{ref}(I_K=10\text{mA}) - 15\text{ mV}$ .
3.  $R_{PS}$  is only provided in HA17431VLP.
4. The maximum value is a design value (not measured).

## Section 3 Characteristics Curves

### HA17431VLP/VP/VPJ

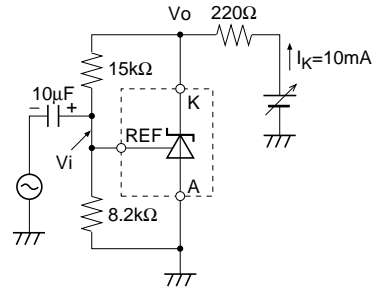
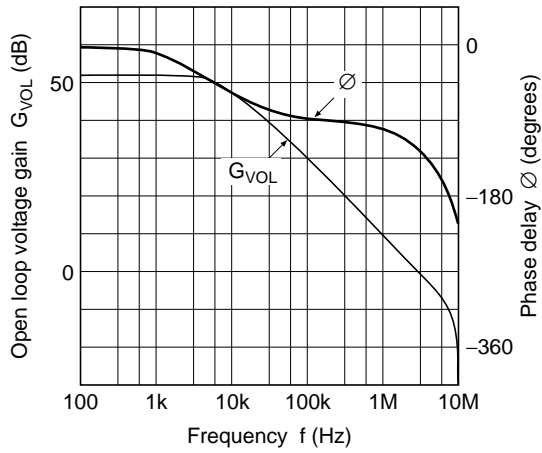


Dynamic Impedance vs. Frequency Characteristics



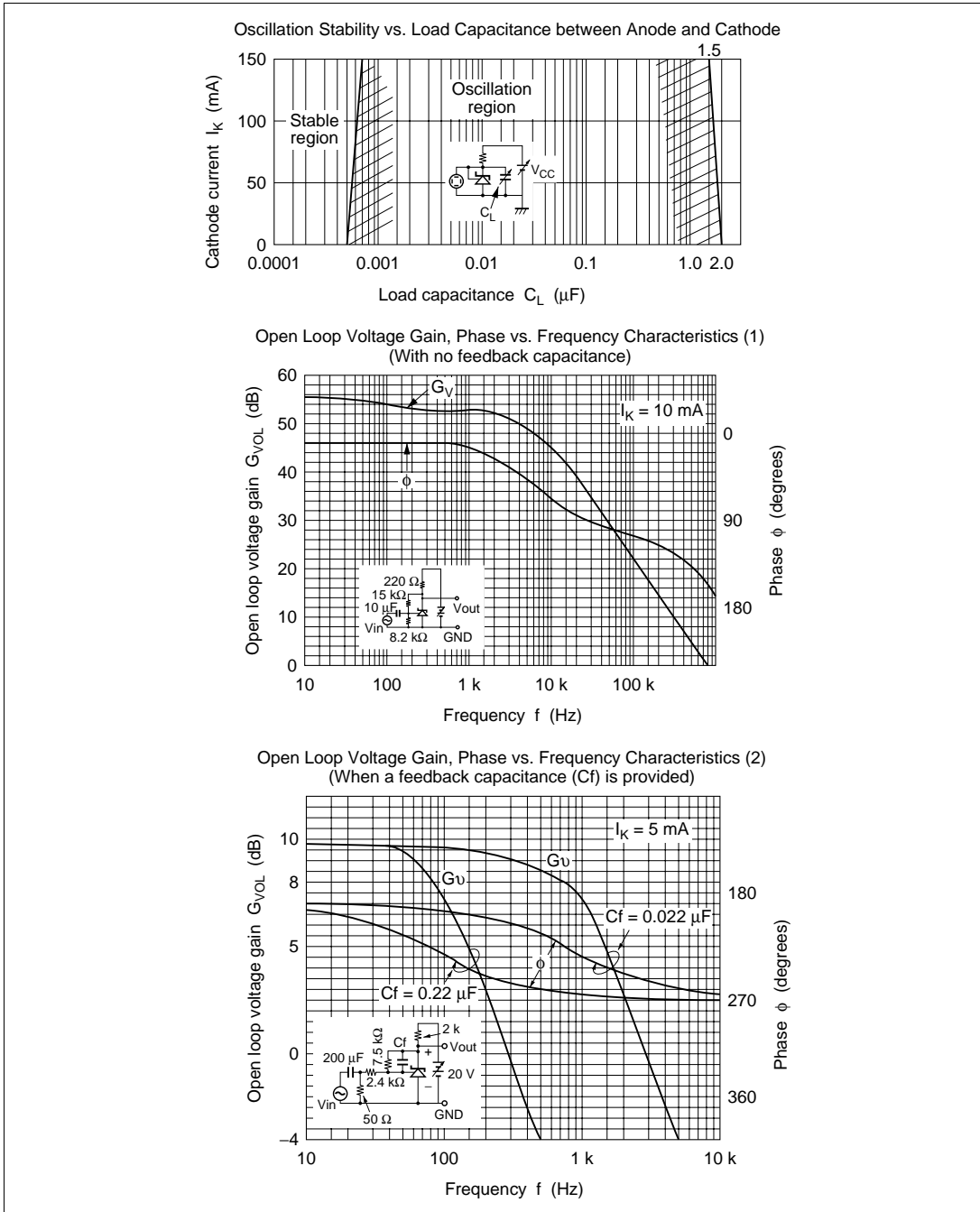
$i_o = 2\text{mA}_{P-P}$   
 $Z_{KA} = \frac{V_K}{i_o} (\Omega)$

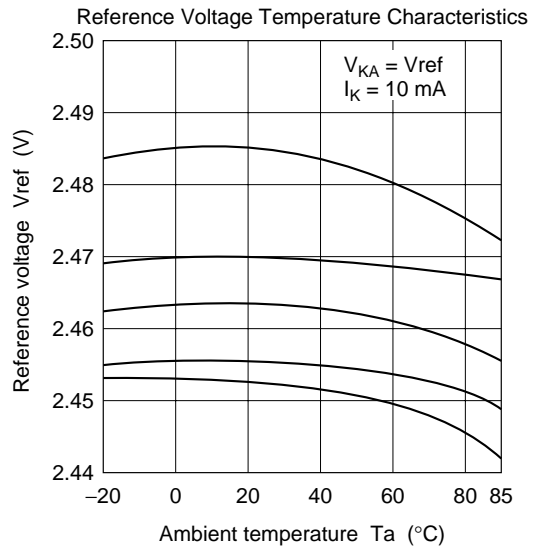
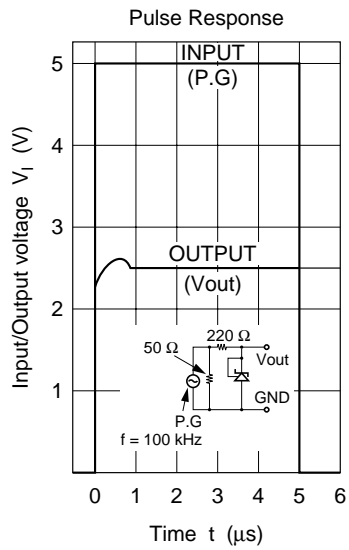
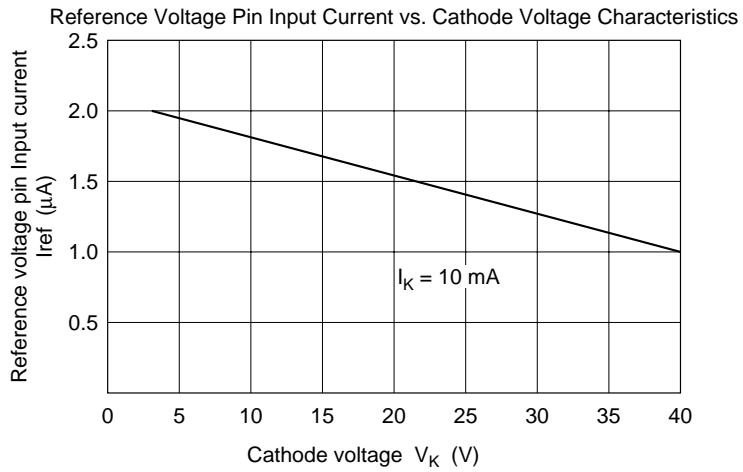
Open Loop Voltage Gain, Phase vs. Frequency Characteristics

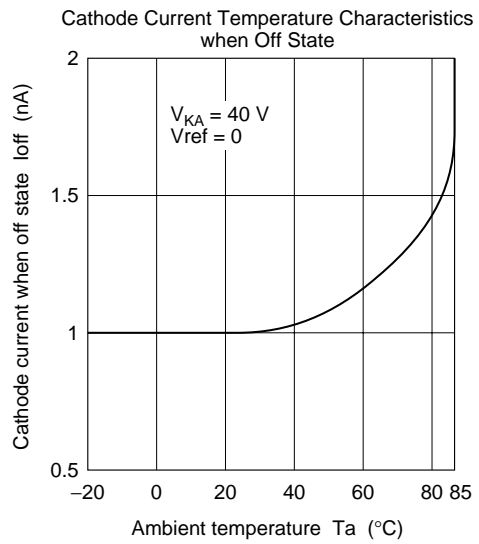
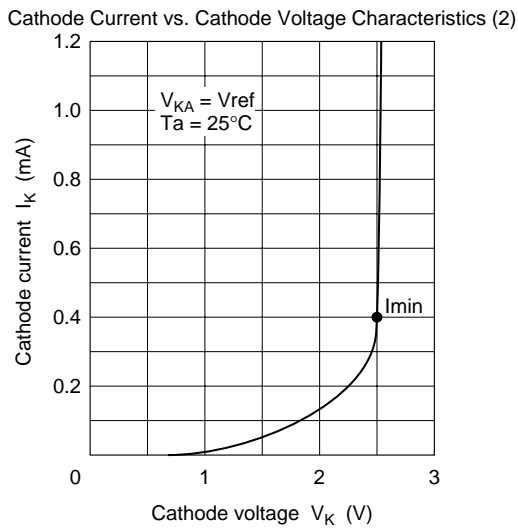
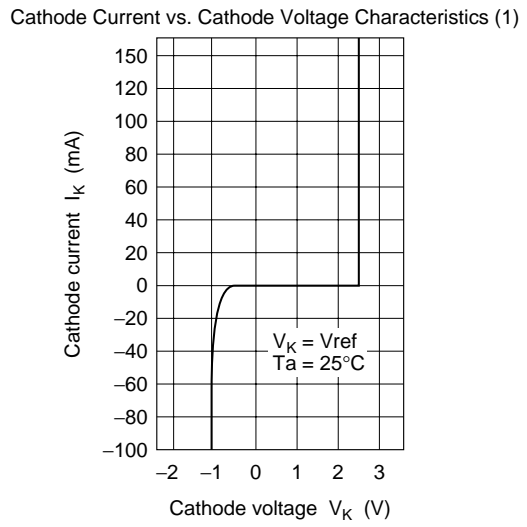
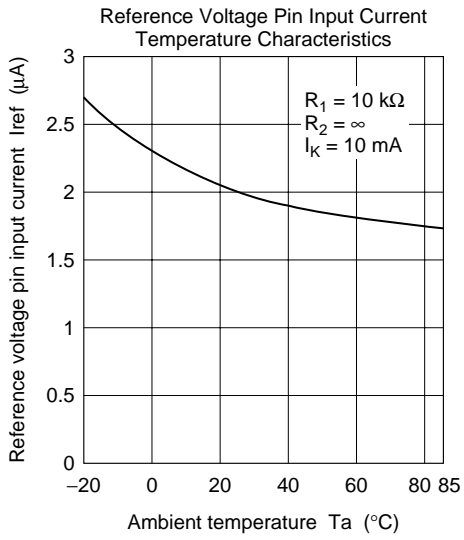


$G = 20\log\left(\frac{V_o}{V_i}\right) (\text{dB})$

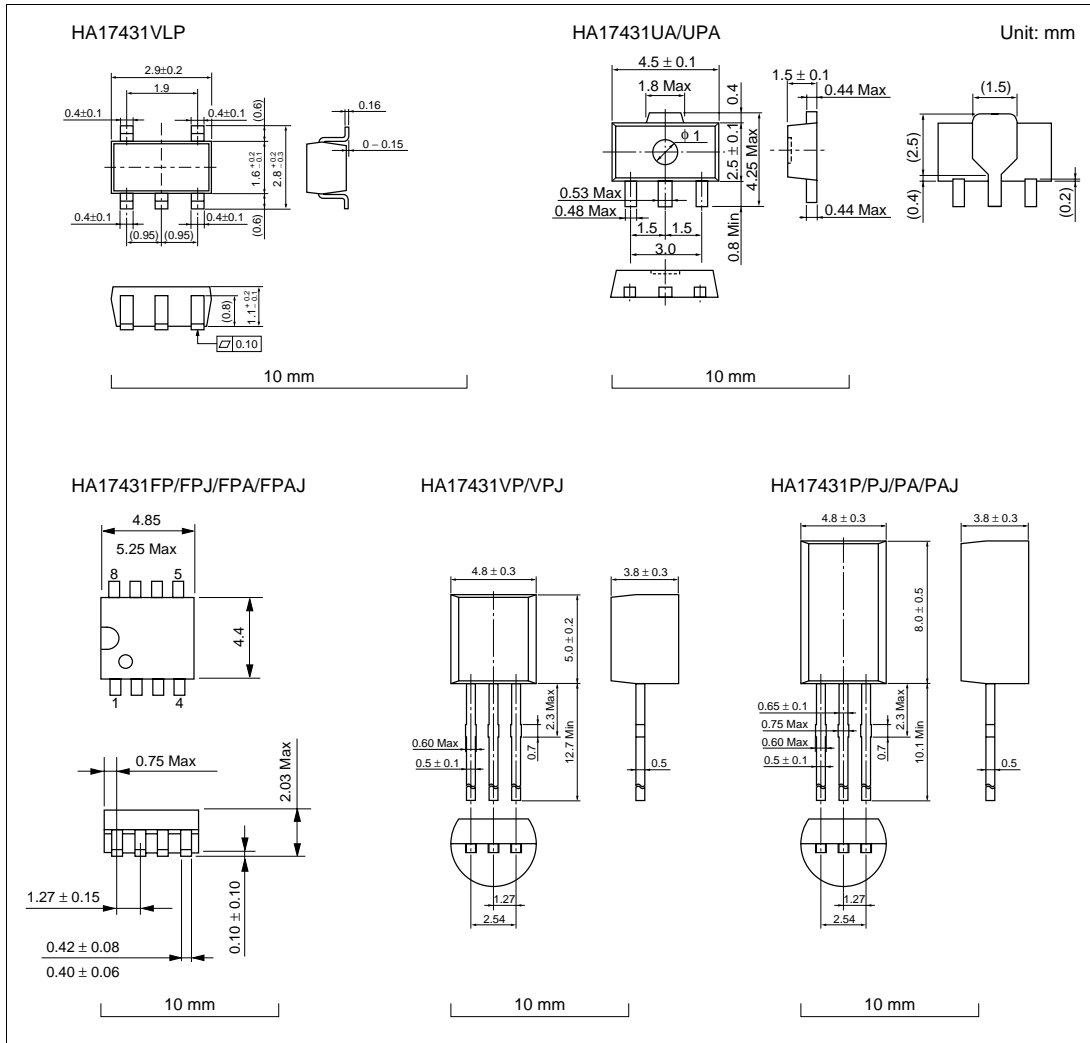
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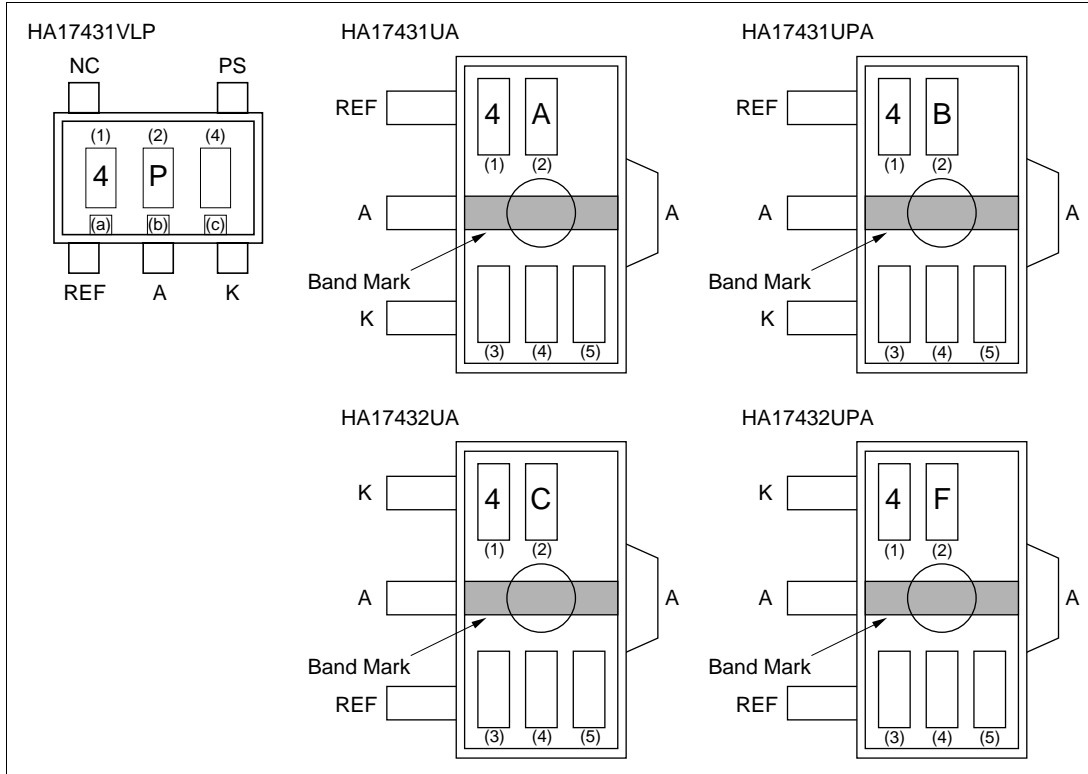
# Section 4 Outline Dimensions





## Section 5 MPAK-5 and UPAK Marking Patterns

The marking patterns shown below are used on MPAK-5 and UPAK products. Note that the product code and mark pattern are different. The pattern is laser printed.



**Figure 5.1 MPAK-5 and UPAK Marking Patterns**

- 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)
HA17431VLP	4	P
HA17431UA	4	A
HA17431UPA	4	B

Product	(1)	(2)
HA17432UA	4	C
HA17432UPA	4	F

3. The letter (3) shows the production year code (the last digit of the year) for UPAK products.
4. The bars (a), (b) and (c) show a production year code for MPAK-5 products as shown below. After 2005 the code is repeated every 8 years.

Year	1997	1998	1999	2000	2001	2002	2003	2004
(a)	Bar	Bar	Bar	Bar	None	None	None	None
(b)	None	None	Bar	Bar	None	None	Bar	Bar
(c)	None	Bar	None	Bar	None	Bar	None	Bar

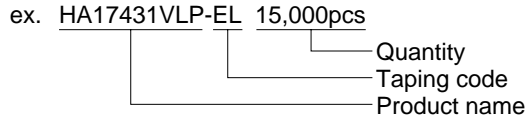
5. The letter (4) shows the production month code (see table below).

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

6. The letter (5) shows manufacturing code for UPAK products.

## Section 6 Ordering Information

Taping specifications must be attached after the product name. The quantity must be a multiple of ordering unit (see table below).

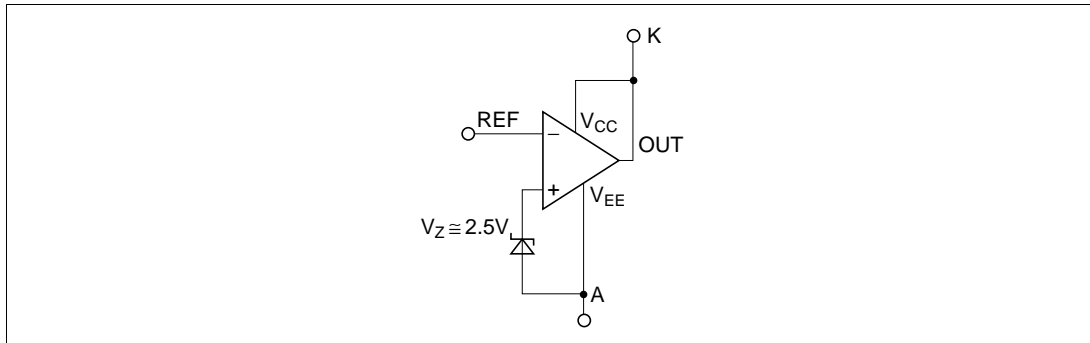


**Table 6.1 Taping Specifications**

Package	Taping Code	Packing	Ordering Unit	Illustration
MPAK-5	EL	Embossed taping L type in 180 $\phi$ reel	3000 pcs	
UPAK	TL	Embossed taping L type in 180 $\phi$ reel	1000 pcs	
TO-92 TO-92MOD	TZ	Fan-folded taping in 336 $\times$ 262 $\times$ 47 mm <sup>3</sup> box (TO-92), Fan-folded taping in 330 $\times$ 200 $\times$ 43 mm <sup>3</sup> box (TO-92MOD)	2500 pcs	
FP-8D	EL	Embossed taping L type in 330 $\phi$ reel	2500 pcs	

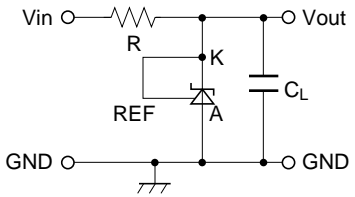
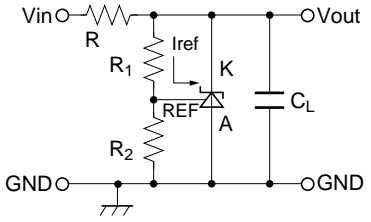
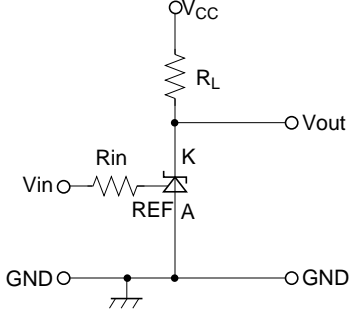
## Section 7 Application Examples

As shown in the figure below, this IC operates as an inverting amplifier, with the REF pin as an 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  $I_{ref}$  of 3.8  $\mu\text{A}$  typ (V version:  $I_{ref} = 2 \mu\text{A}$  typ). The output impedance of the output pin K (cathode) is defined as dynamic impedance  $Z_{KA}$ , and  $Z_{KA}$  is low ( $0.2 \Omega$ ) over a wide cathode current range. A (anode) is used at the minimum potential, such as ground.



**Figure 7.1 Operation Diagram**

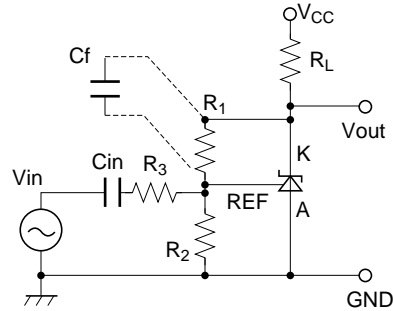
## 7.1 Application Hints

No.	Application Example	Description												
1	Reference voltage generation circuit 	<p>This is the simplest reference voltage circuit. The value of the resistance R is set so that cathode current <math>I_K \geq 1</math> mA.</p> <p>Output is fixed at <math>V_{out} \cong 2.5</math> V.</p> <p>The external capacitor <math>C_L</math> (<math>C_L \geq 3.3 \mu\text{F}</math>) is used to prevent oscillation in normal applications.</p>												
2	Variable output shunt regulator circuit 	<p>This is circuit 1 above with variable output provided.</p> <p>Here, <math>V_{out} \cong 2.5 \text{ V} \times \frac{(R_1 + R_2)}{R_2}</math></p> <p>Since the reference input current <math>I_{ref} = 3.8 \mu\text{A}</math> typ (V version: <math>I_{ref} = 2 \mu\text{A}</math> typ) flows through <math>R_1</math>, resistance values are chosen to allow the resultant voltage drop to be ignored.</p>												
3	Single power supply inverting comparator circuit 	<p>This is an inverting type comparator with an input threshold voltage of approximately 2.5 V. <math>R_{in}</math> is the REF pin protection resistance, with a value of several <math>k\Omega</math> to several tens of <math>k\Omega</math>.</p> <p><math>R_L</math> is the load resistance, selected so that the cathode current <math>I_K \geq 1</math> mA when <math>V_{out}</math> is low.</p> <table border="1"> <thead> <tr> <th>Condition</th> <th><math>V_{in}</math></th> <th><math>V_{out}</math></th> <th>IC</th> </tr> </thead> <tbody> <tr> <td>C1</td> <td>Less than 2.5 V</td> <td><math>V_{CC}</math> (<math>V_{OH}</math>)</td> <td>OFF</td> </tr> <tr> <td>C2</td> <td>2.5 V or more</td> <td>Approx. 2 V (<math>V_{OL}</math>)</td> <td>ON</td> </tr> </tbody> </table>	Condition	$V_{in}$	$V_{out}$	IC	C1	Less than 2.5 V	$V_{CC}$ ( $V_{OH}$ )	OFF	C2	2.5 V or more	Approx. 2 V ( $V_{OL}$ )	ON
Condition	$V_{in}$	$V_{out}$	IC											
C1	Less than 2.5 V	$V_{CC}$ ( $V_{OH}$ )	OFF											
C2	2.5 V or more	Approx. 2 V ( $V_{OL}$ )	ON											

**No. Application Example**

**Description**

4 AC amplifier circuit



This is an AC amplifier with voltage gain  $G = -R_1 / (R_2 // R_3)$ . The input is cut by capacitance  $C_{in}$ , so that the REF pin is driven by the AC input signal, centered on  $2.5 V_{DC}$ .

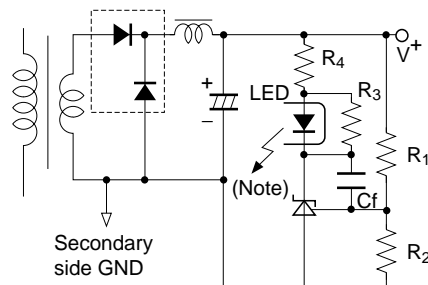
$R_2$  also functions as a resistance that determines the DC cathode potential when there is no input, but if the input level is low and there is no risk of  $V_{out}$  clipping to  $V_{CC}$ , this can be omitted.

To change the frequency characteristic,  $C_f$  should be connected as indicated by the dotted line.

$$\text{Gain } G = \frac{R_1}{R_2 // R_3} \text{ (DC gain)}$$

$$\text{Cutoff frequency } f_c = \frac{1}{2\pi C_f (R_1 // R_2 // R_3)}$$

5 Switching power supply error amplification circuit



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:

$$V_{out} \cong 2.5 V \times \frac{(R_1 + R_2)}{R_2}$$

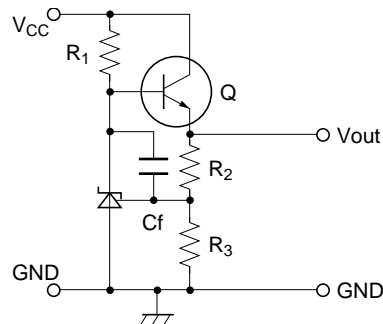
In this circuit, the gain with respect to the  $V_{out}$  error is as follows:

$$G = \frac{R_2}{(R_1 + R_2)} \times \left[ \text{HA17431 open loop gain} \right] \times \left[ \text{Photocoupler total gain} \right]$$

Note: LED: Light emitting diode in photocoupler  
 $R_3$ : Bypass resistor to feed  $I_K (> I_{min})$  when LED current vanishes  
 $R_4$ : LED protection resistance

As stated earlier, the HA17431 open-loop gain is 50 to 60 dB.

6 Constant voltage regulator circuit

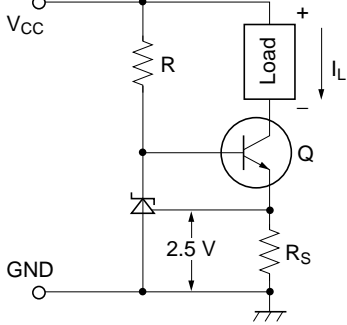
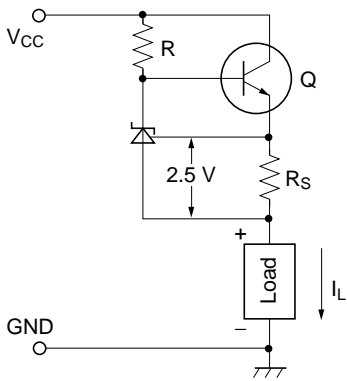


This is a 3-pin regulator with a discrete configuration, in which the output voltage

$$V_{out} = 2.5 V \times \frac{(R_2 + R_3)}{R_3}$$

$R_1$  is a bias resistance for supplying the HA17431 cathode current and the output transistor Q base current.

No.	Application Example	Description
7	Discharge type constant current circuit	<p>This circuit supplies a constant current of <math>I_L \cong \frac{2.5 V}{R_S}</math> [A] into the load. Caution is required since the HA17431 cathode current is also superimposed on <math>I_L</math>.</p> <p>The requirement in this circuit is that the cathode current must be greater than <math>I_{min} = 1 \text{ mA}</math>. The <math>I_L</math> setting therefore must be on the order of several mA or more.</p>
8	Induction type constant current circuit	<p>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 <math>I_L</math>, so that <math>I_L</math> can be kept small (1 mA or less is possible). The constant current value is the same as for circuit 7 above:</p>

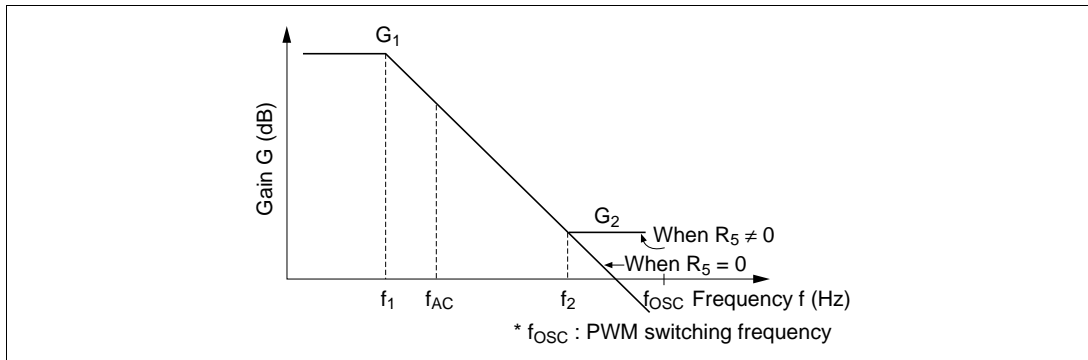






The absolute values of  $R_3$  and  $R_4$  are determined by the HA17431 reference input current  $I_{ref}$  and the AC characteristics described in the next section. The  $I_{ref}$  value is around  $3.8 \mu A$  typ. (V version:  $2 \mu A$  typ)

**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 7.2, the error amplifier characteristic is as shown in figure 7.3.



**Figure 7.3 HA17431 Error Amplification Characteristic**

In figure 7.3, the following formulas are obtained:

Gain

$$G_1 = G_0 \approx 50 \text{ dB (determined by shunt regulator)}$$

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

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  $\Delta V_{ref}/\Delta V_{KA}$ , and is approximately 50 dB.

### 7.2.3 Practical Example

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

$$R_1 = \frac{5\text{V} - 1.05\text{V} - 3\text{V}}{2.5\text{mA} + 0.5\text{mA}} = 317(\Omega) \text{ (330}\Omega \text{ from E24 series)}$$

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

Next, assume that  $R_3 = R_4 = 10 \text{ k}\Omega$ . This gives a  $5 \text{ V}$  output. If  $R_5 = 3.3 \text{ k}\Omega$  and  $C_1 = 0.022 \mu\text{F}$ , the following values are found.

$$G_2 = 3.3 \text{ k}\Omega / 10 \text{ k}\Omega = 0.33 \text{ times (-10 dB)}$$

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

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

### 7.3 Circuit Example AC-DC SMPS

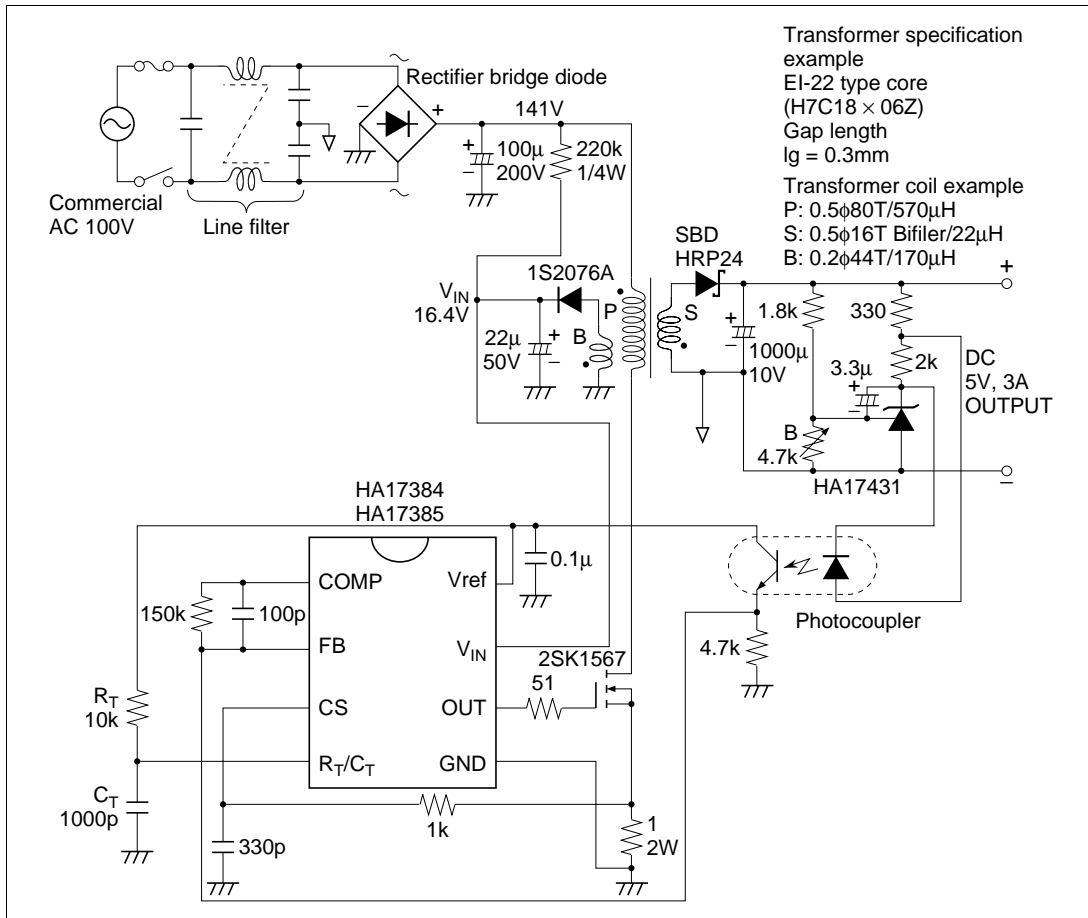


Figure 7.4 Circuit Example AC-DC SMPS

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**HA17431 Series Shunt Regulators  
Application Note**

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