HA17431H Series

Shunt Regulator

HITACHI

ADE-204-070 (Z)

Preliminary
Rev.0
Sep. 2001

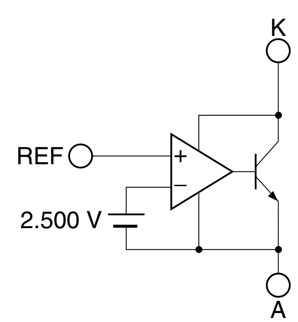
Description

The HA17431H 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 HA17431H series products are provided in a wide range of packages; TO-92 insertion mounting packages and MPAK-5 (5 pin), MPAK (3 pin), UPAK surface mounting packages are available. The on-chip high-precision reference voltage source can provide ±1% accuracy, which have a V_{KA} max of 36 volts.

Features

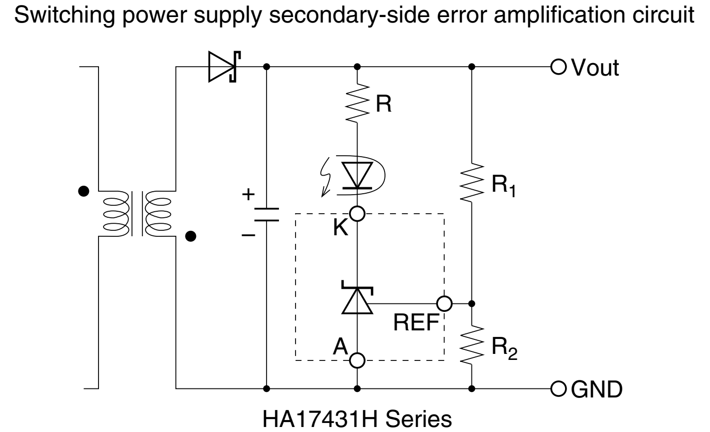
- The reference voltage provide 2.500 V ±1% at Ta = 25°C
- The reference voltage has a low temperature coefficient
- The MPAK-5 (5 pin), MPAK (3 pin) and UPAK miniature packages are optimal for use on high mounting density circuit boards

Block Diagram



Hitachi semiconductor

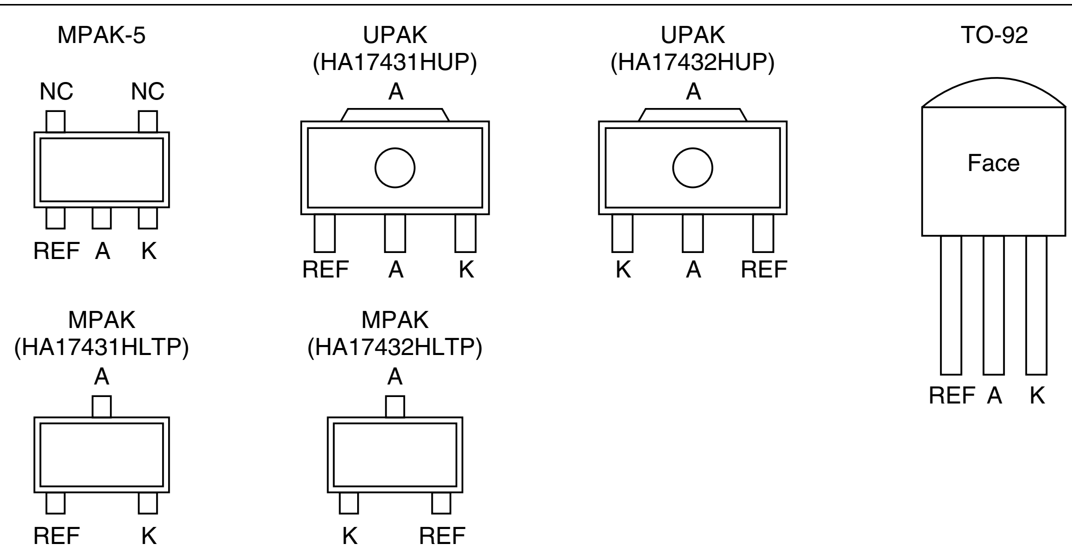
Application Circuit Example



Ordering Information

Item		Package	Temp. Range
Industrial use	HA17431HLP	MPAK-5	–20 to +85°C
	HA17431HP	TO-92	
	HA17431HUP	UPAK	
	HA17432HUP		
	HA17431HLTP	MPAK	
	HA17432HLTP		

Pin Arrangement



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Absolute Maximum Ratings

(Ta = 25°C)

Item	Symbol	Ratings HA17431HLP	HA17431HP	HA17431HUP/ HA17432HUP	HA17431HLTP/ HA17432HLTP	Unit	Notes
Cathode voltage	V_{KA}	36	36	36	36	V	1
Continuous cathode current	I_K	–50 to +50	–50 to +50	–50 to +50	–50 to +50	mA	
Reference input current	Iref	–0.05 to +6	–0.05 to +6	–0.05 to +6	–0.05 to +6	mA	
Power dissipation	P_T	150 *2	500 *3	800 *4	150 *2	MW	
Operating temperature range	Topr	–20 to +85	–20 to +85	–20 to +85	–20 to +85	°C	
Storage temperature	Tstg	–55 to +150	–55 to +150	–55 to +150	–55 to +150	°C	

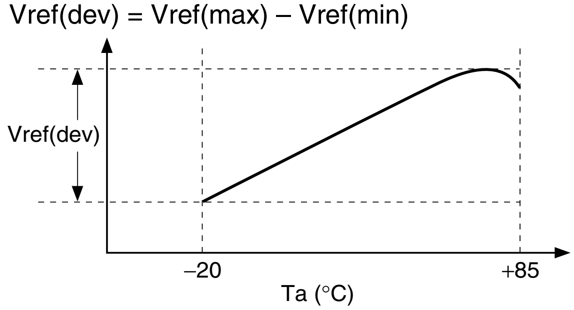
Notes: 1. Voltages are referenced to anode.
2. Ta ≤ 25°C. If Ta > 25°C, derate by 1.2 mW/°C.
3. Ta ≤ 25°C. If Ta > 25°C, derate by 4.0 mW/°C.
4. 15 mm × 25 mm × t0.7mm alumina ceramic board,Ta ≤ 25°C. If Ta > 25°C, derate by 6.4 mW/°C.

Electrical Characteristics

(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	$\Delta Vref/\Delta V_{KA}$	—	2.0	3.7	mV/V	V_{KA} = Vref to 36 V	
Reference input current	Iref	—	0.6	3	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	—	0.06	0.2	mA	V_{KA} = Vref	2
Off state cathode current	Ioff	—	0.001	1.0	µA	V_{KA} = 36 V, Vref = 0 V	
Dynamic impedance	Z_{KA}	—	0.2	0.5	Ω	V_{KA} = Vref, I_K = 1 mA to 50 mA	

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



2. Imin is given by the cathode current at Vref = $Vref_{(IK=10mA)}$ – 15 mV.

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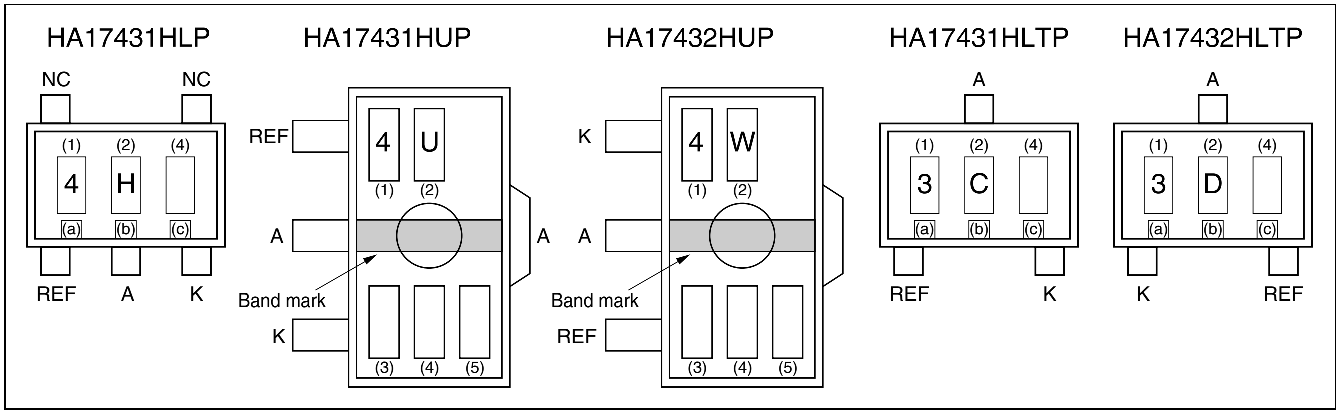
MPAK-5 (5 pin), MPAK (3 pin) and UPAK Marking Patterns

The marking patterns shown below are used on MPAK-5, MPAK and UPAK 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)
HA17431HLP	4	H
HA17431HUP	4	U
HA17432HUP	4	W
HA17431HLTP	3	C
HA17432HLTP	3	D

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 and MPAK products as shown below. After 2009 the code is repeated every 8 years.

Year	2001	2002	2003	2004	2005	2006	2007	2008
(a)	None	None	None	None	Bar	Bar	Bar	Bar
(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.

Application Examples

As shown in figure 1, 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 0.6 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.

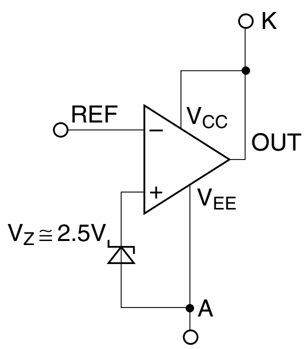
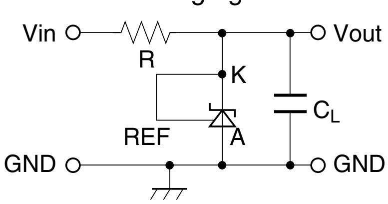
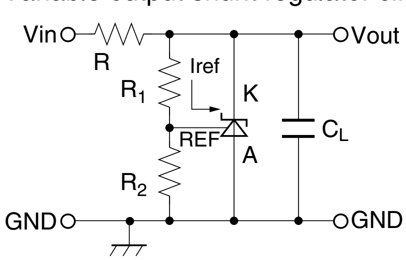


Figure 1 Operation Diagram

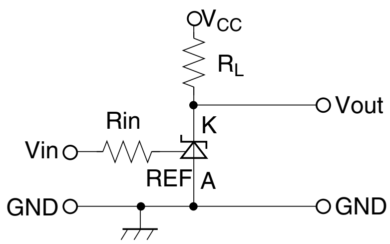
Application Hints

<table>
<tr><th>No.</th><th>Application Example</th><th>Description</th></tr>
<tr><td>1</td><td>Reference voltage generation circuit

</td><td>This is the simplest reference voltage circuit. The value of the resistance R is set so that cathode current $I_K \geq$ 0.2 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.</td></tr>
<tr><td>2</td><td>Variable output shunt regulator circuit

</td><td>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 = 0.6 µA Typ flows through R_1, resistance values are chosen to allow the resultant voltage drop to be ignored.</td></tr>
</table>

Application Hints (cont.)

No. **Application Example** — **Description**

3 Single power supply inverting comparator circuit

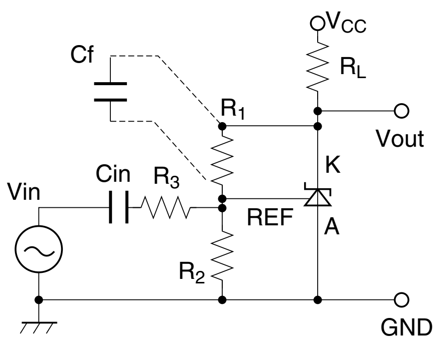


This is an inverting type comparator with an input threshold voltage of approximately 2.5 V. Rin is the REF pin protection resistance, with a value of several kΩ to several tens of kΩ.

R_L is the load resistance, selected so that the cathode current $I_K \geq 0.2$ mA when Vout is low.

Condition	Vin	Vout	IC
C1	Less then 2.5 V	V_{CC} (V_{OH})	OFF
C2	2.5 V or more	Approx. 2 V (V_{OL})	ON

4 AC amplifier circuit



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

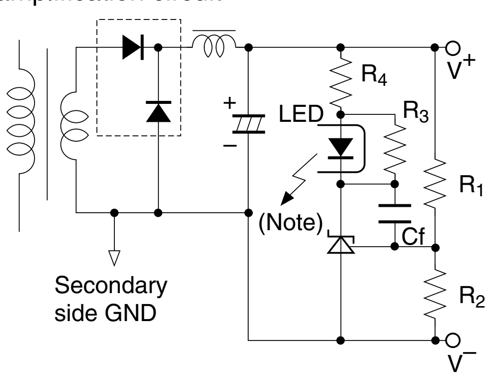
$$\text{Cutoff frequency fc} = \frac{1}{2\pi \, Cf \, (R_1 // R_2 // R_3)}$$

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.

5 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

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:

$$\text{Vout} \cong 2.5 \text{ V} \times \frac{(R_1 + R_2)}{R_2}$$

In this circuit, the gain with respect to the Vout error is as follows:

$$G = \frac{R_2}{(R_1 + R_2)} \times \left[\begin{array}{l}\text{HA17431H open} \\ \text{loop gain}\end{array}\right] \times \left[\begin{array}{l}\text{photocoupler} \\ \text{total gain}\end{array}\right]$$

As stated earlier, the HA17431H open-loop gain is 50 to 60 dB.

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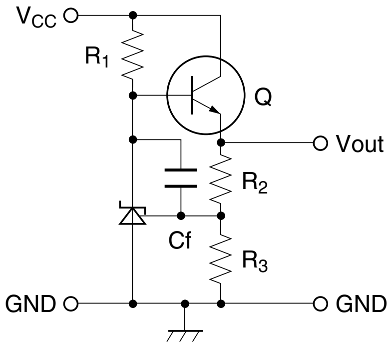
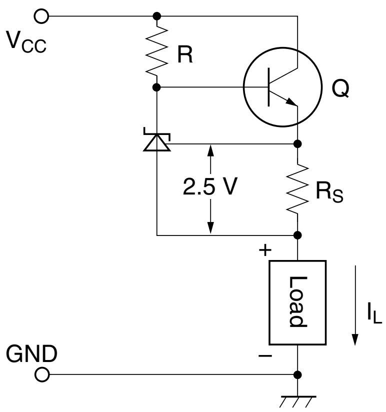
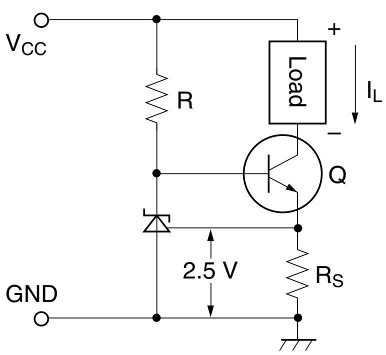
Application Hints (cont.)

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 HA17431H 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 HA17431H cathode current is also superimposed on I_L. The requirement in this circuit is that the cathode current must be greater than Imin = 0.2 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 HA17431H cathode current is not superimposed on I_L, so that I_L can be kept small (0.2 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)

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.

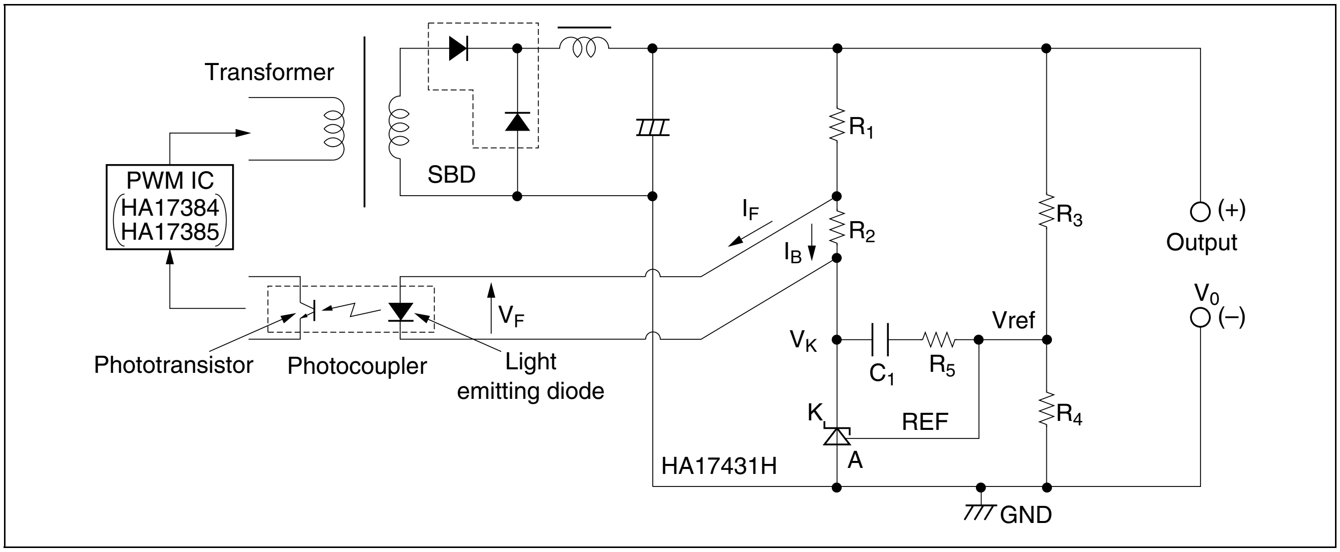


Figure 2 Typical Shunt Regulator/Error Amplifier

Determination of External Constants for the Shunt Regulator

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:

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

V_K is the HA17431H 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:

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

The absolute values of R_3 and R_4 are determined by the HA17431H reference input current Iref and the AC characteristics described in the next section. The Iref value is around 0.6 µA Typ.

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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.

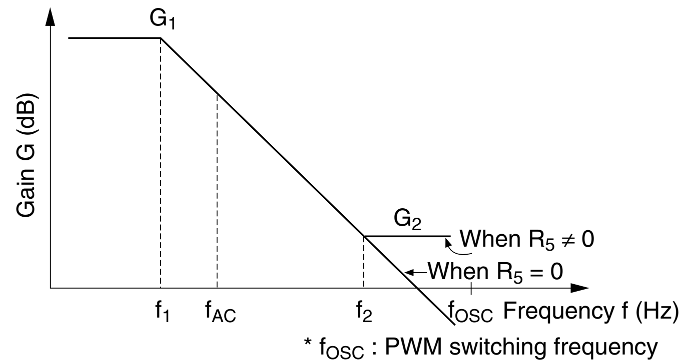

Figure 3 HA17431H Error Amplification Characteristic

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.

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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.

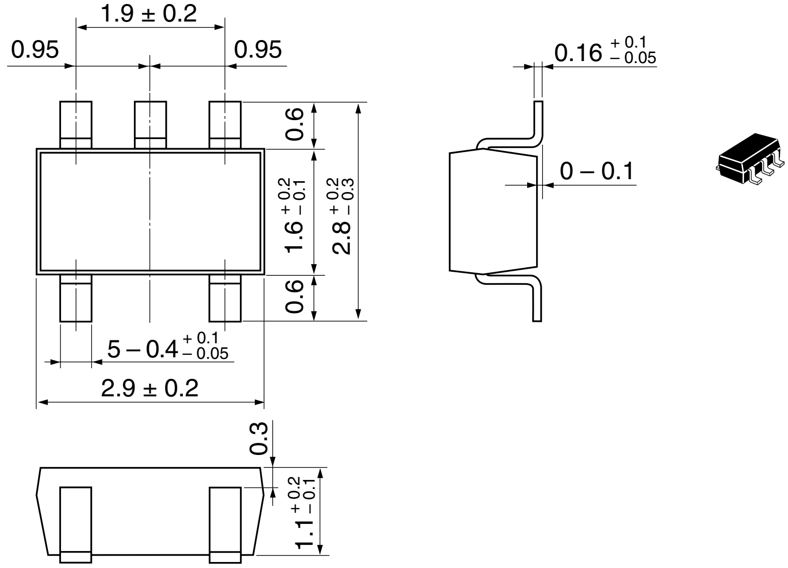
G_2 = 3.3 kΩ / 10 kΩ = 0.33 times (–10 dB)

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

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

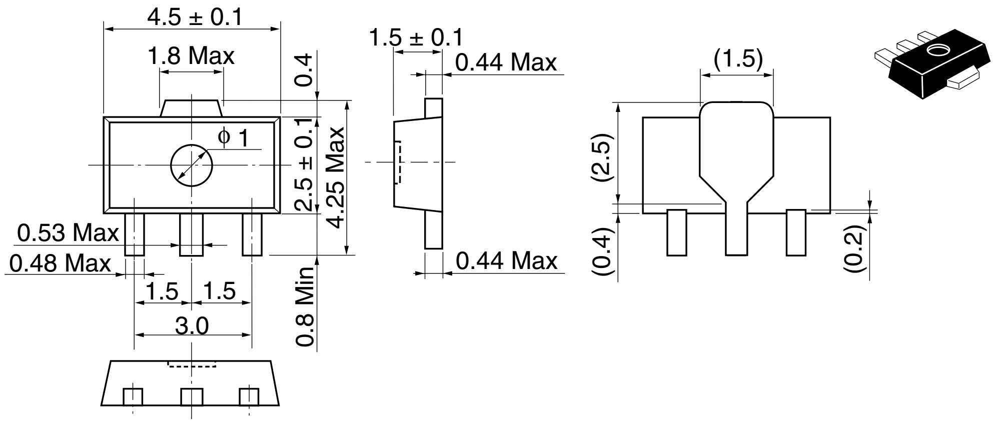
Package Dimensions

As of January, 2001
Unit: mm



Hitachi Code	MPAK-5
JEDEC	—
EIAJ	—
Mass (reference value)	0.015 g

As of January, 2001
Unit: mm



Hitachi Code	UPAK
JEDEC	—
EIAJ	Conforms
Mass (reference value)	0.050 g

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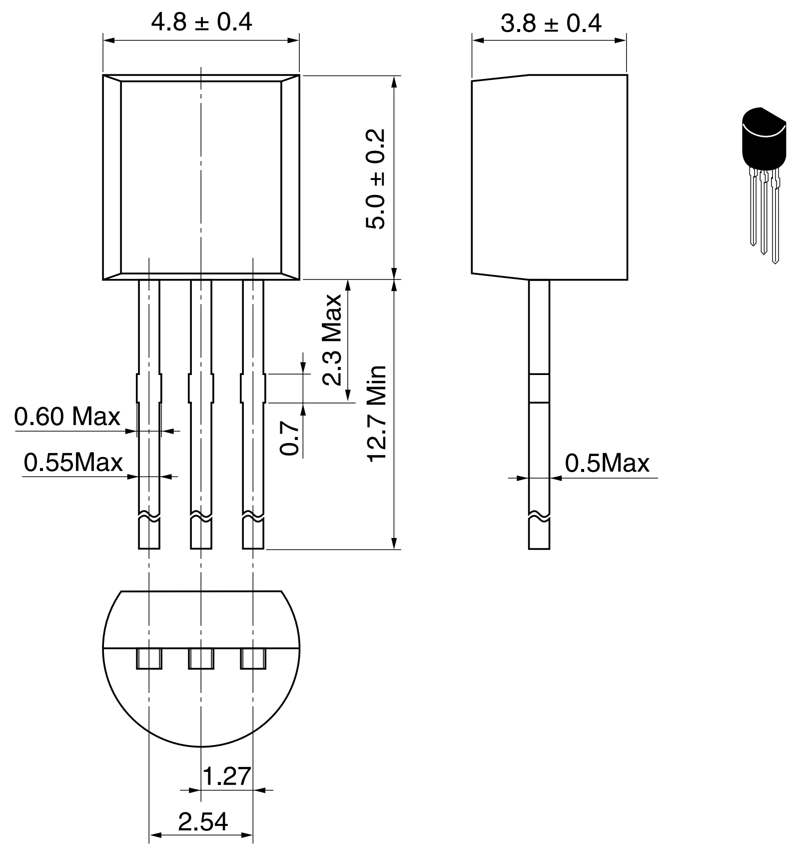
As of January, 2001
Unit: mm



Hitachi Code	TO-92 (1)
JEDEC	Conforms
EIAJ	Conforms
Mass (reference value)	0.25 g

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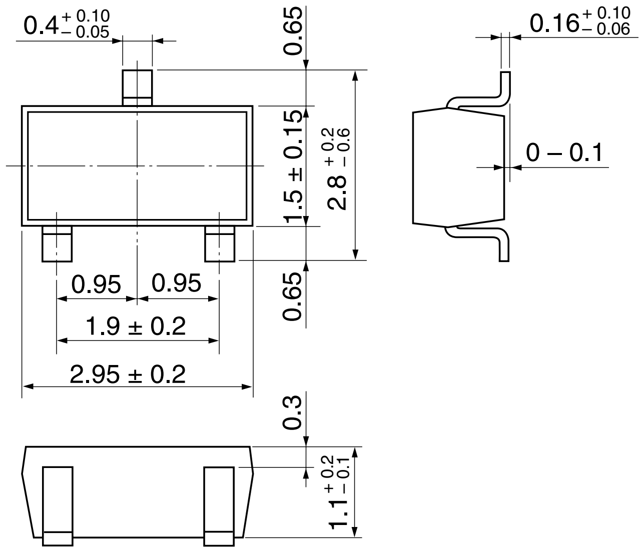
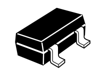
As of January, 2001
Unit: mm





Hitachi Code	MPAK
JEDEC	—
EIAJ	Conforms
Mass (reference value)	0.011 g

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Hitachi, Ltd.
Semiconductor & Integrated Circuits
Nippon Bldg., 2-6-2, Ohte-machi, Chiyoda-ku, Tokyo 100-0004, Japan
Tel: (03) 3270-2111 Fax: (03) 3270-5109

URL http://www.hitachisemiconductor.com/

For further information write to:

Hitachi Semiconductor
(America) Inc.
179 East Tasman Drive
San Jose,CA 95134
Tel: <1> (408) 433-1990
Fax: <1>(408) 433-0223

Hitachi Europe Ltd.
Electronic Components Group
Whitebrook Park
Lower Cookham Road
Maidenhead
Berkshire SL6 8YA, United Kingdom
Tel: <44> (1628) 585000
Fax: <44> (1628) 585200

Hitachi Europe GmbH
Electronic Components Group
Dornacher Straße 3
D-85622 Feldkirchen
Postfach 201, D-85619 Feldkirchen
Germany
Tel: <49> (89) 9 9180-0
Fax: <49> (89) 9 29 30 00

Hitachi Asia Ltd.
Hitachi Tower
16 Collyer Quay #20-00
Singapore 049318
Tel : <65>-538-6533/538-8577
Fax : <65>-538-6933/538-3877
URL : http://semiconductor.hitachi.com.sg

Hitachi Asia Ltd.
(Taipei Branch Office)
4/F, No. 167, Tun Hwa North Road
Hung-Kuo Building
Taipei (105), Taiwan
Tel : <886>-(2)-2718-3666
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