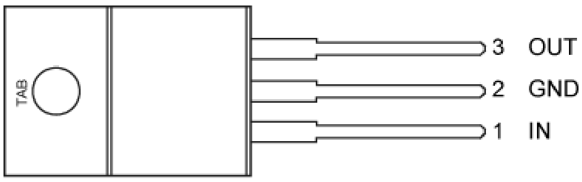
Ordering Information

Part Number		Junction Temperature Range[1]	Voltage	Current	Package
Standard	RoHS Compliant[2]				
HG29300-3.3BU	HG29300-3.3WU [2]	–40°C to +125°C	3.3	3.0A	3-Pin TO-263
HG29300-5.0BT	HG29300-5.0WT [2]	–40°C to +125°C	5	3.0A	3-Pin TO-220
HG29300-5.0BU	HG29300-5.0WU [2]	–40°C to +125°C	5	3.0A	3-Pin TO-263
HG29300-12BT	HG29300-12WT [2]	–40°C to +125°C	12	3.0A	3-Pin TO-220
HG29300-12BU	HG29300-12WU [2]	–40°C to +125°C	12	3.0A	3-Pin TO-263
HG29301-3.3BT	HG29301-3.3WT [2]	–40°C to +125°C	3.3	3.0A	5-Pin TO-220
HG29301-3.3BU	HG29301-3.3WU [2]	–40°C to +125°C	3.3	3.0A	5-Pin TO-263
HG29301-5.0BT	HG29301-5.0WT [2]	–40°C to +125°C	5	3.0A	5-Pin TO-220
HG29301-5.0BU	HG29301-5.0WU [2]	–40°C to +125°C	5	3.0A	5-Pin TO-263
HG29301-12BT	HG29301-12WT [2]	–40°C to +125°C	12	3.0A	5-Pin TO-220
HG29301-12BU	HG29301-12WU [2]	–40°C to +125°C	12	3.0A	5-Pin TO-263
HG29302BT	HG29302WT [2]	–40°C to +125°C	Adjustable	3.0A	5-Pin TO-220
HG29302BU	HG29302WU [2]	–40°C to +125°C	Adjustable	3.0A	5-Pin TO-263
HG29303BT	HG29303WT [2]	–40°C to +125°C	Adjustable	3.0A	5-Pin TO-220
HG29303BU	HG29303WU [2]	–40°C to +125°C	Adjustable	3.0A	5-Pin TO-263

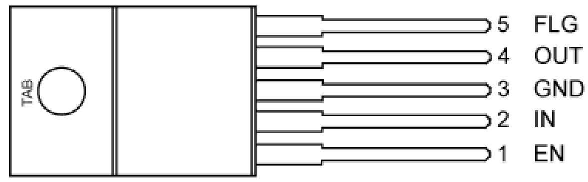
Notes:

1. Junction temperature.
2. RoHS compliant with ‘high-melting solder’ exemption.
3. Special Order; please contact factory for availability.

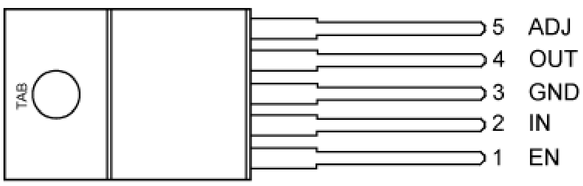
Pin Configuration



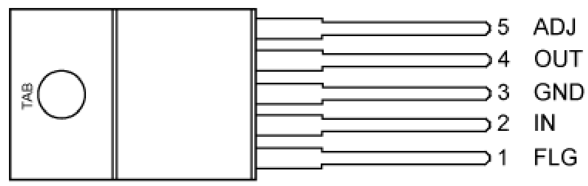
3-Pin TO-220 (T)
HG29300



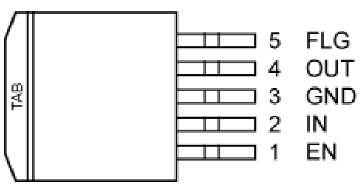
5-Pin TO-220 Fixed Voltage (T)
HG29301



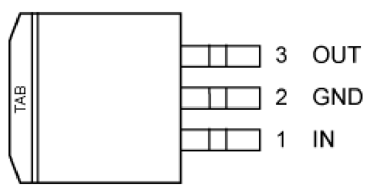
5-Pin TO-220 Adjustable Voltage (T)
HG29302



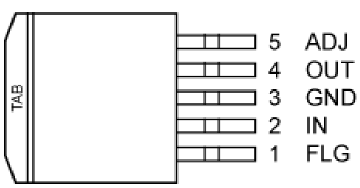
5-Pin TO-220 Adjustable with Flag (T)
HG29303



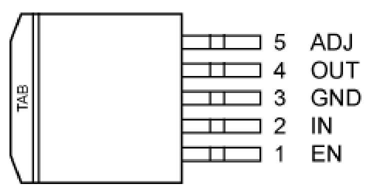
5-Pin TO-263 (D^2Pak) Fixed Voltage (U)
HG29301



3-Pin TO-263 (D^2Pak) (UT)
HG29300



5-Pin TO-263 (D^2Pak) Adjustable with Flag (U)
HG29303



5-Pin TO-263 (D^2Pak) Adjustable Voltage (U)
HG29302

Pin Description

Pin Number TO-220 TO-263	Pin Name
1	INPUT: Supplies the current to the output power device.
2	GND: TAB is also connected internally to the IC's ground on D-PAK.
3	OUTPUT: The regulator output voltage.

Pin Description

Pin Number Fixed TO-220 TO-263	Pin Number Adjustable TO-220 TO-263	Pin Number Adj. with Flag TO-220 TO-263	Pin Name
1	1	—	ENABLE: CMOS compatible control input. Logic high = enable, logic low = shutdown.
2	2	2	INPUT: Supplies the current to the output power device
3, TAB	3, TAB	3, TAB	GND: TAB is also connected internally to the IC's ground on D-PAK.
4	4	4	OUTPUT: The regulator output voltage
—	5	5	ADJUST: Adjustable regulator feedback input that connects to the resistor voltage divider that is placed from OUTPUT to GND in order to set the output voltage.
5	—	1	FLAG: Active low error flag output signal that indicates an output fault condition

Absolute Maximum Ratings[1]

Input Supply Voltage (V_{IN})[1] . . .. –20V to +60V
Enable Input Voltage (V_{EN}). . ... –0.3V to V_{IN}
Lead Temperature (soldering, 5sec.). . ... 260°C
Power Dissipation . . .. Internally Limited
Storage Temperature Range . . .. –65°C to +150°C
ESD Rating. . ...Note 3

Operating Ratings[2]

Operating Junction Temperature . . .. –40°C to +125°C
Maximum Operating Input Voltage 26V
Package Thermal Resistance
TO-220 (θ_{JC}). . ... 2°C/W
TO-263 (θ_{JC}). . ... 2°C/W

Electrical Characteristics[4, 11]

V_{IN} = V_{OUT} + 1V; I_{OUT} = 10mA; T_J = 25°C. **Bold** values indicate –40°C ≤ T_J ≤ +125°C, unless noted.

Parameter	Condition	Min.	Typ.	Max.	Units
Output Voltage	I_{OUT} = 10mA	–1		1	%
	10mA ≤ I_{OUT} ≤ I_{FL}, (V_{OUT} + 1V) ≤ V_{IN} ≤26V	–2		2	
Line Regulation	I_{OUT} = 10mA, (V_{OUT} + 1V) ≤ V_{IN} ≤26V		0.06	0.5	%
Load Regulation	V_{IN} = V_{OUT} + 1V, 10mA ≤ I_{OUT} ≤ 1.5A [8]		0.2	1	%
$\frac{\Delta V_O}{\Delta T}$	Output Voltage[8] Temperature Coefficient.		**20**	**100**	ppm/°C
Dropout Voltage	ΔV_{OUT} = –1%[6] HG29300 I_{OUT} =100mA I_{OUT} = 1.5A I_{OUT} = 3A I_{OUT}		80 250 370	**175** **600**	mV

Notes:

1. Maximum positive supply voltage of 60V must be of limited duration (<100msec) and duty cycle (≤1%). The maximum continuous supply voltage is 26V. Exceeding the absolute maximum rating may damage the device.
2. The device is not guaranteed to function outside its operating rating.
3. Devices are ESD sensitive. Handling precautions recommended.
4. Specification for packaged product only.
5. Dropout voltage is defined as the input-to-output differential when the output voltage drops to 99% of its normal value with V_{OUT} + 1V applied to V_{IN}.
6. V_{IN} = $V_{OUT\ (nominal)}$ + 1V. For example, use V_{IN} = 4.3V for a 3.3V regulator or use 6V for a 5V regulator. Employ pulse-testing procedures to pin current.
7. Ground pin current is the regulator quiescent current. The total current drawn from the source is the sum of the load current plus the ground pin current.
8. Output voltage temperature coefficient is defined as the worst case voltage change divided by the total temperature range.
9. Thermal regulation is defined as the change in output voltage at a time T after a change in power dissipation is applied, excluding load or line regulation effects. Specifications are for a200mA load pulse at VIN = 20V (a 4W pulse) for T = 10ms.
10. Comparator thresholds are expressed in terms of a voltage differential at the Adjust terminal below the nominal reference voltage measured at 6V input. To express these thresholds in terms of output voltage change, multiply by the error amplifier gain = V_{OUT}/V_{REF} = (R1 + R2)/R2. For example, at a programmed output voltage of 5V, the Error output is guaranteed to go low when the output drops by 95mV x 5V/1.240V = 384mV. Thresholds remain constant as a percent of V_{OUT} as V_{OUT} is varied, with the dropout warning occurring at typically 5% below nominal, 7.7% guaranteed.
11. V_{EN} ≤ 0.8V and V_{IN} ≤ 26V, V_{OUT} = 0.
12. When used in dual supply systems where the regulator load is returned to a negative supply, the output voltage must be diode clamped to ground.

Electrical Characteristics[4, 12] (Continued)

$V_{IN} = V_{OUT} + 1V$; $I_{OUT} = 10mA$; $T_J = 25°C$. **Bold** values indicate –40°C ≤ T_J ≤ +125°C, unless noted.

Parameter	Condition		Min.	Typ.	Max.	Units
Ground Current	HG29300 Note 8	$I_{OUT} = 1.5A$, $V_{IN} = V_{OUT} + 1V$ $I_{OUT} = 3A$		10 37	**35**	mA
I_{GRNDDO}Ground Pin Current at Dropout	V_{IN} = 0.5V less than specified V_{OUT} × I_{OUT} = 10mA HG29300			1.7		mA
Current Limit	HG29300	$V_{OUT} = 0V$[7]		4.5	**5.0**	A
e_n, Output Noise Voltage (10Hz to 100kHz) I_L = 100mA	$C_L = 10\mu F$ $C_L = 33\mu F$			400 260		µV (rms)

Reference – HG29302/29303					
Reference Voltage		1.228 **1.215**	1.240	1.252 **1.265**	V
Reference Voltage		**1.203**		**1.277**	V
Adjust Pin Bias Current			40	80 **120**	nA
Reference Voltage Temperature Coefficient	Note 9		20		ppm/°C
Adjust Pin Bias Current Temperature Coefficient			0.1		nA/°C
Flag Output (Error Comparator) – HG29301/29303					
Output Leakage Current	$V_{OH} = 26V$		0.01	1.00 **2.00**	µA
Output Low Voltage	Device set for 5V, $V_{IN} = 4.5V$ $I_{OL} = 250\mu A$		220	300 **400**	mV
Upper Threshold Voltage	Device set for 5V [10]	40 **25**	60		mV
Lower Threshold Voltage	Device set for 5V [10]		75	95 **140**	mV
Hysteresis	Device set for 5V [10]		15		mV

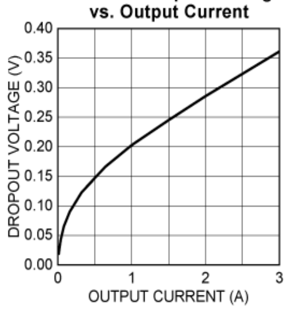
Electrical Characteristics[4, 12] (Continued)

$V_{IN} = V_{OUT} + 1V$; $I_{OUT} = 10mA$; $T_J = 25°C$. **Bold** values indicate –40°C ≤ T_J ≤ +125°C, unless noted.

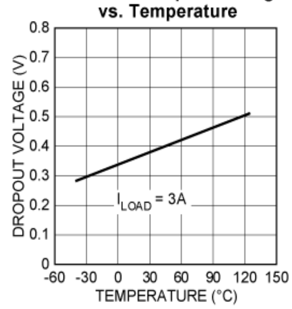
Parameter	Condition	Min.	Typ.	Max.	Units
ENABLE Input – **HG29301/29302**					
Input Logic Voltage Low (OFF) High (ON)		**2.4**		**0.8**	V
Enable Pin Input Current	$V_{EN} = 26V$		100	600 **750**	µA
	$V_{EN} = 0.8V$	0.7		2 **4**	
Regulator Output Current in Shutdown	Note 11		10	**500**	µA

Typical Characteristics (HG2930x)

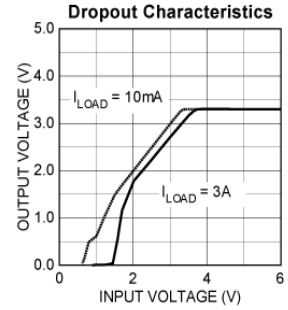
2930x Dropout Voltage vs. Output Current



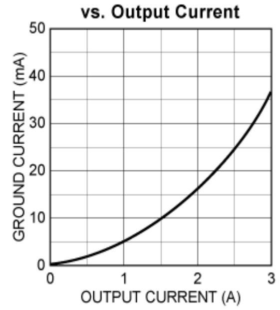
2930x Dropout Voltage vs. Temperature



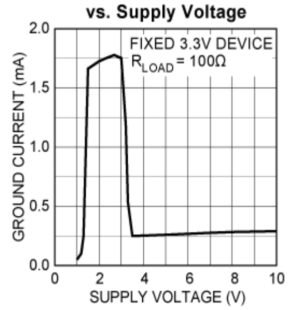
29300-3.3 Dropout Characteristics



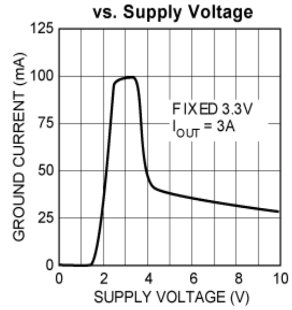
2930x Ground Current vs. Output Current



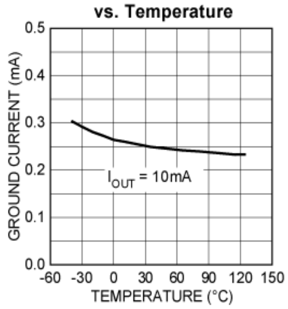
2930x Ground Current vs. Supply Voltage



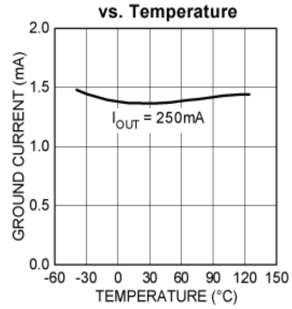
2930x Ground Current vs. Supply Voltage



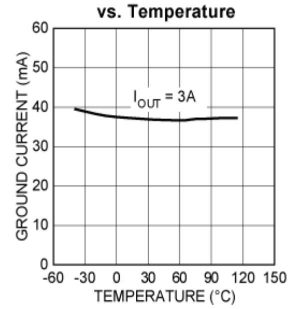
2930x Ground Current vs. Temperature



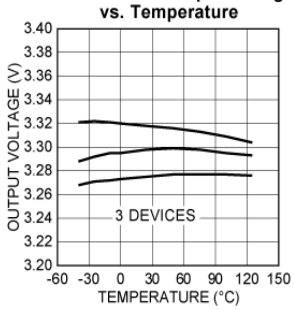
2930x Ground Current vs. Temperature



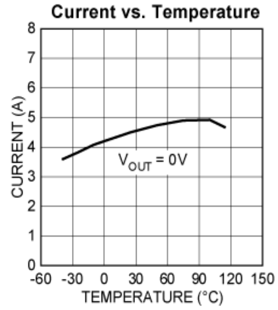
2930x Ground Current vs. Temperature



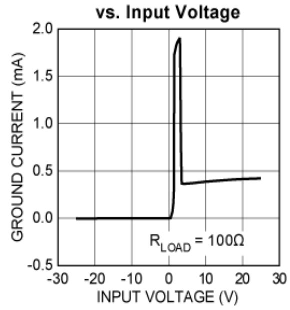
29300-3.3 Output Voltage vs. Temperature



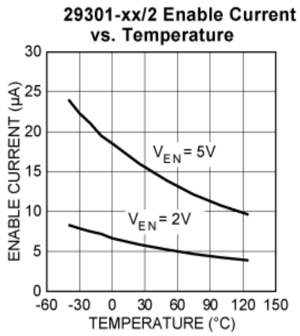
29300-5.0 Short Circuit Current vs. Temperature

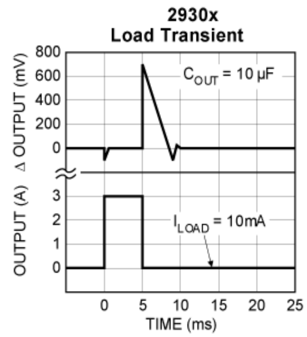


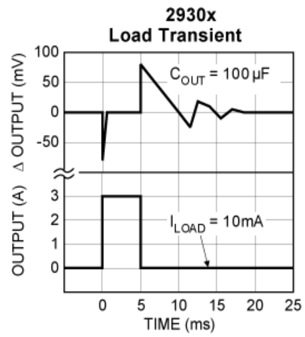
2930x Ground Current vs. Input Voltage

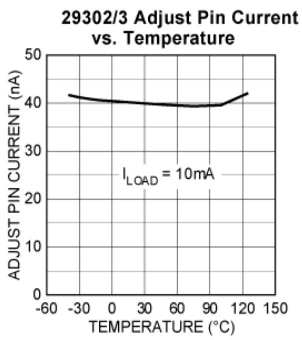


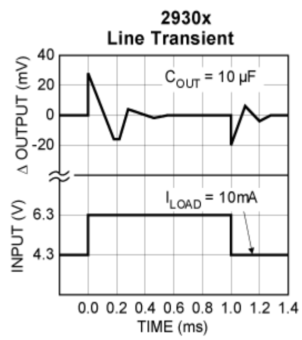
Typical Characteristics (HG2930x) (Continued)

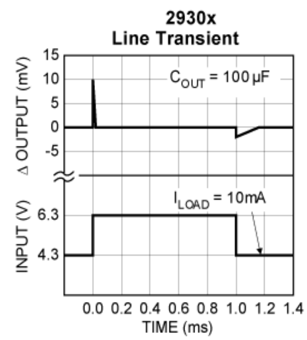


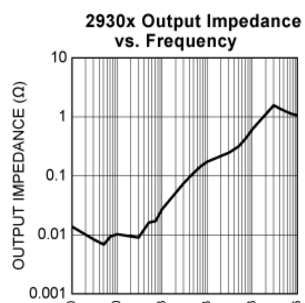




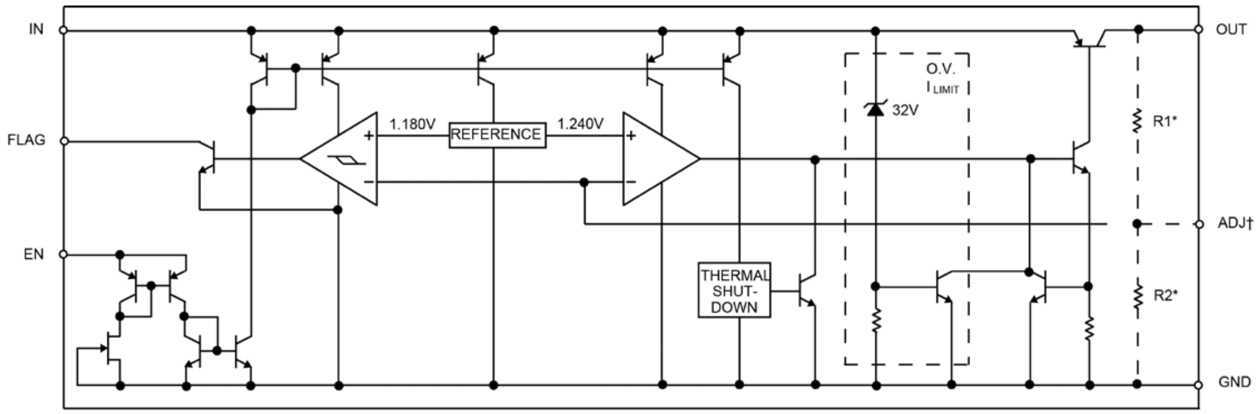








Functional Diagram



* FEEDBACK NETWORK IN FIXED VERSIONS ONLY
† ADJUSTABLE VERSION ONLY

Application Information

The HG29300 are high-performance low-dropout voltage regulators suitable for all moderate to high-current voltage regulator applications. Their 350mV to 425mV typical dropout voltage at full load make them especially valuable in battery powered systems and as high efficiency noise filters in "post-regulator" applications. Unlike older NPN-pass transistor designs, where the minimum dropout voltage is limited by the base-emitter voltage drop and collector-emitter saturation voltage, dropout performance of the PNP output of these devices is limited merely by the low V_{CE} saturation voltage.

A trade-off for the low-dropout voltage is a varying base driver requirement. But Micrel's Super ßeta PNP® process reduces this drive requirement to merely 1% of the load current.

The HG29300 family of regulators are fully protected from damage due to fault conditions. Current limiting is provided. This limiting is linear; output current under overload conditions is constant. Thermal shutdown disables the device when the die temperature exceeds the 125°C maximum safe operating temperature. Line transient protection allows device (and load) survival even when the input voltage spikes between –20V and +60V. When the input voltage exceeds approximately 32V, the over voltage sensor disables the regulator. The output structure of these regulators allows voltages in excess of the desired output voltage to be applied without reverse current flow. HG29301 and HG29302 versions offer a logic level ON/OFF control: when disabled, the devices draw nearly zero current.

An additional feature of this regulator family is a common pinout: a design's current requirement may change up or down yet use the same board layout, as all of these regulators have identical pinouts.

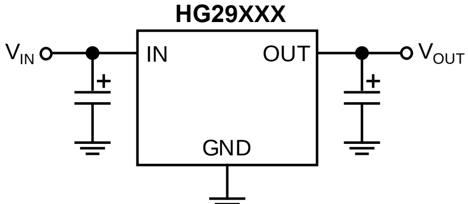


Figure 3. Linear Regulators Require Only Two Capacitors for Operation

Thermal Design

Linear regulators are simple to use. The most complicated design parameters to consider are thermal characteristics. Thermal design requires the following application-specific parameters:

- Maximum ambient temperature, T_A
- Output Current, I_{OUT}
- Output Voltage, V_{OUT}
- Input Voltage, V_{IN}

First, we calculate the power dissipation of the regulator from these numbers and the device parameters from this datasheet.

$$P_D = I_{OUT}(1.01\,V_{IN} - V_{OUT}) \qquad \text{Eq. 1}$$

where the ground current is approximated by 1% of I_{OUT}. Then the heat sink thermal resistance is determined with Equation 2:

$$\theta_{SA} = \frac{T_{JMAX} - T_A}{P_D} - (\theta_{JC} + \theta_{CS}) \qquad \text{Eq. 2}$$

where $T_{JMAX} \le 125°C$ and θ_{CS} is between 0 and 2°C/W.

The heat sink may be significantly reduced in applications where the minimum input voltage is known and is large compared with the dropout voltage. Use a series input resistor to drop excessive voltage and distribute the heat between this resistor and the regulator. The low-dropout properties of Micrel Super ßeta PNP® regulators allow very significant reductions in regulator power dissipation and the associated heat sink without compromising performance. When this technique is employed, a capacitor of at least 0.1µF is needed directly between the input and regulator ground.

Please refer to Application Note 8 and Application Hint 17 for further details and examples on thermal design and heat sink specification.

For example, given an expected maximum ambient temperature (T_A) of 75°C with V_{IN} = 3.3V, V_{OUT} = 2.5V, and I_{OUT} = 1.5A, first calculate the expected P_D using Equation 3:

$$P_D=(3.3V–2.5V)1.5A–(3.3V)(0.016A)=1.1472W \quad \text{Eq. 3}$$

Next, calcualte the junction temperature for the expected power dissipation.

$$T_J=(\theta_{JA}\times P_D)+T_A=(56°C/W\times 1.1472W)+75°C =139.24°C \quad \text{Eq. 4}$$

Now determine the maximum power dissipation allowed that would not exceed the IC's maximum junction temperature (125°C) without the useof a heat sink by:

$$P_{D(MAX)} = (T_{J(MAX)}–T_A)/\theta_{JA} = (125°C–75°C)/(56°C/W) = 0.893W \quad \text{Eq. 5}$$

Capacitor Requirements

For stability and minimum output noise, a capacitor on the regulator output is necessary. The value of this capacitor is dependent upon the output current; lower currents allow smaller capacitors. The HG29300 regulators are stable with the following minimum capacitor values at full load, as noted in Table 1:

Device	Full Load Capacitor
HG29300	10µF

Table 1. Minimum Capacitor Values at Full Load

This capacitor need not be an expensive low ESR type: aluminum electrolytics are adequate. In fact, extremely low ESR capacitors may contribute to instability. Tantalum capacitors are recommended for systems where fast load transient response is important.

Where the regulator is powered from a source with high AC impedance, a 0.1µF capacitor connected between Input and GND is recommended. This capacitor should have good characteristics to above 250kHz.

Device	Minimum Load
HG29300	7mA

Table 2. Minimum Load Currents

Adjustable Regulator Design

The adjustable regulator versions, HG29302 and HG29303, allow programming the output voltage anywhere between 1.25V and the 25V. Two resistors are used. The resistor values are calculated by Equation 6:

$$R_1 = R_2 \times \left(\frac{V_{OUT}}{1.240} - 1\right) \quad \text{Eq. 6}$$

where V_{OUT} is the desired output voltage. Figure 4 shows component definition. Applications with widely varying load currents may scale the resistors to draw the minimum load current required for proper operation (see "Minimum Load Current" sub-section).

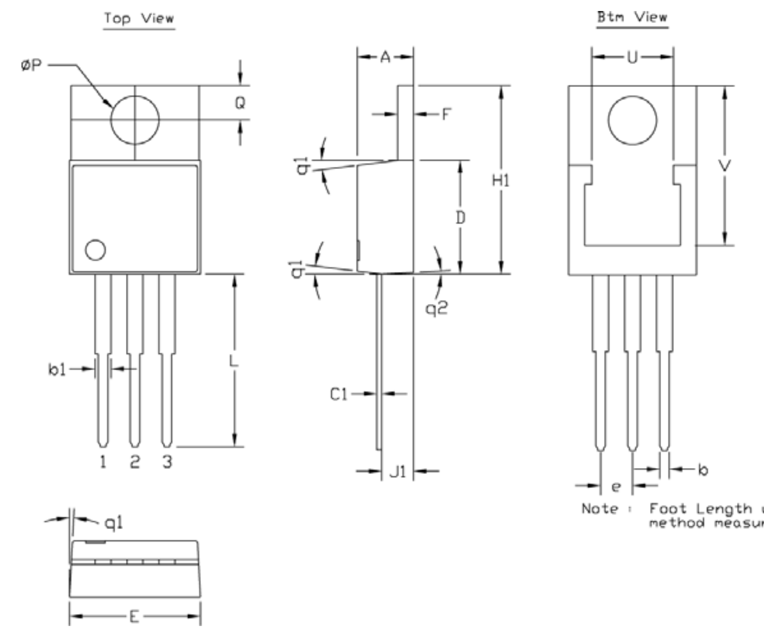
Error Flag

HG29301 and HG29303 versions feature an Error Flag, which looks at the output voltage and signals an error condition when this voltage drops 5% below its expected value. The error flag is an open-collector output that pulls low under fault conditions. It may sink 10mA. Low output voltage signifies a number of possible problems, including an overcurrent fault (the device is in current limit) and low input voltage. The flag output is inoperative during overtemperature shutdown conditions.

Enable Input

HG29301 and HG29302 versions feature an enable (EN) input that allows ON/OFF control of the device. Special design allows "zero" current drain when the device is disabled—only microamperes of leakage current flows. The EN input has TTL/CMOS compatible thresholds for simple interfacing with logic, or may be directly tied to ≤30V. Enabling the regulator requires approximately 20µA of current.

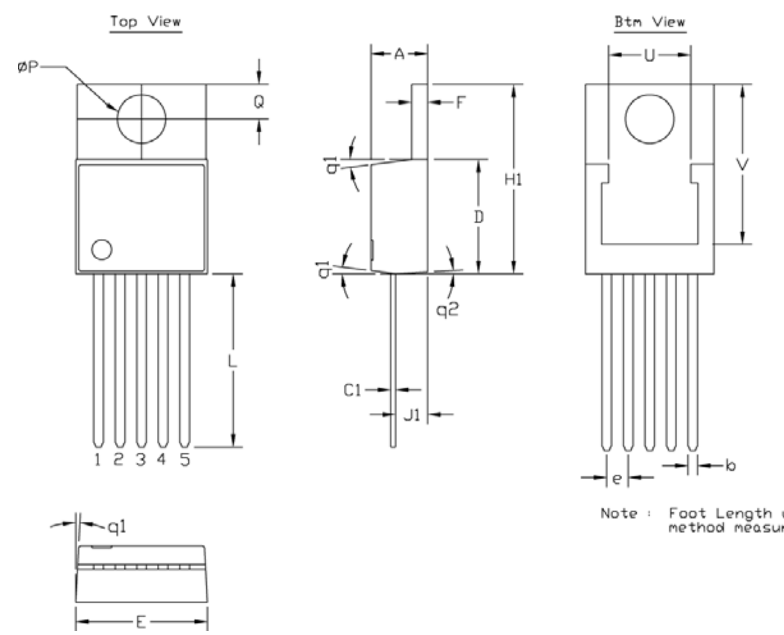
Package Information(1)



POS	INCH	
	MIN	MAX
A	0.160	0.190
b	0.025	0.040
b1	0.045	0.060
C1	0.012	0.022
D	0.351	0.361
E	0.385	0.420
e	0.090	0.110
F	0.045	0.055
H1	0.560	0.595
J1	0.080	0.120
ØP	0.146	0.156
Q	0.103	0.113
L	0.500	0.580
q1	3°	10°
q2	1°	7°
U	0.256 Ref.	
V	0.486 Ref.	

Note : Foot Length using gauge plane method measurement 0.010".

3-Pin TO-220 (T)

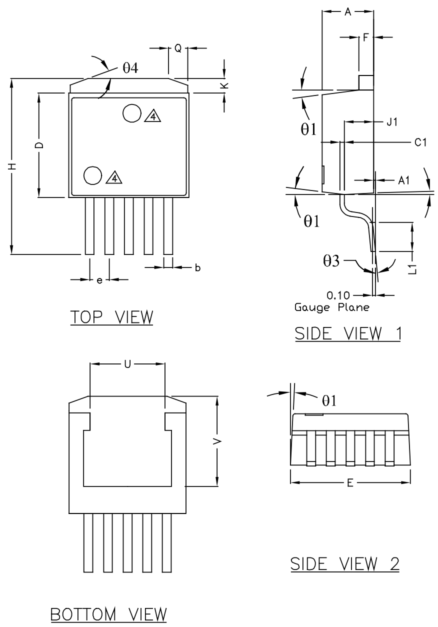


POS	INCH	
	MIN	MAX
A	0.160	0.190
b	0.025	0.040
C1	0.012	0.022
D	0.351	0.361
E	0.385	0.420
e	0.062	0.072
F	0.045	0.055
H1	0.560	0.595
J1	0.080	0.120
ØP	0.146	0.156
Q	0.103	0.113
L	0.500	0.580
q1	3°	10°
q2	1°	7°
U	0.256 Ref.	
V	0.486 Ref.	

Note : Foot Length using gauge plane method measurement 0.010".

5-Pin TO-220 (T)

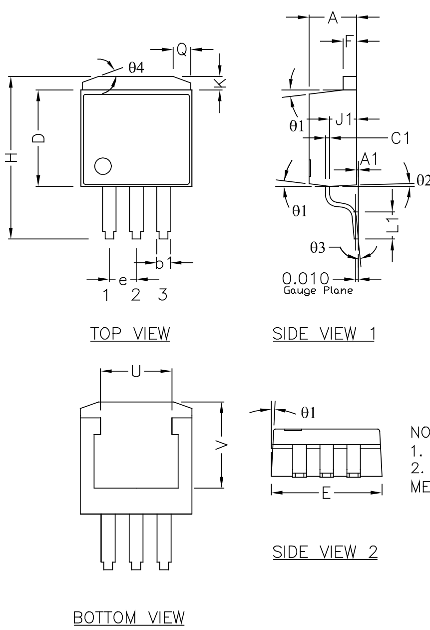
Package Information[1] (Continued)



POS	INCH		MM	
	MIN	MAX	MIN	MAX
A	0.170	0.181	4.318	4.597
A1	0.000	0.012	0.000	0.305
b	0.026	0.036	0.660	0.914
C1	0.012	0.023	0.305	0.584
D	0.330	0.361	8.392	9.169
E	0.396	0.420	10.058	10.668
e	0.062	0.072	1.575	1.829
F	0.045	0.055	1.143	1.397
H	0.575	0.625	14.605	15.875
J1	0.080	0.120	2.032	3.048
K	0.045	0.066	1.143	1.676
L1	0.090	0.110	2.286	2.794
θ1	3°	10°	3°	10°
θ2	1°	7°	1°	7°
θ3	0°	8°	0°	8°
θ4	18°	22°	18°	22°
Q	0.055	0.075	1.397	1.905
U	0.256 Ref.		6.502 Ref.	
V	0.305 Ref.		7.747 Ref.	

NOTE:
1. PACKAGE OUTLINE EXCLUSIVE OF MOLD FLASH & METAL BURR.
2. PACKAGE OUTLINE INCLUSIVE OF PLATING THICKNESS.
3. FOOT LENGTH USING GAUGE PLANE METHOD MEASUREMENT 0.010"
4. PACKAGE TOP MARK MAY BE IN TOP CENTER OR LOWER LEFT CORNER
5. ALL DIMENSIONS ARE IN INCHES/MILLIMETERS.

5-Pin TO-263 (U)



POS	INCH		MM	
	MIN	MAX	MIN	MAX
A	0.170	0.181	4.318	4.597
A1	0.000	0.012	0.000	0.305
b1	0.047	0.053	1.194	1.346
C1	0.012	0.023	0.305	0.584
D	0.330	0.361	8.382	9.169
E	0.396	0.420	10.058	10.668
e	0.095	0.105	2.413	2.667
F	0.045	0.055	1.143	1.397
H	0.575	0.625	14.605	15.875
J1	0.080	0.120	2.032	3.048
L1	0.090	0.110	2.286	2.794
K	0.045	0.066	1.143	1.676
θ1	3°	10°	3°	10°
θ2	1°	7°	1°	7°
θ3	0°	8°	0°	8°
θ4	18°	22°	18°	22°
Q	0.055	0.075	1.397	1.905
U	0.256 Ref.		6.502 Ref.	
V	0.303 Ref.		7.696 Ref.	

NOTES:
1. ALL DIMENSIONS ARE IN INCHES/MILLIMETERS.
2. FOOT LENGTH USING GAUGE PLANE METHOD MEASUREMENT 0.010".

3-Pin TO-263 (U)