AUTOMOTIVE GRADE

CS8321

Micropower 5V, 150mA Low Dropout Linear Regulator

Description

The CS8321 is a precision 5V micropower voltage regulator with very low quiescent current (140µA typ at 1mA load). The 5V output is accurate within ±2% and supplies 150mA of load current with a typical dropout voltage of only 300mV.

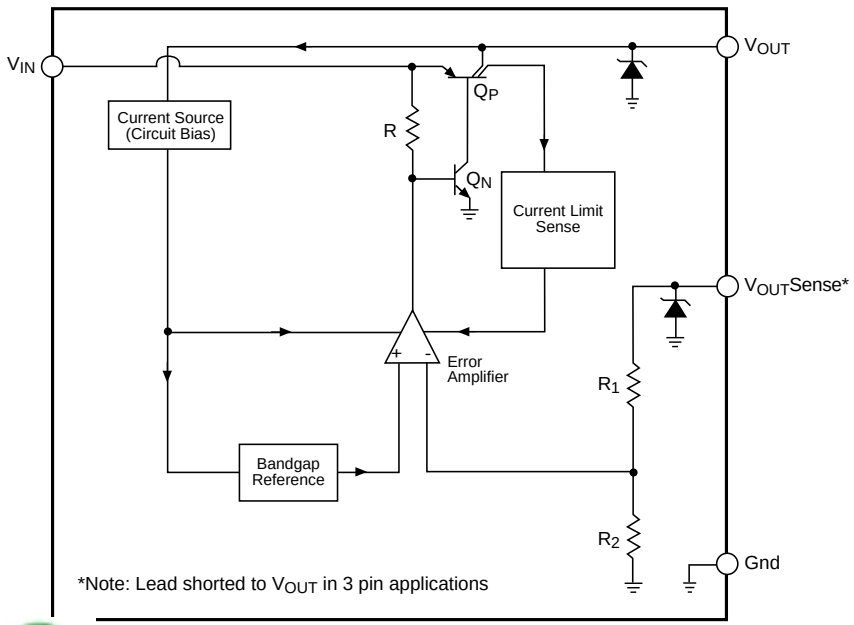
This combination of low quiescent current and outstanding regulator performance makes the CS8321 ideal for any battery operated equipment.

The regulator is protected against reverse battery and short circuit conditions. The device can withstand 45V load dump transients making it suitable for use in automotive environments.

Absolute Maximum Ratings

Transient Input Voltage . . . . . .-15V, 45V
Output Current . . . . . .Internally Limited
ESD Susceptibility (Human Body Model) 2kV
Junction Temperature . . . . . .-40°C to 150°C
Storage Temperature . . . . . .-65C to 150°C
Lead Temperature Soldering
Wave Solder (through hole styles only) . . . . . .10 sec. max, 260°C peak
Reflow (SMD styles only) . . . . . .60 sec. max above 183°C, 230°C peak

Block Diagram

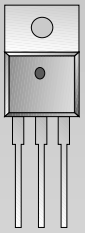


Features

- **5V ±2% Output**
- **Low 140µA (typ) Quiescent Current**
- **150mA Output Current Capability**
- **Fault Protection**
  -15V Reverse Voltage
  Output Current Limit
- **Low Reverse Current (Output to Input)**

Package Options

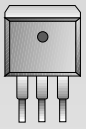
3L TO-220



1. V_{IN}
2. Gnd
3. V_{OUT}

1

3L D^2PAK



1. V_{IN}
2. Gnd
3. V_{OUT}

1

Other Packages: 16L SO, 16L PDIP, 8L SO, 8L PDIP, (consult factory)

ON Semiconductor
2000 South County Trail, East Greenwich, RI 02818
Tel: (401)885–3600 Fax: (401)885–5786
N. American Technical Support: 800-282-9855
Web Site: www.cherry–semi.com

Electrical Characteristics: 6V < V_{IN} < 26V, I_{OUT}=1mA, -40°C ≤ T_A ≤ 125°C, -40°C ≤ T_J ≤ 150°C unless otherwise specified.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
■ Output Stage					
Output Voltage, V_{OUT}	9V < V_{IN} < 16V, 100µA ≤ I_{OUT} ≤ 150mA	4.90	5.00	5.10	V
Dropout Voltage (V_{IN}-V_{OUT})	I_{OUT} = 150mA, -40°C ≤ T_A ≤ 85°C I_{OUT} = 150mA, T_A = 125°C		0.3	0.5 0.6	V V
Quiescent Current, (I_Q)	I_{OUT} = 1mA @ V_{IN} = 13V			200	µA
	I_{OUT} < 50mA @ V_{IN} = 13V I_{OUT} < 150mA @ V_{IN} = 13V		4 15	6 25	mA mA
Load Regulation	V_{IN} = 14V, 100µA < I_{OUT} < 150mA		5	50	mV
Line Regulation	6V < V < 26V, I_{OUT} = 1mA		5	50	mV
Ripple Rejection	7 – V_{IN} – 17V, I_{OUT} = 150mA, *f* = 120Hz	60	75		dB
Current Limit		175	250		mA
Short Circuit Output Current	V_{OUT} = 0V	60	200		mA
Reverse Current	V_{OUT} = 5V, V_{IN} = 0V		140	200	µA

Package Lead Description

PACKAGE LEAD #		LEAD SYMBOL	FUNCTION
3L D²PAK	**3L TO-220**		
1	1	V_{IN}	Input Voltage
2	2	Gnd	Ground. All Gnd leads must be connected to Ground.
3	3	V_{OUT}	5V, ±2%, 150mA Output.

Circuit Description and Application Notes

Voltage Reference and Output Circuitry

The CS8321 is a series pass voltage regulator. It consists of an error amplifier, bandgap voltage reference, PNP pass transistor with antisaturation control, and current limit.

As the voltage at the input, V_{IN}, is increased, Q_N is forward biased via R. Q_N provides base drive for Q_P. As Q_P becomes forward biased, the output voltage, V_{OUT}, begins to rise as Q_P's output current charges the output capacitor. Once V_{OUT} rises to a certain level, the error amplifier becomes biased and provides the appropriate amount of base current to Q_P. The error amplifier monitors the scaled output voltage via an internal voltage divider, R1 and R2, and compares it to the bandgap voltage reference. The error amplifier's output is a current which is equal to the error amplifier's differential input voltage times its transconductance. Therefore, the error amplifier varies the base drive current to Q_N, which provides bias to Q_P, based on the difference between the reference voltage and the scaled output voltage, V_{OUT}.

Antisaturation Protection

An antisaturation control circuit has also been added to prevent the pass transistor from going into deep saturation, which would cause excessive power dissipation due to large bias currents lost to the substrate via a parasitic PNP transistor, as shown in Figure 1.

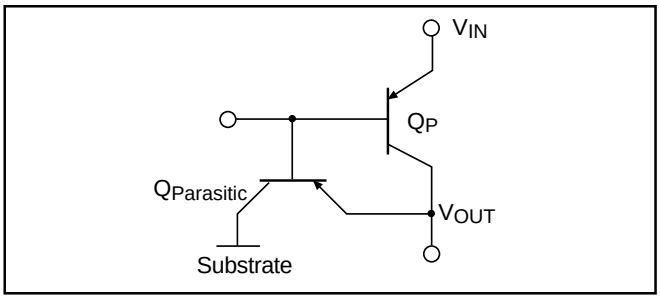


Figure 1. The parasitic PNP transistor which is part of the pass transistor (Q_P) structure.

Current Limit

The output stage is protected against short circuit conditions. As shown in Figure 2, the output current will fold back when the faulted load is continually increased. This technique has been incorporated to limit the total power dissipation across the device during a short circuit condition, since the device does not contain overtemperature shutdown.

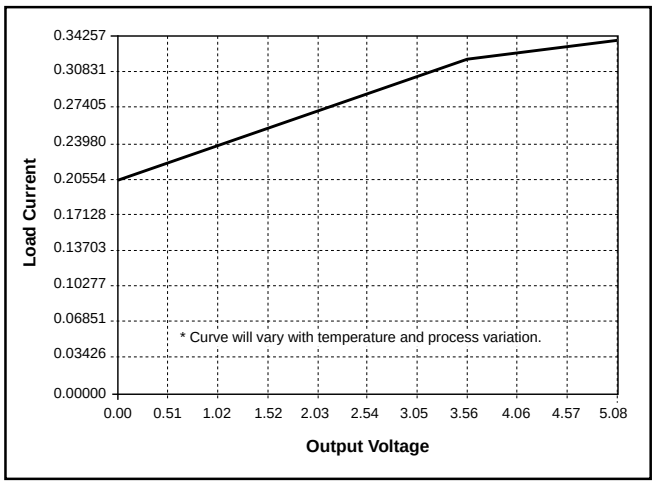
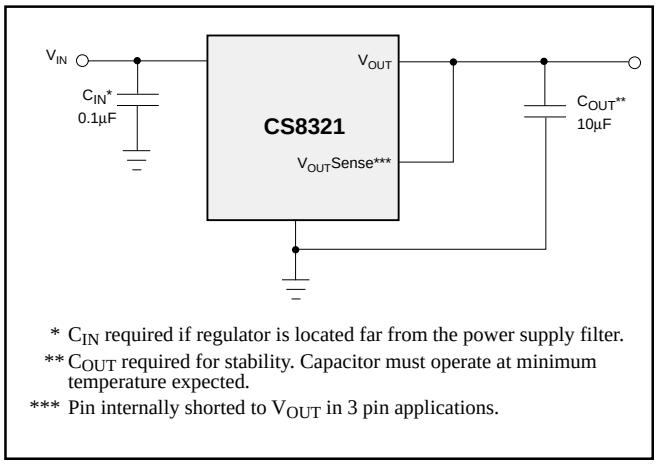


Figure 2. Typical current limit and fold back waveform.

Stability Considerations

The output or compensation capacitor helps determine three main characteristics of a linear regulator: start-up delay, load transient response and loop stability.



* C_{IN} required if regulator is located far from the power supply filter.
** C_{OUT} required for stability. Capacitor must operate at minimum temperature expected.
*** Pin internally shorted to V_{OUT} in 3 pin applications.

Figure 3: Test and application circuit showing output compensation.

The capacitor value and type should be based on cost, availability, size and temperature constraints. A tantalum or aluminum electrolytic capacitor is best, since a film or ceramic capacitor with almost zero ESR can cause instability. The aluminum electrolytic capacitor is the least expensive solution, but, if the circuit operates at low temperatures (-25°C to -40°C), both the value and ESR of the capacitor will vary considerably. The capacitor manufacturers data sheet usually provides this information.

The value for the output capacitor C_{OUT} shown in Figure 3 should work for most applications, however it is not necessarily the best solution.

To determine an acceptable value for C_{OUT} for a particular application, start with a tantalum capacitor of the recommended value and work towards a less expensive alternative part.

Step 1: Place the completed circuit with a tantalum capacitor of the recommended value in an environmental chamber at the lowest specified operating temperature and monitor the outputs with an oscilloscope. A decade box connected in series with the capacitor will simulate the higher ESR of an aluminum capacitor. Leave the decade box outside the chamber, the small resistance added by the longer leads is negligible.

Step 2: With the input voltage at its maximum value, increase the load current slowly from zero to full load while observing the output for any oscillations. If no oscillations are observed, the capacitor is large enough to ensure a stable design under steady state conditions.

Step 3: Increase the ESR of the capacitor from zero using the decade box and vary the load current until oscillations appear. Record the values of load current and ESR that cause the greatest oscillation. This represents the worst case load conditions for the regulator at low temperature.

Step 4: Maintain the worst case load conditions set in step 3 and vary the input voltage until the oscillations increase. This point represents the worst case input voltage conditions.

Step 5: If the capacitor is adequate, repeat steps 3 and 4 with the next smaller valued capacitor. A smaller capacitor will usually cost less and occupy less board space. If the output oscillates within the range of expected operating conditions, repeat steps 3 and 4 with the next larger standard capacitor value.

Step 6: Test the load transient response by switching in various loads at several frequencies to simulate its real working environment. Vary the ESR to reduce ringing.

Step 7: Remove the unit from the environmental chamber and heat the IC with a heat gun. Vary the load current as instructed in step 5 to test for any oscillations.

Once the minimum capacitor value with the maximum ESR is found, a safety factor should be added to allow for the tolerance of the capacitor and any variations in regulator performance. Most good quality aluminum electrolytic capacitors have a tolerance of ± 20% so the minimum value found should be increased by at least 50% to allow for this tolerance plus the variation which will occur at low temperatures. The ESR of the capacitor should be less than 50% of the maximum allowable ESR found in step 3 above.

Circuit Description and Application Notes: continued

Calculating Power Dissipation in a Single Output Linear Regulator

The maximum power dissipation for a single output regulator (Figure 3) is:

$$P_{D(max)}=\left(V_{IN(max)}-V_{OUT(min)}\right)I_{OUT(max)}+V_{IN(max)}I_Q \quad (1)$$

where:

$V_{IN(max)}$ is the maximum input voltage,

$V_{OUT(min)}$ is the minimum output voltage,

$I_{OUT(max)}$ is the maximum output current for the application, and

I_Q is the quiescent current the regulator consumes at $I_{OUT(max)}$.

Once the value of $P_{D(max)}$ is known, the maximum permissible value of $R_{\Theta JA}$ can be calculated:

$$R_{\Theta JA} = \frac{150°C - T_A}{P_D} \quad (2)$$

The value of $R_{\Theta JA}$ can then be compared with those in the package section of the data sheet. Those packages with $R_{\Theta JA}$'s less than the calculated value in equation 2 will keep the die temperature below 150°C.

In some cases, none of the packages will be sufficient to dissipate the heat generated by the IC, and an external heatsink will be required.

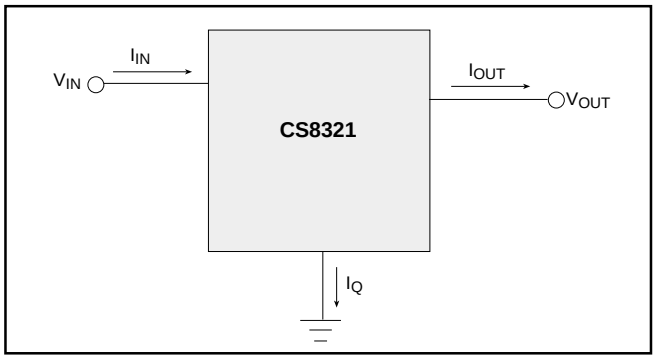


Figure 4: Single output regulator with key performance parameters labeled.

Heatsinks

A heatsink effectively increases the surface area of the package to improve the flow of heat away from the IC and into the surrounding air.

Each material in the heat flow path between the IC and the outside environment will have a thermal resistance. Like series electrical resistances, these resistances are summed to determine the value of $R_{\Theta JA}$:

$$R_{\Theta JA} = R_{\Theta JC} + R_{\Theta CS} + R_{\Theta SA} \quad (3)$$

where:

$R_{\Theta JC}$ = the junction–to–case thermal resistance,

$R_{\Theta CS}$ = the case–to–heatsink thermal resistance, and

$R_{\Theta SA}$ = the heatsink–to–ambient thermal resistance.

$R_{\Theta JC}$ appears in the package section of the data sheet. Like $R_{\Theta JA}$, it too is a function of package type. $R_{\Theta CS}$ and $R_{\Theta SA}$ are functions of the package type, heatsink and the interface between them. These values appear in heatsink data sheets of heatsink manufacturers.

Package Specification

PACKAGE DIMENSIONS IN mm(INCHES)

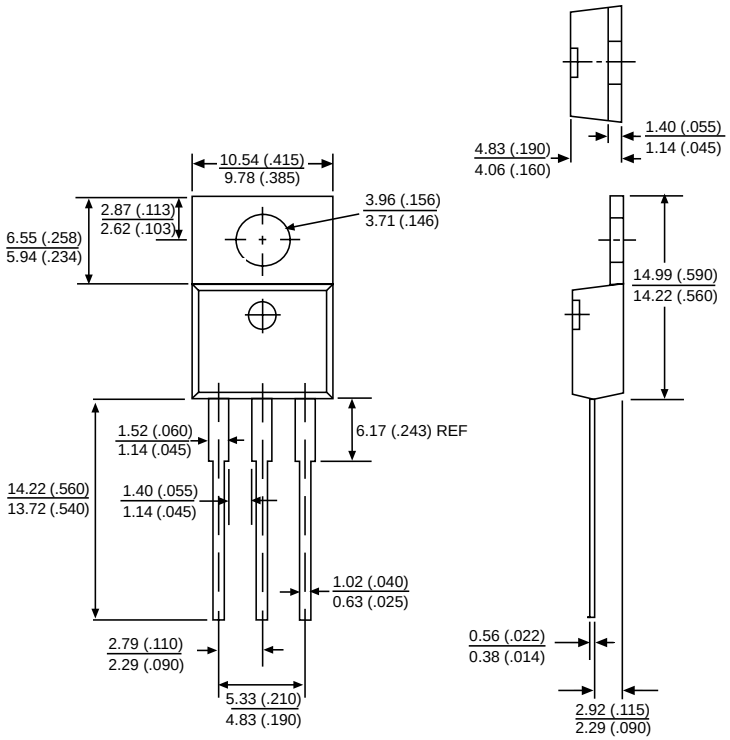
PACKAGE THERMAL DATA

Thermal Data		3L TO-220	3L D^2PAK	
$R_{\Theta JC}$	typ	3.5	1.0*	°C / W
$R_{\Theta JA}$	typ	50	10 - 50**	°C / W

**Depending on die area*

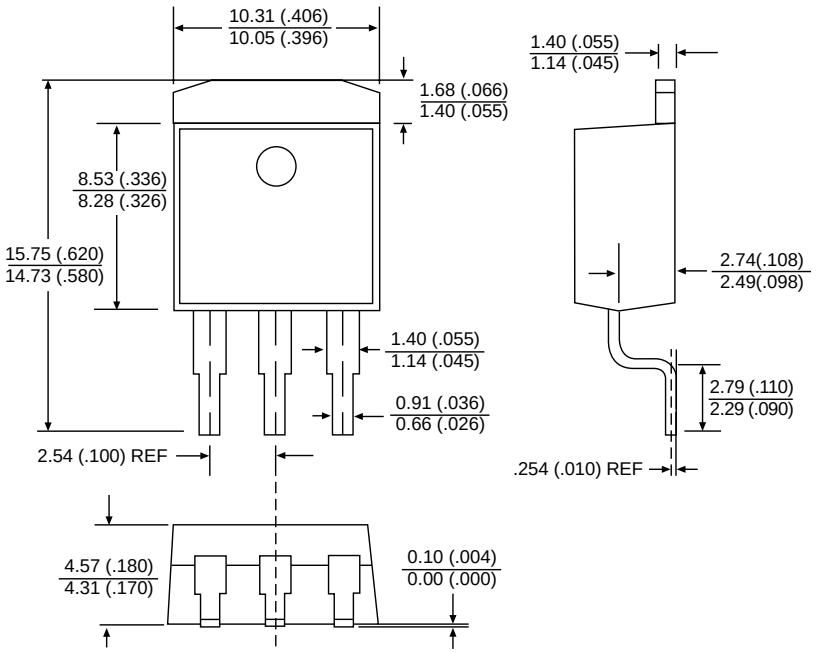
***Depending on thermal properties of substrate.* $R_{\Theta JA} = R_{\Theta JC} + R_{\Theta CA}$

3 Lead TO-220 (T) Straight



Package Specification: continued

3 Lead D²PAK (DP)



Ordering Information

Part Number	Description
CS8321YT3	3L TO-220 Straight
CS8321YDP3	3L D²PAK
CS8321YDPR3	3L D²PAK *(tape & reel)*

Notes

Notes