CS8221

Micropower 5.0 V, 100 mA Low Dropout Linear Regulator

The CS8221 is a precision 5.0 V, 100 mA micropower voltage regulator with very low quiescent current (60 μA typical at 100 μA load). The 5.0 V output is accurate within ±2.0% and supplies 100 mA of load current with a maximum dropout voltage of only 600 mV.

The regulator is protected against reverse battery, short circuit, overvoltage, and over temperature conditions. The device can withstand 74 V peak transients making it suitable for use in automotive environments. The CS8221 is pin for pin compatible with the LM2931.

Features
- Low Quiescent Current (60 μA @ 100 μA Load)
- 5.0 V ±2.0% Output
- 100 mA Output Current Capability
- Internally Fused Leads in SO–8 Package
- Fault Protection
  - +74 V Peak Transient Voltage
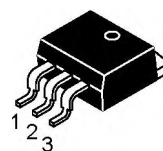 - −15 V Reverse Voltage
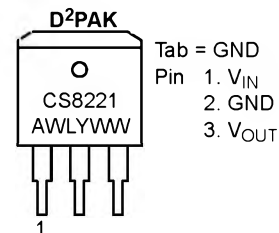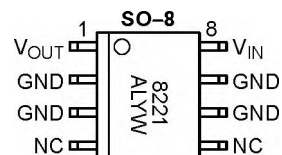 - Short Circuit
  - Thermal Shutdown

ON Semiconductor™

SO–8
DF SUFFIX
CASE 751

D²PAK
3–PIN
DP SUFFIX
CASE 418E

PIN CONNECTIONS AND MARKING INDIAGRAM

SO–8

1 V$_{OUT}$	8 V$_{IN}$
GND	GND
GND	GND
NC	NC

8221
ALYW

D²PAK

CS8221
AWLYWW

Tab = GND
Pin 1. V$_{IN}$
      2. GND
      3. V$_{OUT}$

A = Assembly Location
WL, L = Wafer Lot
YY, Y = Year
WW, W = Work Week

ORDERING INFORMATION*

Device	Package	Shipping
CS8221YDF8	SO–8	95 Units/Rail
CS8221YDFR8	SO–8	2500 Tape & Reel
CS8221YDP3	D²PAK, 3–PIN	50 Units/Rail
CS8221YDPR3	D²PAK, 3–PIN	750 Tape & Reel

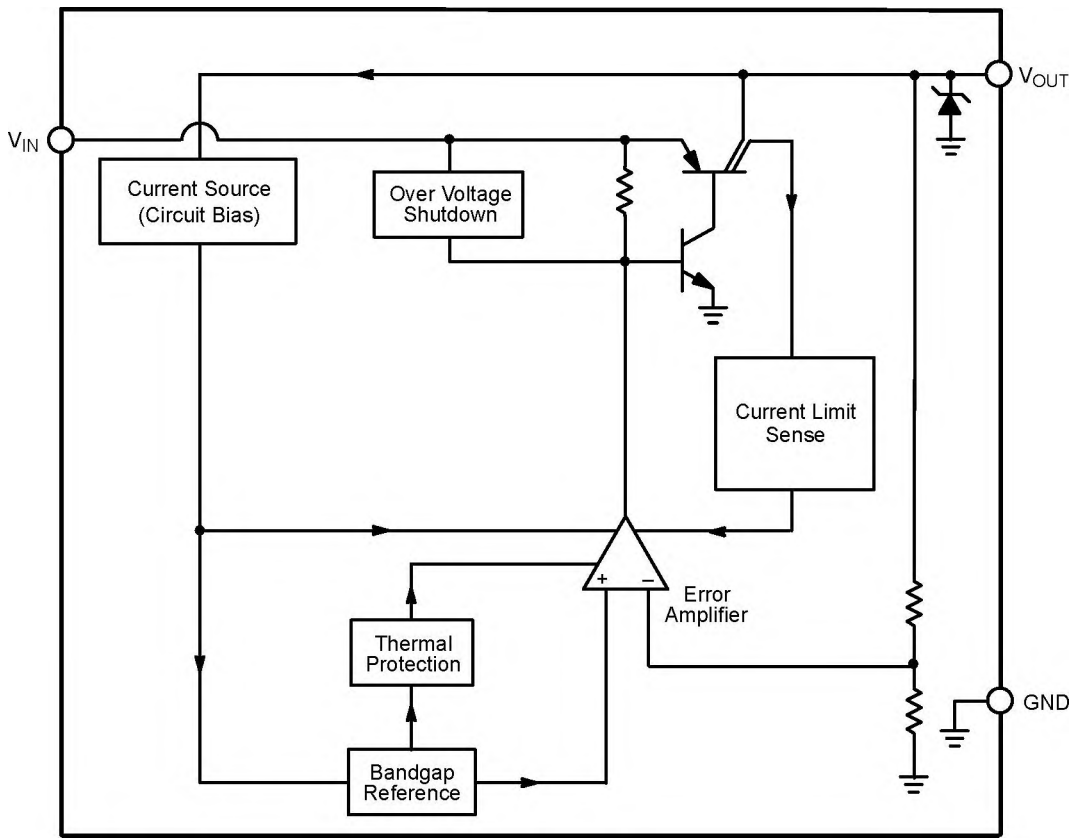*Contact your local sales representative for TO–92 package option.

CS8221

Figure 1. Block Diagram

ABSOLUTE MAXIMUM RATINGS*

Rating		Value	Unit
Junction Temperature Range, T_J		−40 to +150	°C
Storage Temperature Range, $T_{STORAGE}$		−55 to +150	°C
Power Dissipation		Internally Limited	−
Peak Transient Voltage (60 V Load Dump @ V_{IN} = 14 V)		−15, 74	V
Input Operating Range		−0.5 to 26	V
Output Current		Internally Limited	−
Electrostatic Discharge (Human Body Model)		2.0	kV
Lead Temperature Soldering:	Reflow (Note 1)	230 peak	°C

1. 60 seconds maximum above 183°.

*The maximum package power dissipation must be observed.

ELECTRICAL CHARACTERISTICS (6.0 ≤ V_{IN} ≤ 26 V, I_{OUT} = 1.0 mA, −40°C ≤ T_J ≤ 125°C unless otherwise noted.)

Characteristic	Test Conditions	Min	Typ	Max	Unit
Output Stage					
Output Voltage, V_{OUT}	9.0 V < V_{IN} < 26 V, 100 μA ≤ I_{OUT} ≤ 100 mA	4.9	5.0	5.1	V
	6.0 V ≤ V_{IN} ≤ 26 V, 100 μA ≤ I_{OUT} ≤ 100 mA	4.85	5.0	5.15	V
Dropout Voltage ($V_{IN} - V_{OUT}$)	I_{OUT} = 100 mA	−	400	600	mV
	I_{OUT} = 100 μA	−	100	150	mV
Load Regulation	V_{IN} = 14 V, 100 μA ≤ I_{OUT} ≤ 100 mA,	−	5.0	50	mV
Line Regulation	6.0 V < V < 26 V, I_{OUT} = 1.0 mA	−	5.0	50	mV
Quiescent Current, (I_Q)	I_{OUT} = 100 μA, V_{IN} = 6.0 V	−	60	120	μA
	I_{OUT} = 50 mA	−	4.0	6.0	mA
	I_{OUT} = 100 mA	−	12	20	mA
Ripple Rejection	7.0 ≤ V_{IN} ≤ 17 V, I_{OUT} = 100 mA, f = 120 Hz	60	75	−	dB
Current Limit	−	125	200	−	mA
Short Circuit Output Current	V_{OUT} = 0 V	40	125	−	μA
Thermal Shutdown (Note 2)	−	150	180	−	°C
Overvoltage Shutdown	V_{OUT} ≤ 1.0 V	30	34	38	V

2. This parameter is guaranteed by design, but not parametrically tested in production.

PACKAGE LEAD DESCRIPTION

PACKAGE LEAD #		LEAD SYMBOL	FUNCTION
SO–8	D²PAK		
1	3	V_{OUT}	5.0 V, ±2.0%, 100 mA Output.
2, 3, 6, 7	2	GND	Ground.
4	–	NC	No Connection.
5	–	NC	No Connection.
8	1	V_{IN}	Input Voltage.

CS8221

CIRCUIT DESCRIPTION

VOLTAGE REFERENCE AND OUTPUT CIRCUITRY

Output Stage Protection

The output stage is protected against overvoltage, short circuit and thermal runaway conditions (Figure 2).
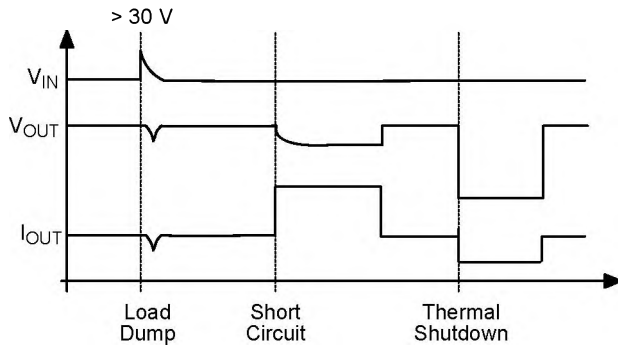

Figure 2. Typical Circuit Waveforms for Output Stage Protection

If the input voltage rises above 30 V, the output shuts down. This response protects the internal circuitry and enables the IC to survive unexpected voltage transients.

Should the junction temperature of the power device exceed 180°C (typ) the power transistor is turned off. Thermal shutdown is an effective means to prevent die overheating since the power transistor is the principle heat source in the IC.
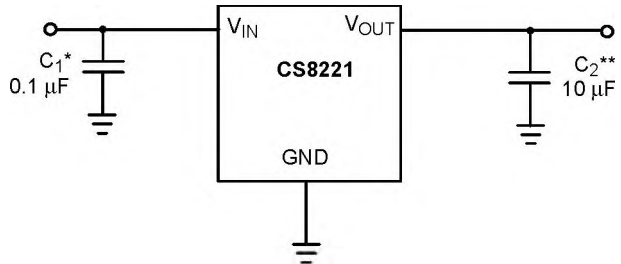
*C_1 is required if regulator is far from the power source filter.

**C_2 is required for stability.

Figure 3. Application and Test Diagram

APPLICATION NOTES

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.

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 optimized 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: Increase the temperature to your highest operating temperature. 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 $\pm 20\%$ 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.

CALCULATING POWER DISSIPATION IN A SINGLE OUTPUT LINEAR REGULATOR

The maximum power dissipation for a single output regulator (Figure 4) is:

$$P_{D(max)} = [V_{IN(max)} - V_{OUT(min)}]I_{OUT(max)} + V_{IN(max)}I_Q \quad (1)$$
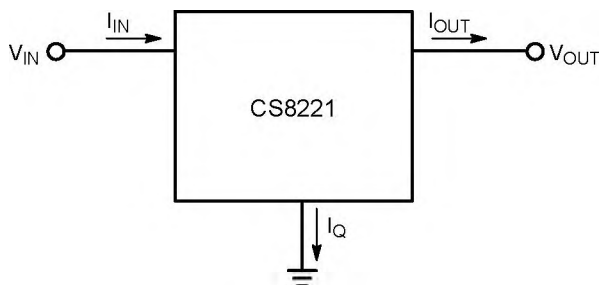
where:

$V_{IN(max)}$ 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.

HEAT SINKS

A heat sink 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 heat sink data sheets of heat sink manufacturers.

Figure 4. Single Output Regulator With Key Performance Parameters Labeled

PACKAGE THERMAL DATA

Parameter		SO–8	D²PAK, 3–PIN	Unit
$R_{\Theta JC}$	Typical	25	4.2	°C/W
$R_{\Theta JA}$	Typical	110	10–50*	°C/W

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