

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 μ A typical at 100 μ A load). The 5.0 V output is accurate within $\pm 2.0\%$ 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 μ A @ 100 μ A Load)
- 5.0 V $\pm 2.0\%$ 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
- These are Pb-Free Devices

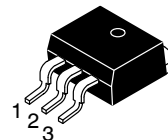


ON Semiconductor®

<http://onsemi.com>

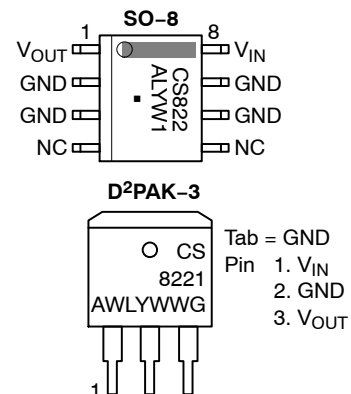


**SO-8
DF SUFFIX
CASE 751**



**D²PAK-3
DP SUFFIX
CASE 418AB**

PIN CONNECTIONS AND MARKING DIAGRAM



CS8221 = Specific Device Code
A = Assembly Location
WL, L = Wafer Lot
Y = Year
WW, W = Work Week
G or ■ = Pb-Free Package

ORDERING INFORMATION*

Device	Package	Shipping†
CS8221YDFR8G	SO-8 (Pb-Free)	2500/Tape & Reel
CS8221YDP3G	D ² PAK-3 (Pb-Free)	50 Units/Rail
CS8221YDPR3G	D ² PAK-3 (Pb-Free)	750/Tape & Reel

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

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specification Brochure, BRD8011/D.

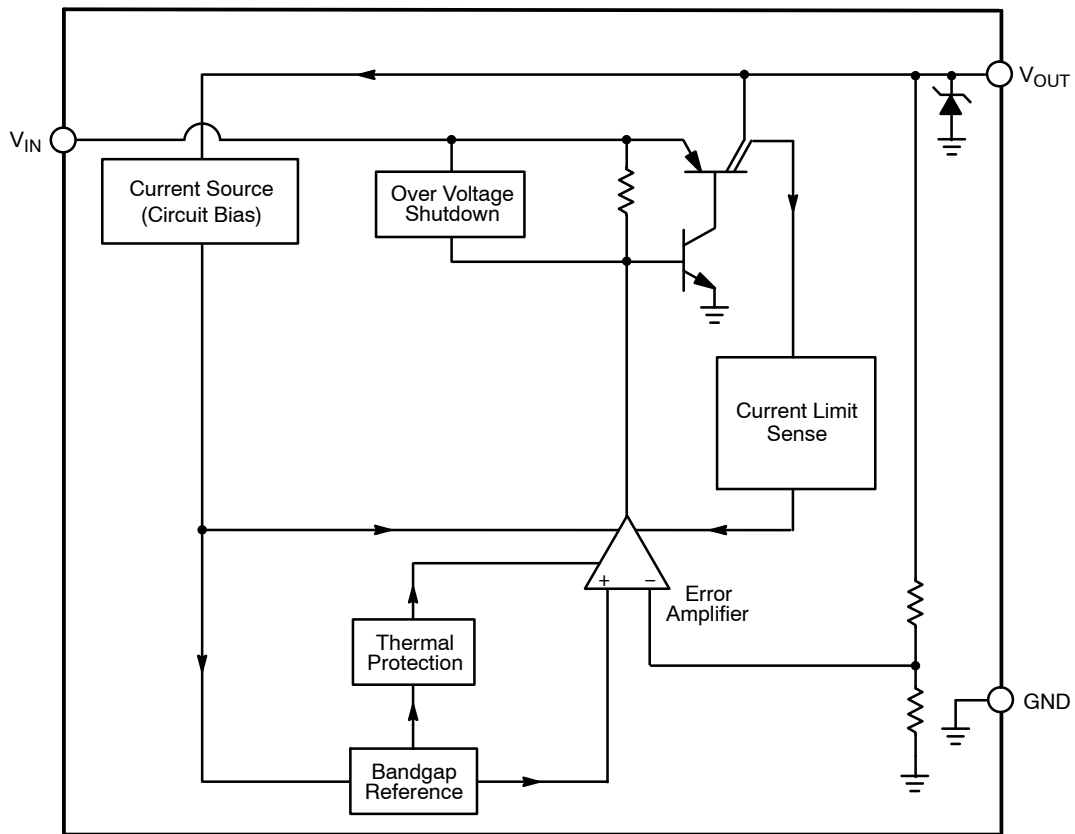


Figure 1. Block Diagram

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

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

1. 60 seconds maximum above 183°.

*The maximum package power dissipation must be observed.

CS8221

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 6.0 V ≤ V _{IN} ≤ 26 V, 100 μA ≤ I _{OUT} ≤ 100 mA	4.9 4.85	5.0 5.0	5.1 5.15	V V
Dropout Voltage (V _{IN} − V _{OUT})	I _{OUT} = 100 mA I _{OUT} = 100 μA	– –	400 100	600 150	mV 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 I _{OUT} = 50 mA I _{OUT} = 100 mA	– – –	60 4.0 12	120 6.0 20	μA mA 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	D ² PAK-3		
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.

TYPICAL PERFORMANCE CHARACTERISTICS

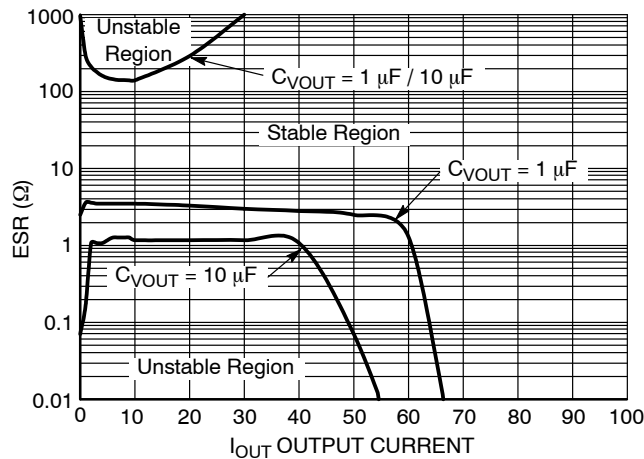


Figure 2. CS8221 Output Stability

CIRCUIT DESCRIPTION

VOLTAGE REFERENCE AND OUTPUT CIRCUITRY

Output Stage Protection

The output stage is protected against overvoltage, short circuit and thermal runaway conditions (Figure 3).

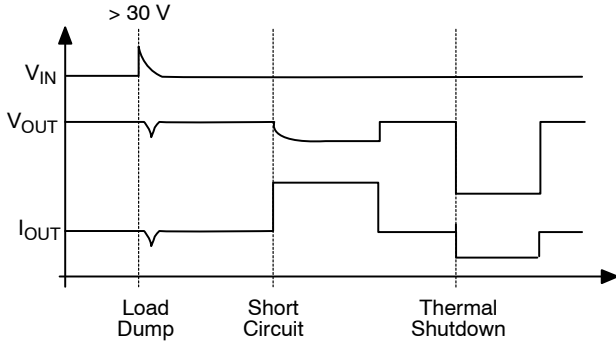
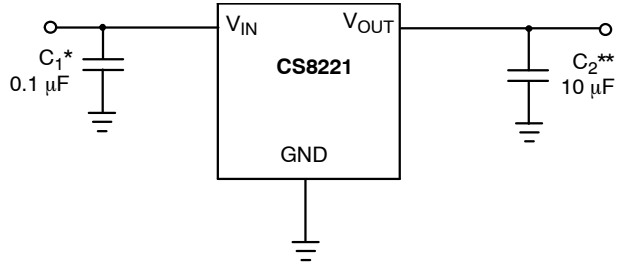


Figure 3. Typical Circuit Waveforms for Output Stage Protection

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.



*C₁ is required if regulator is far from the power source filter.

**C₂ is required for stability.

Figure 4. 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 4 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 5) 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:

$$R_{\theta JA} = \frac{150^\circ\text{C} - T_A}{P_D} \quad (2)$$

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.

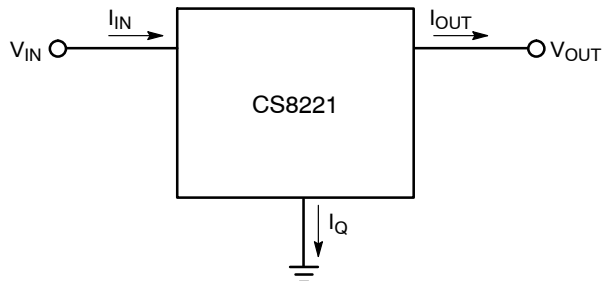


Figure 5. Single Output Regulator With Key Performance Parameters Labeled

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

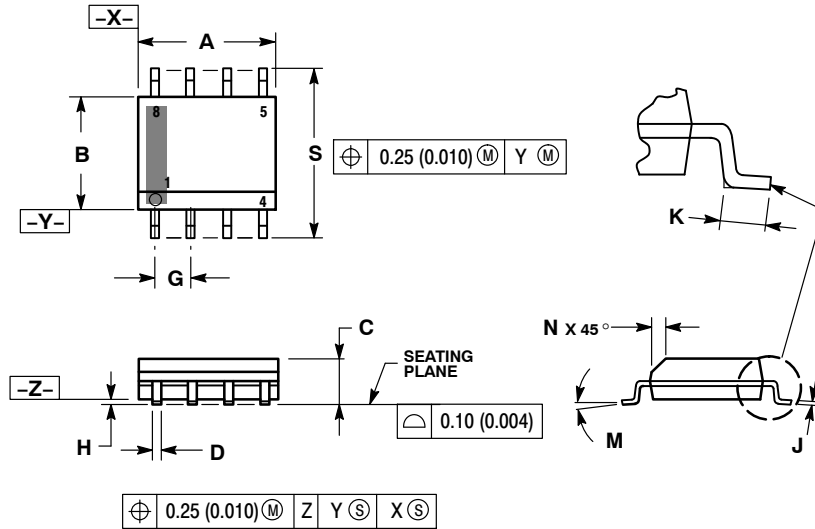
$R_{\theta SA}$ = the heatsink-to-ambient thermal resistance.

$R_{\theta JC}$ 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.

CS8221

PACKAGE DIMENSIONS

SO-8
DF SUFFIX
CASE 751-07
ISSUE AJ

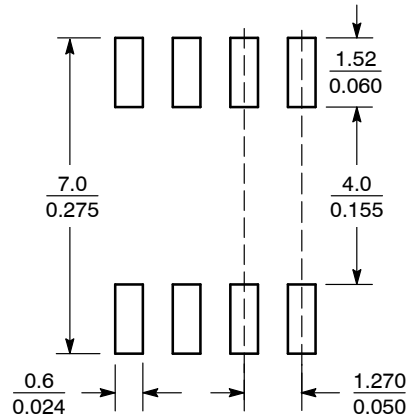


NOTES:

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSION A AND B DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.
5. DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 (0.005) TOTAL IN EXCESS OF THE D DIMENSION AT MAXIMUM MATERIAL CONDITION.
6. 751-01 THRU 751-06 ARE OBSOLETE. NEW STANDARD IS 751-07.

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	4.80	5.00	0.189	0.197
B	3.80	4.00	0.150	0.157
C	1.35	1.75	0.053	0.069
D	0.33	0.51	0.013	0.020
G	1.27 BSC		0.050 BSC	
H	0.10	0.25	0.004	0.010
J	0.19	0.25	0.007	0.010
K	0.40	1.27	0.016	0.050
M	0 °	8 °	0 °	8 °
N	0.25	0.50	0.010	0.020
S	5.80	6.20	0.228	0.244

SOLDERING FOOTPRINT*



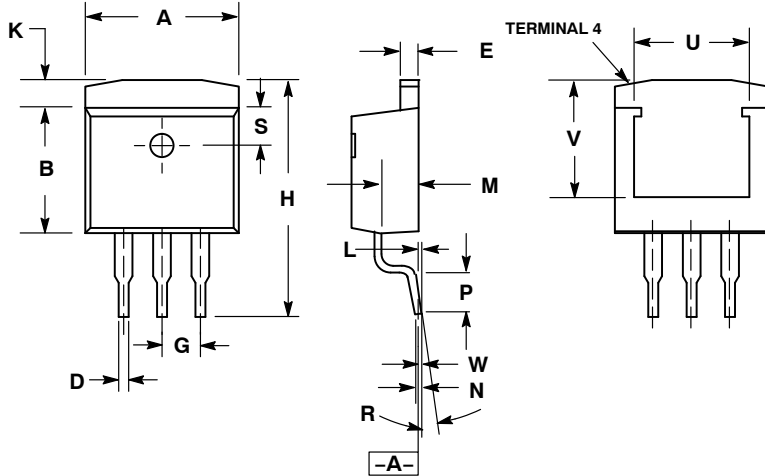
SCALE 6:1 $\left(\frac{\text{mm}}{\text{inches}} \right)$

*For additional information on our Pb-Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

CS8221

PACKAGE DIMENSIONS

D²PAK-3 DP SUFFIX CASE 418AB-01 ISSUE O



NOTES:

1. DIMENSIONS AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. PACKAGE OUTLINE EXCLUSIVE OF MOLD FLASH AND METAL BURRS.
4. PACKAGE OUTLINE INCLUSIVE OF PLATING THICKNESS.
5. FOOT LENGTH MEASURED AT INTERCEPT POINT BETWEEN DATUM A AND LEAD SURFACE.


DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.396	0.406	10.05	10.31
B	0.330	0.340	8.38	8.64
C	0.170	0.180	4.31	4.57
D	0.026	0.036	0.66	0.91
E	0.045	0.055	1.14	1.40
G	0.100 REF		2.54 REF	
H	0.580	0.620	14.73	15.75
K	0.055	0.066	1.40	1.68
L	0.000	0.010	0.00	0.25
M	0.098	0.108	2.49	2.74
N	0.017	0.023	0.43	0.58
P	0.090	0.110	2.29	2.79
R	0°	8°	0°	8°
S	0.095	0.105	2.41	2.67
U	0.30 REF		7.62 REF	
V	0.305 REF		7.75 REF	
W	0.010		0.25	

PACKAGE THERMAL DATA

Parameter		SO-8	D ² PAK-3	Unit
R _{θJC}	Typical	25	4.2	°C/W
R _{θJA}	Typical	110	10-50*	°C/W

* Depending on thermal properties of substrate. R_{θJA} = R_{θJC} = R_{θCA}

SMART REGULATOR is a registered trademark of Semiconductor Components Industries, LLC (SCILLC).

ON Semiconductor and  are registered trademarks of Semiconductor Components Industries, LLC (SCILLC). SCILLC reserves the right to make changes without further notice to any products herein. SCILLC makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does SCILLC assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. "Typical" parameters which may be provided in SCILLC data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. SCILLC does not convey any license under its patent rights nor the rights of others. SCILLC products are not designed, intended, or authorized for use as components in systems intended for surgical implant into the body, or other applications intended to support or sustain life, or for any other application in which the failure of the SCILLC product could create a situation where personal injury or death may occur. Should Buyer purchase or use SCILLC products for any such unintended or unauthorized application, Buyer shall indemnify and hold SCILLC and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that SCILLC was negligent regarding the design or manufacture of the part. SCILLC is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner.

PUBLICATION ORDERING INFORMATION

LITERATURE FULFILLMENT:
Literature Distribution Center for ON Semiconductor
P.O. Box 5163, Denver, Colorado 80217 USA
Phone: 303-675-2175 or 800-344-3860 Toll Free USA/Canada
Fax: 303-675-2176 or 800-344-3867 Toll Free USA/Canada
Email: orderlit@onsemi.com

N. American Technical Support: 800-282-9855 Toll Free
USA/Canada
Europe, Middle East and Africa Technical Support:
Phone: 421 33 790 2910
Japan Customer Focus Center
Phone: 81-3-5773-3850

ON Semiconductor Website: www.onsemi.com

Order Literature: <http://www.onsemi.com/orderlit>

For additional information, please contact your local Sales Representative

CS8221/D