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# CAT3200, CAT3200-5

## Low Noise Regulated Charge Pump DC-DC Converter

### Description

The CAT3200 and CAT3200-5 are switched capacitor boost converters that deliver a low noise, regulated output voltage. The CAT3200-5 gives a fixed regulated 5 V output. The CAT3200 has an adjustable output using external resistors. The constant frequency 2 MHz charge pump allows small 1  $\mu$ F ceramic capacitors to be used.

Maximum output loads of up to 100 mA can be supported over a wide range of input supply voltages (2.7 V to 4.5 V) making the device ideal for battery-powered applications.

A shutdown control input allows the device to be placed in power-down mode, reducing the supply current to less than 1  $\mu$ A.

In the event of short circuit or overload conditions, the device is fully protected by both foldback current limiting and thermal overload detection. In addition, a soft start, slew rate control circuit limits inrush current during power-up.

The CAT3200-5 is available in a 6-lead, 1 mm max thin SOT23 package. The CAT3200 is available in an 8-lead MSOP package.

### Features

- Constant High Frequency (2 MHz) Operation
- 100 mA Output Current
- Regulated Output Voltage (5 V Fixed CAT3200-5, Adjustable CAT3200)
- Low Quiescent Current (1.7 mA Typ.)
- Input Voltage Operation down to 2.7 V
- Soft Start, Slew Rate Control
- Thermal Overload Shutdown Protection
- Low Value External Capacitors (1  $\mu$ F)
- Foldback Current Overload Protection
- Shutdown Current less than 1  $\mu$ A
- CAT3200-5 in Low Profile (1 mm Thin) 6-lead TSOT-23 Package
- CAT3200 in MSOP-8 Package
- These Devices are Pb-Free, Halogen Free/BFR Free and are RoHS Compliant

### Applications

- 3 V to 5 V Boost Conversion
- White LED Driver
- USB On-The-Go 5 V Supply
- Local 5 V Supply from Lower Rail
- Battery Backup Systems
- Handheld Portable Devices



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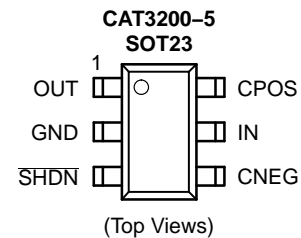
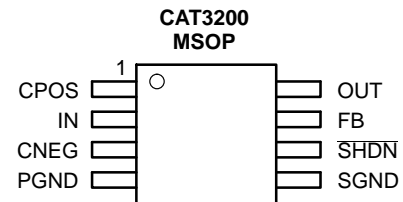


MSOP-8  
Z SUFFIX  
CASE 846AD



TSOT-23  
TD SUFFIX  
CASE 419AF

### PIN CONFIGURATIONS



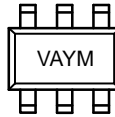
### ORDERING INFORMATION

Device	Package	Shipping
CAT3200TDI-GT3	TSOT23-6* (Pb-Free)	3,000 / Tape & Reel
CAT3200ZI-GT3	MSOP-8* (Pb-Free)	3,000 / Tape & Reel

\* NiPdAu lead finish

# CAT3200, CAT3200-5

## MARKING DIAGRAMS



ABRU = CAT3200ZI-GT3  
 VA = CAT3200TDI-GT3  
 Y = Production Year (Last Digit)  
 M = Production Month (1-9, O, N, D)  
 R = Production Revision

## Typical Application

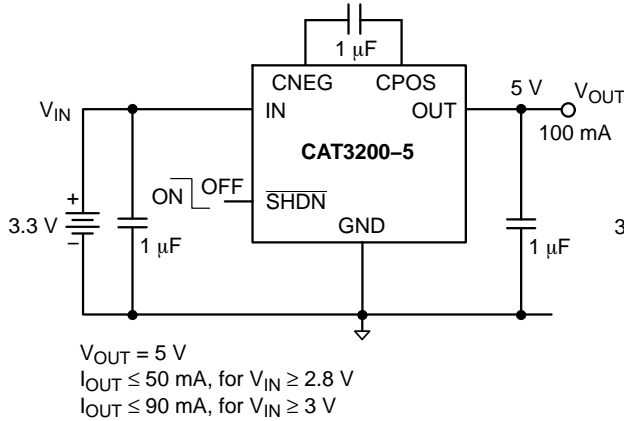


Figure 1. Typical Application – 5 V Output

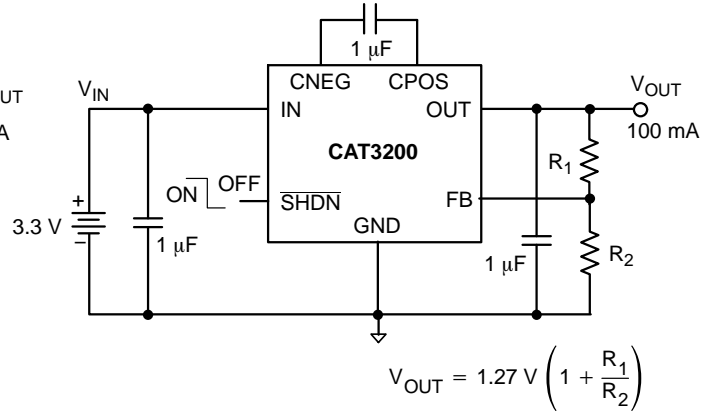


Figure 2. Typical Application – Adjustable Output

Table 1. PIN DESCRIPTIONS

Designation	Description
OUT	Regulated output voltage.
GND	Ground reference for all voltages.
SHDN	Shutdown control logic input (Active LOW)
CNEG	Negative connection for the flying capacitor.
IN	Input power supply.
CPOS	Positive connection for the flying capacitor.
FB	Feedback to set the output voltage.
PGND	Power ground.
SGND	Signal ground.

Table 2. ABSOLUTE MAXIMUM RATINGS

Parameters	Ratings	Units
$V_{IN}$ , $V_{OUT}$ , SHDN, CNEG, CPOS Voltage	-0.6 to +6.0	V
$V_{OUT}$ Short Circuit Duration	Indefinite	
Output Current	200	mA
ESD Protection (HBM)	2000	V
Junction Temperature	150	°C
Storage Temperature Range	-65 to +160	°C
Lead Soldering Temperature (10 sec)	300	°C
Power Dissipation (SOT23-6)	0.3	W
Power Dissipation (8-MSOP)	0.5	W

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

# CAT3200, CAT3200-5

**Table 3. RECOMMENDED OPERATING CONDITIONS**

Parameters	Ratings	Units
$V_{IN}$	2.7 to 4.5	V
$C_{IN}$ , $C_{OUT}$ , $C_{FLY}$	1	$\mu$ F
$I_{LOAD}$	0 to 100	mA
Ambient Temperature Range	-40 to +85	$^{\circ}$ C

Functional operation above the stresses listed in the Recommended Operating Ranges is not implied. Extended exposure to stresses beyond the Recommended Operating Ranges limits may affect device reliability.

**Table 4. ELECTRICAL SPECIFICATIONS**

(Recommended operating conditions unless otherwise specified.  $C_{IN}$ ,  $C_{OUT}$ ,  $C_{FLY}$  are 1  $\mu$ F ceramic capacitors and  $V_{IN}$  is set to 3.6 V.)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
$V_{OUT}$	Regulated Output	$I_{LOAD} \leq 40$ mA, $V_{IN} \geq 2.7$ V $I_{LOAD} \leq 100$ mA, $V_{IN} \geq 3.1$ V	4.8	5.0	5.2	V
$V_{LINE}$	Line Regulation	$3.1$ V $\leq V_{IN} \leq 4.5$ V, $I_{LOAD} = 50$ mA		6		mV
$V_{LOAD}$	Load Regulation	$I_{LOAD} = 10$ mA to 100 mA, $V_{IN} = 3.6$ V		20		mV
$F_{OSC}$	Switching Frequency		1.3	2.0	2.6	MHz
$V_R$	Output Ripple Voltage	$I_{LOAD} = 100$ mA CAT3200-5 Only		30		mVp-p
$\eta$	Efficiency	$I_{LOAD} = 50$ mA, $V_{IN} = 3$ V, CAT3200-5		80		%
$I_{GND}$	Ground Current	$I_{LOAD} = 0$ mA, $\overline{SHDN} = V_{IN}$		1.6	4	mA
$I_{SHDN}$	Shutdown Input Current	$I_{LOAD} = 0$ mA, $\overline{SHDN} = 0$ V			1	$\mu$ A
$V_{FB}$	FB Voltage	CAT3200 Only	1.22	1.27	1.32	V
$I_{FB}$	FB Input Current	CAT3200 Only	-50		50	nA
$R_{OL}$	Open-Loop Resistance	$I_{LOAD} = 100$ mA, $V_{IN} = 3$ V (Note 1)		10		$\Omega$
$T_{ON}$	$V_{OUT}$ Turn-on time (10% to 90%)	$I_{LOAD} = 0$ mA, $V_{IN} = 3$ V		0.5		ms
$V_{IHSHDN}$	High Detect Shutdown Threshold			0.8	1.3	V
$V_{ILSHDN}$	Low Detect Shutdown Threshold		0.4			V
$I_{ROUT}$	Reverse Leakage into OUT pin	$V_{OUT} = 5$ V, Shutdown mode (Note 2)		15	30	$\mu$ A
$I_{SC}$	Short-circuit Output	$V_{OUT} = 0$ V		80		mA
$T_{SD}$	Thermal Shutdown			160		$^{\circ}$ C
$T_{HYST}$	Thermal Hysteresis			20		$^{\circ}$ C

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

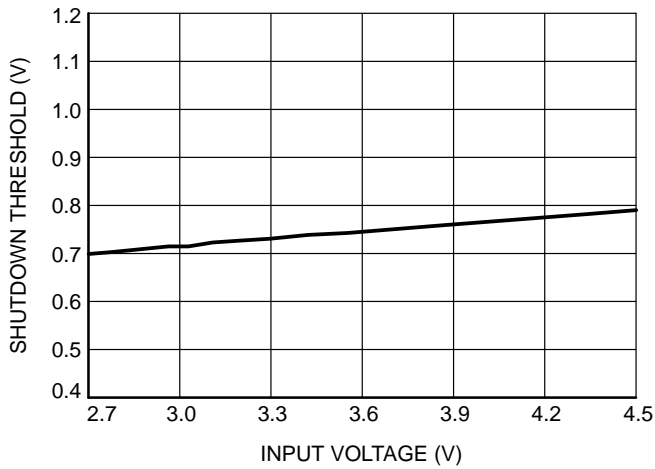
1.  $R_{OL} = (2V_{IN} - V_{OUT})/I_{OUT}$

2. In the event of a controlled shutdown, the output will be isolated from the input, but will remain connected to the internal resistor feedback network. This will cause a small level of reverse current to flow back into the device to ground.

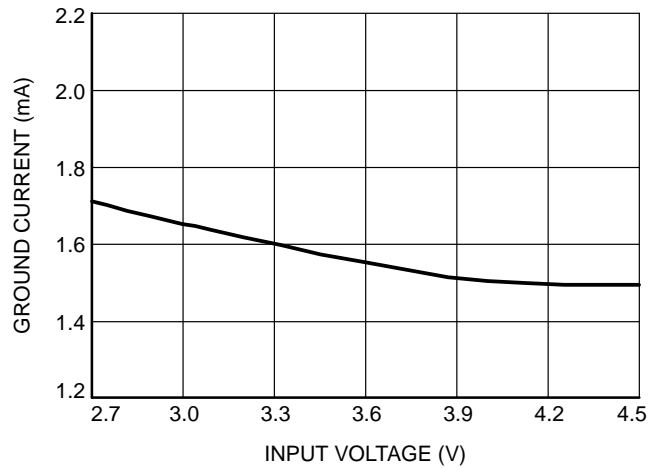
# CAT3200, CAT3200-5

## TYPICAL PERFORMANCE CHARACTERISTICS (CAT3200-5)

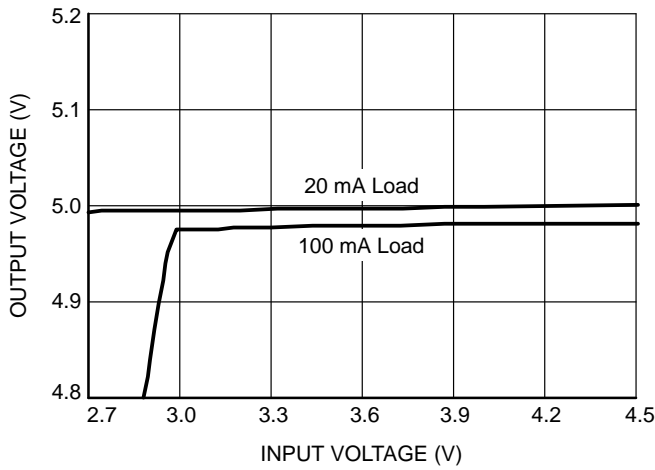
( $T_{AMB} = 25^{\circ}\text{C}$ ,  $C_{IN} = C_{OUT} = C_{FLY} = 1 \mu\text{F}$ ,  $V_{IN} = 3.3 \text{ V}$  unless specified otherwise.)



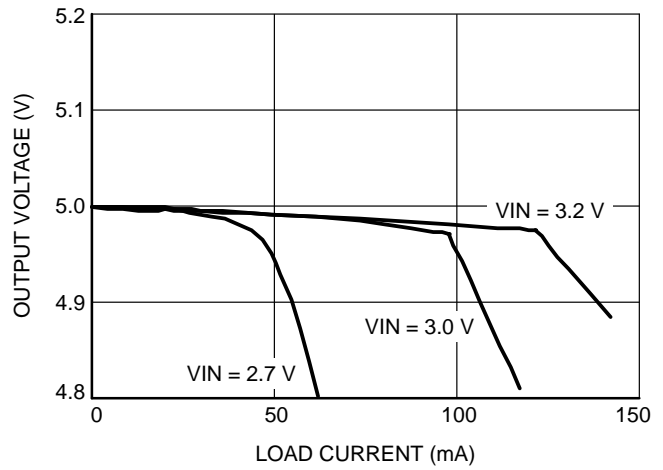
**Figure 3. Shutdown Input Threshold vs. Supply Voltage**



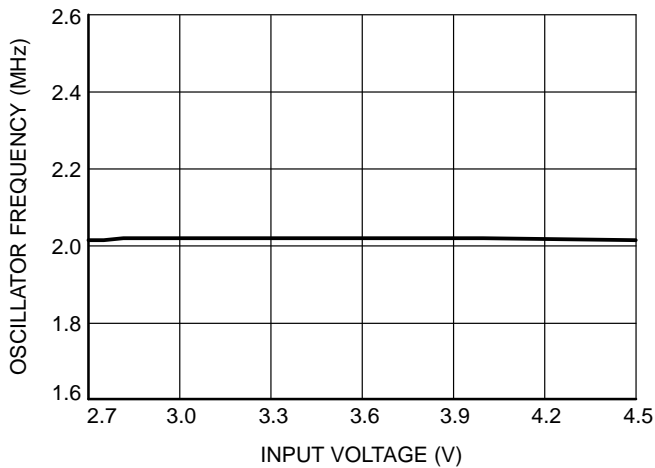
**Figure 4. Ground Current vs. Supply Voltage (No Load)**



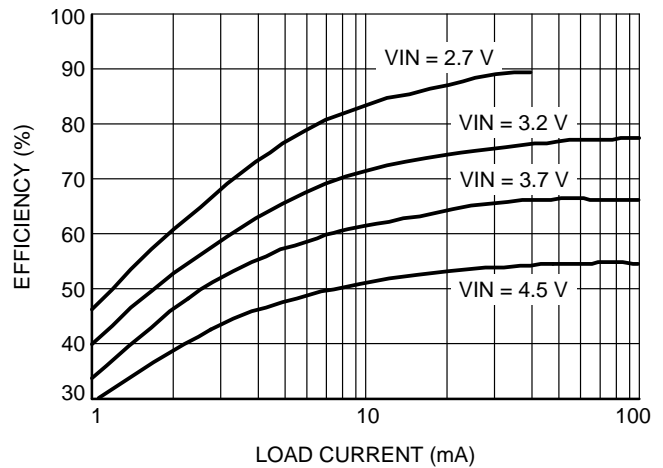
**Figure 5. Line Regulation**



**Figure 6. Load Regulation**



**Figure 7. Oscillator Frequency vs. Supply Voltage**

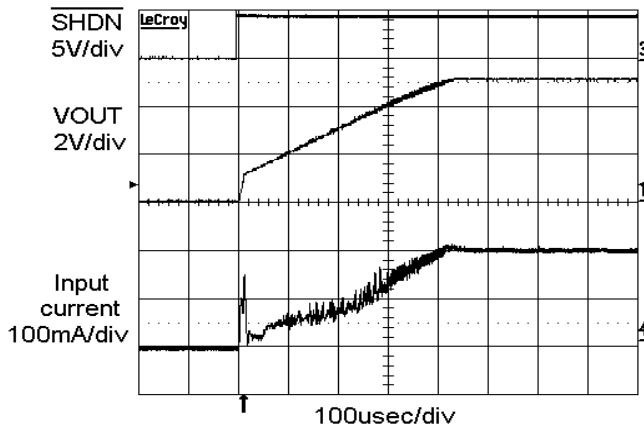


**Figure 8. Efficiency vs. Load Current**

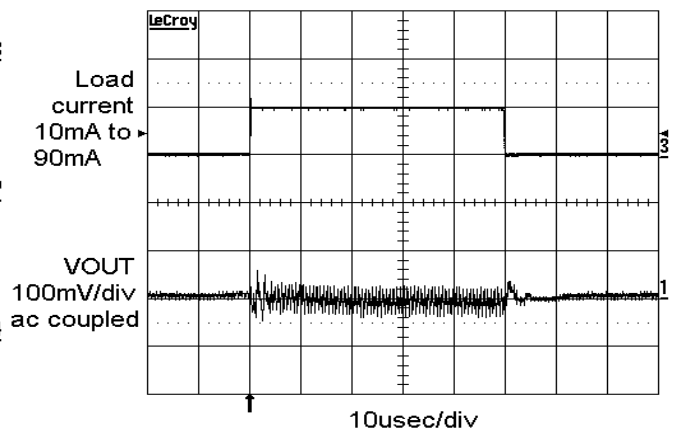
# CAT3200, CAT3200-5

## TYPICAL PERFORMANCE CHARACTERISTICS (CAT3200-5)

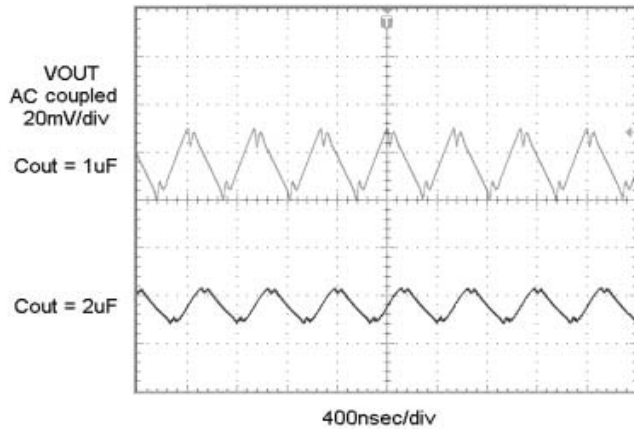
( $T_{AMB} = 25^{\circ}\text{C}$ ,  $C_{IN} = C_{OUT} = C_{FLY} = 1 \mu\text{F}$ ,  $V_{IN} = 3.3 \text{ V}$  unless specified otherwise.)



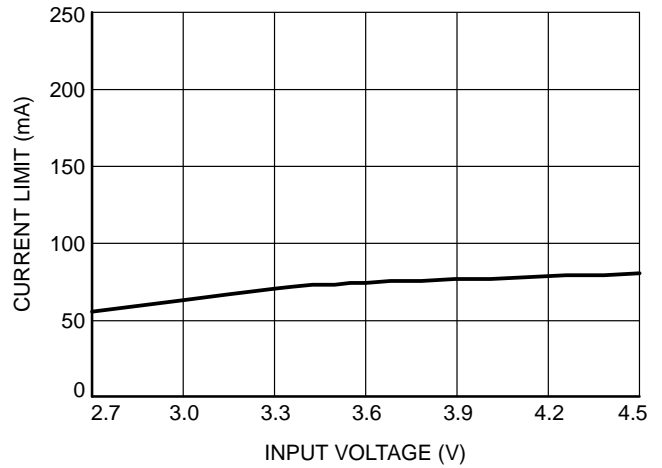
**Figure 9. Soft Start Power Up (90 mA Load, 3.3 V Input)**



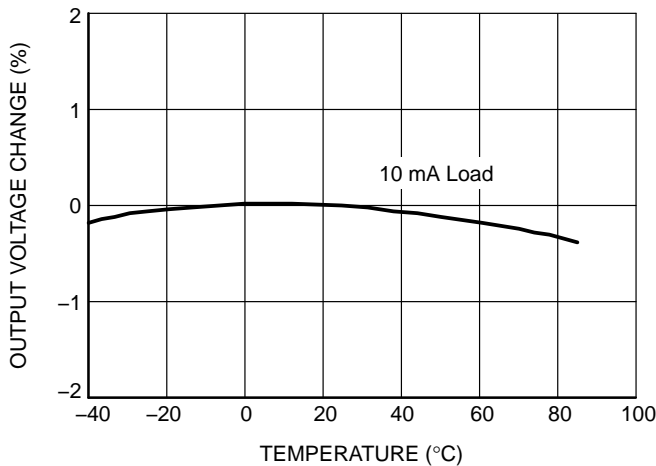
**Figure 10. Load Step Response (3.3 V Input)**



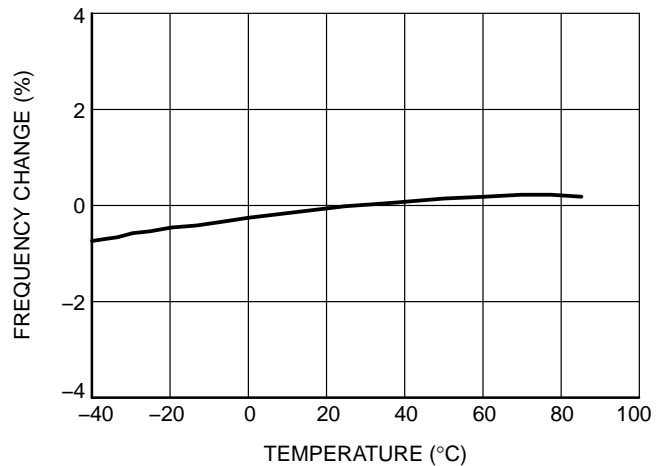
**Figure 11. Output Ripple (100 mA Load, 3.3 V Input)**



**Figure 12. Short Circuit Current vs. Supply Voltage**



**Figure 13. Output Voltage Change vs. Temperature**



**Figure 14. Oscillator Frequency Change vs. Temperature**

## CAT3200, CAT3200-5

### Block Diagram

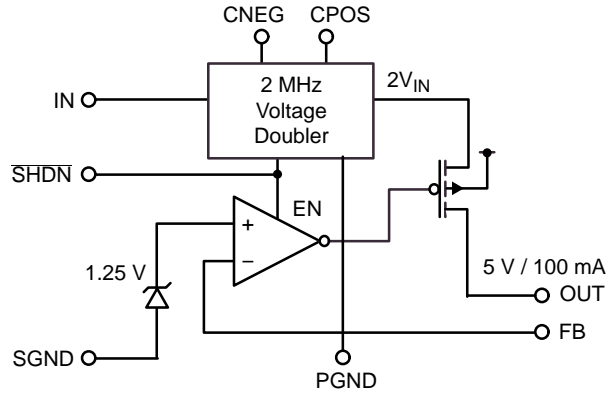


Figure 15. CAT3200 Adjustable Output

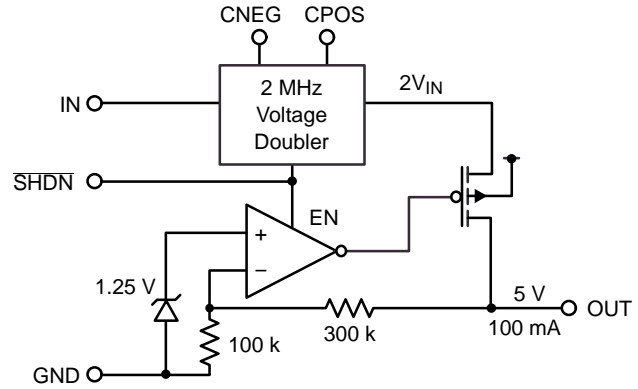


Figure 16. CAT3200-5 5 V Fixed Output

### Pin Functions

**IN** is the power supply. During normal operation the device draws a supply current which is almost constant. A very brief interval of non-conduction will occur at the switching frequency. The duration of the non-conduction interval is set by the internal non-overlapping “break-before-make” timing. IN should be bypassed with a 1  $\mu\text{F}$  to 4.7  $\mu\text{F}$  low ESR (Equivalent Series Resistance) ceramic capacitor.

For filtering, a low ESR ceramic bypass capacitor (1  $\mu\text{F}$ ) in close proximity to the IN pin prevents noise from being injected back into the power supply.

**SHDN** is the logic control input (Active LOW) that places the device into shutdown mode. The internal logic is CMOS and the pin does not use an internal pull-down resistor. The **SHDN** pin should not be allowed to float.

**CPOS**, **CNEG** are the positive and negative connections respectively for the charge pump flying capacitor. A low ESR ceramic capacitor (1  $\mu\text{F}$ ) should be connected between these pins. During initial power-up it may be possible for the capacitor to experience a voltage reversal and for this reason, avoid using a polarized (tantalum or aluminum) flying capacitor.

**OUT** is the regulated output voltage to power the load. During normal operation, the device will deliver a train of current pulses to the pin at a frequency of 2 MHz. Adequate filtering on the pin can typically be achieved through the use

a low ESR ceramic bypass capacitor (1  $\mu\text{F}$  to 4.7  $\mu\text{F}$ ) in close proximity to the OUT pin. The ESR of the output capacitor will directly influence the output ripple voltage.

When the shutdown mode is entered, the output is immediately isolated from the input supply, however, the output will remain connected to the internal feedback resistor network (400 k $\Omega$ ). The feedback network will result in a reverse current of 10  $\mu\text{A}$  to 20  $\mu\text{A}$  to flow back through the device to ground.

Whenever the device is taken out of shutdown mode, the output voltage will experience a slew rate controlled power-up. Full operating voltage is typically achieved in less than 0.5 msec.

**GND** is the ground reference for all voltages on CAT3200-5 devices.

**FB** (CAT3200 Only) is the feedback input pin. An output divider should be connected from OUT to FB to program the output voltage.

**PGND** (CAT3200 Only). Is the same as GND for the CAT3200-5 except for the internal reference connection to SGND.

**SGND** (CAT3200 Only) Ground pin for the internal reference. The CNEG connection is switched to this pin during the normal charge pump operation.

## CAT3200, CAT3200-5

### Device Operation

The CAT3200/CAT3200-5 use a switched capacitor charge pump to boost the voltage at IN to a regulated output voltage. Regulation is achieved by sensing the output voltage through an internal resistor divider (CAT3200-5) and modulating the charge pump output current based on the error signal. A 2-phase non-overlapping clock activates the charge pump switches. The flying capacitor is charged from the IN voltage on the first phase of the clock. On the second phase of the clock it is stacked in series with the input voltage and connected to OUT. The charging and discharging of the flying capacitor continues at a free running frequency of typically 2 MHz.

In shutdown mode all circuitry is turned off and the CAT3200/CAT3200-5 draw only leakage current from the  $V_{IN}$  supply. OUT is disconnected from IN. The  $\overline{SHDN}$  pin is a CMOS input with a threshold voltage of approximately 0.8 V. The CAT3200/CAT3200-5 is in shutdown when a logic LOW is applied to the  $\overline{SHDN}$  pin. The  $\overline{SHDN}$  pin is a high impedance CMOS input.  $\overline{SHDN}$  does not have an internal pull-down resistor and should not be allowed to float and. It must always be driven with a valid logic level.

### Short-Circuit and Thermal Protection

The CAT3200 and CAT3200-5 have built-in short-circuit current limiting and over temperature protection. During overload conditions, output current is limited to approximately 225 mA. At higher temperatures, or if the input voltage is high enough to cause excessive chip self heating, the thermal shutdown circuit shuts down the charge pump as the junction temperature exceeds approximately 160°C. Once the junction temperature drops back to approximately 140°C, the charge pump is enabled.

The CAT3200 and CAT3200-5 will cycle in and out of thermal shutdown indefinitely without latch-up or damage until a short-circuit on OUT is removed.

### Programming the CAT3200 Output Voltage (FB Pin)

The CAT3200-5 version has an internal resistive divider to program the output voltage. The programmable CAT3200 may be set to an arbitrary voltage via an external resistive divider. Since it employs a voltage doubling charge pump, it is not possible to achieve output voltages greater than twice the available input voltage. Figure 17 shows the required voltage divider connection. The voltage divider ratio is given by the formula:

$$\frac{R1}{R2} = \frac{V_{OUT}}{1.27 V} - 1$$

Typical values for total voltage divider resistance can range from several kΩs up to 1 MΩ.

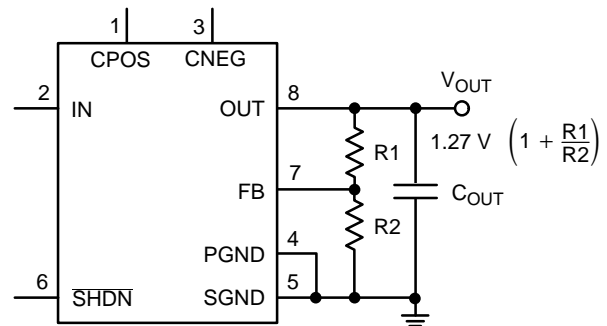


Figure 17. Programming the Adjustable CAT3200



## Application Information

### Ceramic Capacitors

Ceramic capacitors of different dielectric materials lose their capacitance with higher temperature and voltage at different rates. For example, a capacitor made of X5R or X7R material will retain most of its capacitance from -40°C to 85°C whereas a Z5U or Y5V style capacitor will lose considerable capacitance over that range.

Z5U and Y5V capacitors may also have voltage coefficient causing them to lose 60% or more of their capacitance when the rated voltage is applied. When comparing different capacitors it is often useful consider the amount of achievable capacitance for a given case size rather than discussing the specified capacitance value. For example, over rated voltage and temperature conditions, a 1 µF, 10 V, Y5V ceramic capacitor in an 0603 case may not provide any more capacitance than a 0.22 µF, 10 V, X7R available in the same 0603 case. For many CAT3200/CAT3200-5 applications these capacitors can be considered roughly equivalent.

The capacitor manufacturer's data sheet should be consulted to determine what value of capacitor is needed to ensure the desired capacitance at all temperatures and voltages. Below is a list of ceramic capacitor manufacturers and how to contact them:

**Table 5. CERAMIC CAPACITOR MANUFACTURERS**

Capacitor Manufacturer	Web	Phone
Murata	www.murata.com	814.237.1431
AVX/Kemet	www.avxcorp.com	843.448.9411
Vishay	www.vishay.com	
Kemet	www.kemet.com	408.986.0424
Taiyo Yuden	www.t-yuden.com	408.573.4150

### Thermal Management

For higher input voltages and maximum output current there can be substantial power dissipation in the CAT3200/CAT3200-5. If the junction temperature increases to 160°C, the thermal shutdown circuitry will automatically turn off the output.

A good thermal connection to the PC board is recommended to reduce the chip temperature. Connecting the GND pin (Pins 4/5 for CAT3200, Pin 2 for CAT3200-5) to a ground plane, and maintaining a solid ground plane under the device reduces the overall thermal resistance.

The overall junction to ambient thermal resistance ( $\theta_{JA}$ ) for device power dissipation ( $P_D$ ) consists primarily of two paths in series. The first path is the junction to the case ( $\theta_{JC}$ ) which is defined by the package style, and the second path is case to ambient ( $\theta_{CA}$ ) thermal resistance which is dependent on board layout. The final operating junction temperature for any set of conditions can be estimated by the following thermal equation:

$$T_{JUNC} = T_{AMB} + P_D (\theta_{JC}) + P_D (\theta_{CA}) \\ = T_{AMB} + P_D (\theta_{JA})$$

The CAT3200 in SOT23 package, when mounted on printed circuit board with two square inches of copper allocated for "heat spreading", will result with an overall  $\theta_{JA}$  of less than 150°C/W.

For a typical application operating from a 3.8 V input supply, the maximum power dissipation is 260 mW (100 mA x 3 V). This would result if a maximum junction temperature of:

$$T_{JUNC} = T_{AMB} + P_D (\theta_{JA}) \\ = 85^\circ\text{C} + 0.26 \text{ W} (150^\circ\text{C/W}) \\ = 85^\circ\text{C} + 39^\circ\text{C} = 124^\circ\text{C}$$

The use of multi-layer board construction with power planes will further enhance the overall thermal performance. In the event of no dedicated copper area being used for heat spreading, a multi-layer board will typically provide the CAT3200 with an overall  $\theta_{JA}$  of 200°C/W. This level of thermal conduction would allow up to 200 mW be safely dissipated within the device.

# CAT3200, CAT3200-5

## Typical Applications

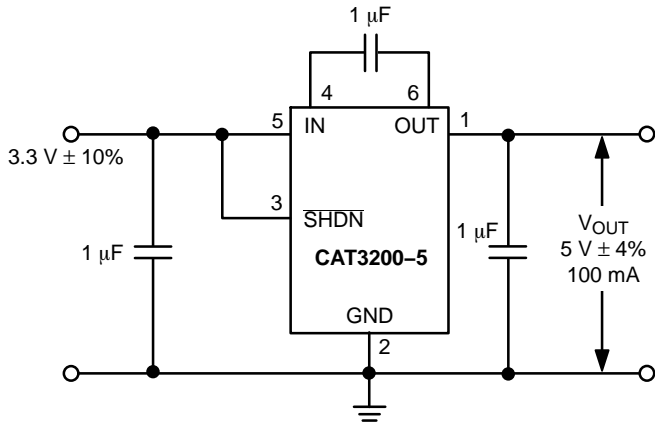


Figure 18. 3.3 V Supply to 5 V

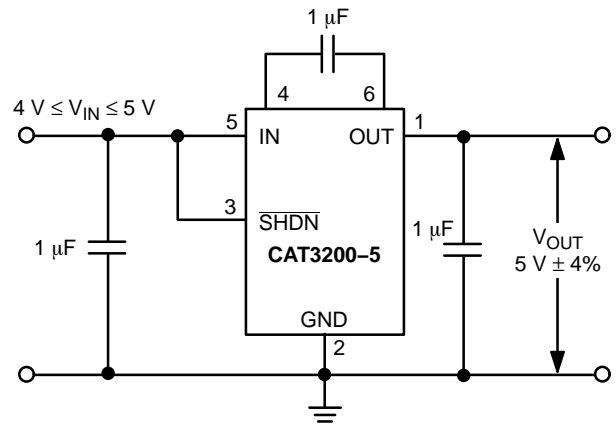


Figure 19. USB Port to Regulated 5 V Power Supply

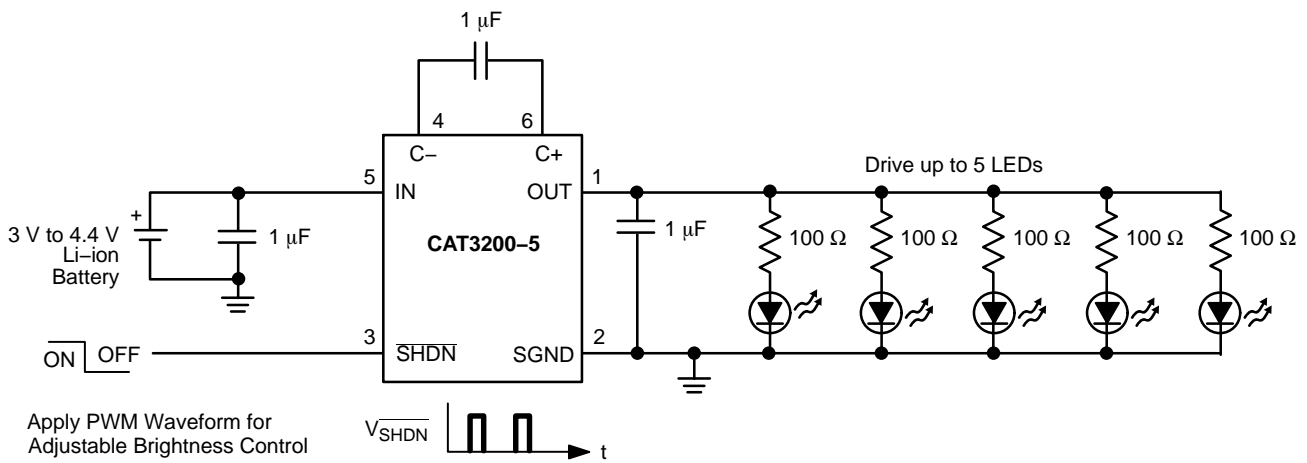


Figure 20. Lithium-Ion Battery to 5 V White or Blue LED Driver

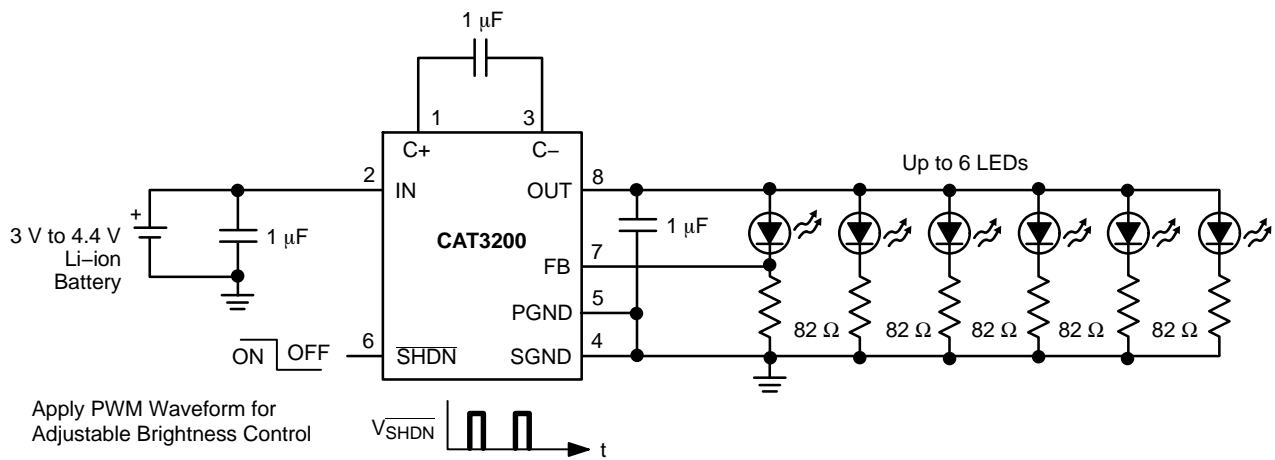


Figure 21. White or Blue LED Driver with LED Current Control

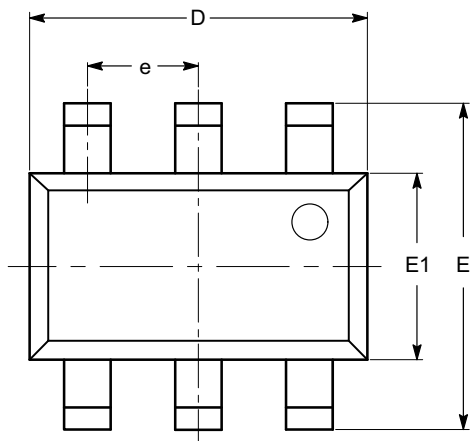
# MECHANICAL CASE OUTLINE

## PACKAGE DIMENSIONS



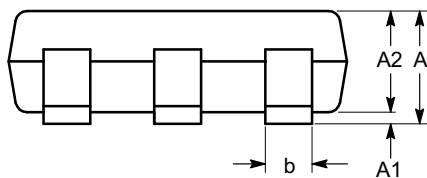
TSOT-23, 6 LEAD  
CASE 419AF-01  
ISSUE O

DATE 19 DEC 2008

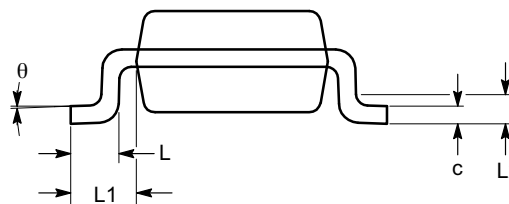


TOP VIEW

SYMBOL	MIN	NOM	MAX
A			1.00
A1	0.01	0.05	0.10
A2	0.80	0.87	0.90
b	0.30		0.45
c	0.12	0.15	0.20
D	2.90 BSC		
E	2.80 BSC		
E1	1.60 BSC		
e	0.95 TYP		
L	0.30	0.40	0.50
L1	0.60 REF		
L2	0.25 BSC		
$\theta$	0°		8°



SIDE VIEW



END VIEW

**Notes:**

- (1) All dimensions are in millimeters. Angles in degrees.
- (2) Complies with JEDEC MO-193.

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<b>DESCRIPTION:</b>	<b>TSOT-23, 6 LEAD</b>	<b>PAGE 1 OF 1</b>

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# MECHANICAL CASE OUTLINE

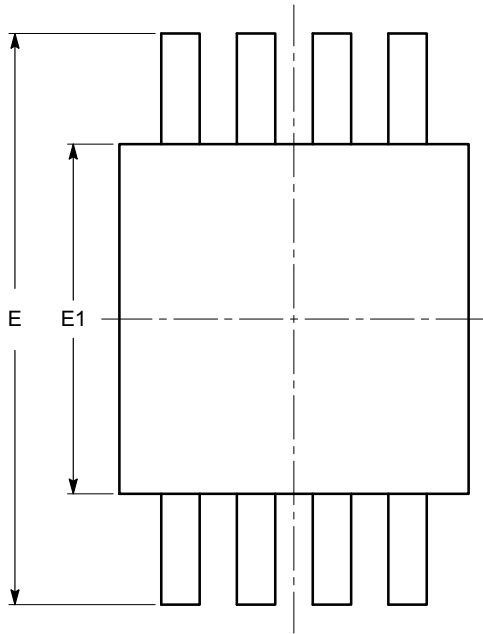
## PACKAGE DIMENSIONS

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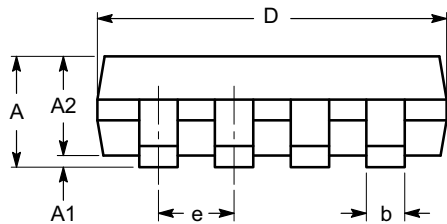
MSOP 8, 3x3  
CASE 846AD-01  
ISSUE O

DATE 19 DEC 2008

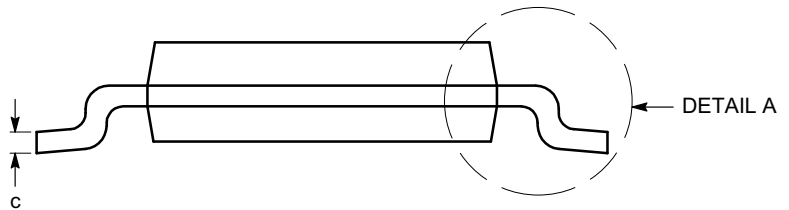


TOP VIEW

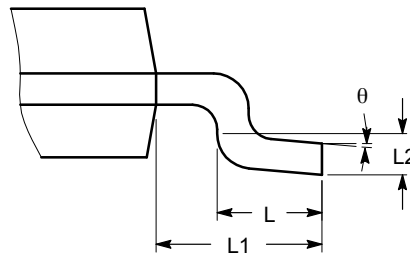
SYMBOL	MIN	NOM	MAX
A			1.10
A1	0.05	0.10	0.15
A2	0.75	0.85	0.95
b	0.22		0.38
c	0.13		0.23
D	2.90	3.00	3.10
E	4.80	4.90	5.00
E1	2.90	3.00	3.10
e	0.65 BSC		
L	0.40	0.60	0.80
L1	0.95 REF		
L2	0.25 BSC		
$\theta$	0°		6°



SIDE VIEW



END VIEW



DETAIL A

**Notes:**

- (1) All dimensions are in millimeters. Angles in degrees.
- (2) Complies with JEDEC MO-187.

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