

# Micropower 8-Bit Current Sink Output D/A Converter

## FEATURES

- **Precision Full-Scale DAC Output Current at 25°C: 50µA ±3%**
- Wide Output Voltage DC Compliance: 2V to 10V
- Wide Supply Range:  $3V \leq V_{CC} \leq 6.5V$
- Supply Current in Shutdown: 0.2µA
- Low Supply Current: 130µA
- Available in 8-Pin SO
- Triple Mode™ Interface
  1. Standard 3-Wire Mode
  2. 1-Wire Pulse Mode Interface: Increment-Only
  3. 2-Wire Pulse Mode Interface: Increment/Decrement
- DAC Value Read Back Capability in 3-Wire Mode
- DAC Powers Up at Midrange
- **DAC Contents Are Retained in Shutdown**

## APPLICATIONS

- LCD Contrast Control
- Backlight Brightness Control
- Power Supply Voltage Adjustment
- Battery Charger Voltage/Current Adjustment
- GaAs FET Bias Adjustment
- Trimmer Pot Elimination

## DESCRIPTION

The LTC<sup>®</sup>1428-50 is a micropower 8-bit current sink output D/A converter (DAC) with an output range of 0µA to 50µA. In 3.3V or 5V systems, the DAC I<sub>OUT</sub> pin can be biased from 2V to 10V. Supply current is only 130µA. Shutdown mode drops the supply current to 0.2µA.

The LTC1428-50 communicates with external circuitry by using one of three interface modes: standard 3-wire serial mode or one of two pulse modes. Upon power-up, the internal counter resets to 10000000B, the DAC output assumes midrange and the chip configures to 3-wire or pulse mode depending on the CS signal level.

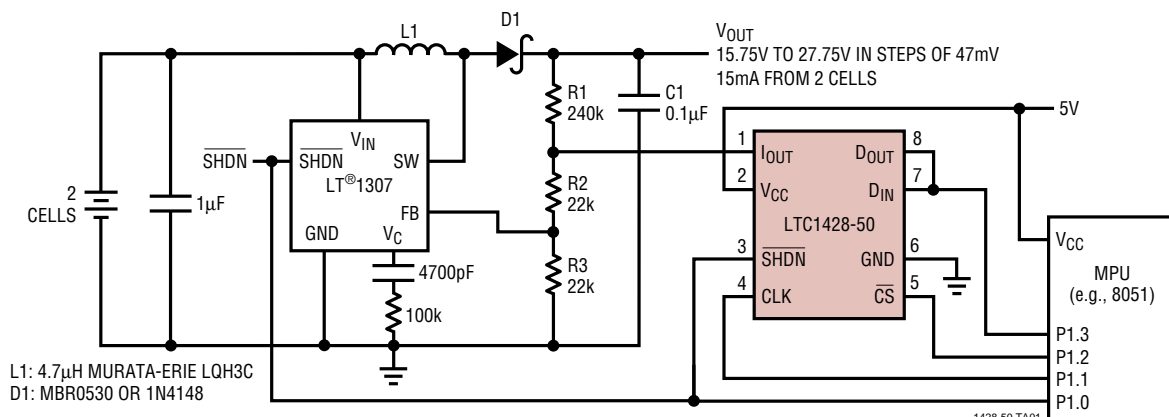
In 3-wire mode, the system MPU can serially transfer 8-bit data to and from the LTC1428-50. In pulse mode, the upper six bits of the DAC output program for increment-only (1-wire interface) or increment/decrement (2-wire interface) operation depending on the D<sub>IN</sub> signal level. In increment-only mode, the counter rolls over and sets the DAC to zero if the counter increases beyond full scale. In increment/decrement mode, the counter stops incrementing at full scale, stops decrementing at zero scale and does not roll over.

LTC1428-50 is available in an 8-pin SO package.

LT, LTC and LT are registered trademarks of Linear Technology Corporation. Triple Mode is a trademark of Linear Technology Corporation.

## TYPICAL APPLICATION

**Digitally Controlled LCD Bias Generator (Standard 3-Wire Mode)**



### ABSOLUTE MAXIMUM RATINGS

(Note 1)

Supply Voltage ( $V_{CC}$ ) .....	7V
Input Voltage (All Inputs) .....	-0.3V to ( $V_{CC} + 0.3V$ )
Output Voltage	
$I_{OUT}$ .....	-0.3V to 10V
$D_{OUT}$ .....	-0.3V to ( $V_{CC} + 0.3V$ )
Short-Circuit Duration (All Outputs) .....	Indefinite
Operating Temperature Range .....	0°C to 70°C
Storage Temperature Range .....	-65°C to 150°C
Lead Temperature (Soldering, 10 sec) .....	300°C

### PACKAGE/ORDER INFORMATION

	ORDER PART NUMBER
	LTC1428CS8-50
	S8 PART MARKING
	14285

Consult factory for Industrial and Military grade parts.

### ELECTRICAL CHARACTERISTICS $V_{CC} = 3.3V$ , $T_A = 25^\circ C$ , unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
$V_{CC}$			3.0		6.5	V
$I_{CC}$	Supply Current	$\overline{V_{SHDN}} = V_{DIN} = \overline{V_{CS}} = V_{CC}$ , $V_{CLK} = 0V$ , $D_{OUT} = NC$ , $I_{OUT} = NC$ Shutdown		130 0.2	225 10	$\mu A$ $\mu A$
	DAC Resolution			8		Bits
	DAC Full-Scale Current	$I_{OUT}$ Bias Voltage = 2.5V	48.5 47.5	50 50	51.5 52.5	$\mu A$ $\mu A$
	DAC Zero-Scale Current	$I_{OUT}$ Bias Voltage = 2.5V			200	nA
	DAC Differential Nonlinearity	Monotonicity Guaranteed, No Missing Codes			$\pm 0.9$	LSB
	Supply Voltage Rejection	$V_{CC} = 3V$ to 6.5V, Full Scale Current, $I_{OUT}$ Bias Voltage = 2.5V		$\pm 1$	$\pm 4$	LSB
	Output Voltage Rejection	$V_{CC} = 5V$ , Full Scale Current, $2V \leq V(I_{OUT}) \leq 3V$			$\pm 1$	LSB
		$V_{CC} = 5V$ , Full Scale Current, $3V \leq V(I_{OUT}) \leq 10V$		$\pm 1$	$\pm 4$	LSB
	Logic Input Current	$0V \leq V_{IN} \leq V_{CC}$			$\pm 1$	$\mu A$
$V_{IH}$	High Level Input Voltage	$V_{CC} = 5V$ $V_{CC} = 3.3V$	2.0 1.9			V V
$V_{IL}$	Low Level Input Voltage	$V_{CC} = 5V$ $V_{CC} = 3.3V$			0.80 0.45	V V
$V_{OH}$	High Level Output Voltage	$V_{CC} = 5V$ , $I_O = 400\mu A$ $V_{CC} = 3.3V$ , $I_O = 400\mu A$	2.4 2.1			V V
$V_{OL}$	Low Level Output Voltage	$V_{CC} = 5V$ , $I_O = 2mA$ $V_{CC} = 3.3V$ , $I_O = 1mA$			0.4 0.4	V V
$I_{OZ}$	Three-State Output Leakage	$\overline{V_{CS}} = V_{CC}$			$\pm 5$	$\mu A$

**RECOMMENDED OPERATING CONDITIONS**  $V_{CC} = 5V$ , unless otherwise specified. (Notes 2, 3)

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
<b>Serial Interface</b>						
$f_{CLK}$	Clock Frequency		●		2	MHz
$t_{CKS}$	Setup Time, CLK↓ Before $\overline{CS}$ ↓		●	150		ns
$t_{CSS}$	Setup Time, $\overline{CS}$ ↓ Before CLK↑		●	400		ns
$t_{DV}$	$\overline{CS}$ ↓ to $D_{OUT}$ Valid	See Test Circuits	●	150		ns
$t_{DS}$	$D_{IN}$ Setup Time Before CLK↑		●	150		ns
$t_{DH}$	$D_{IN}$ Hold Time After CLK↑		●	150		ns
$t_{DO}$	CLK↓ to $D_{OUT}$ Valid	See Test Circuits	●	150		ns
$t_{CKHI}$	CLK High Time		●	200		ns
$t_{CKLO}$	CLK Low Time		●	250		ns
$t_{CSH}$	CLK↓ Before $\overline{CS}$ ↑		●	150		ns
$t_{DZ}$	$\overline{CS}$ ↑ to $D_{OUT}$ in Hi-Z	See Test Circuits	●		400	ns
$t_{CKH}$	$\overline{CS}$ ↑ Before CLK↑		●		400	ns
$t_{CSLO}$	$\overline{CS}$ Low Time	$f_{CLK} = 2MHz$ (Note 4) $V_{CLK} = 0V$	●	4550 400		ns ns
$t_{CSHI}$	$\overline{CS}$ High Time		●	400		ns

The ● denotes specifications which apply over the full operating temperature range.

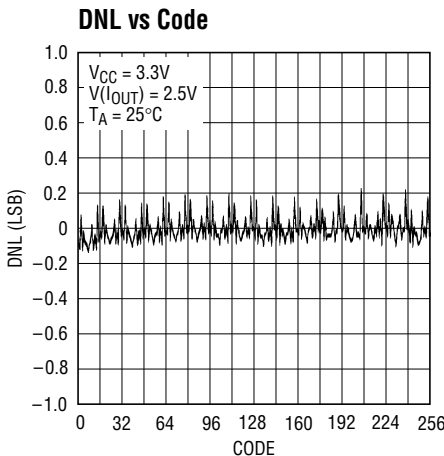
**Note 1:** Absolute Maximum Ratings are those values beyond which the life of the device may be impaired.

**Note 2:** Timing for all input signals is measured at 0.8V for a High-to-Low transition and at 2V for a Low-to-High transition.

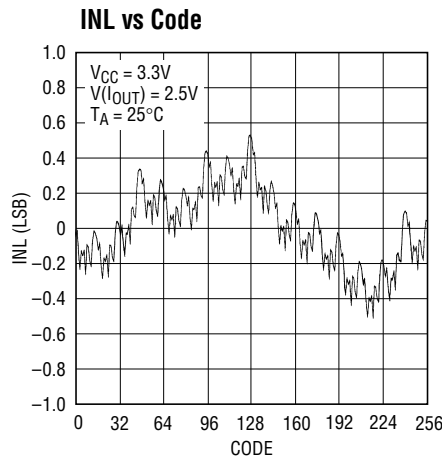
**Note 3:** Timing specifications are guaranteed by design but not tested.

**Note 4:** This is the minimum time required for valid data transfer.

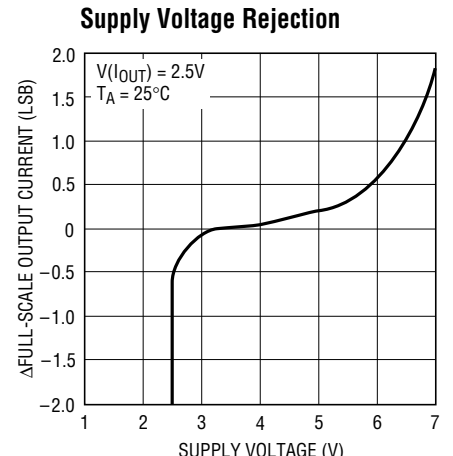
**TYPICAL PERFORMANCE CHARACTERISTICS**



1428-50 G01



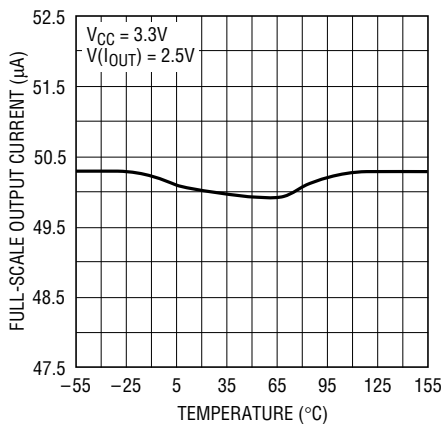
1428-50 G02



1428-50 G03

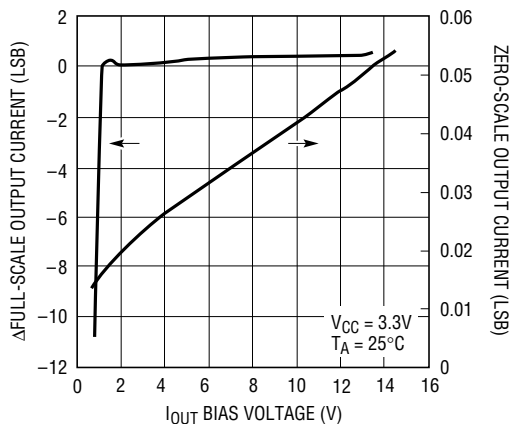
## TYPICAL PERFORMANCE CHARACTERISTICS

### Temperature Variation



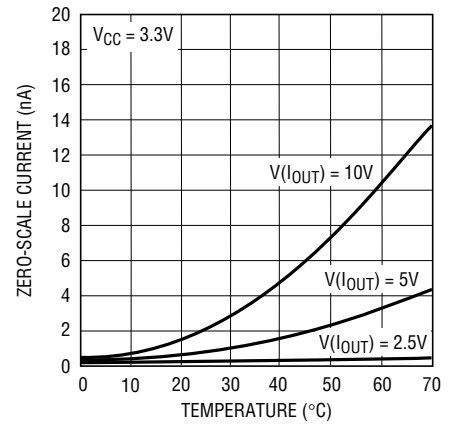
1428-50 G04

### Bias Voltage Rejection



1428-50 G05

### Zero-Scale I<sub>OUT</sub> vs Temperature



1428-50 G06

## PIN FUNCTIONS

**I<sub>OUT</sub> (Pin 1):** DAC Current Sink Output. In 3.3V or 5V systems, the DAC I<sub>OUT</sub> pin can be biased from 2V to 10V.

**V<sub>CC</sub> (Pin 2):** Voltage Supply (3V ≤ V<sub>CC</sub> ≤ 6.5V). This supply must be kept free from noise and ripple by bypassing directly to a ground plane.

**SHDN (Pin 3):** Shutdown. A logic low puts the chip into shutdown mode. The digital setting for the DAC is retained.

**CLK (Pin 4):** Shift Clock. This clock synchronizes the serial data and has a Schmitt trigger input.

**CS (Pin 5):** Chip Select Input. In 3-wire mode, a logic low enables the LTC1428-50. Upon power-up, a logic high

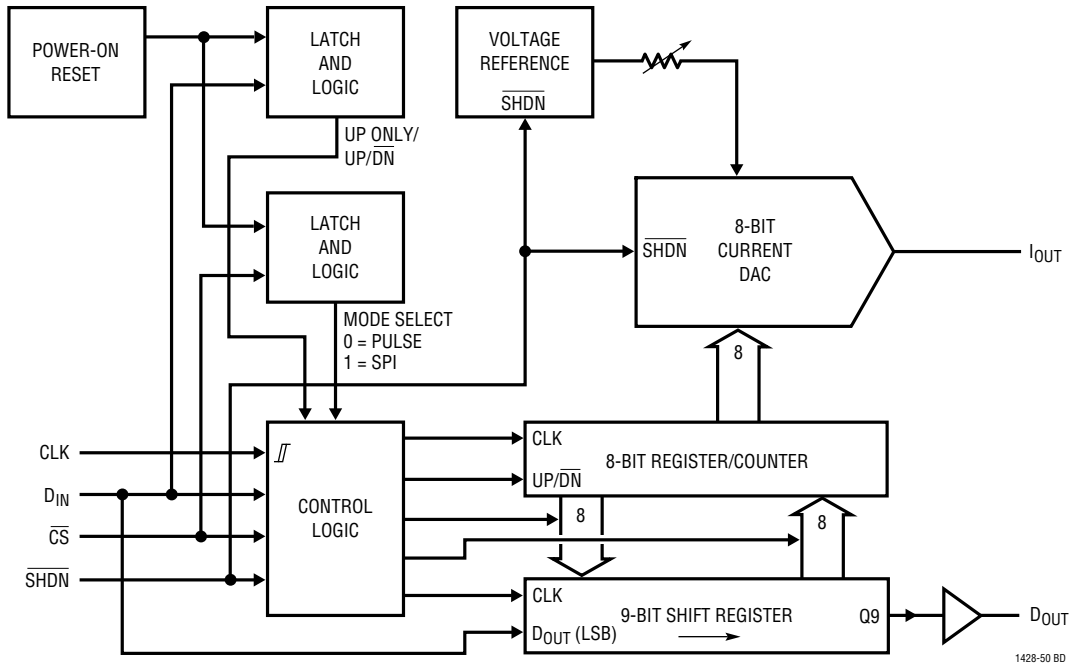
puts the chip into pulse mode. If  $\overline{CS}$  ever goes low, the chip is configured into 3-wire mode until V<sub>CC</sub> is reset.

**GND (Pin 6):** Ground. Ground should be tied directly to a ground plane.

**D<sub>IN</sub> (UP/DN)(Pin 7):** Data Input. In 3-wire mode, the DAC data is shifted into D<sub>IN</sub>. In pulse mode, upon power-up a logic high puts the counter into increment-only mode. If D<sub>IN</sub> ever goes low, the counter is configured in increment/decrement mode until V<sub>CC</sub> is reset.

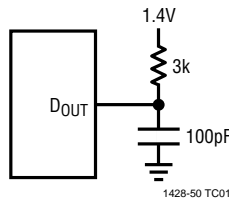
**D<sub>OUT</sub> (Pin 8):** Data Output. In 3-wire mode, on every conversion D<sub>OUT</sub> serially outputs the previous 8-bit DAC data. In pulse mode, D<sub>OUT</sub> is three-stated.

# BLOCK DIAGRAM

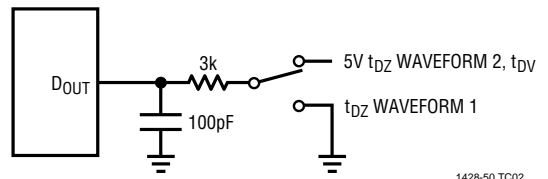


# TEST CIRCUITS

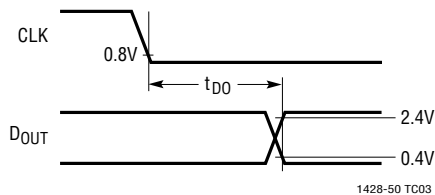
Load Circuit for  $t_{D0}$



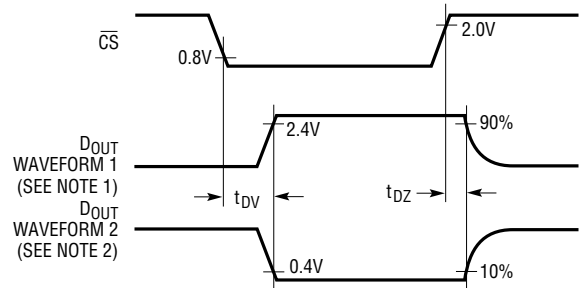
Load Circuit for  $t_{DZ}$ ,  $t_{DV}$



Voltage Waveforms for  $t_{D0}$



Voltage Waveforms for  $t_{DZ}$ ,  $t_{DV}$



NOTE 1: WAVEFORM 1 IS FOR AN OUTPUT WITH INTERNAL CONDITIONS SUCH THAT THE OUTPUT IS HIGH UNLESS DISABLED BY CS

NOTE 2: WAVEFORM 2 IS FOR AN OUTPUT WITH INTERNAL CONDITIONS SUCH THAT THE OUTPUT IS LOW UNLESS DISABLED BY CS

## SERIAL I/O OPERATING SEQUENCE

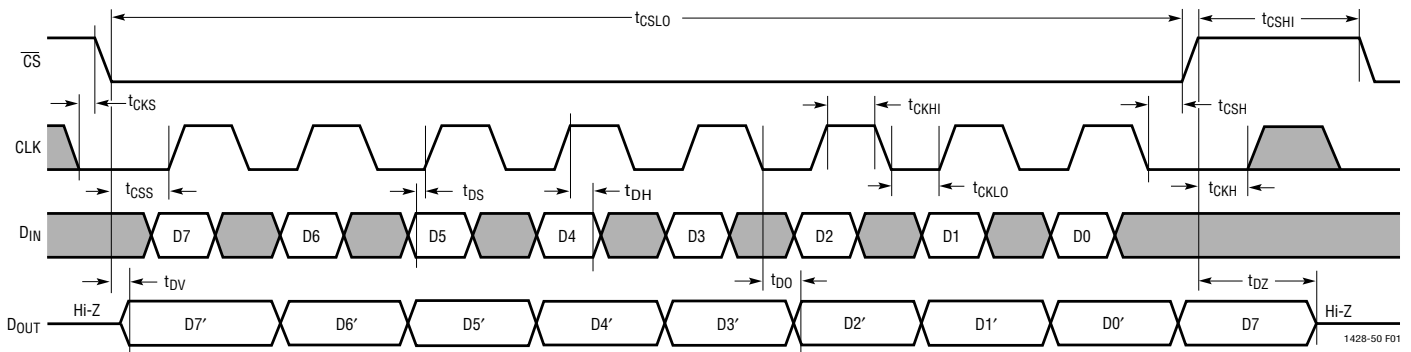


Figure 1. 3-Wire Interface Timing Specification

## APPLICATIONS INFORMATION

### 8-BIT CURRENT OUTPUT DAC

The LTC1428-50 is an 8-bit, current sink output digital-to-analog (DAC) converter. The LTC1428-50 is guaranteed monotonic and is digitally adjustable in 256 equal steps. Upon power up, the counter resets to 1000000B and the DAC output assumes midrange. The I<sub>OUT</sub> pin can be biased from 2V to 10V. The LTC1428-50 features a full-scale output current of 50µA ±3% at room temperature (±5% over temperature). This device also includes a flexible serial digital interface that allows easy interconnection to a variety of digital systems.

### DIGITAL INTERFACE

#### Automatic Mode Selection

The LTC1428-50 includes a serial interface capable of communicating with the host system using one of three protocols; standard 3-wire mode, a 2-wire up/down pulse mode and a 1-wire increment-only pulse mode. The LTC1428-50 is designed to autoconfigure itself depending on the method

of data presentation. A diagram illustrating this autodetection behavior is shown in Figure 2. At power-up, the interface is set to 1-wire pulse mode. If the  $\overline{CS}$  line ever goes low (as it will at the beginning of a valid 3-wire serial transfer) the chip immediately reconfigures itself into 3-wire mode and remains in this mode until power is cycled. If  $\overline{CS}$  stays high, the device stays in pulse mode and monitors the UP/DN pin to determine whether to switch to 2-wire mode. If UP/DN ever goes low (as it will the first time a “down” command is given) the chip switches into 2-wire pulse mode and remains in this mode until power is cycled. In a properly configured 1-wire system,  $\overline{CS}$  and UP/DN will always remain high. 2-wire pulse mode systems must provide a single logic low pulse before the first data pulses are sent to prevent the LTC1428-50 from remaining in 1-wire mode if the first several pulses are logic high.

#### Standard 3-Wire Mode (Figure 3)

Refer to the Serial Interface Operating Sequence in Figure 1. When operating in 3-wire mode, the LTC1428-50 will interface directly with most standard 3- or 4-wire serial interface systems. The clock (CLK) input synchronizes the data transfer with each input bit captured at the rising edge of CLK and each output data bit shifted through D<sub>OUT</sub> at the falling edge. Data is shifted into and out of the LTC1428-50 starting with the MSB bit. A falling edge at  $\overline{CS}$  initiates the data transfer and brings the D<sub>OUT</sub> pin out of three-state. The serial 8-bit data representing the new DAC setting is shifted into the D<sub>IN</sub> pin. Simultaneously, the previous DAC setting is shifted out of the D<sub>OUT</sub> pin. After the new data is

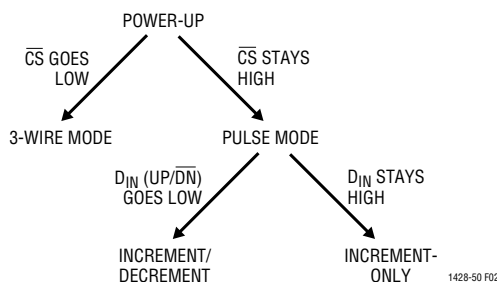
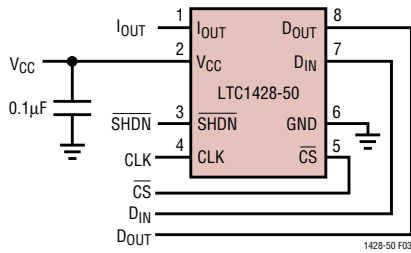


Figure 2. LTC1428-50 Operating Modes

## APPLICATIONS INFORMATION

shifted in, a rising edge at  $\overline{CS}$  transfers the data from the input shift register into the DAC register. The DAC output assumes the new value and the  $D_{OUT}$  pin returns to a high-impedance state.

$$I_{OUT} = (B7\ B6\ B5\ B4\ B3\ B2\ B1\ B0)I_{FULLSCALE}/255$$

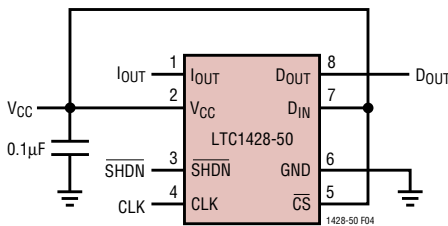


$D_{IN}$  AND  $D_{OUT}$  CAN BE TIED TOGETHER FOR HALF-DUPLEX DATA TRANSFER

**Figure 3. 3-Wire Mode; Serial Interface (3-Wire Control by  $\overline{CS}$ , CLK and  $D_{IN}$ )**

### 1-Wire Interface (Pulse Mode, Figure 4)

In 1-wire pulse mode, each rising edge at CLK increments the upper six bits of the DAC register by one count. When incremented beyond 11111100B, the counter rolls over and sets the DAC to the minimum value (00000000B). In this way, a single pulse applied to CLK increases the DAC output by a single 4LSB step and 63 pulses decrease the



**Figure 4. Pulse Mode: Increment Only (1-Wire Control by CLK)**

DAC output by one step. The last two LSBs are always zero in pulse mode.

$$I_{OUT} = (B7\ B6\ B5\ B4\ B3\ B2\ 0\ 0)I_{FULLSCALE}/255$$

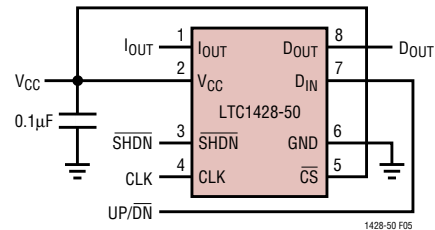
To configure the LTC1428-50 in 1-wire pulse mode, tie both the  $\overline{CS}$  and  $D_{IN}$  pins to  $V_{CC}$ .

### 2-Wire Interface (Pulse Mode, Figure 5)

In 2-wire pulse mode, a logic high at  $UP/\overline{DN}$  programs the DAC register to increment and each rising edge at CLK increments the upper six bits of the register by one count. Similarly, a logic low at  $UP/\overline{DN}$  programs the DAC register to decrement and a rising edge at CLK decrements the upper six bits of the register by one count. Each count in 2-wire mode changes the DAC output by a single 4LSB step. The DAC register stops incrementing at 1111100B and stops decrementing at 0000000B and will not roll over in 2-wire pulse mode. The last two LSBs are always zero in pulse mode.

$$I_{OUT} = (B7\ B6\ B5\ B4\ B3\ B2\ 0\ 0)I_{FULLSCALE}/255$$

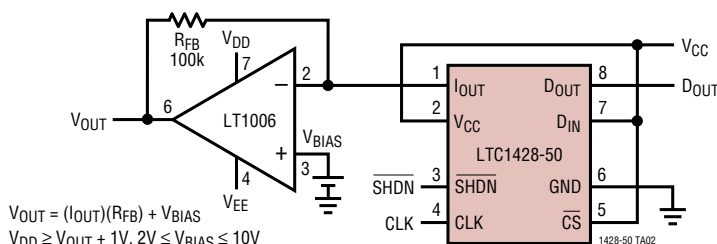
To configure the LTC1428-50 in 2-wire pulse mode, tie  $\overline{CS}$  to  $V_{CC}$  and bring the  $UP/\overline{DN}$  pin low at least once during power-up.



**Figure 5. Pulse Mode; Increment/Decrement (2-Wire Control by CLK and  $UP/\overline{DN}$ )**

## TYPICAL APPLICATION

### Pulse Mode: Increment-Only (1-Wire Control by CLK) with Voltage Output

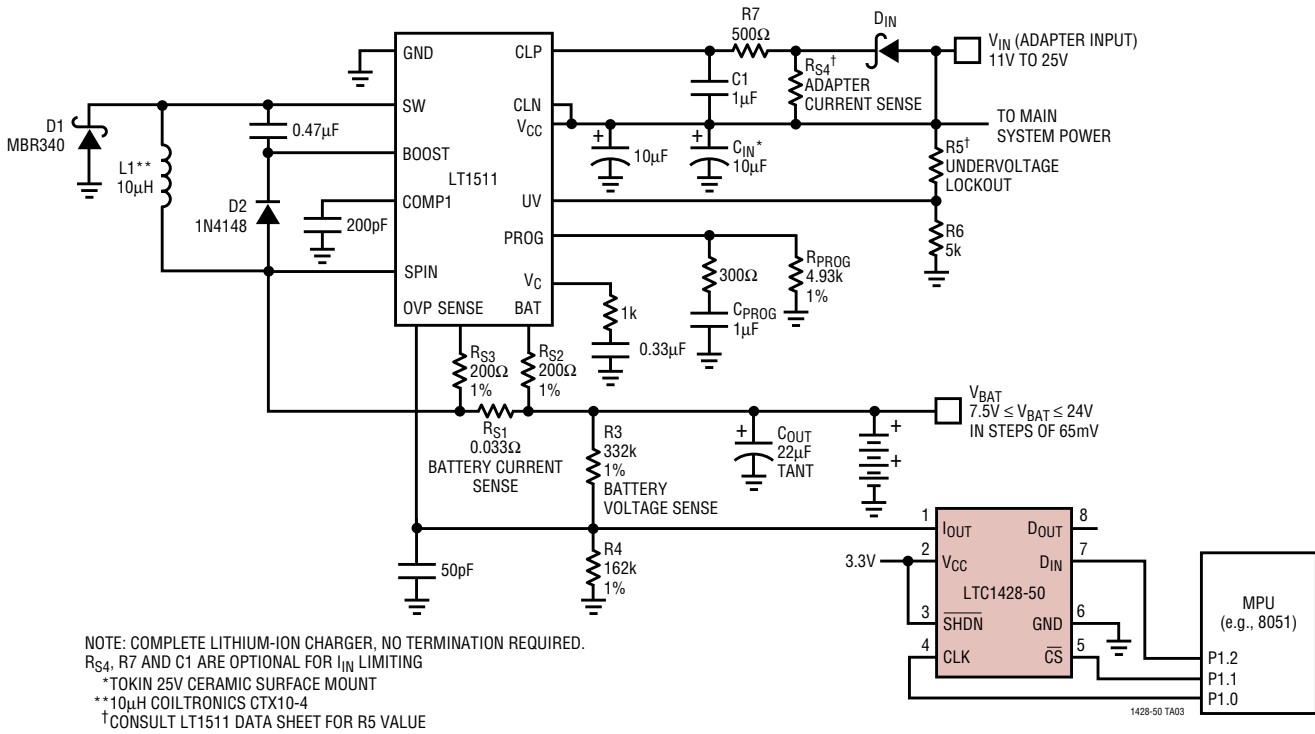


$$V_{OUT} = (I_{OUT})(R_{FB}) + V_{BIAS}$$

$$V_{DD} \geq V_{OUT} + 1V, 2V \leq V_{BIAS} \leq 10V$$

**TYPICAL APPLICATION**

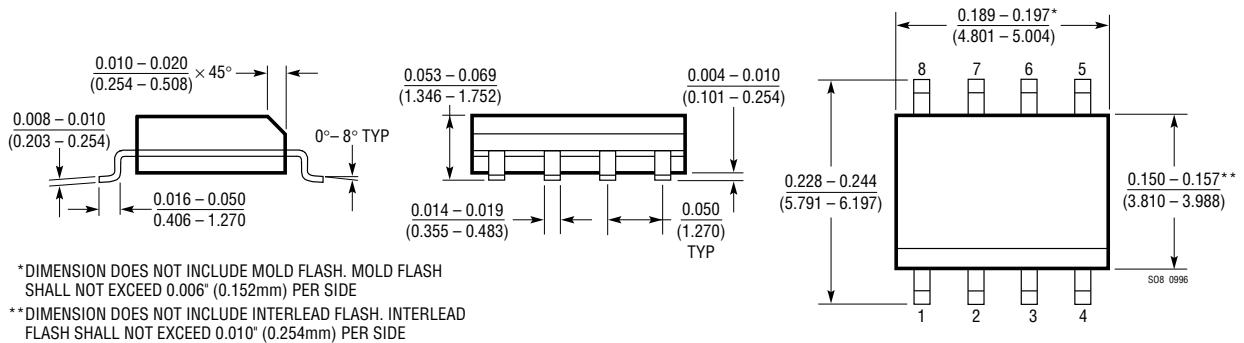
**Digitally Adjustable 3A Lithium-Ion Battery Charger**



**PACKAGE DESCRIPTION**

Dimensions in inches (millimeters) unless otherwise noted.

**S8 Package**  
**8-Lead Plastic Small Outline (Narrow 0.150)**  
 (LTC DWG # 05-08-1610)



**RELATED PARTS**

PART NUMBER	DESCRIPTION	COMMENTS
LTC1329	8-Bit Current Output D/A Converter	Current Source Output, Full-Scale Current 10µA or 50µA
LTC1451	12-Bit Micropower Serial Input V <sub>OUT</sub> DAC	Higher Resolution, 8-Pin SO
LTC1452	12-Bit Multiplying Serial Input V <sub>OUT</sub> DAC	Higher Resolution, 8-Pin SO
LTC8043	12-Bit Multiplying Serial Input I <sub>OUT</sub> DAC	Higher Resolution, 8-Pin SO