

16-Bit Rail-to-Rail Micropower DACs in SO-8 Package

FEATURES

- **16-Bit Monotonicity Over Temperature**
- **Deglitched Rail-to-Rail Voltage Output**
- **SO-8 Package**
- $I_{CC(TYP)}$: 600 μ A
- Internal Reference: 2.048V (LTC1655)
1.25V (LTC1655L)
- Maximum DNL Error: ± 1 LSB
- Settling Time: 20 μ s to ± 1 LSB
- 750kHz Max Update Rate
- Power-On Reset to Zero Volts
- 3-Wire Cascadable Serial Interface
- Low Cost
- Pin Compatible Upgrade for LTC1451 12-Bit DAC Family

APPLICATIONS

- Digital Calibration
- Industrial Process Control
- Automatic Test Equipment
- Cellular Telephones

DESCRIPTION

The LTC[®]1655/LTC1655L are rail-to-rail voltage output, 16-bit digital-to-analog converters in an SO-8 package. They include an output buffer and a reference. The 3-wire serial interface is compatible with SPI/QSPI and MICROWIRE[™] protocols. The CLK input has a Schmitt trigger that allows direct optocoupler interface.

The LTC1655 has an onboard 2.048V reference that can be overdriven to a higher voltage. The output swings from 0V to 4.096V when using the internal reference. The typical power dissipation is 3.0mW on a single 5V supply.

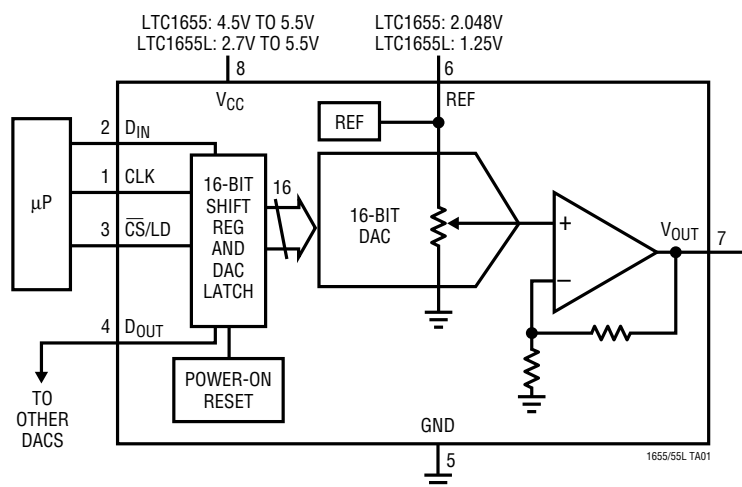
The LTC1655L has an onboard 1.25V reference that can be overdriven to a higher voltage. The output swings from 0V to 2.5V when using the internal reference. The typical power dissipation is 1.8mW on a single 3V supply.

The LTC1655/LTC1655L are pin compatible with Linear Technology's 12-bit V_{OUT} DAC family, allowing an easy upgrade path. They are the only buffered 16-bit DACs in an SO-8 package and they include an onboard reference for standalone performance.

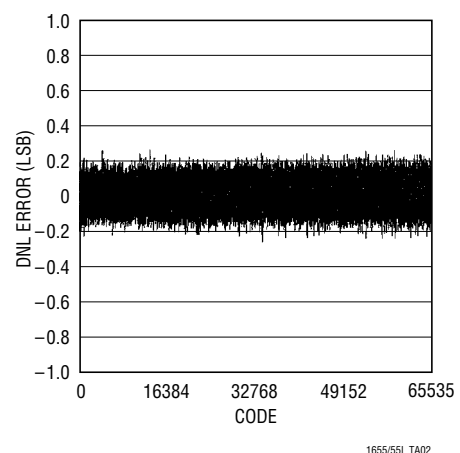
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FUNCTIONAL BLOCK DIAGRAM

Functional Block Diagram: 16-Bit Rail-to-Rail DAC



**Differential Nonlinearity
vs Input Code**



ABSOLUTE MAXIMUM RATINGS

(Note 1)

V_{CC} to GND	–0.5V to 7.5V
TTL Input Voltage	–0.5V to 7.5V
V_{OUT} , REF	–0.5V to $V_{CC} + 0.5V$
Maximum Junction Temperature	125°C
Operating Temperature Range	
LTC1655C/LTC1655LC	0°C to 70°C
LTC1655I/LTC1655LI	–40°C to 85°C
Storage Temperature Range	–65°C to 150°C
Lead Temperature (Soldering, 10 sec)	300°C

PACKAGE/ORDER INFORMATION

<p>TOP VIEW</p> <p>CLK 1, DIN 2, CS/LD 3, DOUT 4, 8 VCC, 7 VOUT, 6 REF, 5 GND</p> <p>N8 PACKAGE 8-LEAD PDIP, S8 PACKAGE 8-LEAD PLASTIC SO</p> <p>$T_{JMAX} = 125^{\circ}C$, $\theta_{JA} = 100^{\circ}C/W$ (N8) $T_{JMAX} = 125^{\circ}C$, $\theta_{JA} = 150^{\circ}C/W$ (S8)</p>	ORDER PART NUMBER
	LTC1655CN8 LTC1655IN8 LTC1655CS8 LTC1655IS8 LTC1655LCN8 LTC1655LIN8 LTC1655LCS8 LTC1655LIS8
	S8 PART MARKING
	1655 1655I 1655L 1655LI

Consult factory for Military grade parts.

ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25^{\circ}C$.
 $V_{CC} = 4.5V$ to $5.5V$ (LTC1655), $V_{CC} = 2.7V$ to $5.5V$ (LTC1655L); V_{OUT} unloaded, REF unloaded, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
DAC						
	Resolution	●	16			Bits
	Monotonicity	●	16			Bits
DNL	Differential Nonlinearity	Guaranteed Monotonic (Note 2)				
		LTC1655, REF = 2.2V, $V_{CC} = 5V$ (Note 8) (External)	●	±0.3	±1.0	LSB
		LTC1655L, REF = 2.2V, $V_{CC} = 5V$ (Note 8) (External)	●	±0.5	±1.0	LSB
INL	Integral Nonlinearity	LTC1655, REF = 2.2V, $V_{CC} = 5V$ (Note 8) (External)	●	±8	±20	LSB
		LTC1655L, REF = 2.2V, $V_{CC} = 5V$ (Note 8) (External)	●	±8	±20	LSB
ZSE	Zero Scale Error	LTC1655	●	0	3.0	mV
		LTC1655L	●	0	3.5	mV
V_{OS}	Offset Error	Measured at Code 200				
		LTC1655, REF = 2.2V, $V_{CC} = 5V$ (Note 8) (External)	●	±0.5	±3.0	mV
		LTC1655L, REF = 1.3V, $V_{CC} = 2.7V$ (Note 8) (External)	●	±0.5	±3.5	mV
$V_{OS}TC$	Offset Error Tempco			±5		μV/°C
	Gain Error	REF = 2.2V (External), $V_{CC} = 5V$ (Note 8)	●	±5	±16	LSB
	Gain Error Drift			0.5		ppm/°C
Power Supply						
V_{CC}	Positive Supply Voltage	For Specified Performance				
		LTC1655	●	4.5	5.5	V
		LTC1655L	●	2.7	5.5	V
I_{CC}	Supply Current	(Note 3)	●	600	1200	μA

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SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Op Amp DC Performance							
	Short-Circuit Current Low	V_{OUT} Shorted to GND	●		70	120	mA
		LTC1655 LTC1655L	●		70	140	mA
	Short-Circuit Current High	V_{OUT} Shorted to V_{CC}	●		80	140	mA
		LTC1655 LTC1655L	●		70	150	mA
	Output Impedance to GND	Input Code = 0	●		40	120	Ω
		LTC1655 LTC1655L	●		70	160	Ω
	Output Line Regulation	Input Code = 65535, with Internal Reference				± 3	mV/V

AC Performance

	Voltage Output Slew Rate	(Note 4)	●	± 0.3	± 0.7		V/ μs
	Voltage Output Settling Time	(Note 4) to 0.0015% (16-Bit Settling Time), $V_{CC} = 5\text{V}$			20		μs
		(Note 4) to 0.012% (13-Bit Settling Time), $V_{CC} = 5\text{V}$			10		μs
	Digital Feedthrough	(Note 5)			0.3		nV-s
	Midscale Glitch Impulse	DAC Switched Between 8000 _H and 7FFF _H			12		nV-s
	Output Voltage Noise Spectral Density	LTC1655, At 1kHz			280		nV/ $\sqrt{\text{Hz}}$
		LTC1655L, At 1kHz			220		nV/ $\sqrt{\text{Hz}}$

Reference Output

	Reference Output Voltage	LTC1655	●	2.036	2.048	2.060	V
		LTC1655L	●	1.240	1.250	1.260	V
	Reference Input Range	(Notes 6, 7) LTC1655		2.2		$V_{CC}/2$	V
		LTC1655L		1.3		$V_{CC}/2$	V
	Reference Output Tempco	LTC1655			5		ppm/ $^\circ\text{C}$
		LTC1655L			10		ppm/ $^\circ\text{C}$
	Reference Input Resistance	LTC1655, REF Overdriven to 2.2V	●	8.5	13		k Ω
		LTC1655L, REF Overdriven to 1.3V	●	7.0	13		k Ω
	Reference Short-Circuit Current		●		40	100	mA
	Reference Output Line Regulation					± 1.5	mV/V
	Reference Load Regulation	$I_{OUT} = 100\mu\text{A}$	●			5	mV/A
	Reference Output Voltage Noise Spectral Density	LTC1655, At 1kHz			150		nV/ $\sqrt{\text{Hz}}$
		LTC1655L, At 1kHz			115		nV/ $\sqrt{\text{Hz}}$

Digital I/O

V_{IH}	Digital Input High Voltage	LTC1655	●	2.4			V
		LTC1655L	●	2.0			V
V_{IL}	Digital Input Low Voltage	LTC1655	●			0.8	V
		LTC1655L	●			0.6	V
V_{OH}	Digital Output High Voltage	LTC1655, $I_{OUT} = -1\text{mA}$	●	$V_{CC} - 1.0$			V
		LTC1655L, $I_{OUT} = -1\text{mA}$	●	$V_{CC} - 0.7$			V
V_{OL}	Digital Output Low Voltage	LTC1655, $I_{OUT} = 1\text{mA}$	●			0.4	V
		LTC1655L, $I_{OUT} = 1\text{mA}$	●			0.4	V

ELECTRICAL CHARACTERISTICS

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SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
I_{LEAK}	Digital Input Leakage	$V_{IN} = \text{GND to } V_{CC}$	●		± 10	μA
C_{IN}	Digital Input Capacitance	(Note 7)			10	pF

Switching

t_1	D_{IN} Valid to CLK Setup	LTC1655 LTC1655L	● ●	40 60		ns ns
t_2	D_{IN} Valid to CLK Hold	LTC1655 LTC1655L	● ●	0 0		ns ns
t_3	CLK High Time	LTC1655 LTC1655L	● ●	40 60		ns ns
t_4	CLK Low Time	LTC1655 LTC1655L	● ●	40 60		ns ns
t_5	$\overline{\text{CS/LD}}$ Pulse Width	LTC1655 LTC1655L	● ●	50 80		ns ns
t_6	LSB CLK to $\overline{\text{CS/LD}}$	LTC1655 LTC1655L	● ●	40 60		ns ns
t_7	$\overline{\text{CS/LD}}$ Low to CLK	LTC1655 LTC1655L	● ●	20 30		ns ns
t_8	D_{OUT} Output Delay	LTC1655, $C_{LOAD} = 15\text{pF}$ LTC1655L, $C_{LOAD} = 15\text{pF}$	● ●	20 20	120 300	ns ns
t_9	CLK Low to $\overline{\text{CS/LD}}$ Low	LTC1655 LTC1655L	● ●	20 30		ns ns

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

Note 2: Nonlinearity is defined from code 128 to code 65535 (full scale). See Applications Information.

Note 3: DAC switched between all 1s and all 0s. $V_{FS} = 4.096\text{V}$.

Note 4: Digital inputs at 0V or V_{CC} .

Note 5: Part is clocked with pin toggling between 1s and 0s, $\overline{\text{CS/LD}}$ is low.

Note 6: Reference can be overdriven (see Applications Information).

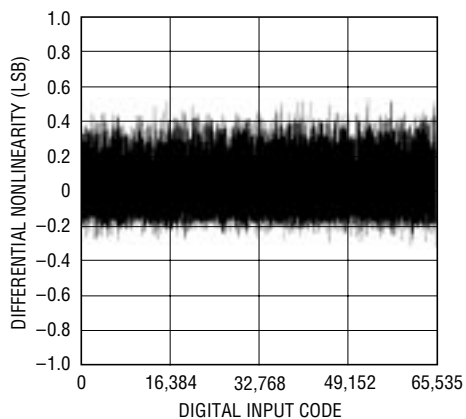
Note 7: Guaranteed by design. Not subject to test.

Note 8: Guaranteed by correlation for other reference and supply conditions.

TYPICAL PERFORMANCE CHARACTERISTICS

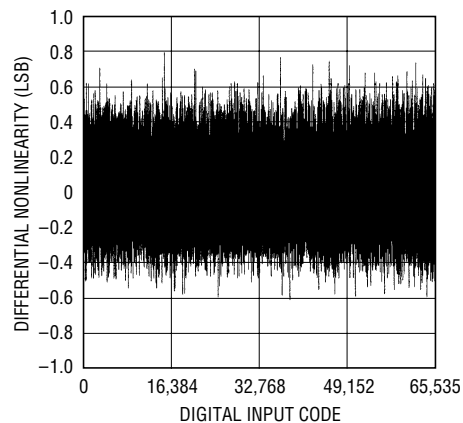
$V_{CC} = 5V$ (LTC1655), $V_{CC} = 3V$ (LTC1655L) unless otherwise noted.

TC1655 Differential Nonlinearity



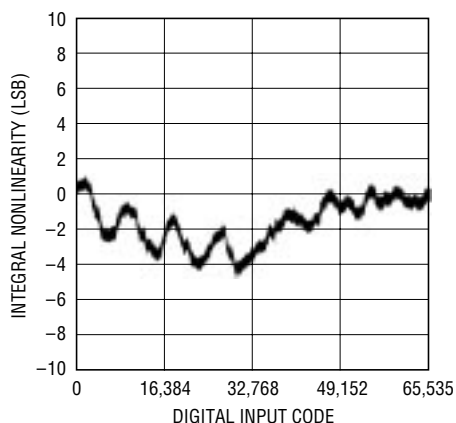
1655/55L G01

LTC1655L Differential Nonlinearity



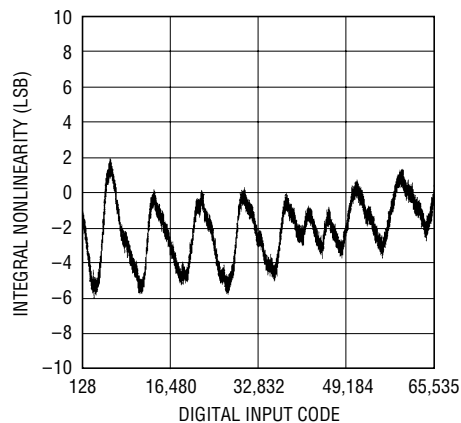
1655/55L G01a

LTC1655 Integral Nonlinearity



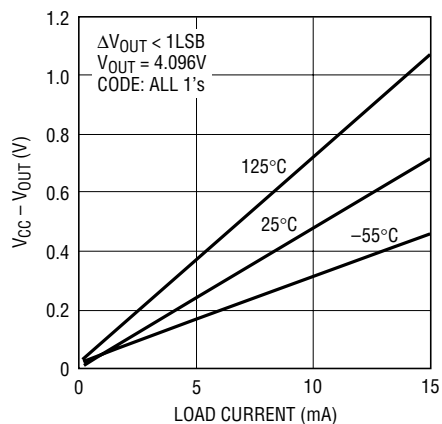
1655/55L G02

LTC1655L Integral Nonlinearity



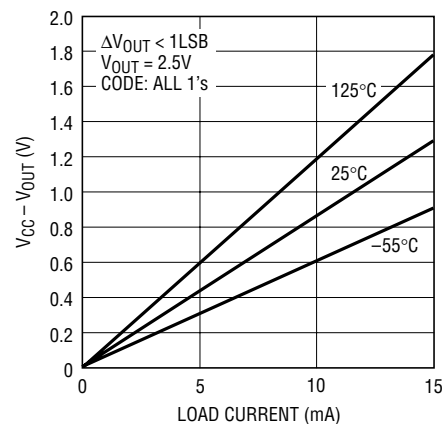
1655/55L G02a

LTC1655 Minimum Supply Headroom for Full Output Swing vs Load Current



1655/55L G03

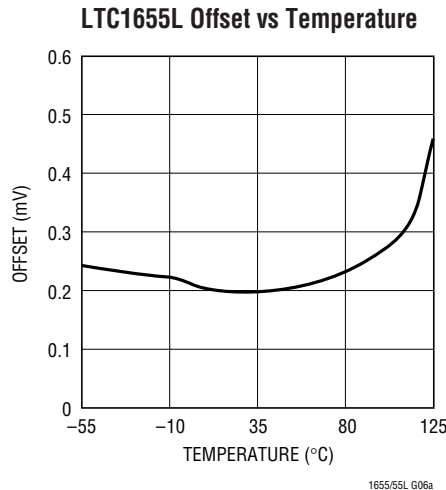
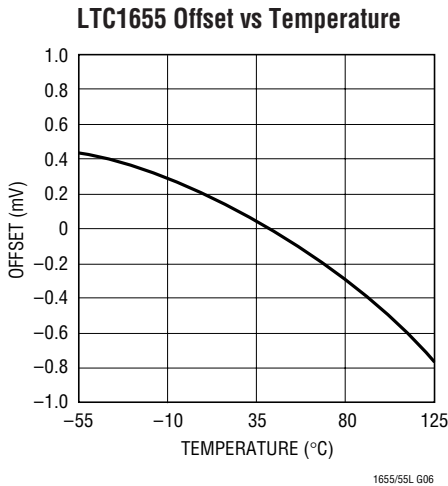
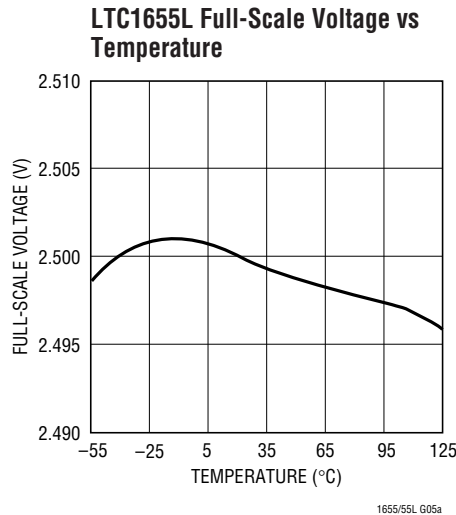
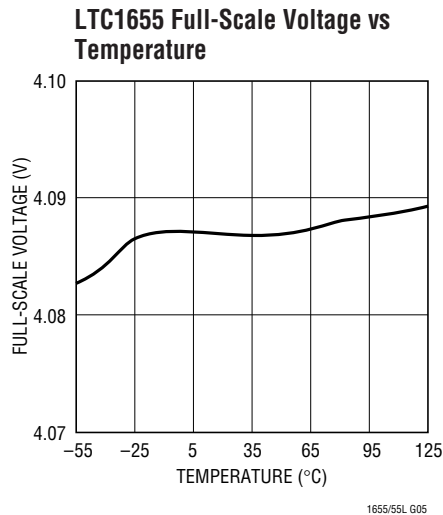
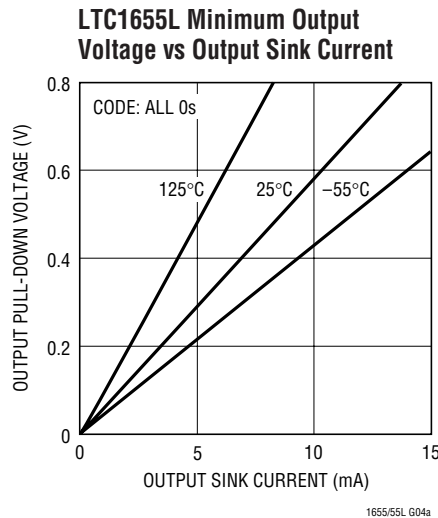
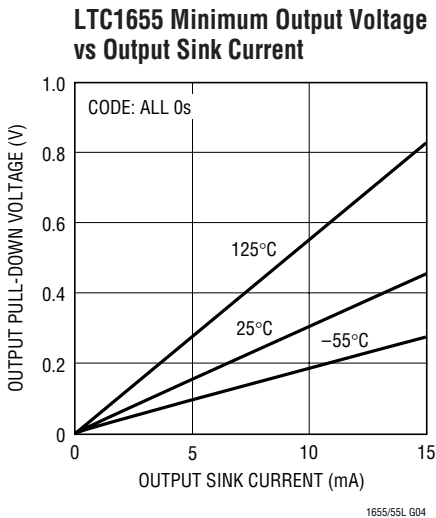
LTC1655L Minimum Supply Headroom for Full Output Swing vs Load Current



1655/55L G03a

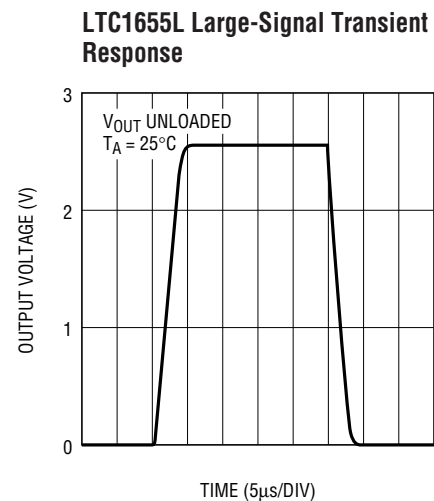
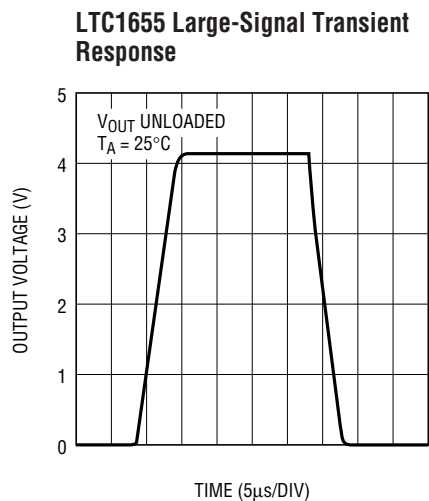
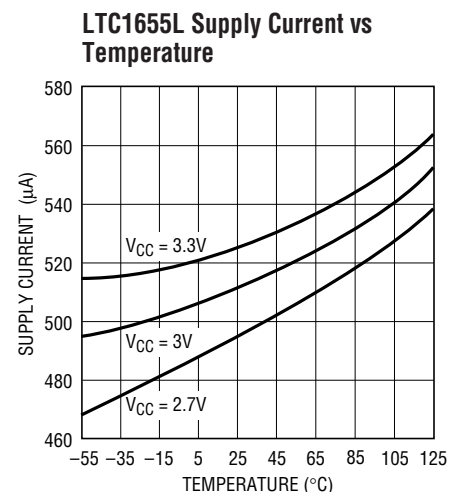
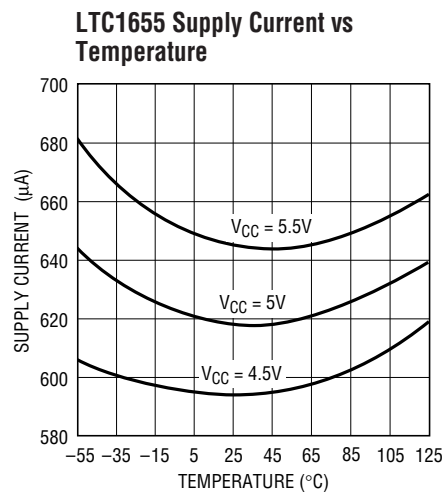
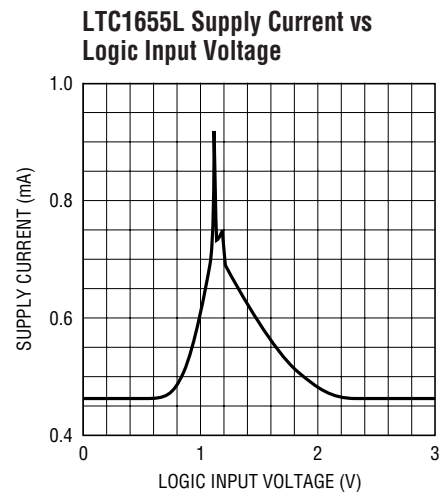
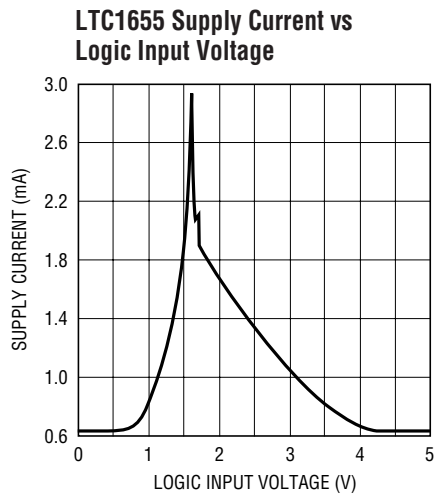
TYPICAL PERFORMANCE CHARACTERISTICS

V_{CC} = 5V (LTC1655), V_{CC} = 3V (LTC1655L) unless otherwise noted.



TYPICAL PERFORMANCE CHARACTERISTICS

$V_{CC} = 5V$ (LTC1655), $V_{CC} = 3V$ (LTC1655L) unless otherwise noted.



PIN FUNCTIONS

CLK (Pin 1): The TTL Level Input for the Serial Interface Clock.

D_{IN} (Pin 2): The TTL Level Input for the Serial Interface Data. Data on the D_{IN} pin is latched into the shift register on the rising edge of the serial clock and is loaded MSB first. The LTC1655/LTC1655L requires a 16-bit word.

$\overline{\text{CS/LD}}$ (Pin 3): The TTL Level Input for the Serial Interface Enable and Load Control. When $\overline{\text{CS/LD}}$ is low, the CLK signal is enabled, so the data can be clocked in. When $\overline{\text{CS/LD}}$ is pulled high, data is loaded from the shift register into the DAC register, updating the DAC output.

D_{OUT} (Pin 4): Output of the Shift Register. Becomes valid on the rising edge of the serial clock and swings from GND to V_{CC}.

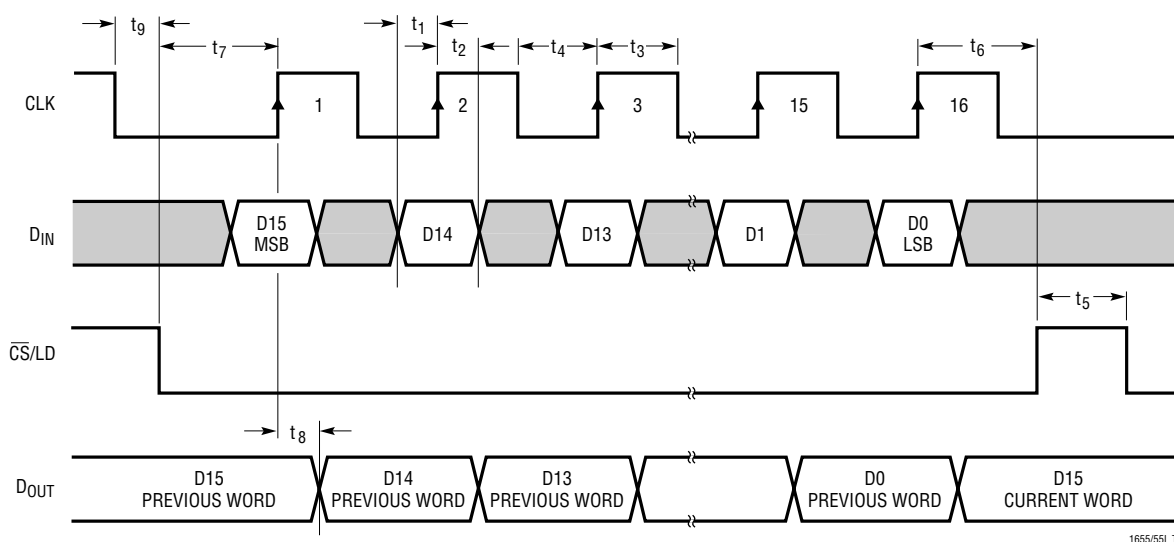
GND (Pin 5): Ground.

REF (Pin 6): Reference. Output of the internal reference is 2.048V (LTC1655), 1.25V (LTC1655L). There is a gain of two from this pin to the output. The reference can be overdriven from 2.2V to V_{CC}/2 (LTC1655) and 1.3V to V_{CC}/2 (LTC1655L). When tied to V_{CC}/2, the output will swing from GND to V_{CC}. The output can only swing to within its offset specification of V_{CC} (see Applications Information).

V_{OUT} (Pin 7): Deglitched Rail-to-Rail Voltage Output. V_{OUT} clears to 0V on power-up.

V_{CC} (Pin 8): Positive Supply Input. $4.5\text{V} \leq V_{\text{CC}} \leq 5.5\text{V}$ (LTC1655), $2.7\text{V} \leq V_{\text{CC}} \leq 5.5\text{V}$ (LTC1655L). Requires a 0.1μF bypass capacitor to ground.

TIMING DIAGRAM



1655/55L TD

DEFINITIONS

Differential Nonlinearity (DNL): The difference between the measured change and the ideal 1LSB change for any two adjacent codes. The DNL error between any two codes is calculated as follows:

$$\text{DNL} = (\Delta V_{\text{OUT}} - \text{LSB}) / \text{LSB}$$

Where ΔV_{OUT} is the measured voltage difference between two adjacent codes.

Digital Feedthrough: The glitch that appears at the analog output caused by AC coupling from the digital inputs when they change state. The area of the glitch is specified in (nV)(sec).

Full-Scale Error (FSE): The deviation of the actual full-scale voltage from ideal. FSE includes the effects of offset and gain errors (see Applications Information).

Gain Error (GE): The difference between the full-scale output of a DAC from its ideal full-scale value after offset error has been adjusted.

Integral Nonlinearity (INL): The deviation from a straight line passing through the endpoints of the DAC transfer curve (Endpoint INL). Because the output cannot go below zero, the linearity is measured between full scale and the

lowest code that guarantees the output will be greater than zero. The INL error at a given input code is calculated as follows:

$$\text{INL} = [V_{\text{OUT}} - V_{\text{OS}} - (V_{\text{FS}} - V_{\text{OS}})(\text{code}/65535)] / \text{LSB}$$

Where V_{OUT} is the output voltage of the DAC measured at the given input code.

Least Significant Bit (LSB): The ideal voltage difference between two successive codes.

$$\text{LSB} = 2V_{\text{REF}}/65536$$

Resolution (n): Defines the number of DAC output states (2^n) that divide the full-scale range. Resolution does not imply linearity.

Voltage Offset Error (V_{OS}): Nominally, the voltage at the output when the DAC is loaded with all zeros. A single supply DAC can have a true negative offset, but the output cannot go below zero (see Applications Information).

For this reason, single supply DAC offset is measured at the lowest code that guarantees the output will be greater than zero.

OPERATION

Serial Interface

The data on the D_{IN} input is loaded into the shift register on the rising edge of the clock. The MSB is loaded first. The DAC register loads the data from the shift register when $\overline{\text{CS}}/\text{LD}$ is pulled high. The clock is disabled internally when $\overline{\text{CS}}/\text{LD}$ is high. Note: CLK must be low before $\overline{\text{CS}}/\text{LD}$ is pulled low to avoid an extra internal clock pulse. The input word must be 16 bits wide.

The buffered output of the 16-bit shift register is available on the D_{OUT} pin which swings from GND to V_{CC} .

Multiple LTC1655s/LTC1655Ls may be daisy-chained together by connecting the D_{OUT} pin to the D_{IN} pin of the next chip while the clock and $\overline{\text{CS}}/\text{LD}$ signals remain common to all chips in the daisy chain. The serial data is clocked to all

of the chips, then the $\overline{\text{CS}}/\text{LD}$ signal is pulled high to update all of them simultaneously. The shift register and DAC register are cleared to all 0s on power-up.

Voltage Output

The LTC1655/LTC1655L rail-to-rail buffered output can source or sink 5mA over the entire operating temperature range while pulling to within 600mV of the positive supply voltage or ground. The output stage is equipped with a deglitcher that gives a midscale glitch of 12nV-s. At power-up, the output clears to 0V.

The output swings to within a few millivolts of either supply rail when unloaded and has an equivalent output resistance of 40 Ω (70 Ω for the LTC1655L) when driving a load to the rails. The output can drive 1000pF without going into oscillation.

APPLICATIONS INFORMATION

Rail-to-Rail Output Considerations

In any rail-to-rail DAC, the output swing is limited to voltages within the supply range.

If the DAC offset is negative, the output for the lowest codes limits at 0V as shown in Figure 1b.

Similarly, limiting can occur near full-scale when the REF pin is tied to $V_{CC}/2$. If $V_{REF} = V_{CC}/2$ and the DAC full-scale

error (FSE) is positive, the output for the highest codes limits at V_{CC} as shown in Figure 1c. No full-scale limiting can occur if V_{REF} is less than $(V_{CC} - FSE)/2$.

Offset and linearity are defined and tested over the region of the DAC transfer function where no output limiting can occur.

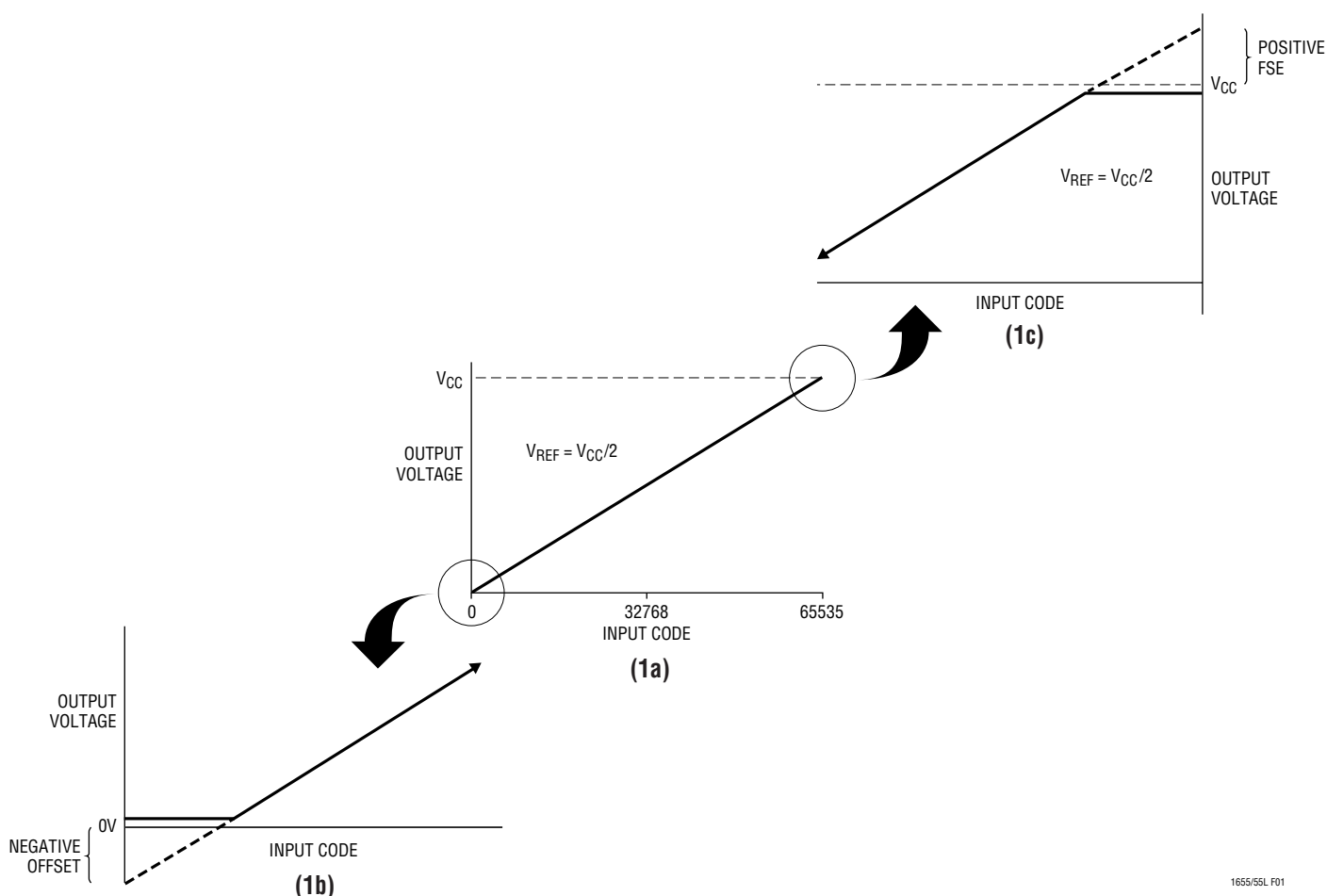


Figure 1. Effects of Rail-to-Rail Operation On a DAC Transfer Curve. (a) Overall Transfer Function (b) Effect of Negative Offset for Codes Near Zero Scale (c) Effect of Positive Full-Scale Error for Input Codes Near Full Scale When $V_{REF} = V_{CC}/2$

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is used for the digitally controlled 0mA to 16mA current. R_S is a sense resistor and the op amp modulates the transistor Q1 to provide the 4mA to 20mA current through this resistor. The potentiometers allow for offset and full-scale adjustment. The control circuitry dissipates well under the 4mA budget at zero scale.

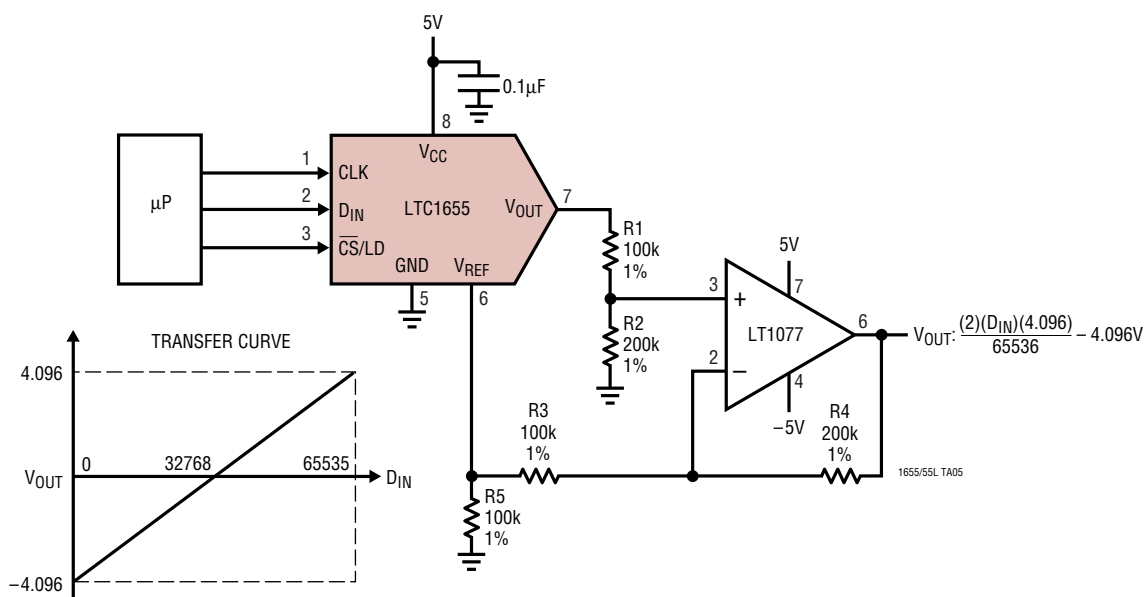
The diagram shows a precision current source circuit. At the top left, an LT[®]1121-5 optoisolator provides optoisolated inputs to the LTC1655. The LTC1655 is configured with its V_{CC} (pin 8) and V_{REF} (pin 6) connected to a 6V to 30V supply (V_{LOOP}). Its GND (pin 5) is connected to the common ground. The CLK (pin 1), D_{IN} (pin 2), and CS/LD (pin 3) inputs are connected to the output of the LT[®]1121-5. The V_{OUT} (pin 7) is connected to a 75kΩ resistor (1% tolerance) in series with a 5kΩ potentiometer. The other end of the potentiometer is connected to the non-inverting input (pin 3) of an LT[®]1077 op-amp. The op-amp's inverting input (pin 2) is connected to ground. The op-amp's output (pin 6) is connected to the emitter of a 2N3440 transistor (Q1). The transistor's base is connected to the wiper of the 5kΩ potentiometer. The collector of Q1 is connected to the V_{LOOP} supply. A 1kΩ resistor is connected between the op-amp output and the transistor base. The current I_{OUT} is measured through a 10Ω sense resistor (R_S) connected between the collector of Q1 and ground. A 3kΩ resistor is connected between the op-amp output and the 75kΩ resistor. The LTC1655 also has a V_{REF} input (pin 6) connected to a 150kΩ resistor (1% tolerance) in series with a 20kΩ potentiometer, which is also connected to the V_{LOOP} supply. The LTC1655 has a D_{IN} input (pin 2) and a CS/LD input (pin 3). The LT[®]1121-5 has an IN input and an OUT output. The OUT output is connected to the D_{IN} input of the LTC1655. The IN input is connected to the CS/LD input of the LTC1655. The LT[®]1121-5 also has a 1μF capacitor connected between its IN and OUT pins. The LT[®]1077 has a 1kΩ resistor connected between its output (pin 6) and its inverting input (pin 2). The 2N3440 transistor has a 1kΩ resistor connected between its base and the op-amp output (pin 6). The 2N3440 transistor has a 10Ω resistor (R_S) connected between its collector and ground. The current I_{OUT} is measured through R_S. The V_{LOOP} supply is labeled as 6V TO 30V. The circuit is labeled 1655/55L TA03.

TYPICAL APPLICATIONS

This circuit shows how to make a bipolar output 16-bit DAC with a wide output swing using an LTC1655 and an LT1077. R1 and R2 resistively divide down the LTC1655 output and an offset is summed in using the LTC1655 onboard 2.048V reference and R3 and R4. R5 ensures that

the onboard reference is always sourcing current and never has to sink any current even when V_{OUT} is at full scale. The LT1077 output will have a wide bipolar output swing of $-4.096V$ to $4.096V$ as shown in the figure below. With this output swing $1LSB = 125\mu V$.

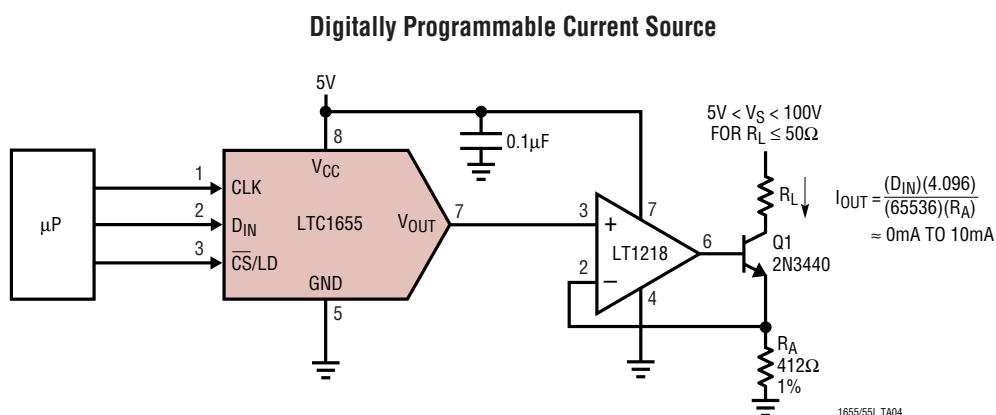
A Wide Swing, Bipolar Output 16-Bit DAC



TYPICAL APPLICATIONS

This circuit shows a digitally programmable current source from an external voltage source using an external op amp, an LT1218 and an NPN transistor (2N3440). Any digital word from 0 to 65535 is loaded into the LTC1655 and its output correspondingly swings from 0V to 4.096V. This voltage will be forced across the resistor R_A . If R_A is

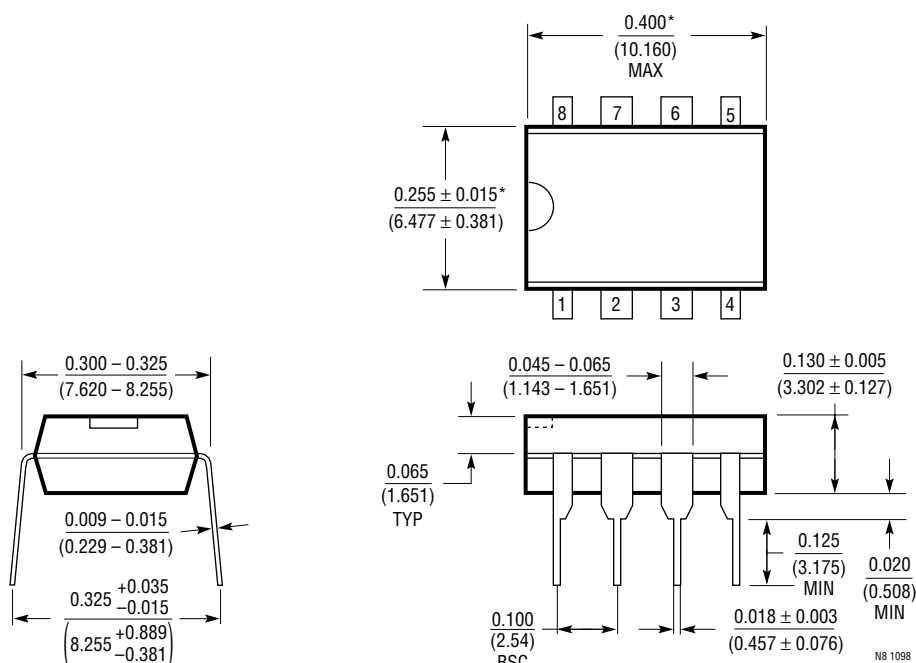
chosen to be 412Ω , the output current will range from 0mA at zero scale to 10mA at full scale. The minimum voltage for V_S is determined by the load resistor R_L and Q1's V_{CESAT} voltage. With a load resistor of 50Ω , the voltage source can be 5V.



PACKAGE DESCRIPTION

Dimensions in inches (millimeters) unless otherwise noted.

N8 Package
8-Lead PDIP (Narrow 0.300)
 (LTC DWG # 05-08-1510)



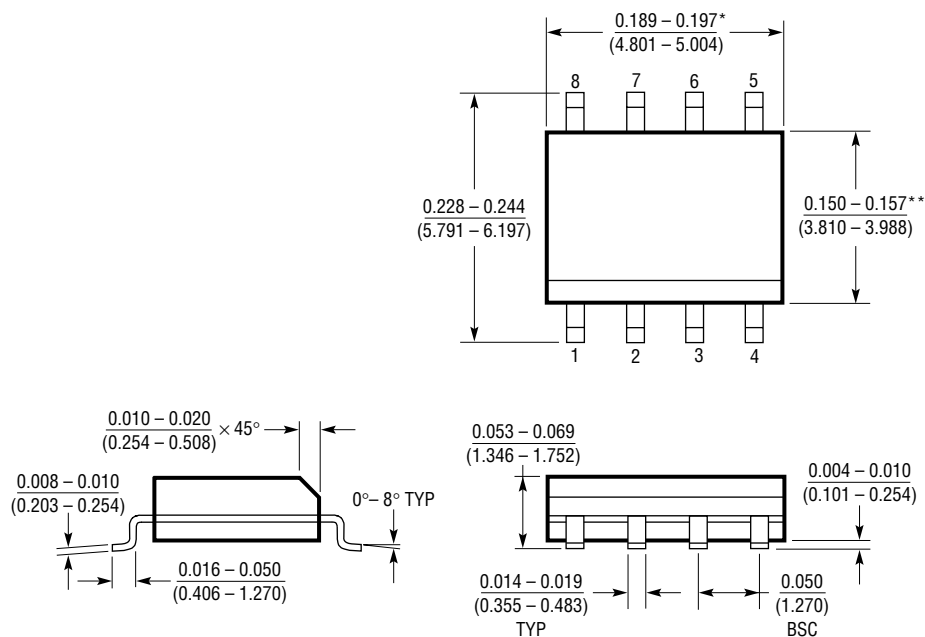
*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
 MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.010 INCH (0.254mm)

N8 1098

PACKAGE DESCRIPTION

Dimensions in inches (millimeters) unless otherwise noted.

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



*DIMENSION DOES NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

**DIMENSION DOES NOT INCLUDE INTERLEAD FLASH. INTERLEAD FLASH SHALL NOT EXCEED 0.010" (0.254mm) PER SIDE

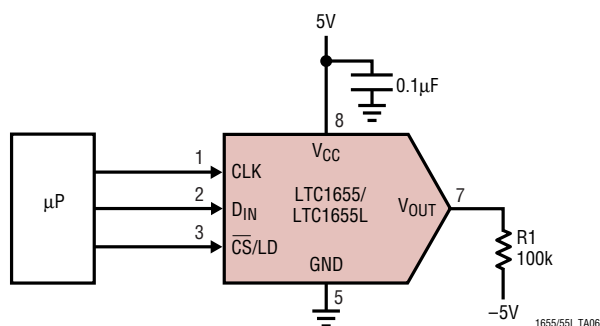
S08 1298

TYPICAL APPLICATION

This circuit shows how to measure negative offset. Since LTC1655/LTC1655L operate on a single supply, if its offset is negative, the output for code 0 limits to 0V. To

measure this negative offset, a negative supply is needed. Connect resistor R1 as shown in the figure below. The output voltage is the offset when code 0 is loaded in.

Negative Offset Measurement



RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LTC1257	Single 12-Bit V_{OUT} DAC, Full Scale: 2.048V, V_{CC} : 4.75V to 15.75V, in Reference Can Be Overdriven Up to 12V, i.e., $FS_{MAX} = 12V$	5V to 15V Single Supply, Complete V_{OUT} DAC SO-8 Package
LTC1446/ LTC1446L	Dual 12-Bit V_{OUT} DACs in SO-8 Package	LTC1446: $V_{CC} = 4.5V$ to 5.5V, $V_{OUT} = 0V$ to 4.095V LTC1446L: $V_{CC} = 2.7V$ to 5.5V, $V_{OUT} = 0V$ to 2.5V
LTC1448	Dual 12-Bit V_{OUT} DAC, V_{CC} : 2.7V to 5.5V	Output Swings from GND to REF. REF Input Can Be Tied to V_{CC}
LTC1450/ LTC1450L	Single 12-Bit V_{OUT} DACs with Parallel Interface	LTC1450: $V_{CC} = 4.5V$ to 5.5V, $V_{OUT} = 0V$ to 4.095V LTC1450L: $V_{CC} = 2.7V$ to 5.5V, $V_{OUT} = 0V$ to 2.5V
LTC1451	Single Rail-to-Rail 12-Bit DAC, Full Scale: 4.095V, V_{CC} : 4.5V to 5.5V, Internal 2.048V Reference Brought Out to Pin	5V, Low Power Complete V_{OUT} DAC in SO-8 Package
LTC1452	Single Rail-to-Rail 12-Bit V_{OUT} Multiplying DAC, V_{CC} : 2.7V to 5.5V	Low Power, Multiplying V_{OUT} DAC with Rail-to-Rail Buffer Amplifier in SO-8 Package
LTC1453	Single Rail-to-Rail 12-Bit V_{OUT} DAC, Full Scale: 2.5V, V_{CC} : 2.7V to 5.5V	3V, Low Power, Complete V_{OUT} DAC in SO-8 Package
LTC1454/ LTC1454L	Dual 12-Bit V_{OUT} DACs in SO-16 Package with Added Functionality	LTC1454: $V_{CC} = 4.5V$ to 5.5V, $V_{OUT} = 0V$ to 4.095V LTC1454L: $V_{CC} = 2.7V$ to 5.5V, $V_{OUT} = 0V$ to 2.5V
LTC1456	Single Rail-to-Rail Output 12-Bit DAC with Clear Pin, Full Scale: 4.095V, V_{CC} : 4.5V to 5.5V	Low Power, Complete V_{OUT} DAC in SO-8 Package with Clear Pin
LTC1458/ LTC1458L	Quad 12 Bit Rail-to-Rail Output DACs with Added Functionality	LTC1458: $V_{CC} = 4.5V$ to 5.5V, $V_{OUT} = 0V$ to 4.095V LTC1458L: $V_{CC} = 2.7V$ to 5.5V, $V_{OUT} = 0V$ to 2.5V
LTC1650	Single 16-Bit V_{OUT} Industrial DAC in 16-Pin SO, $V_{CC} = \pm 5V$	Low Power, Deglitched, 4-Quadrant Multiplying V_{OUT} DAC, Output Swing $\pm 4.5V$
LTC1654	Dual 14-Bit DAC	1LSB DNL, 2 DACs in SO-8 Footprint
LTC1657/ LTC1657L	Single 16-Bit V_{OUT} DAC with Parallel Interface	LTC1657: $V_{CC} = 5V$, Low Power, Deglitched, $V_{OUT} = 0V$ to 4.096V LTC1657L: $V_{CC} = 3V$, Low Power, Deglitched, $V_{OUT} = 0V$ to 2.5V
LTC1658	Single Rail-to-Rail 14-Bit V_{OUT} DAC in 8-Pin MSOP, $V_{CC} = 2.7V$ to 5.5V	Low Power, Multiplying V_{OUT} DAC in MS8 Package. Output Swings from GND to REF. REF Input Can Be Tied to V_{CC}
LTC1659	Single Rail-to-Rail 12-Bit V_{OUT} DAC in 8-Pin MSOP, $V_{CC} = 2.7V$ to 5.5V	Low Power, Multiplying V_{OUT} DAC in MS8 Package. Output Swings from GND to REF. REF Input Can Be Tied to V_{CC}