

# 14-Bit and 16-Bit Parallel Low Glitch Multiplying DACs with 4-Quadrant Resistors

## FEATURES

- True 16-Bit Performance Over Industrial Temperature Range
- DNL and INL: 1LSB Max
- On-Chip 4-Quadrant Resistors Allow Precise 0V to 10V, 0V to -10V or  $\pm 10V$  Outputs
- Pin Compatible 14- and 16-Bit Parts
- Asynchronous Clear Pin
  - LTC1591/LTC1597: Reset to Zero Scale
  - LTC1591-1/LTC1597-1: Reset to Midscale
- Glitch Impulse < 2nV-s
- 28-Lead SSOP Package
- Low Power Consumption: 10 $\mu$ W Typ
- Power-On Reset

## APPLICATIONS

- Process Control and Industrial Automation
- Direct Digital Waveform Generation
- Software-Controlled Gain Adjustment
- Automatic Test Equipment

## DESCRIPTION

The LTC<sup>®</sup>1591/LTC1597 are pin compatible, parallel input 14-bit and 16-bit multiplying current output DACs that operate from a single 5V supply. INL and DNL are accurate to 1LSB over the industrial temperature range in both 2- and 4-quadrant multiplying modes. True 16-bit 4-quadrant multiplication is achieved with on-chip 4-quadrant multiplication resistors.

These DACs include an internal deglitcher circuit that reduces the glitch impulse to less than 2nV-s (typ). The asynchronous CLR pin resets the LTC1591/LTC1597 to zero scale and LTC1591-1/LTC1597-1 to midscale.

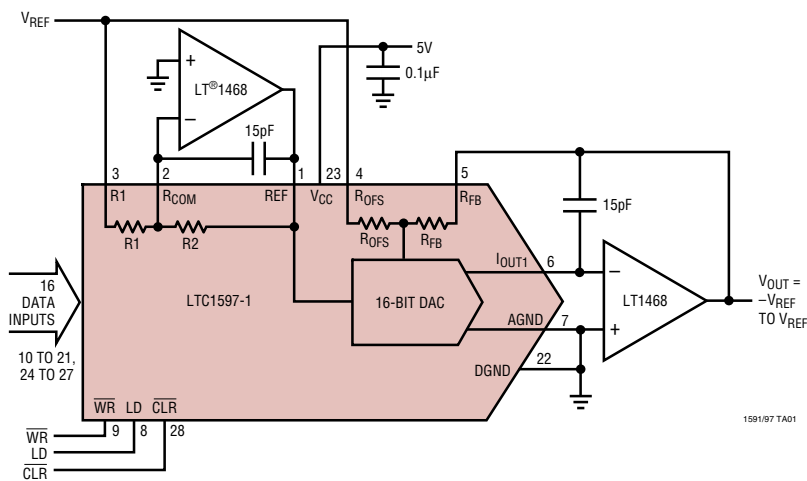
The LTC1591/LTC1597 are available in 28-pin SSOP and PDIP packages and are specified over the industrial temperature range.

For serial interface 16-bit current output DACs refer to the LTC1595/LTC1596 data sheet.

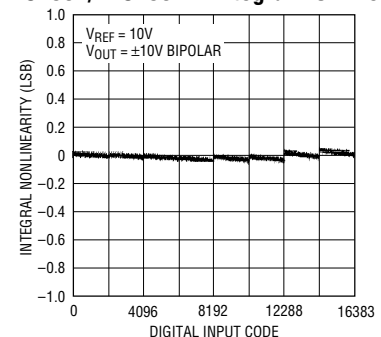
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## TYPICAL APPLICATION

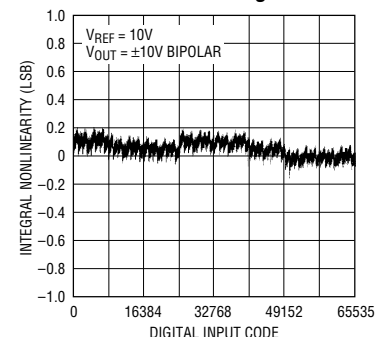
16-Bit, 4-Quadrant Multiplying DAC with a Minimum of External Components



LTC1591/LTC1591-1 Integral Nonlinearity



LTC1597/LTC1597-1 Integral Nonlinearity



# LTC1591/LTC1597

## ABSOLUTE MAXIMUM RATINGS (Note 1)

$V_{CC}$ to AGND .....	–0.5V to 7V
$V_{CC}$ to DGND .....	–0.5V to 7V
AGND to DGND .....	$V_{CC} + 0.5V$
DGND to AGND .....	$V_{CC} + 0.5V$
REF, $R_{OFS}$ , $R_{FB}$ , $R_1$ , $R_{COM}$ to AGND, DGND .....	$\pm 25V$
Digital Inputs to DGND .....	–0.5V to ( $V_{CC} + 0.5V$ )
$I_{OUT1}$ to AGND .....	–0.5V to ( $V_{CC} + 0.5V$ )
Maximum Junction Temperature .....	125°C

Operating Temperature Range	
LTC1591C/LTC1591-1C	
LTC1597C/LTC1597-1C .....	0°C to 70°C
LTC1591I/LTC1591-1I	
LTC1597I/LTC1597-1I .....	–40°C to 85°C
Storage Temperature Range .....	–65°C to 150°C
Lead Temperature (Soldering, 10 sec) .....	300°C

## PACKAGE/ORDER INFORMATION

<div style="text-align: center;">TOP VIEW</div>	ORDER PART NUMBER	<div style="text-align: center;">TOP VIEW</div>	ORDER PART NUMBER
<div style="display: flex; justify-content: space-between;"> <div> <b>G PACKAGE</b> 28-LEAD PLASTIC SSOP </div> <div> <b>N PACKAGE</b> 28-LEAD NARROW PDIP </div> </div> <div style="margin-top: 10px;"> <math>T_{JMAX} = 125^{\circ}C</math>, <math>\theta_{JA} = 95^{\circ}C/W</math> (G)  <math>T_{JMAX} = 125^{\circ}C</math>, <math>\theta_{JA} = 70^{\circ}C/W</math> (N) </div>	LTC1591CG LTC1591CN LTC1591IG LTC1591IN LTC1591-1CG LTC1591-1CN LTC1591-1IG LTC1591-1IN	<div style="display: flex; justify-content: space-between;"> <div> <b>G PACKAGE</b> 28-LEAD PLASTIC SSOP </div> <div> <b>N PACKAGE</b> 28-LEAD NARROW PDIP </div> </div> <div style="margin-top: 10px;"> <math>T_{JMAX} = 125^{\circ}C</math>, <math>\theta_{JA} = 95^{\circ}C/W</math> (G)  <math>T_{JMAX} = 125^{\circ}C</math>, <math>\theta_{JA} = 70^{\circ}C/W</math> (N) </div>	LTC1597ACG LTC1597ACN LTC1597BCG LTC1597BCN LTC1597-1ACG LTC1597-1ACN LTC1597-1BCG LTC1597-1BCN LTC1597AIG LTC1597AIN LTC1597BIG LTC1597BIN LTC1597-1AIG LTC1597-1AIN LTC1597-1BIG LTC1597-1BIN
<b>Order Options</b> Tape and Reel: Add #TR Lead Free: Add #PBF Lead Free Tape and Reel: Add #TRPBF Lead Free Part Marking: <a href="http://www.linear.com/leadfree/">http://www.linear.com/leadfree/</a>			

Consult LTC Marketing for parts specified with wider operating temperature ranges.

## ELECTRICAL CHARACTERISTICS

$V_{CC} = 5V \pm 10\%$ ,  $V_{REF} = 10V$ ,  $I_{OUT1} = AGND = DGND = 0V$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		LTC1591/-1 MIN TYP MAX	LTC1597B/-1B MIN TYP MAX	LTC1597A/-1A MIN TYP MAX	UNITS
Accuracy							
	Resolution		●	14	16	16	Bits
	Monotonicity		●	14	16	16	Bits
INL	Integral Nonlinearity	(Note 2) T <sub>A</sub> = 25°C T <sub>MIN</sub> to T <sub>MAX</sub>	●	±1 ±1	±2 ±2	±0.25 ±1 ±0.35 ±1	LSB LSB
DNL	Differential Nonlinearity	T <sub>A</sub> = 25°C T <sub>MIN</sub> to T <sub>MAX</sub>	●	±1 ±1	±1 ±1	±0.2 ±1 ±0.2 ±1	LSB LSB
GE	Gain Error	Unipolar Mode (Note 3) T <sub>A</sub> = 25°C T <sub>MIN</sub> to T <sub>MAX</sub>	●	±4 ±6	±16 ±24	2 ±16 3 ±16	LSB LSB
		Bipolar Mode (Note 3) T <sub>A</sub> = 25°C T <sub>MIN</sub> to T <sub>MAX</sub>	●	±4 ±6	±16 ±24	2 ±16 3 ±16	LSB LSB
	Gain Temperature Coefficient	(Note 4) ΔGain/ΔTemperature	●	1 2	1 2	1 2	ppm/°C
	Bipolar Zero-Scale Error	T <sub>A</sub> = 25°C T <sub>MIN</sub> to T <sub>MAX</sub>	●	±3 ±5	±10 ±16	±5 ±8	LSB LSB
I <sub>LKG</sub>	OUT1 Leakage Current	(Note 5) T <sub>A</sub> = 25°C T <sub>MIN</sub> to T <sub>MAX</sub>	●	±5 ±15	±5 ±15	±5 ±15	nA nA
PSRR	Power Supply Rejection Ratio	V <sub>CC</sub> = 5V ±10	●	±0.1 ±1	±0.4 ±2	±0.4 ±2	LSB/V

$V_{CC} = 5V \pm 10\%$ ,  $V_{REF} = 10V$ ,  $I_{OUT1} = AGND = DGND = 0V$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
<b>Reference Input</b>						
$R_{REF}$	DAC Input Resistance (Unipolar)	(Note 6)	●	4.5	6 10	k $\Omega$
$R1/R2$	R1/R2 Resistance (Bipolar)	(Notes 6, 13)	●	9	12 20	k $\Omega$
$R_{OFS}, R_{FB}$	Feedback and Offset Resistances	(Note 6)	●	9	12 20	k $\Omega$

**AC Performance (Note 4)**

	Output Current Settling Time	(Notes 7, 8)		1	$\mu s$
	Midscale Glitch Impulse	(Note 12)		2	nV-s
	Digital-to-Analog Glitch Impulse	(Note 9)		1	nV-s
	Multiplying Feedthrough Error	$V_{REF} = \pm 10V$ , 10kHz Sine Wave		1	mV <sub>P-P</sub>
THD	Total Harmonic Distortion	(Note 10)		108	dB
	Output Noise Voltage Density	(Note 11)		10	nV/ $\sqrt{Hz}$
	Harmonic Distortion (Digital Waveform Generation)	Unipolar Mode (Note 14)			
		2nd Harmonic		94	dB
		3rd Harmonic		101	dB
		SFDR		94	dB
		Bipolar Mode (Note 14)			
		2nd Harmonic		94	dB
		3rd Harmonic		101	dB
		SFDR		94	dB

**ELECTRICAL CHARACTERISTICS** The ● denotes specifications that apply over the full operating temperature range.  $V_{CC} = 5V \pm 10\%$ ,  $V_{REF} = 10V$ ,  $I_{OUT1} = AGND = DGND = 0V$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Analog Outputs (Note 4)							
C <sub>OUT</sub>	Output Capacitance (Note 4)	DAC Register Loaded to All 1s: C <sub>OUT1</sub> DAC Register Loaded to All 0s: C <sub>OUT1</sub>	● ●		115 70	130 80	pF pF
Digital Inputs							
V <sub>IH</sub>	Digital Input High Voltage		●	2.4			V
V <sub>IL</sub>	Digital Input Low Voltage		●			0.8	V
I <sub>IN</sub>	Digital Input Current		●		0.001	±1	μA
C <sub>IN</sub>	Digital Input Capacitance	(Note 4) V <sub>IN</sub> = 0V	●			8	pF
Timing Characteristics							
t <sub>DS</sub>	Data to $\overline{WR}$ Setup Time		●	60			ns
t <sub>DH</sub>	Data to $\overline{WR}$ Hold Time		●	0			ns
t <sub>WR</sub>	$\overline{WR}$ Pulse Width		●	60			ns
t <sub>LD</sub>	LD Pulse Width		●	110			ns
t <sub>CLR</sub>	Clear Pulse Width		●	60			ns
t <sub>LWD</sub>	$\overline{WR}$ to LD Delay Time		●	0			ns
Power Supply							
V <sub>DD</sub>	Supply Voltage		●	4.5	5	5.5	V
I <sub>DD</sub>	Supply Current	Digital Inputs = 0V or V <sub>CC</sub>	●			10	μA

**Note 1:** Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

**Note 2:**  $\pm 1LSB = \pm 0.006\%$  of full scale =  $\pm 61ppm$  of full scale for the LTC1591/LTC1591-1.  $\pm 1LSB = \pm 0.0015\%$  of full scale =  $\pm 15.3ppm$  of full scale for the LTC1597/LTC1597-1.

**Note 3:** Using internal feedback resistor.

**Note 4:** Guaranteed by design, not subject to test.

**Note 5:**  $I_{(OUT1)}$  with DAC register loaded to all 0s.

**Note 6:** Typical temperature coefficient is 100ppm/°C.

**Note 7:**  $I_{OUT1}$  load = 100 $\Omega$  in parallel with 13pF.

**Note 8:** To 0.006% for a full-scale change, measured from the rising edge of LD for the LTC1591/LTC1591-1. To 0.0015% for a full-scale change, measured from the rising edge of LD for the LTC1597/LTC1597-1.

**Note 9:**  $V_{REF} = 0V$ . DAC register contents changed from all 0s to all 1s or all 1s to all 0s.

**Note 10:**  $V_{REF} = 6V_{RMS}$  at 1kHz. DAC register loaded with all 1s.

**Note 11:** Calculation from  $e_n = \sqrt{4kTRB}$  where: k = Boltzmann constant (J/°K), R = resistance ( $\Omega$ ), T = temperature (°K), B = bandwidth (Hz).

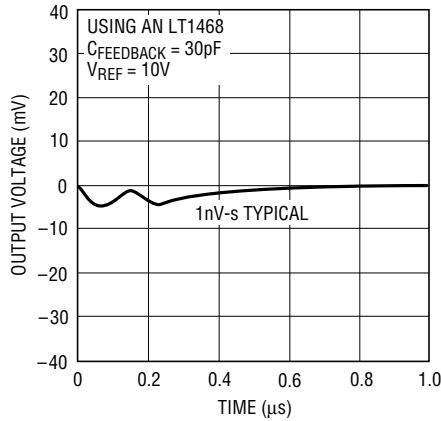
**Note 12:** Midscale transition code: 01 1111 1111 1111 to 10 0000 0000 0000 for the LTC1591/LTC1591-1 and 0111 1111 1111 1111 to 1000 0000 0000 0000 for the LTC1597/LTC1597-1.

**Note 13:** R1 and R2 are measured between R1 and  $R_{COM}$ , REF and  $R_{COM}$ .

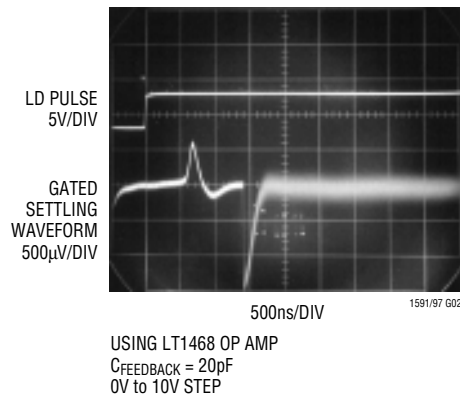
**Note 14:** Measured using the LT1468 op amp in unipolar mode for I/V converter and LT1468 I/V and LT1001 reference inverter in bipolar mode. Sample Rate = 50kHz, Signal Frequency = 1kHz,  $V_{REF} = 5V$ ,  $T_A = 25^\circ C$ .

# TYPICAL PERFORMANCE CHARACTERISTICS (LTC1591/LTC1597)

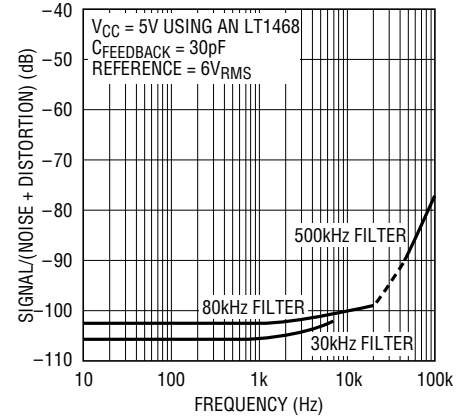
### Midscale Glitch Impulse



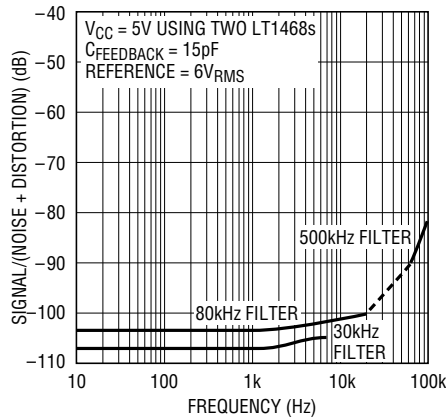
### Full-Scale Settling Waveform



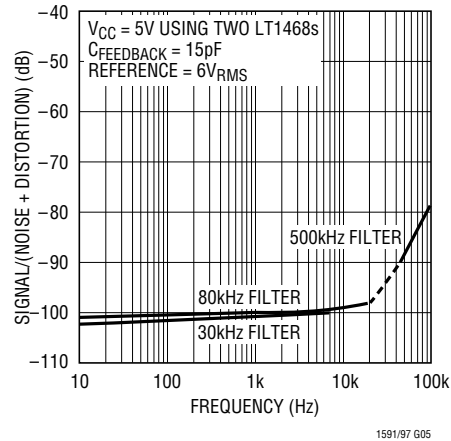
### Unipolar Multiplying Mode Signal-to-(Noise + Distortion) vs Frequency



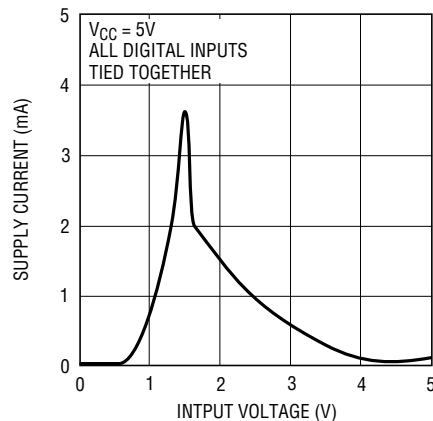
### Bipolar Multiplying Mode Signal-to-(Noise + Distortion) vs Frequency, Code = All Zeros



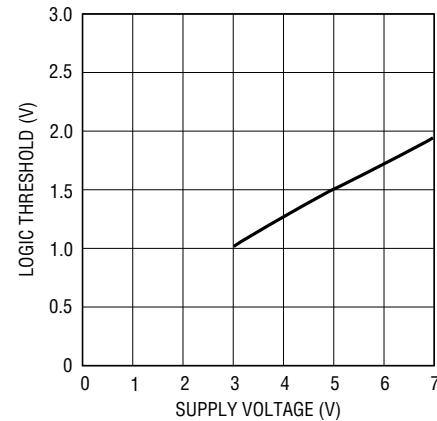
### Bipolar Multiplying Mode Signal-to-(Noise + Distortion) vs Frequency, Code = All Ones



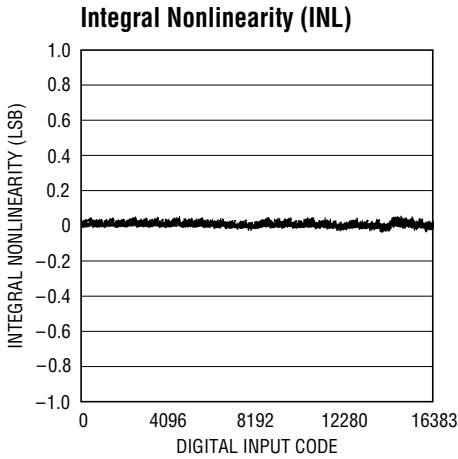
### Supply Current vs Input Voltage



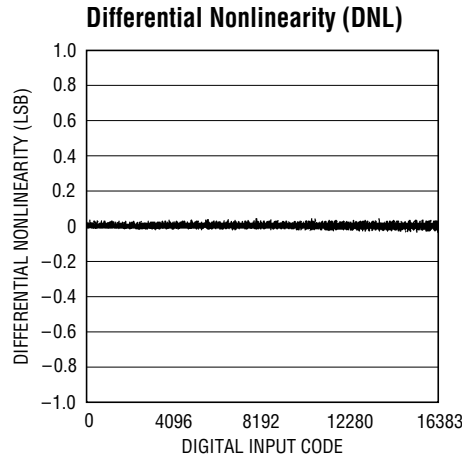
### Logic Threshold vs Supply Voltage



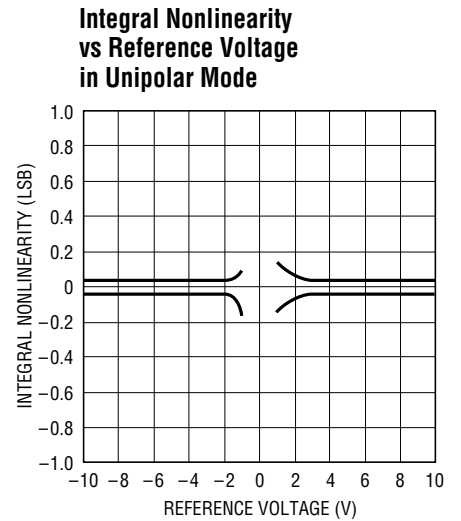
# TYPICAL PERFORMANCE CHARACTERISTICS (LTC1591)



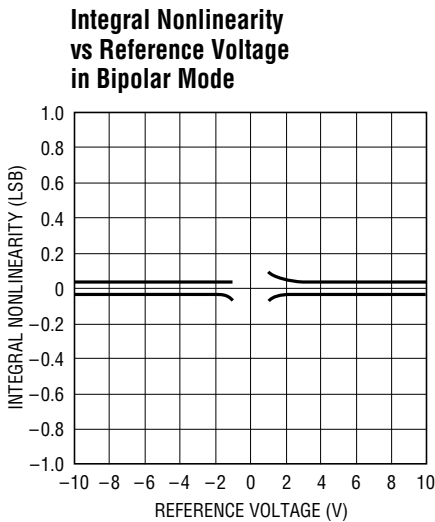
1591 G01



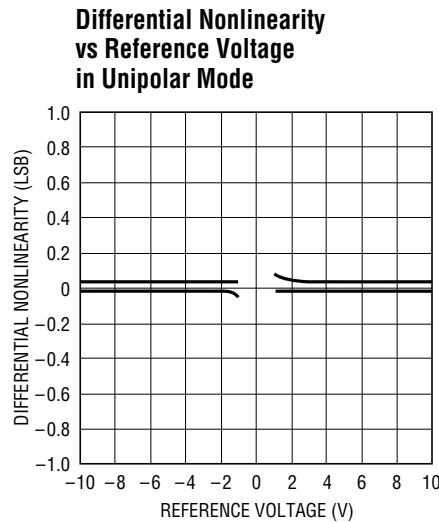
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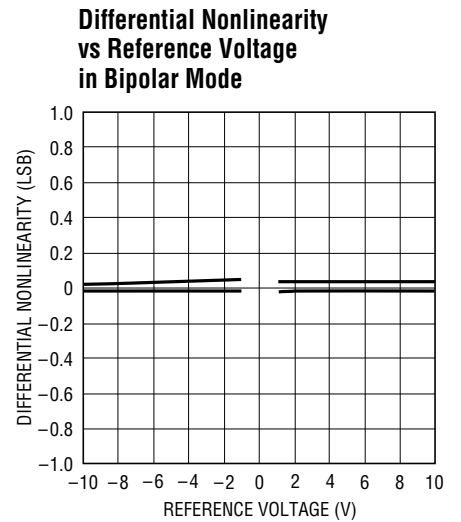
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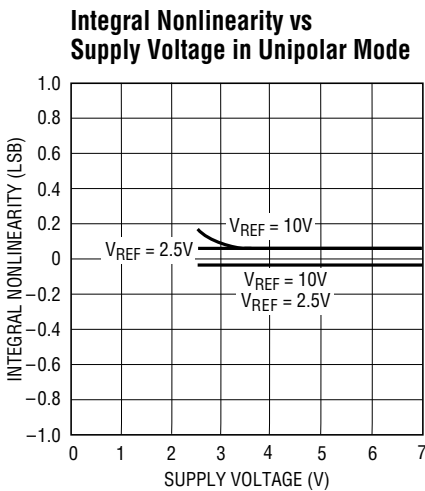
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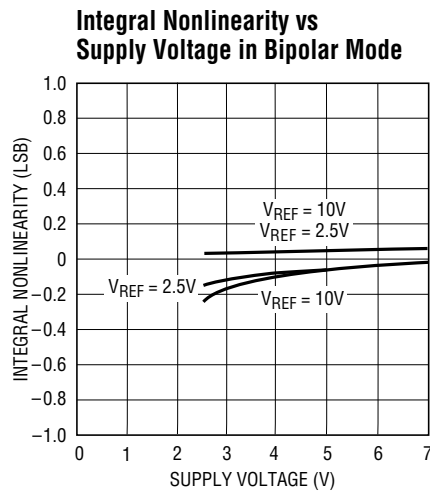
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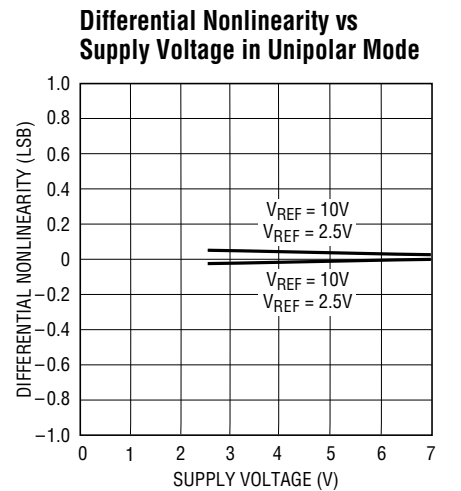
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1591 G07



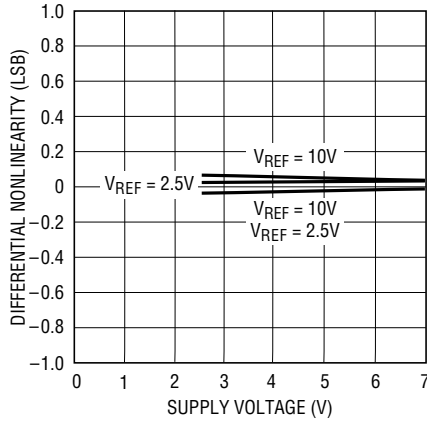
1591 G08



1591 G09  
15917fa

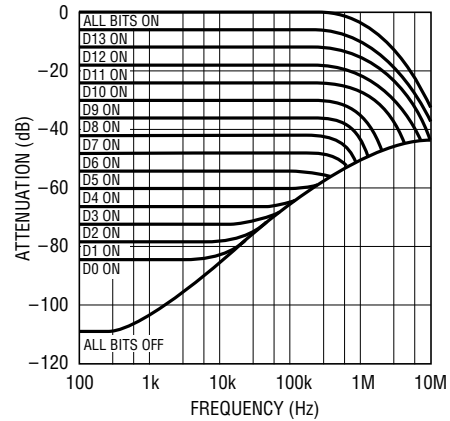
# TYPICAL PERFORMANCE CHARACTERISTICS (LTC1591)

### Differential Nonlinearity vs Supply Voltage in Bipolar Mode

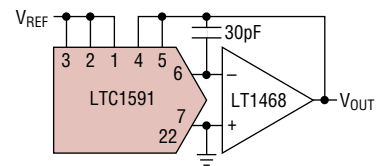


1591 G10

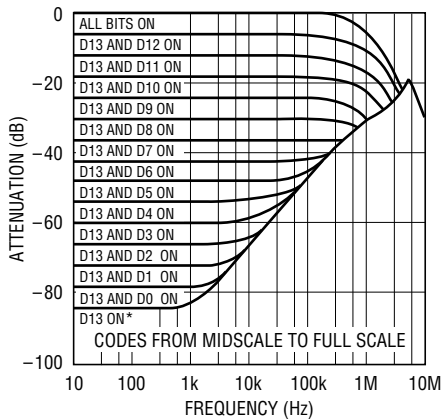
### Unipolar Multiplying Mode Frequency Response vs Digital Code



1591 G11

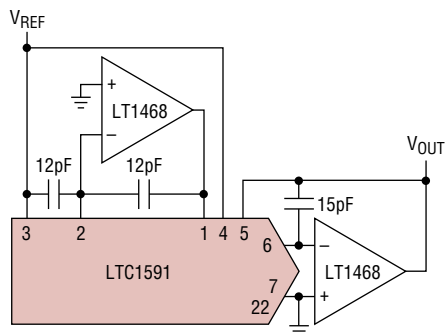


### Bipolar Multiplying Mode Frequency Response vs Digital Code

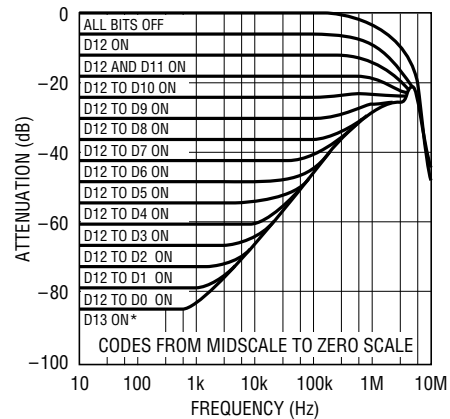


1591 G12

\*DAC ZERO VOLTAGE OUTPUT LIMITED BY BIPOLAR ZERO ERROR TO -84dB TYPICAL (-70dB MAX)

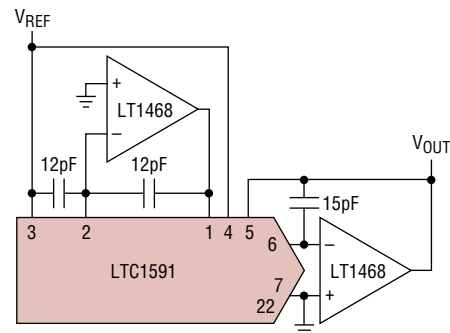


### Bipolar Multiplying Mode Frequency Response vs Digital Code



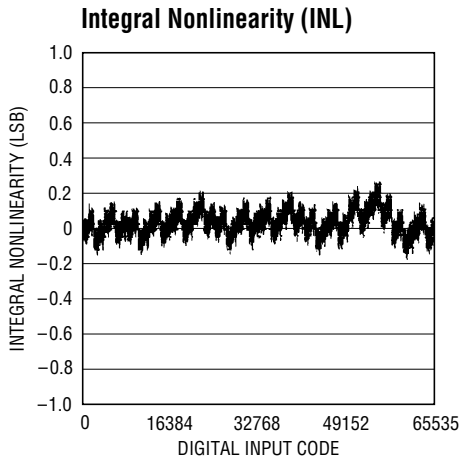
1591 G13

\*DAC ZERO VOLTAGE OUTPUT LIMITED BY BIPOLAR ZERO ERROR TO -84dB TYPICAL (-70dB MAX)

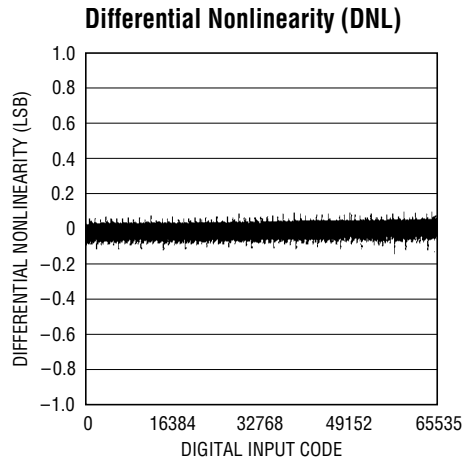


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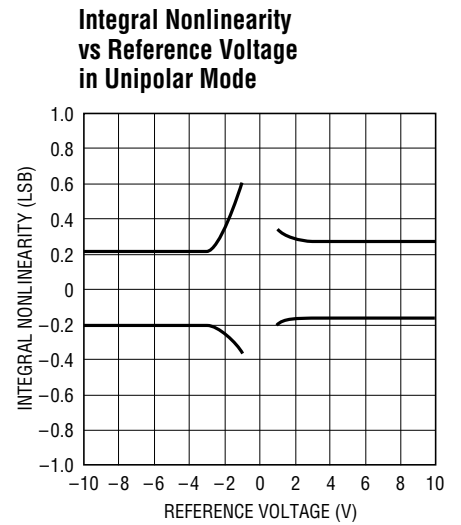
# TYPICAL PERFORMANCE CHARACTERISTICS (LTC1597)



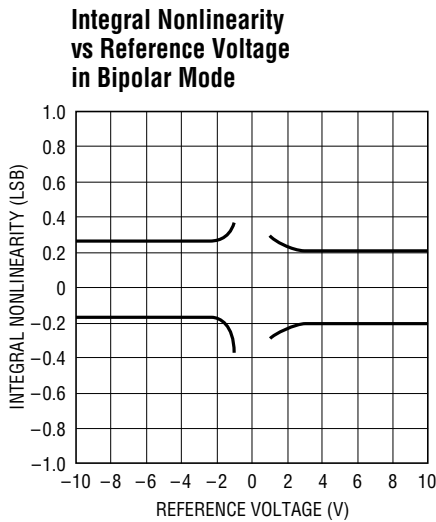
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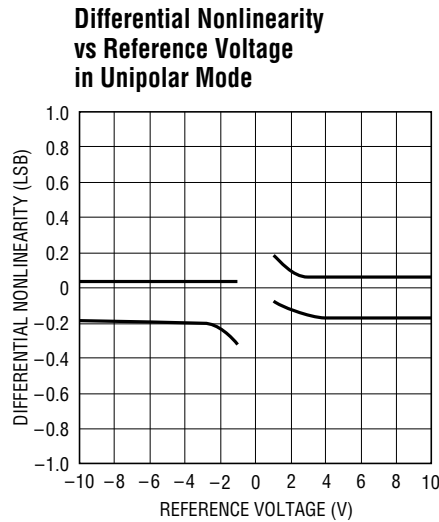
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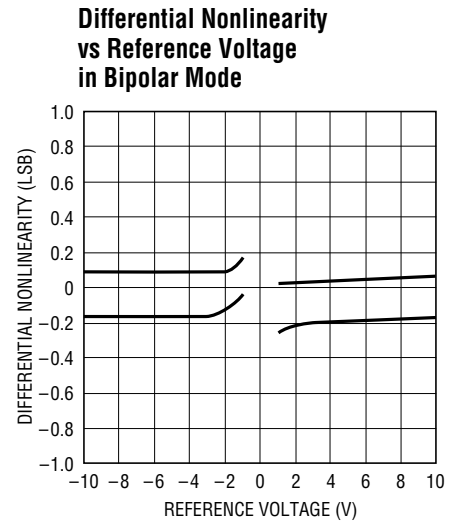
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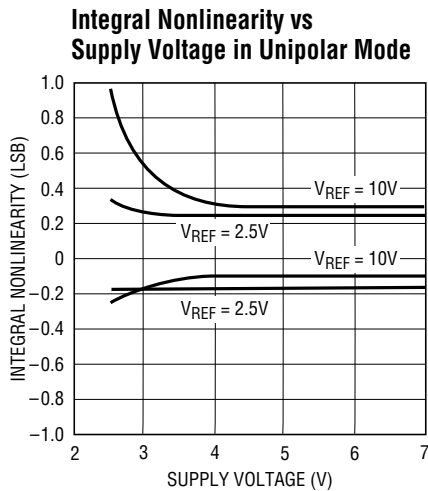
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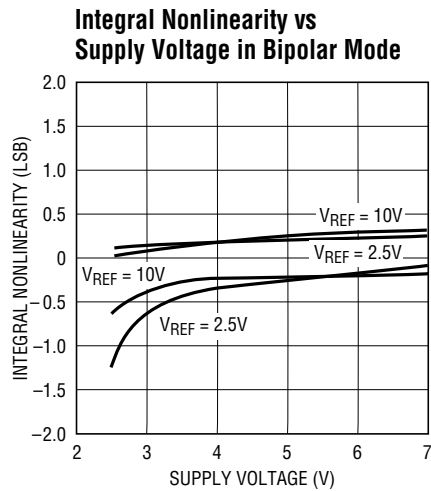
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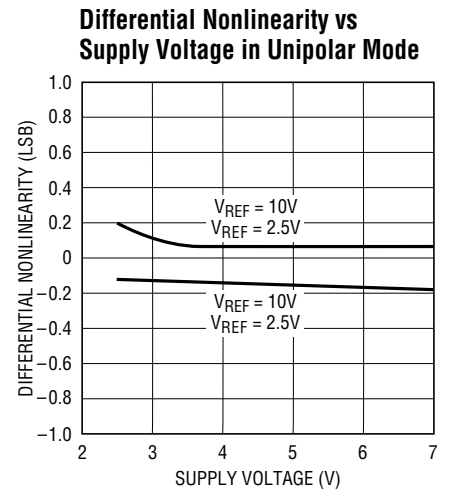
1597 G06



1597 G07



1597 G08

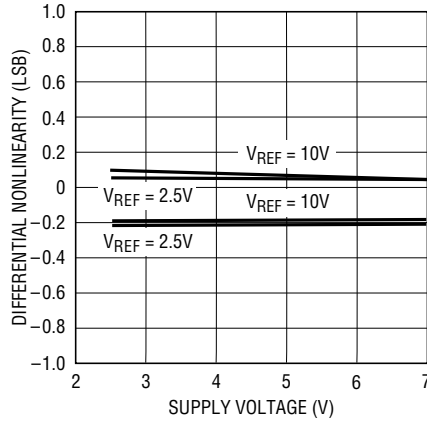


1597 G09  
15917fa



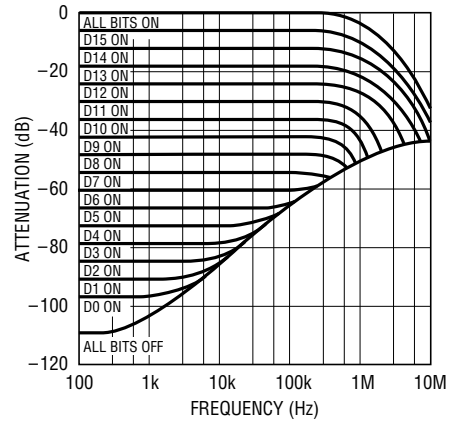
# TYPICAL PERFORMANCE CHARACTERISTICS (LTC1597)

## Differential Nonlinearity vs Supply Voltage in Bipolar Mode

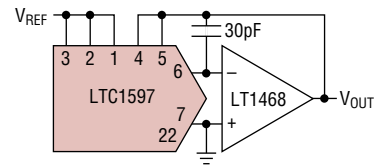


1597 G10

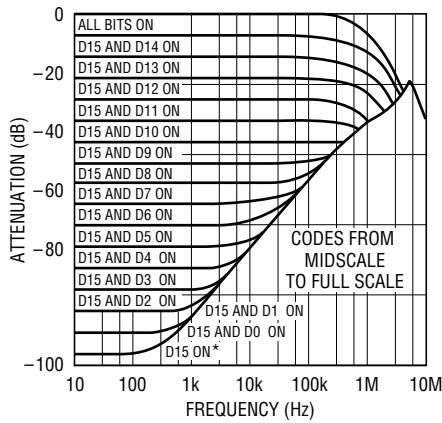
## Unipolar Multiplying Mode Frequency Response vs Digital Code



1597G11

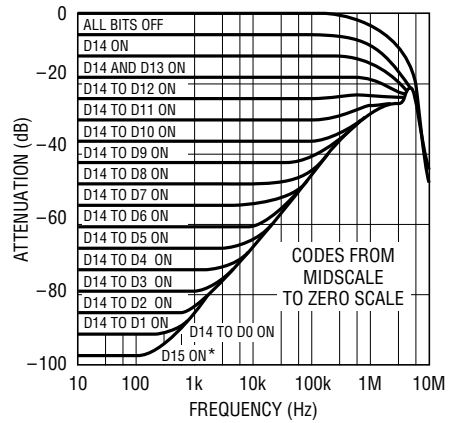


## Bipolar Multiplying Mode Frequency Response vs Digital Code



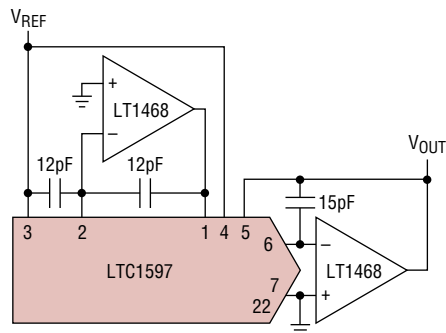
1597 G12

## Bipolar Multiplying Mode Frequency Response vs Digital Code

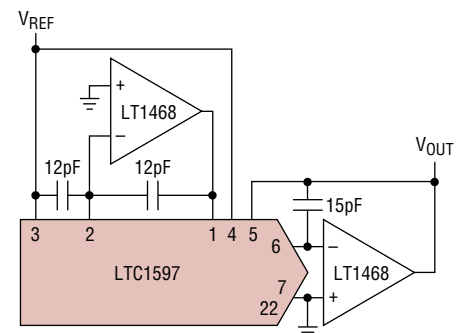


1597 G13

\*DAC ZERO VOLTAGE OUTPUT LIMITED BY BIPOLAR ZERO ERROR TO -96dB TYPICAL (-78dB MAX, A GRADE)



\*DAC ZERO VOLTAGE OUTPUT LIMITED BY BIPOLAR ZERO ERROR TO -96dB TYPICAL (-78dB MAX, A GRADE)



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## PIN FUNCTIONS

### LTC1591

**REF (Pin 1):** Reference Input and 4-Quadrant Resistor R2. Typically  $\pm 10V$ , accepts up to  $\pm 25V$ . In 2-Quadrant mode this is the reference input. In 4-quadrant mode, this pin is driven by external inverting reference amplifier.

**R<sub>COM</sub> (Pin 2):** Center Tap Point of the Two 4-Quadrant Resistors R1 and R2. Normally tied to the inverting input of an external amplifier in 4-quadrant operation, otherwise shorted to the REF pin. See Figures 1a and 2a.

**R1 (Pin 3):** 4-Quadrant Resistor R1. In 2-quadrant operation short to the REF pin. In 4-quadrant mode tie to R<sub>OFFS</sub> (Pin 4).

**R<sub>OFFS</sub> (Pin 4):** Bipolar Offset Resistor. Typically swings  $\pm 10V$ , accepts up to  $\pm 25V$ . In 2-quadrant operation tie to R<sub>FB</sub>. In 4-quadrant operation tie to R1.

**R<sub>FB</sub> (Pin 5):** Feedback Resistor. Normally tied to the output of the current to voltage converter op amp. Swings to  $\pm V_{REF}$ .  $V_{REF}$  is typically  $\pm 10V$ .

**I<sub>OUT1</sub> (Pin 6):** DAC Current Output. Tie to the inverting input of the current to voltage converter op amp.

**AGND (Pin 7):** Analog Ground. Tie to ground.

**LD (Pin 8):** DAC Digital Input Load Control Input. When LD is taken to a logic high, data is loaded from the input register into the DAC register, updating the DAC output.

**WR (Pin 9):** DAC Digital Write Control Input. When  $\overline{WR}$  is taken to a logic low, data is loaded from the digital input pins into the 14-bit wide input register.

**DB13 to D2 (Pins 10 to 21):** Digital Input Data Bits.

**DGND (Pin 22):** Digital Ground. Tie to ground.

**V<sub>CC</sub> (Pin 23):** The Positive Supply Input.  $4.5V \leq V_{CC} \leq 5.5V$ . Requires a bypass capacitor to ground.

**DB1, DB0 (Pins 24, 25):** Digital Input Data Bits.

**NC (Pins 26, 27):** No Connect.

**CLR (Pin 28):** Digital Clear Control Function for the DAC. When CLR is taken to a logic low, it sets the DAC output and all internal registers to zero code for the LTC1591 and midscale code for the LTC1591-1.

### LTC1597

**REF (Pin 1):** Reference Input and 4-Quadrant Resistor R2. Typically  $\pm 10V$ , accepts up to  $\pm 25V$ . In 2-Quadrant mode this is the reference input. In 4-quadrant mode, this pin is driven by external inverting reference amplifier.

**R<sub>COM</sub> (Pin 2):** Center Tap Point of the Two 4-Quadrant Resistors R1 and R2. Normally tied to the inverting input of an external amplifier in 4-quadrant operation, otherwise shorted to the REF pin. See Figures 1b and 2b.

**R1 (Pin 3):** 4-Quadrant Resistor R1. In 2-quadrant operation short to the REF pin. In 4-quadrant mode tie to R<sub>OFFS</sub> (Pin 4).

**R<sub>OFFS</sub> (Pin 4):** Bipolar Offset Resistor. Typically swings  $\pm 10V$ , accepts up to  $\pm 25V$ . In 2-quadrant operation tie to R<sub>FB</sub>. In 4-quadrant operation tie to R1.

**R<sub>FB</sub> (Pin 5):** Feedback Resistor. Normally tied to the output of the current to voltage converter op amp. Swings to  $\pm V_{REF}$ .  $V_{REF}$  is typically  $\pm 10V$ .

**I<sub>OUT1</sub> (Pin 6):** DAC Current Output. Tie to the inverting input of the current to voltage converter op amp.

**AGND (Pin 7):** Analog Ground. Tie to ground.

**LD (Pin 8):** DAC Digital Input Load Control Input. When LD is taken to a logic high, data is loaded from the input register into the DAC register, updating the DAC output.

**WR (Pin 9):** DAC Digital Write Control Input. When  $\overline{WR}$  is taken to a logic low, data is loaded from the digital input pins into the 16-bit wide input register.

**DB15 to D4 (Pins 10 to 21):** Digital Input Data Bits.

**DGND (Pin 22):** Digital Ground. Tie to ground.

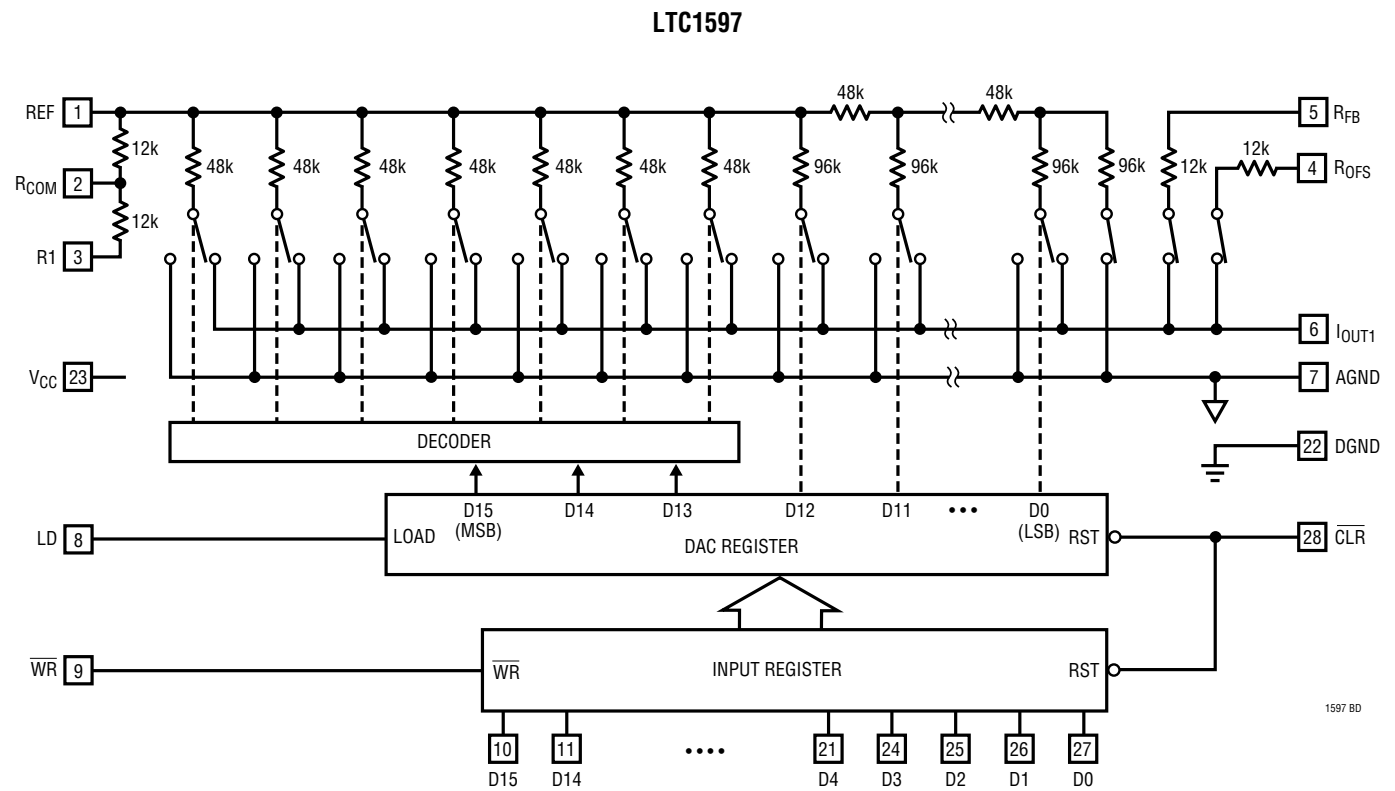
**V<sub>CC</sub> (Pin 23):** The Positive Supply Input.  $4.5V \leq V_{CC} \leq 5.5V$ . Requires a bypass capacitor to ground.

**DB3 to DB0 (Pins 24 to 27):** Digital Input Data Bits.

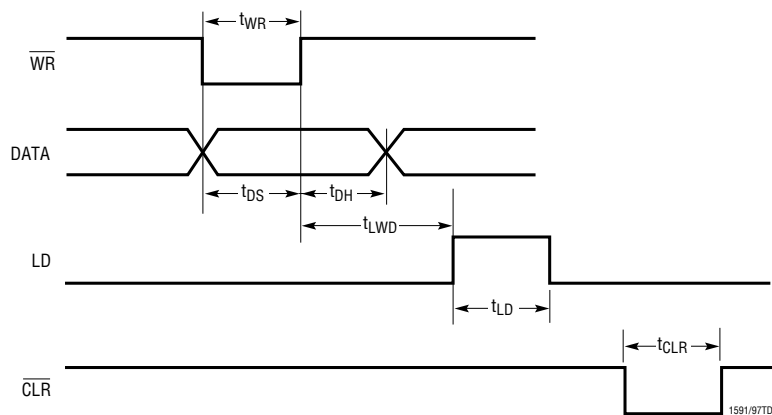
**CLR (Pin 28):** Digital Clear Control Function for the DAC. When CLR is taken to a logic low, it sets the DAC output and all internal registers to zero code for the LTC1597 and midscale code for the LTC1597-1.



BLOCK DIAGRAMS



TIMING DIAGRAM



## APPLICATIONS INFORMATION

### Description

The LTC1591/LTC1597 are 14-/16-bit multiplying, current output DACs with a full parallel 14-/16-bit digital interface. The devices operate from a single 5V supply and provide both unipolar 0V to  $-10\text{V}$  or 0V to  $10\text{V}$  and bipolar  $\pm 10\text{V}$  output ranges from a  $10\text{V}$  or  $-10\text{V}$  reference input. They have three additional precision resistors on chip for bipolar operation. Refer to the block diagrams regarding the following description.

The 14-/16-bit DACs consist of a precision R-2R ladder for the 11/13LSBs. The 3MSBs are decoded into seven segments of resistor value R. Each of these segments and the R-2R ladder carries an equally weighted current of one eighth of full scale. The feedback resistor  $R_{FB}$  and 4-quadrant resistor  $R_{OFS}$  have a value of  $R/4$ . 4-quadrant resistors R1 and R2 have a magnitude of  $R/4$ . R1 and R2 together with an external op amp (see Figure 2) invert the reference input voltage and applies it to the 14-/16-bit DAC input REF, in 4-quadrant operation. The REF pin presents a constant input impedance of  $R/8$  in unipolar mode and  $R/12$  in bipolar mode. The output impedance of the current output pin  $I_{OUT1}$  varies with DAC input code. The  $I_{OUT1}$  capacitance due to the NMOS current steering switches also varies with input code from 70pF to 115pF. An added feature of these devices, especially for waveform generation, is a proprietary deglitcher that reduces glitch energy to below 2nV-s over the DAC output voltage range.

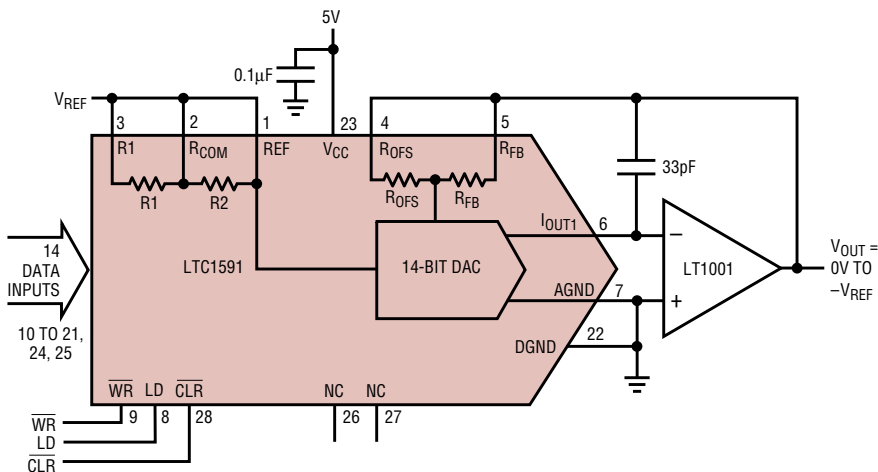
### Digital Section

The LTC1591/LTC1597 are 14-/16-bit wide full parallel data bus inputs. The devices are double-buffered with two 14-/16-bit registers. The double-buffered feature permits the update of several DACs simultaneously. The input register is loaded directly from a 16-bit microprocessor bus when the  $\overline{\text{WR}}$  pin is brought to a logic low level. The second register (DAC register) is updated with the data from the input register when the  $\overline{\text{LD}}$  pin is brought to a logic high level. Updating the DAC register updates the DAC output with the new data. To make both registers transparent for flowthrough mode, tie  $\overline{\text{WR}}$  low and  $\overline{\text{LD}}$  high. However, this defeats the deglitcher operation and output glitch impulse may increase. The deglitcher is activated on the rising edge of the  $\overline{\text{LD}}$  pin. The versatility of the interface also allows the use of the input and DAC registers in a master slave or edge-triggered configuration. This mode of operation occurs when  $\overline{\text{WR}}$  and  $\overline{\text{LD}}$  are tied together. The asynchronous clear pin resets the LTC1591/LTC1597 to zero scale and the LTC1591-1/LTC1597-1 to midscale.  $\overline{\text{CLR}}$  resets both the input and DAC registers. These devices also have a power-on reset. Table 1 shows the truth table for the LTC1591/LTC1597.

### Unipolar Mode

#### (2-Quadrant Multiplying, $V_{OUT} = 0\text{V}$ to $-V_{REF}$ )

The LTC1591/LTC1597 can be used with a single op amp to provide 2-quadrant multiplying operation as shown in Figure 1. With a fixed  $-10\text{V}$  reference, the circuits shown give a precision unipolar 0V to  $10\text{V}$  output swing.



Unipolar Binary Code Table

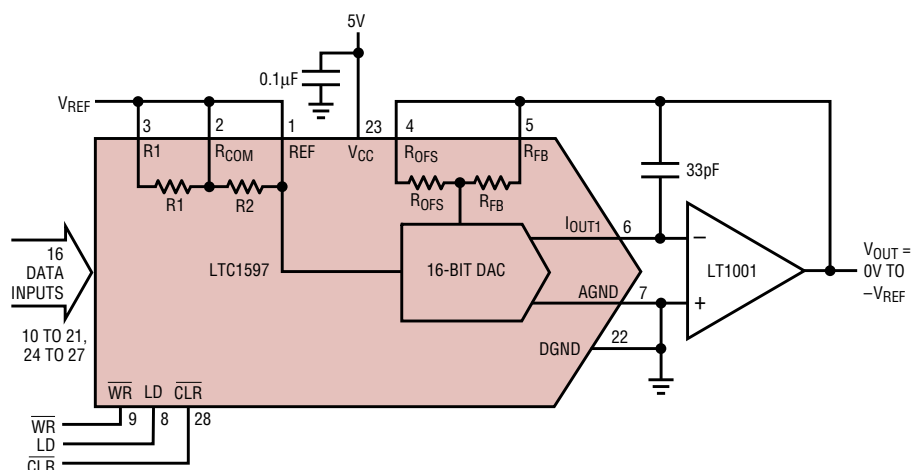
DIGITAL INPUT BINARY NUMBER IN DAC REGISTER				ANALOG OUTPUT $V_{OUT}$
MSB		LSB		
1111	1111	1111	11	$-V_{REF}$ (16,383/16,384)
1000	0000	0000	00	$-V_{REF}$ (8,192/16,384) = $-V_{REF}/2$
0000	0000	0000	01	$-V_{REF}$ (1/16,384)
0000	0000	0000	00	0V

1591/97 F01a

Figure 1a. Unipolar Operation (2-Quadrant Multiplication)  $V_{OUT} = 0\text{V}$  to  $-V_{REF}$

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## APPLICATIONS INFORMATION



**Figure 1b. Unipolar Operation (2-Quadrant Multiplication)  $V_{OUT} = 0V$  to  $-V_{REF}$**

DIGITAL INPUT BINARY NUMBER IN DAC REGISTER				ANALOG OUTPUT V <sub>OUT</sub>
MSB			LSB	
1111	1111	1111	1111	-V <sub>REF</sub> (65,535/65,536)
1000	0000	0000	0000	-V <sub>REF</sub> (32,768/65,536) = -V <sub>REF</sub> /2
0000	0000	0000	0001	-V <sub>REF</sub> (1/65,536)
0000	0000	0000	0000	0V

## Bipolar Mode

**(4-Quadrant Multiplying,  $V_{OUT} = -V_{REF}$  to  $V_{REF}$ )**

The LTC1591/LTC1597 contain on chip all the 4-quadrant resistors necessary for bipolar operation. 4-quadrant multiplying operation can be achieved with a minimum of external components, a capacitor and a dual op amp, as shown in Figure 2. With a fixed 10V reference, the circuit shown gives a precision bipolar  $-10\text{V}$  to  $10\text{V}$  output swing.

## Op Amp Selection

Because of the extremely high accuracy of the 14-/16-bit LTC1591/LTC1597, thought should be given to op amp selection in order to achieve the exceptional performance of which the part is capable. Fortunately, the sensitivity of INL and DNL to op amp offset has been greatly reduced compared to previous generations of multiplying DACs.

Op amp offset will contribute mostly to output offset and gain and will have minimal effect on INL and DNL. For the LTC1597, a 500 $\mu$ V op amp offset will cause about 0.55LSB INL degradation and 0.15LSB DNL degradation with a 10V full-scale range. The main effects of op amp offset will be a degradation of zero-scale error equal to the op amp

offset, and a degradation of full-scale error equal to twice the op amp offset. For the LTC1597, the same 500 $\mu$ V op amp offset (2mV offset for LTC1591) will cause a 3.3LSB zero-scale error and a 6.5LSB full-scale error with a 10V full-scale range.

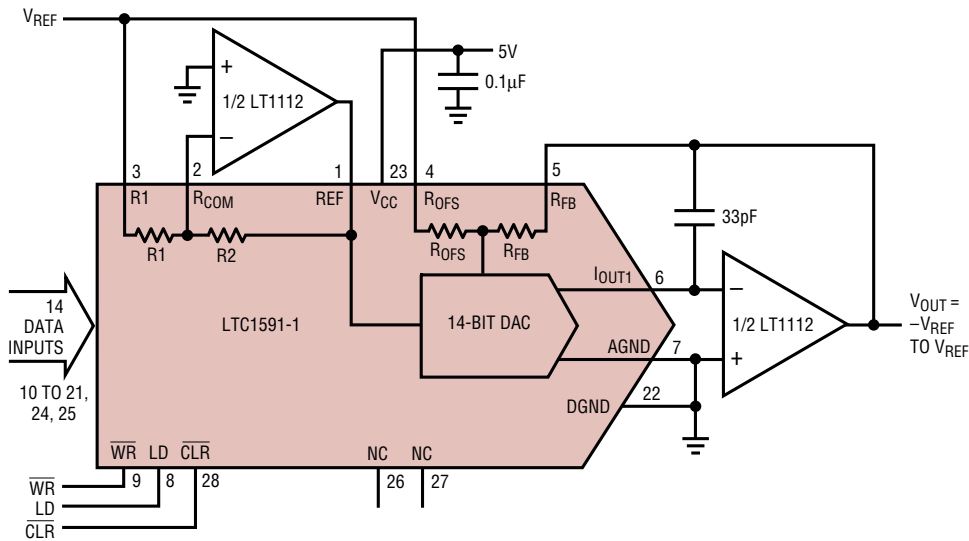
Op amp input bias current ( $I_{BIAS}$ ) contributes only a zero-scale error equal to  $I_{BIAS}(R_{FB}/R_{OFS}) = I_{BIAS}(6k)$ . For a thorough discussion of 16-bit DAC settling time and op amp selection, refer to Application Note 74, “*Component and Measurement Advances Ensure 16-Bit DAC Settling Time*.”

## Reference Input and Grounding

For optimum performance the reference input of the LTC1597 should be driven by a source impedance of less than 1k $\Omega$ . However, these DACs have been designed to minimize source impedance effects. An 8k $\Omega$  source impedance degrades both INL and DNL by 0.2LSB.

As with any high resolution converter, clean grounding is important. A low impedance analog ground plane and star grounding should be used. AGND must be tied to the star ground with as low a resistance as possible.

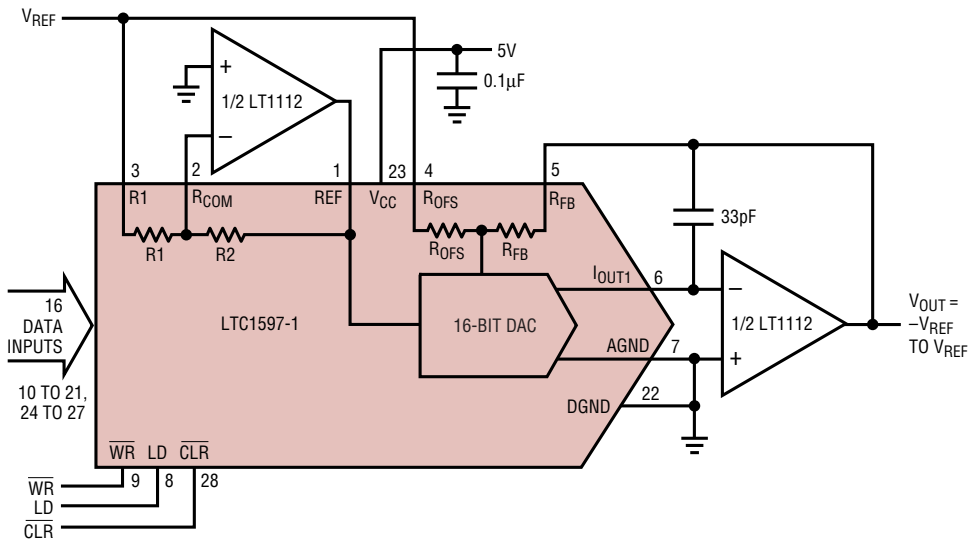
## APPLICATIONS INFORMATION



Bipolar Offset Binary Code Table

DIGITAL INPUT BINARY NUMBER IN DAC REGISTER				ANALOG OUTPUT $V_{OUT}$
MSB			LSB	
1111	1111	1111	11	$V_{REF}$ (8,191/8,192)
1000	0000	0000	01	$V_{REF}$ (1/8,192)
1000	0000	0000	00	0V
0111	1111	1111	11	$-V_{REF}$ (1/8,192)
0000	0000	0000	00	$-V_{REF}$

1591/97 F02a

Figure 2a. Bipolar Operation (4-Quadrant Multiplication)  $V_{OUT} = -V_{REF}$  to  $V_{REF}$ 

Bipolar Offset Binary Code Table

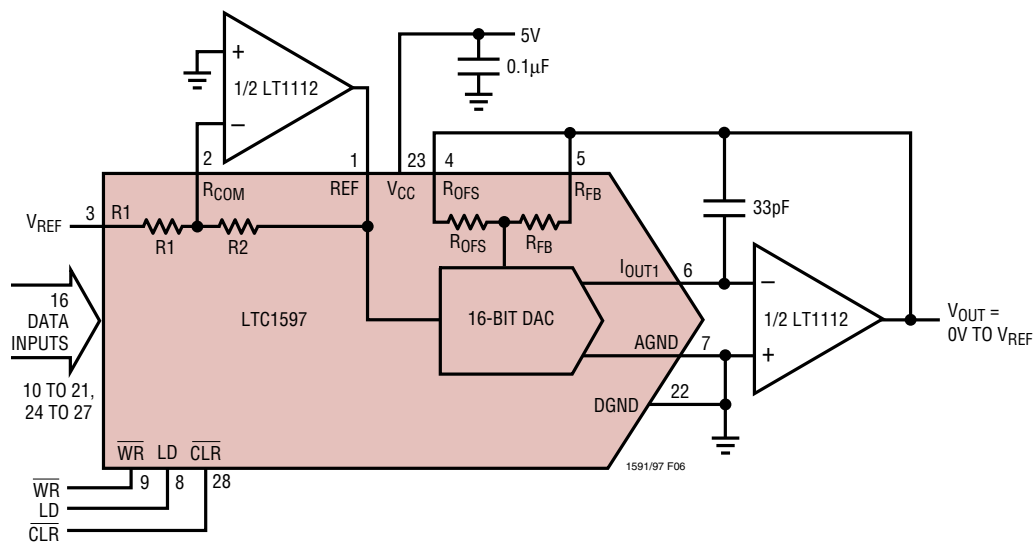
DIGITAL INPUT BINARY NUMBER IN DAC REGISTER				ANALOG OUTPUT $V_{OUT}$
MSB			LSB	
1111	1111	1111	1111	$V_{REF}$ (32,767/32,768)
1000	0000	0000	0001	$V_{REF}$ (1/32,768)
1000	0000	0000	0000	0V
0111	1111	1111	1111	$-V_{REF}$ (1/32,768)
0000	0000	0000	0000	$-V_{REF}$

1591/97 F02b

Figure 2b. Bipolar Operation (4-Quadrant Multiplication)  $V_{OUT} = -V_{REF}$  to  $V_{REF}$

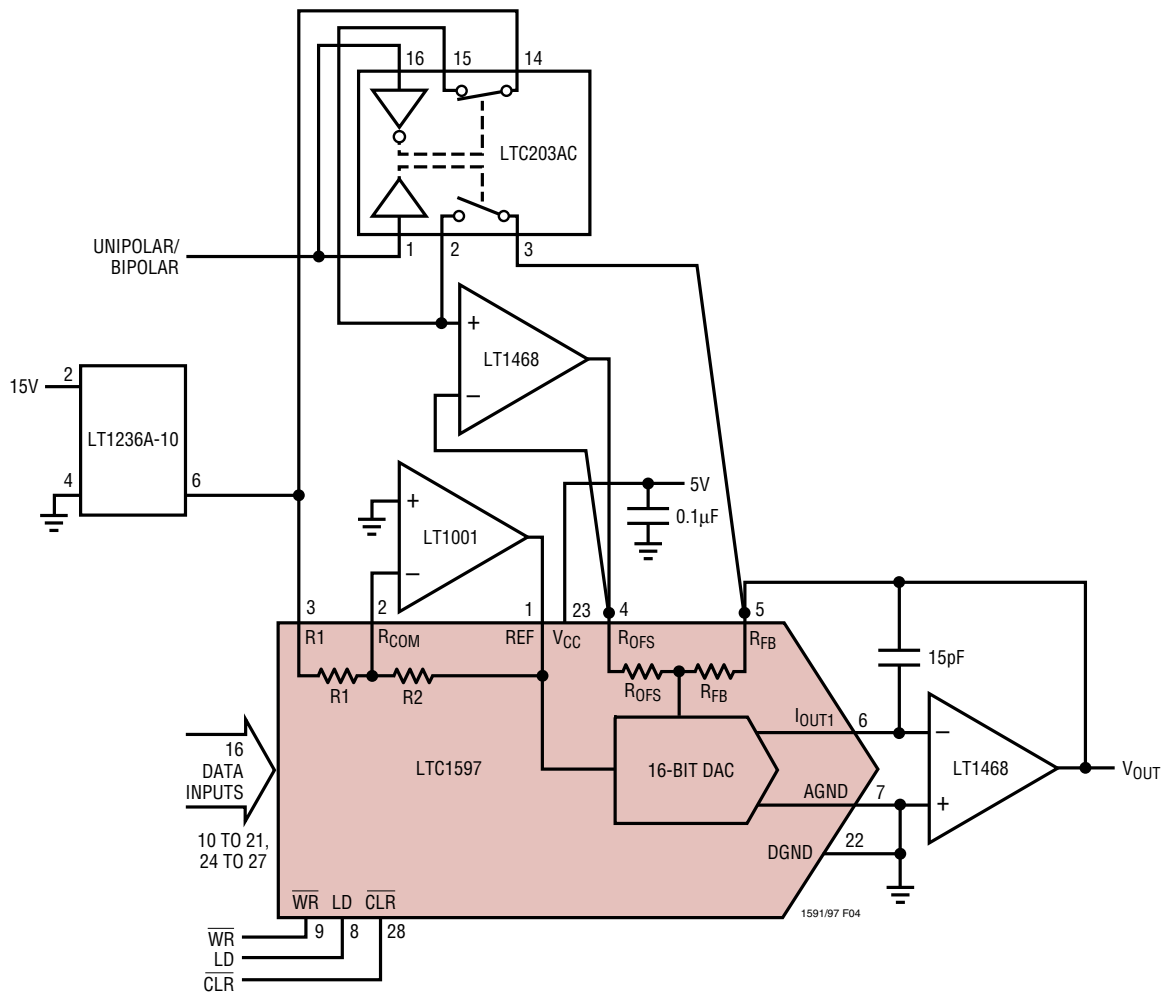
TYPICAL APPLICATIONS

Noninverting Unipolar Operation (2-Quadrant Multiplication)  $V_{OUT} = 0V$  to  $V_{REF}$





## TYPICAL APPLICATIONS

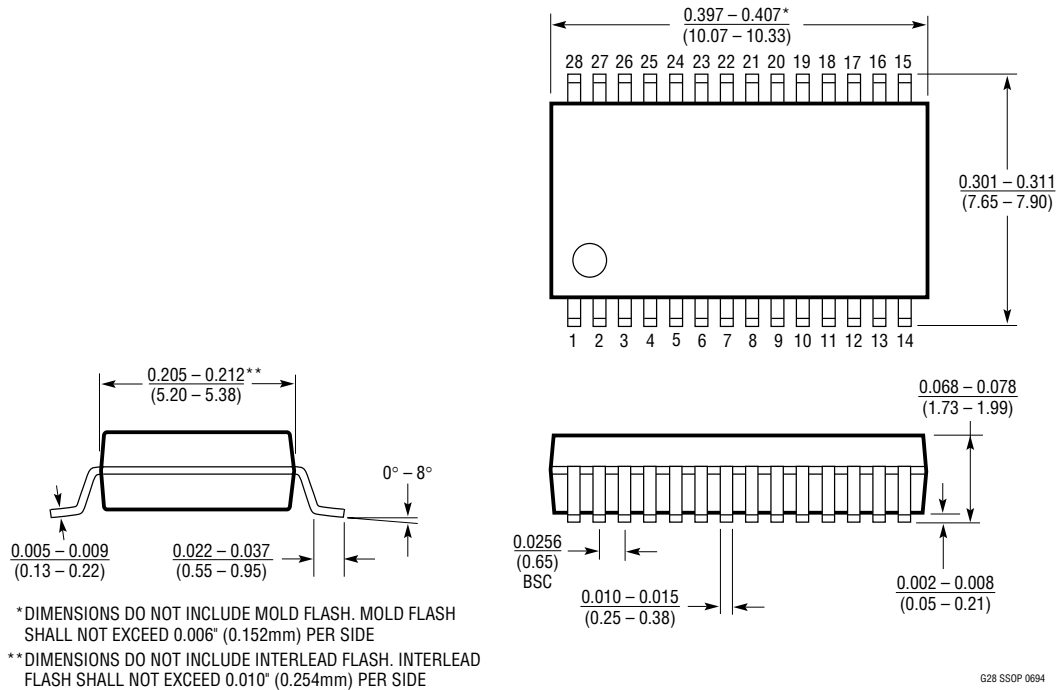
16-Bit  $V_{OUT}$  DAC Programmable Unipolar/Bipolar Configuration



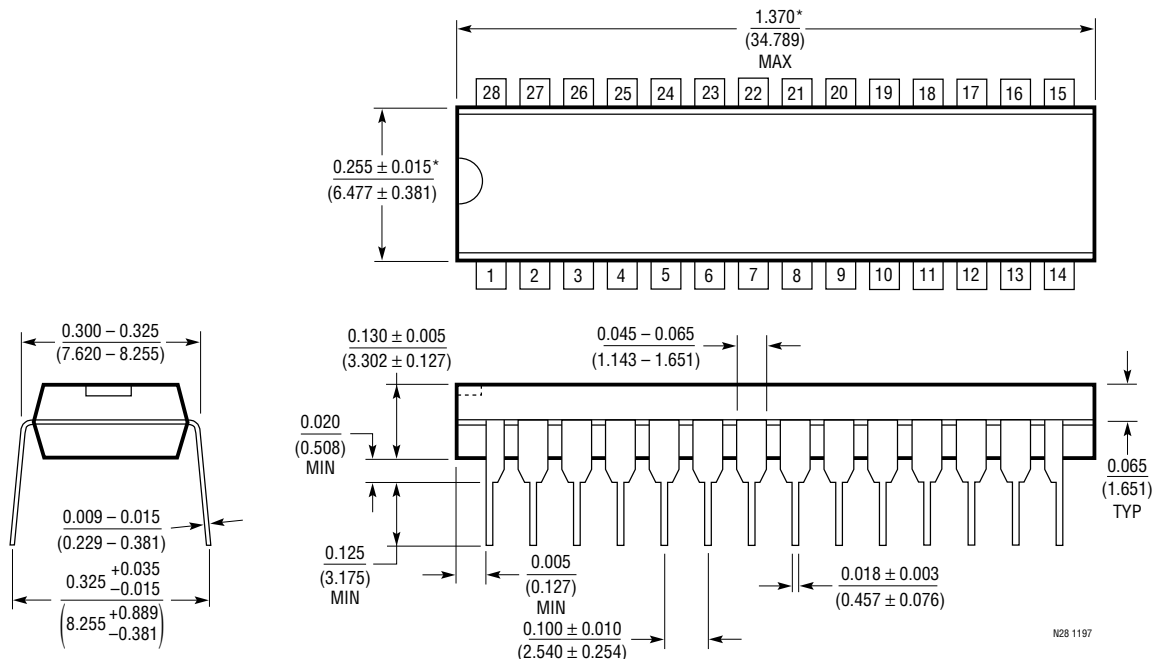
**PACKAGE DESCRIPTION**

Dimensions in inches (millimeters) unless otherwise noted.

**G Package**  
**28-Lead Plastic SSOP (0.209)**  
 (LTC DWG # 05-08-1640)

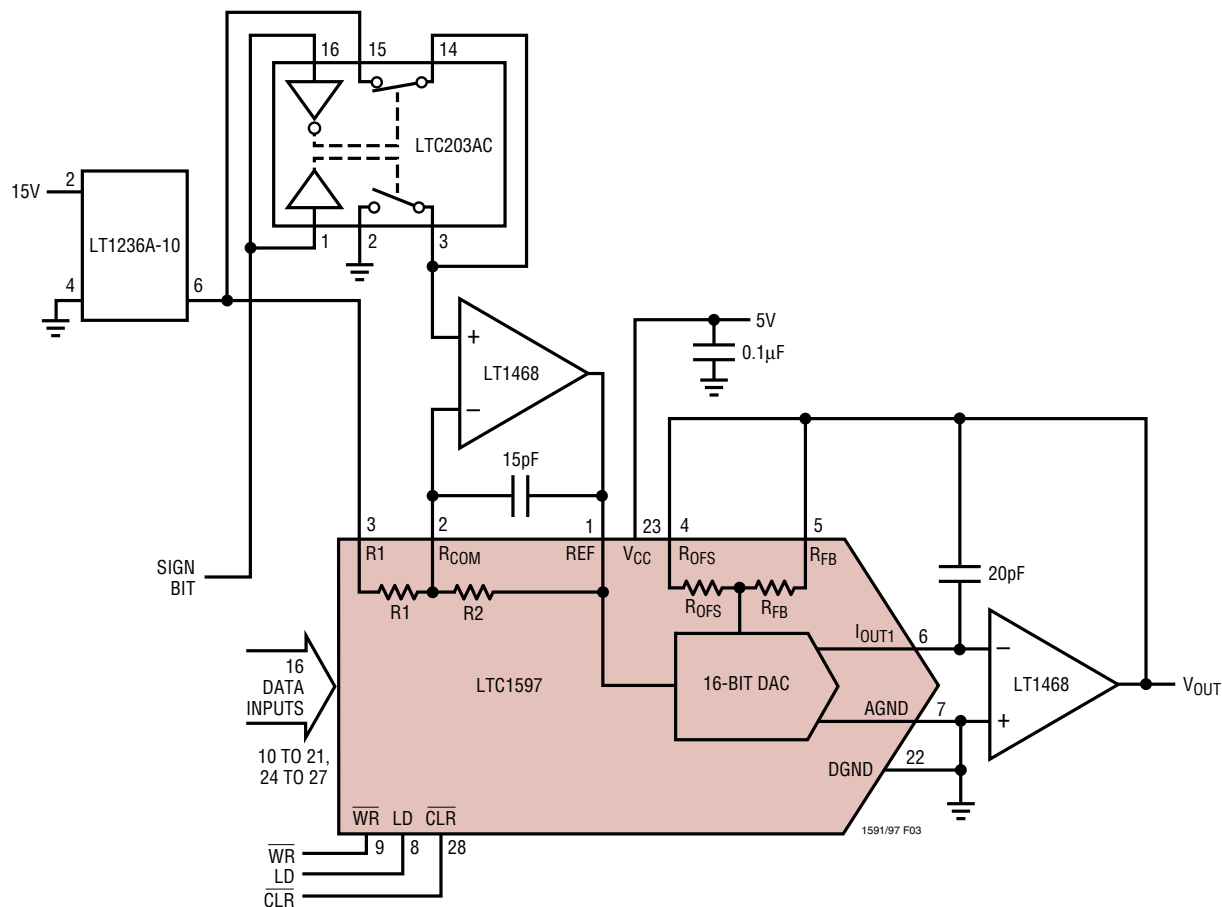


**N Package**  
**28-Lead PDIP (Narrow 0.300)**  
 (LTC DWG # 05-08-1510)



TYPICAL APPLICATION

17-Bit Sign Magnitude DAC with Bipolar Zero Error of 140µV (0.92LSB at 17 Bits) at 25°C



RELATED PARTS

PART NUMBER		DESCRIPTION	COMMENTS
Op Amps	LT1001	Precision Operational Amplifier	Low Offset, Low Drift
	LT1112	Dual Low Power, Precision Picoamp Input Op Amp	Low Offset, Low Drift
	LT1468	90MHz, 22V/µs, 16-Bit Accurate Op Amp	Precise, 1µs Settling to 0.0015%
DACs	LTC1595/LTC1596	Serial 16-Bit Current Output DACs	Low Glitch, ±1LSB Maximum INL, DNL
	LTC1650	Serial 16-Bit Voltage Output DAC	Low Noise and Glitch Rail-to-Rail VOUT
	LTC1658	Serial 14-Bit Voltage Output DAC	Low Power, 8-Lead MSOP Rail-to-Rail VOUT
ADCs	LTC1418	14-Bit, 200ksps 5V Sampling ADC	16mW Dissipation, Serial and Parallel Outputs
	LTC1604	16-Bit, 333ksps Sampling ADC	±2.5V Input, SINAD = 90dB, THD = 100dB
	LTC1605	Single 5V, 16-Bit 100ksps ADC	Low Power, ±10V Inputs
References	LT1236	Precision Reference	Ultralow Drift, 5ppm/°C, High Accuracy 0.05%