



# 14-Bit, 260MSPS High-Dynamic Performance DAC

MAX5195

## General Description

The MAX5195 is an advanced, 14-bit, 260MSPS digital-to-analog converter (DAC) designed to meet the demanding performance requirements of signal synthesis applications found in wireless base stations and other communication systems. Operating from a single 5V supply, this DAC offers exceptional dynamic performance such as 77dBc spurious-free dynamic range (SFDR) at  $f_{OUT} = 19.4\text{MHz}$ , while supporting update rates beyond 260MSPS.

The MAX5195 current-source array architecture supports a full-scale current range of 10mA to 20mA, which allows a differential output voltage swing between 0.5V<sub>P-P</sub> and 1V<sub>P-P</sub>.

The MAX5195 features an integrated 1.2V bandgap reference and control amplifier to ensure high accuracy and low-noise performance. Additionally, a separate reference input pin allows the user to apply an external reference source for optimum flexibility.

The digital and clock inputs of the MAX5195 are designed for differential LVPECL-compatible voltage levels.

The MAX5195 is available in a 48-lead QFN package with exposed paddle and is specified for the extended industrial temperature range (-40°C to +85°C).

## Applications

- Base Stations:
  - Single-/Multi-Carrier UMTS, GSM
- LMDS, MMDS, Point-to-Point Microwave
- Direct IF Synthesis
- Digital-Signal Synthesis
- Broadband Cable Systems
- Automated Test Equipment
- Instrumentation

## Features

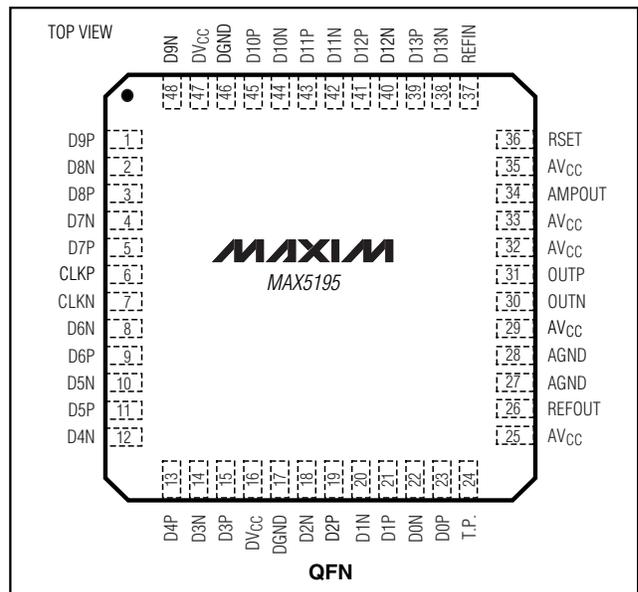
- ◆ 260MSPS Output Update Rate
- ◆ Excellent SFDR Performance
  - To Nyquist (-12dBFS)
  - At 19.4MHz Output = 77dBc
  - At 51.6MHz Output = 76dBc
- ◆ Industry-Leading IMD Performance
  - For 4 Tones (-15dBFS)
  - At 18MHz Output = 86dBc
  - At 31MHz Output = 84dBc
- ◆ Low Noise Performance
  - SNR = 160dB/Hz at  $f_{OUT} = 19.4\text{MHz}$
- ◆ On-Chip 1.2V Bandgap Reference
- ◆ 20mA Full-Scale Current
- ◆ Single 5V Supply
- ◆ Differential LVPECL-Compatible Digital Inputs
- ◆ 48-Lead QFN-EP Package

## Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
MAX5195EGM	-40°C to +85°C	48 QFN-EP*

\*EP = Exposed paddle.

## Pin Configuration



# 14-Bit, 260Msps High-Dynamic Performance DAC

## ABSOLUTE MAXIMUM RATINGS

AV <sub>CC</sub> , DV <sub>CC</sub> to AGND	-0.3V to +6V
AV <sub>CC</sub> , DV <sub>CC</sub> to DGND	-0.3V to +6V
AGND to DGND	-0.3V to +0.3V
D0N–D013, D0P–D13P, T.P. to DGND	-0.3V to +3.6V
OUTP, OUTN, AMPOUT, REFOUT, CLKP, CLKN, RSET to AGND	-0.3V to +6V
REFIN Voltage Range	-0.3V to +6V

Continuous Power Dissipation (T <sub>A</sub> = +70°C) 48-Pin QFN-EP (thermal resistance $\theta_{JA}$ = +37°C/W)	2162W
Operating Temperature Range	-40°C to +85°C
Junction Temperature	+150°C
Storage Temperature Range	-60°C to +150°C
Lead Temperature (soldering, 10s)	+300°C

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## ELECTRICAL CHARACTERISTICS

(AV<sub>CC</sub> = DV<sub>CC</sub> = 5V, AGND = DGND = 0, external reference V<sub>REFIN</sub> = 1.196V, R<sub>T</sub> = 27.4Ω referenced to AV<sub>CC</sub>, V<sub>OUT</sub> = 1V<sub>P-P</sub>, R<sub>SET</sub> = 3.83kΩ, f<sub>CLK</sub> = 156MHz, T<sub>A</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>, unless otherwise noted. Typical values are at T<sub>A</sub> = +25°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>STATIC PERFORMANCE</b>						
Resolution				14		LSB
Integral Nonlinearity	INL	Best-straight-line fit		±2		LSB
Differential Nonlinearity	DNL	T <sub>A</sub> = +25°C	-3.3	±1.5	+3.0	LSB
Offset Error	V <sub>OS</sub>	(Note 1)		0.05	0.1	%FS
Full-Scale Gain Error (Note 2)	GE	Internal reference		2.5	6	%FS
		External reference		1.6	4	
<b>DYNAMIC PERFORMANCE</b>						
Maximum Throughput Rate	f <sub>CLK</sub>		260			MHz
Signal-to-Noise Ratio	SNR	Full-scale output, within Nyquist window, f <sub>CLK</sub> = 260MHz, f <sub>OUT</sub> = 19.4MHz		160		dB/Hz
Spurious-Free Dynamic Range to Nyquist, -12dBFS	SFDR	f <sub>CLK</sub> = 156MHz	f <sub>OUT</sub> = 1MHz, -2dBFS	89		dBc
			f <sub>OUT</sub> = 19.42MHz	77		
		f <sub>CLK</sub> = 260MHz	f <sub>OUT</sub> = 51.67MHz	76		
			f <sub>OUT</sub> = 19.4MHz	74		
Spurious-Free Dynamic Range ±10MHz Window, -12dBFS	SFDR	f <sub>CLK</sub> = 156MHz	f <sub>OUT</sub> = 19.42MHz	82		dBc
			f <sub>OUT</sub> = 51.67MHz	75		
		f <sub>CLK</sub> = 260MHz	f <sub>OUT</sub> = 19.42MHz	82		
			f <sub>OUT</sub> = 51.61MHz	76		
2nd-Order Harmonic Distortion, -12dBFS	HD2	f <sub>CLK</sub> = 156MHz	f <sub>OUT</sub> = 1.27MHz	-88		dBc
			f <sub>OUT</sub> = 9.53MHz	-86		
			f <sub>OUT</sub> = 19.42MHz	-82		
			f <sub>OUT</sub> = 28.82MHz	-79		
			f <sub>OUT</sub> = 38.42MHz	-77		
		f <sub>OUT</sub> = 51.67MHz	-79			
		f <sub>CLK</sub> = 260MHz	f <sub>OUT</sub> = 70.05MHz	-72		

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## ELECTRICAL CHARACTERISTICS (continued)

( $V_{CC} = DV_{CC} = 5V$ ,  $AGND = DGND = 0$ , external reference  $V_{REFIN} = 1.196V$ ,  $R_T = 27.4\Omega$  referenced to  $V_{CC}$ ,  $V_{OUT} = 1V_{P-P}$ ,  $R_{SET} = 3.83k\Omega$ ,  $f_{CLK} = 156MHz$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ C$ .)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
3rd-Order Harmonic Distortion, -12dBFS	HD3	$f_{CLK} = 156MHz$	$f_{OUT} = 1.27MHz$		-90		dBc
			$f_{OUT} = 9.53MHz$		-85		
			$f_{OUT} = 19.42MHz$		-81		
			$f_{OUT} = 28.82MHz$		-78		
			$f_{OUT} = 38.42MHz$		-78		
			$f_{OUT} = 51.64MHz$		-79		
2-Tone IMD, -9dBFS, 200kHz Frequency Spacing	IM3	$f_{CLK} = 156MHz$	$f_{OUT} = 18MHz$		92		dBc
			$f_{OUT} = 31MHz$		90		
		$f_{CLK} = 260MHz$	$f_{OUT} = 18MHz$		91		
			$f_{OUT} = 31MHz$		89		
2-Tone IMD, -12dBFS, 200kHz Frequency Spacing	IM3	$f_{CLK} = 156MHz$	$f_{OUT} = 18MHz$		89		dBc
			$f_{OUT} = 31MHz$		87		
		$f_{CLK} = 260MHz$	$f_{OUT} = 18MHz$		88		
			$f_{OUT} = 31MHz$		87		
4-Tone Power Ratio, -15dBFS, 200kHz Frequency Spacing	MTPR	$f_{CLK} = 156MHz$	$f_{OUT} = 18MHz$		86		dBc
			$f_{OUT} = 31MHz$		84		
		$f_{CLK} = 260MHz$	$f_{OUT} = 18MHz$		86		
			$f_{OUT} = 31MHz$		84		
4-Tone Power Ratio, -18dBFS, 200kHz Frequency Spacing	MTPR	$f_{CLK} = 156MHz$	$f_{OUT} = 18MHz$		81		dBc
			$f_{OUT} = 31MHz$		79		
		$f_{CLK} = 260MHz$	$f_{OUT} = 18MHz$		81		
			$f_{OUT} = 31MHz$		78		
8-Tone Power Ratio, -21dBFS, 200kHz Frequency Spacing	MTPR	$f_{CLK} = 156MHz$	$f_{OUT} = 18MHz$		80		dBc
			$f_{OUT} = 31MHz$		77		
		$f_{CLK} = 260MHz$	$f_{OUT} = 18MHz$		79		
			$f_{OUT} = 31MHz$		76		
8-Tone Power Ratio, -24dBFS, 200kHz Frequency Spacing	MTPR	$f_{CLK} = 156MHz$	$f_{OUT} = 18MHz$		75		dBc
			$f_{OUT} = 31MHz$		73		
		$f_{CLK} = 260MHz$	$f_{OUT} = 18MHz$		76		
			$f_{OUT} = 31MHz$		74		

### REFERENCE AND CONTROL AMPLIFIER

Internal Reference Voltage Range	$V_{REFOUT}$		1.136	1.196	1.255	V
Reference Input Voltage Range	$V_{REFIN}$			1.196 ±8%		V
Internal Reference Voltage Drift	$TC_{REF}$			30		$\mu V/^\circ C$
Internal Reference	$I_{SINK}$			200		$\mu A$
Sink/Source Current	$I_{SOURCE}$			1.5		mA
Amplifier Input Impedance	$R_{IN}$			1		$M\Omega$

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## ELECTRICAL CHARACTERISTICS (continued)

( $AV_{CC} = DV_{CC} = 5V$ ,  $AGND = DGND = 0$ , external reference  $V_{REFIN} = 1.196V$ ,  $R_T = 27.4\Omega$  referenced to  $AV_{CC}$ ,  $V_{OUT} = 1V_{P-P}$ ,  $R_{SET} = 3.83k\Omega$ ,  $f_{CLK} = 156MHz$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ C$ .)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>ANALOG OUTPUT TIMING</b>						
Output Fall Time	$t_{FALL}$	90% to 10%		0.8		ns
Output Rise Time	$t_{RISE}$	10% to 90%		0.8		ns
Glitch Energy				0.5		pV-s
<b>TIMING CHARACTERISTICS</b>						
Data-to-Clock Setup Time (D0N–D13N, D0P–D13P)	$t_{SETUP}$	Referenced to the rising edge, Figure 4		0.5	1	ns
Data-to-Clock Hold Time (D0N–D13N, D0P–D13P)	$t_{HOLD}$	Referenced to the rising edge, Figure 4		0.5	1.1	ns
Propagation Delay Time	$t_{PD}$	(Note 3)		0.5		ns
Minimum Clock Pulse Width High	$t_{CH}$	CLKP, CLKN	1.6			ns
Minimum Clock Pulse Width Low	$t_{CL}$	CLKP, CLKN	1.6			ns
<b>LOGIC INPUTS (D0N–D13N, D0P–D13P, CLKP, CLKN)</b>						
Input Logic High	$V_{IH}$		2.4			V
Input Logic Low	$V_{IL}$				1.6	V
Input Logic Current, Logic High	$I_{IH}$	$V_{IH} = 2.4V$	-300	50	+300	$\mu A$
Input Logic Current, Logic Low	$I_{IL}$	$V_{IL} = 1.6V$	-300	10	+300	$\mu A$
Digital Input Capacitance	$C_{IN}$			2		pF
<b>POWER SUPPLIES</b>						
Analog Supply Voltage Range	$AV_{CC}$		4.75	5	5.25	V
Digital Supply Voltage Range	$DV_{CC}$		4.75	5	5.25	V
Analog Supply Current	$I_{AVCC}$	$AV_{CC} = DV_{CC} = 5V$		48	58	mA
Digital Supply Current	$I_{DVCC}$	$AV_{CC} = DV_{CC} = 5V$		190	230	mA
Power Dissipation	$P_{DISS}$	$AV_{CC} = DV_{CC} = 5V$		1190	1440	mW
Power-Supply Rejection Ratio	PSRR	$AV_{CC} = DV_{CC} = 5V \pm 5\%$ (Note 4)		0.2		%FS/V

**Note 1:** Offset error is the deviation of the output voltage from its ideal value at midscale.

**Note 2:** Full-scale gain error is the deviation of the output voltage from the ideal full-scale value. The actual full-scale voltage is determined by  $V_{OUTP} - V_{OUTN}$ , when D0P–D13P are set high and D0N–D13N are set low.

**Note 3:** Propagation delay is the time difference between the active edge of the clock and the active edge of the output.

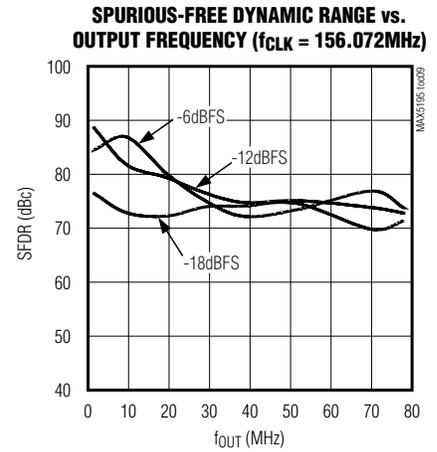
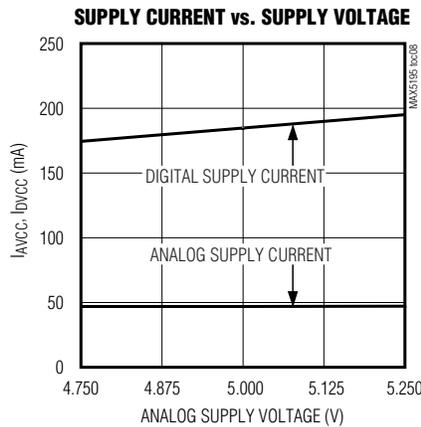
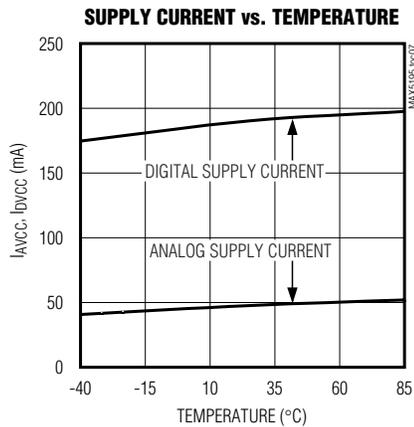
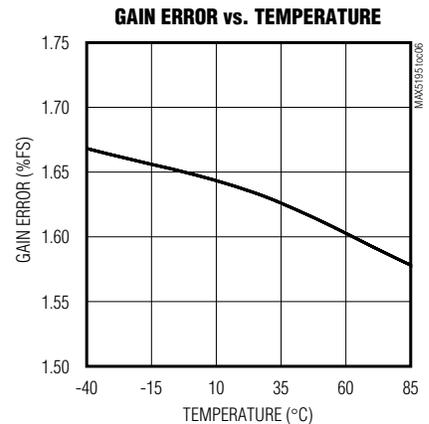
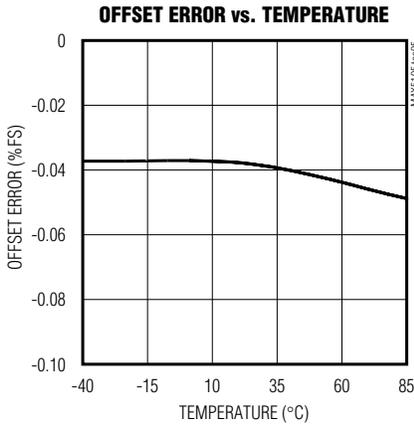
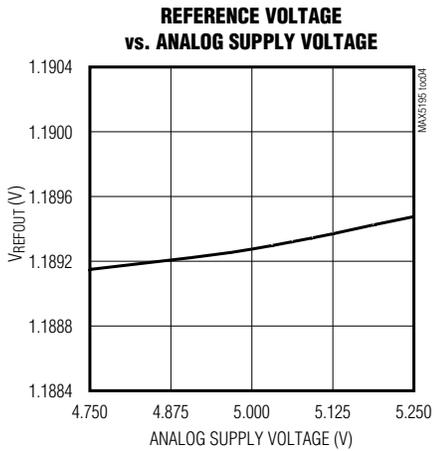
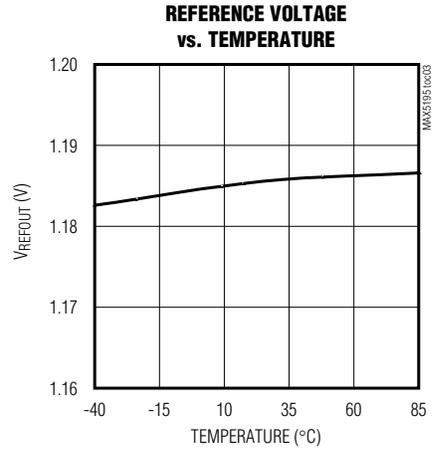
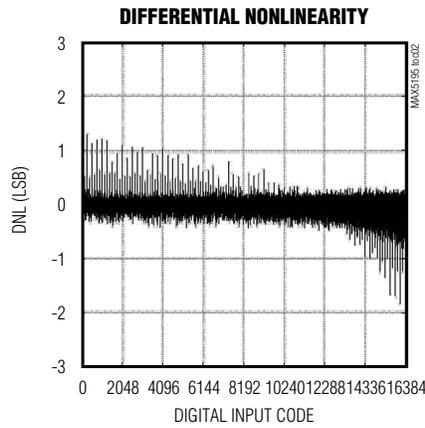
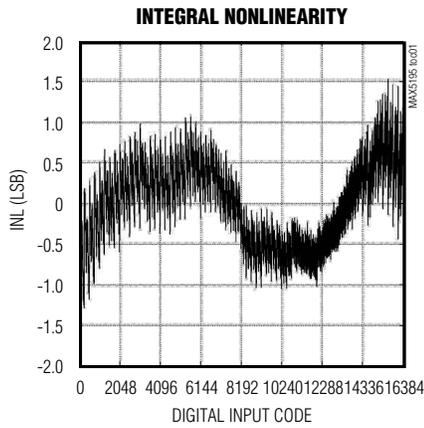
**Note 4:** Power-supply rejection ratio is the full-scale output change as the supply voltage varies over its specified range.

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## Typical Operating Characteristics

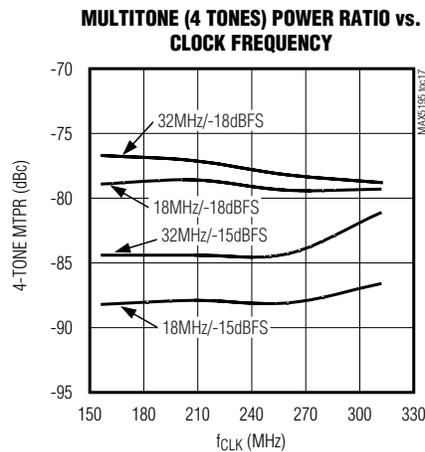
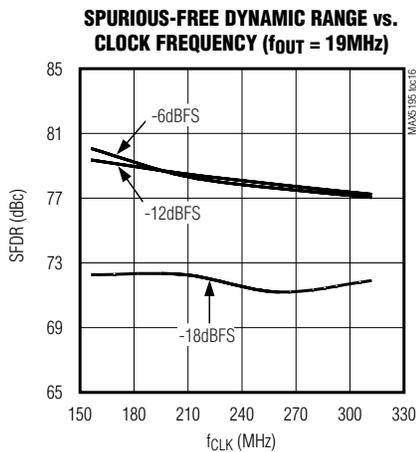
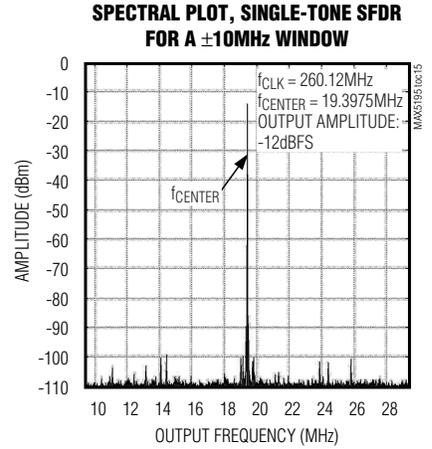
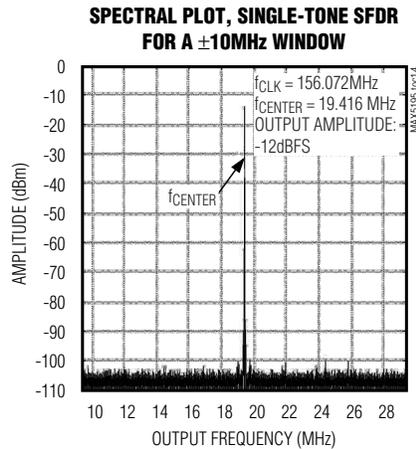
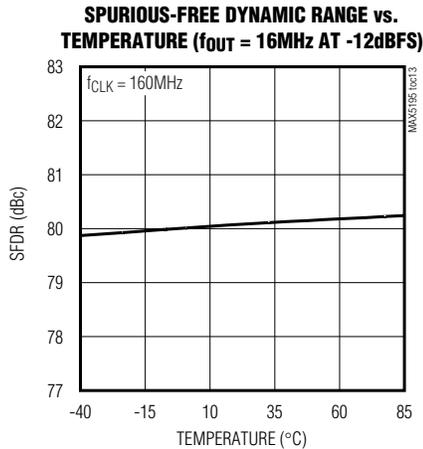
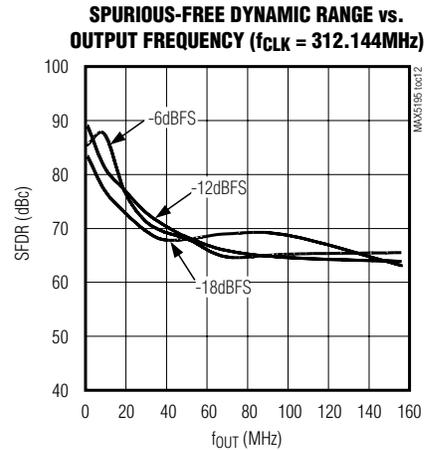
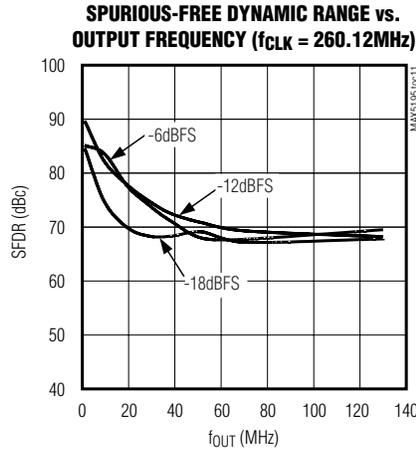
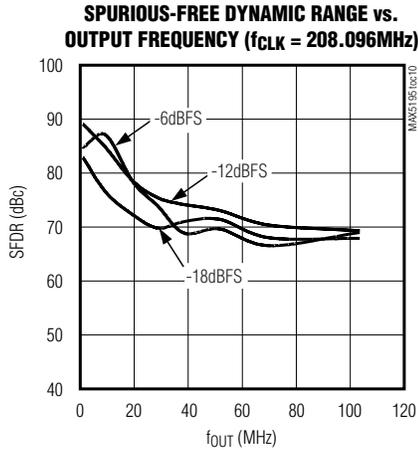
( $V_{CC} = DV_{CC} = 5V$ , external reference  $V_{REFIN} = 1.196V$ ,  $f_{CLK} = 156.072MHz$ ,  $R_T = 27.4\Omega$  referenced to  $V_{CC}$ ,  $C_L = 15pF$ ,  $V_{OUT} = 1V_{P-P}$ ,  $R_{SET} = 3.83k\Omega$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



# 14-Bit, 260Mps High-Dynamic Performance DAC

## Typical Operating Characteristics (continued)

( $V_{CC} = DV_{CC} = 5V$ , external reference  $V_{REFIN} = 1.196V$ ,  $f_{CLK} = 156.072MHz$ ,  $R_T = 27.4\Omega$  referenced to  $AV_{CC}$ ,  $C_L = 15pF$ ,  $V_{OUT} = 1VP-P$ ,  $R_{SET} = 3.83k\Omega$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

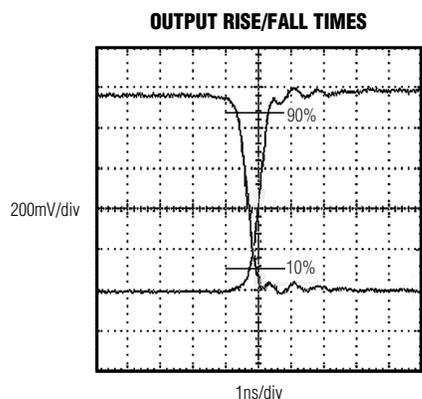
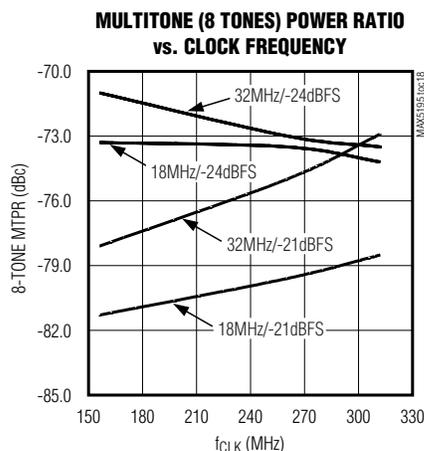


# 14-Bit, 260MSPS High-Dynamic Performance DAC

**MAX5195**

## Typical Operating Characteristics (continued)

( $V_{CC} = DV_{CC} = 5V$ , external reference  $V_{REFIN} = 1.196V$ ,  $f_{CLK} = 156.072MHz$ ,  $R_T = 27.4\Omega$  referenced to  $AV_{CC}$ ,  $C_L = 15pF$ ,  $V_{OUT} = 1VP-P$ ,  $R_{SET} = 3.83k\Omega$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



## Pin Description

PIN	NAME	FUNCTION
1	D9P	Data Bit 9
2	D8N	Complementary Data Bit 8
3	D8P	Data Bit 8
4	D7N	Complementary Data Bit 7
5	D7P	Data Bit 7
6	CLKP	Converter Clock Input. Positive input terminal for LVPECL-compatible differential converter clock.
7	CLKN	Complementary Converter Clock Input. Negative input terminal for LVPECL-compatible differential converter clock.
8	D6N	Complementary Data Bit 6
9	D6P	Data Bit 6
10	D5N	Complementary Data Bit 5
11	D5P	Data Bit 5
12	D4N	Complementary Data Bit 4
13	D4P	Data Bit 4
14	D3N	Complementary Data Bit 3
15	D3P	Data Bit 3
16, 47	DV <sub>CC</sub>	Digital Supply Voltage. Accepts a 4.75V to 5.25V supply voltage range. Bypass to DGND with a capacitor combination of 10 $\mu$ F in parallel with 0.1 $\mu$ F and 47pF.
17, 46	DGND	Digital Ground
18	D2N	Complementary Data Bit 2
19	D2P	Data Bit 2
20	D1N	Complementary Data Bit 1
21	D1P	Data Bit 1
22	D0N	Complementary Data Bit 0 (LSB)

# 14-Bit, 260Msps High-Dynamic Performance DAC

## Pin Description (continued)

PIN	NAME	FUNCTION
23	D0P	Data Bit 0 (LSB)
24	T.P.	Test Point. Must be connected to LVPECL high level (2.4V) for optimum dynamic performance.
25, 29, 32, 33, 35	AVCC	Analog Supply Voltage. Accepts a 4.75V to 5.25V supply voltage range. Bypass to AGND with a capacitor combination of 10 $\mu$ F in parallel with 0.1 $\mu$ F and 47pF.
26	REFOUT	Reference Output. Output of the internal 1.2V precision bandgap reference. Bypass with a 1 $\mu$ F capacitor to AGND, if an external reference source is used.
27, 28	AGND	Analog Ground
30	OUTN	Complementary DAC Output. Negative terminal for differential voltage output.
31	OUTP	DAC Output. Positive terminal for differential voltage output.
34	AMPOUT	Control Amplifier Output. For stable operation, bypass to AGND with a combination of a 3k $\Omega$ resistor in parallel with a 1.5 $\mu$ F tantalum capacitor.
36	RSET	Output Current Set Resistor. External resistor (3.83k $\Omega$ to 7.66k $\Omega$ ) sets the full-scale current of the DAC.
37	REFIN	Reference Input. Accepts an input voltage range of 1.196V $\pm$ 8%. Bypass to AGND with a 0.1 $\mu$ F capacitor, when used with the internal bandgap reference.
38	D13N	Complementary Data Bit 13 (MSB)
39	D13P	Data Bit 13 (MSB)
40	D12N	Complementary Data Bit 12
41	D12P	Data Bit 12
42	D11N	Complementary Data Bit 11
43	D11P	Data Bit 11
44	D10N	Complementary Data Bit 10
45	D10P	Data Bit 10
48	D9N	Complementary Data Bit 9

# 14-Bit, 260MSPS High-Dynamic Performance DAC

**MAX5195**

## Detailed Description

### Architecture

The MAX5195 is a high-performance, 14-bit, segmented current-source array DAC (Figure 1) capable of operating with clock speeds up to 260MHz. The converter consists of separate input and DAC registers, followed by a current-source array. This current-source array is capable of generating differential full-scale currents in the range of 10mA to 20mA. An internal R2R resistor network, in combination with external 27.4Ω termination resistors, convert these differential output currents into a differential output voltage with a peak-to-peak output voltage range of 0.5V to 1V. An integrated 1.2V bandgap reference, control amplifier, and user-selectable, external resistor determine the data converter's full-scale output range.

### Internal Reference and Control Amplifier

The MAX5195 supports operation with the on-chip 1.2V bandgap reference or an external reference voltage source. REFIN serves as the input for an external reference source, and REFOUT provides a 1.2V output voltage, if the internal reference is used. For internal reference operation, REFIN and REFOUT must be connected together and decoupled with a 1μF capacitor in parallel with a 0.1μF capacitor for stable operation.

The MAX5195 reference circuit also employs a control amplifier, designed to regulate the full-scale current  $I_{FS}$  for the differential current outputs of the MAX5195. For stable operation, the output AMPOUT of this amplifier must be bypassed with a 3kΩ resistor in parallel with a 1.5μF tantalum capacitor to AGND. Configured as a voltage-to-current amplifier, the output current can be calculated as follows:

$$I_{FS} = 64 \times I_{REF} - 1LSB$$

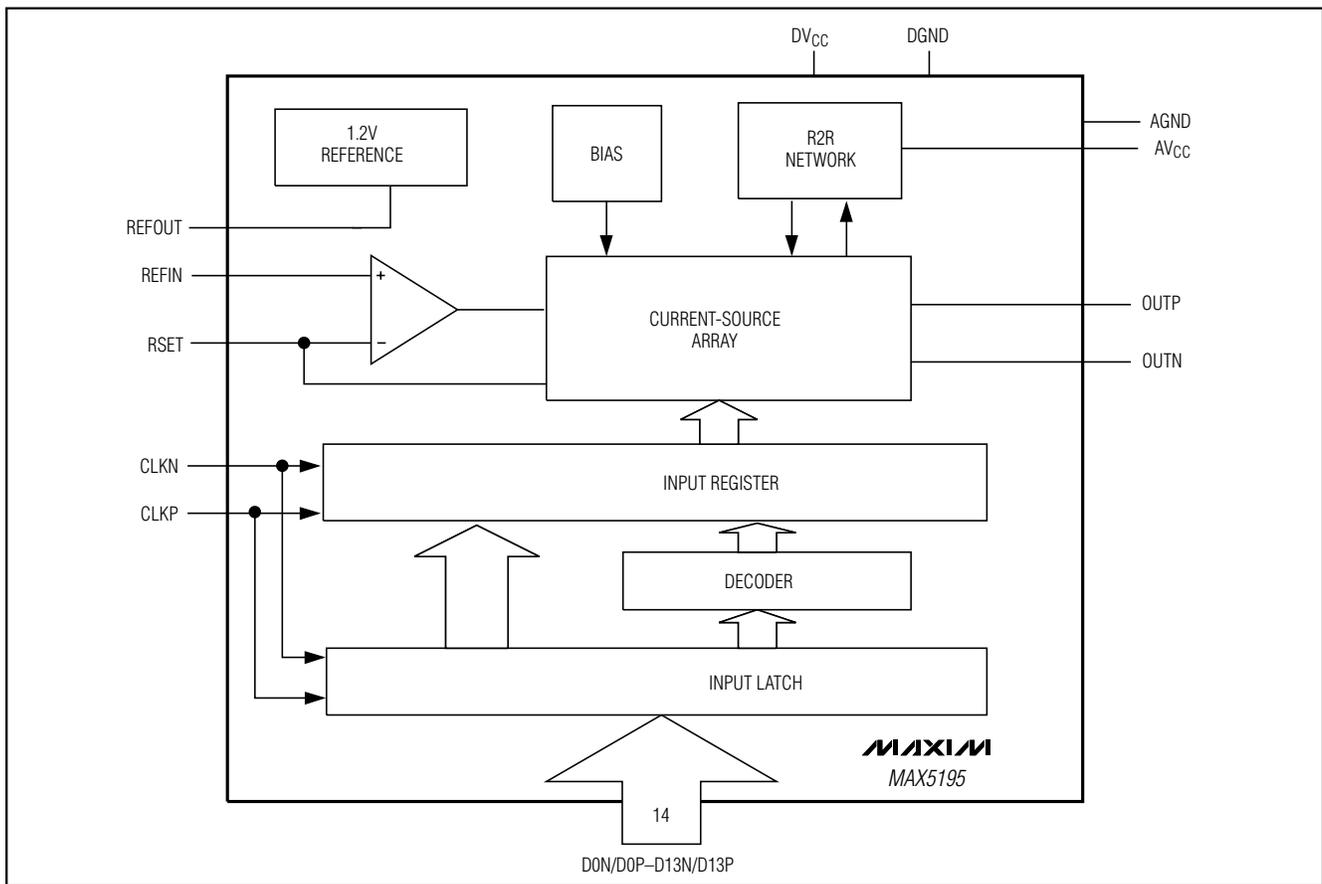


Figure 1. Simplified MAX5195 Block Diagram



# 14-Bit, 260MSPS High-Dynamic Performance DAC

**Table 2. LVPECL Voltage Levels**

PARAMETER	MINIMUM LVPECL SPECIFICATION	MAXIMUM LVPECL SPECIFICATION
Input Voltage High	$V_{CC}^{**} - 1.16V$	$V_{CC}^{**} - 0.88V$
Input Voltage Low	$V_{CC}^{**} - 1.81V$	$V_{CC}^{**} - 1.48V$
Common-Mode Level	$V_{CC}^{**} - 1.3V$	

\*\* $V_{CC}$  is the supply voltage associated with the LVPECL source. A typical  $V_{CC}$  level associated with LVPECL is 3.3V, which sets the common-mode level to 2V, allowing a typical peak-to-peak signal swing of 0.8V.

### LVPECL-Compatible Digital Inputs (D0P-D13P, D0N-D13N)

The MAX5195 digital interface consists of 14 differential, LVPECL-compatible digital input pins. These inputs follow standard positive binary coding where D0P and D0N represent the differential inputs to the least significant bit (LSB), and D13P and D13N represent the differential pair associated with the most significant bit (MSB). D0P/N through D13P/N accept LVPECL input levels of 0.8V<sub>P-P</sub> (Table 2).

Each of the digital input terminals can be terminated with a separate 50Ω resistor; however, to achieve the lowest noise performance, it is recommended to terminate each differential pair with a 100Ω resistor located between the positive and negative input terminals.

### Clock Inputs (CLKP, CLKN) and Data Timing Relationship

The MAX5195 features differential, LVPECL-compatible clock inputs. Internal edge-triggered flip-flops latch the input word on the rising edge of the clock-input pair CLKP/CLKN. The DAC is updated with the data word on the next rising edge of the clock input. This results in a conversion latency of one clock cycle. The MAX5195

provides for minimum setup and hold times (<2ns), allowing for noncritical external interface timing (Figure 4).

For best AC performance, a differential, DC-coupled clock signal with LVPECL-compatible voltage levels (Table 2) should be used. The MAX5195 operates properly with a clock duty cycle set within the limits listed in the *Electrical Characteristics* table. However, a 50% duty cycle should be utilized for optimum dynamic performance. To maintain the DAC's excellent dynamic performance, clock and data signals should originate from separate signal sources.

### Analog Outputs (OUTP, OUTN)

The MAX5195's current array is designed to drive full-scale currents of 10mA to 20mA into an internal R<sub>2R</sub> resistor network (R<sub>R2R</sub>). To achieve the desired differential output voltage range of 0.5V<sub>P-P</sub> to 1V<sub>P-P</sub>, both OUTP and OUTN should be externally terminated into 27.4Ω (R<sub>T</sub>), resulting in a combined load of R<sub>LOAD</sub> = 25Ω (Figure 5):

$$R_{LOAD} = R_{R2R} \parallel R_T$$

$$R_{LOAD} = (285\Omega \times 27.4\Omega) / (285\Omega + 27.4\Omega)$$

$$R_{LOAD} = 25\Omega$$

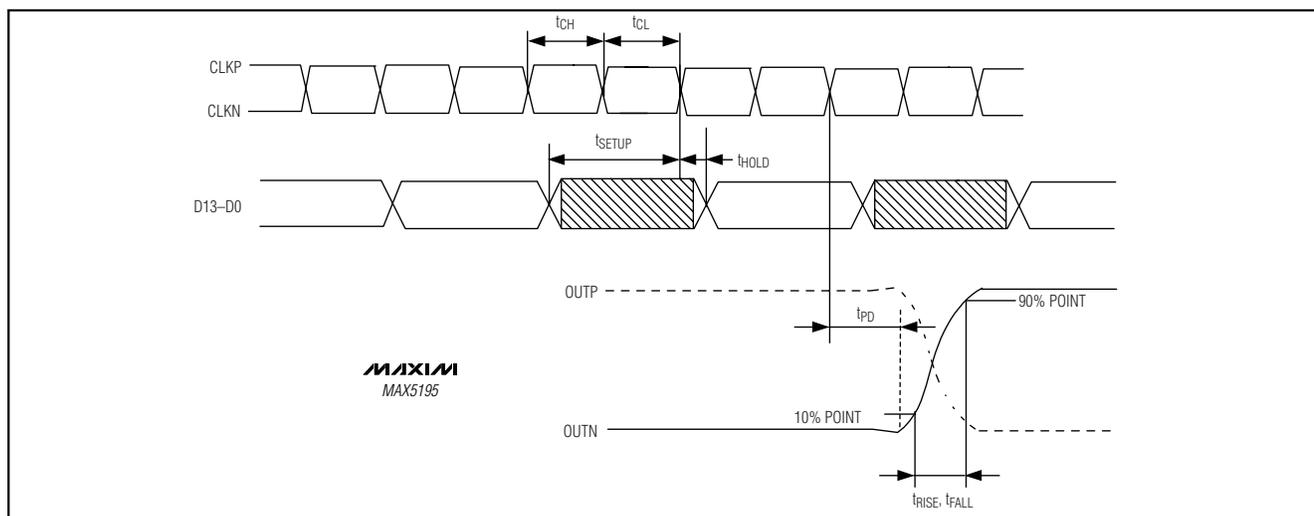


Figure 4. Input/Output Timing Information

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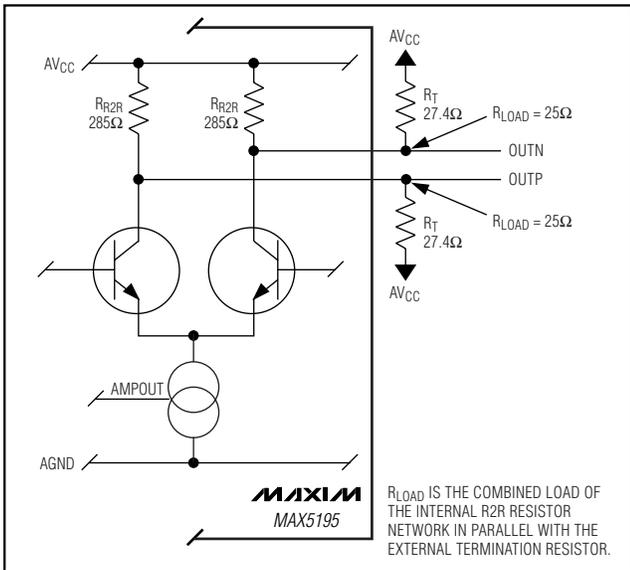


Figure 5. Simplified Output Architecture

With a full-scale current of 10mA (20mA), both outputs OUTP and OUTN achieve a 0.25V (0.5V) voltage swing each, resulting in a 0.5V<sub>P-P</sub> (1V<sub>P-P</sub>) differential output signal. For applications that require an even smaller output voltage swing, the termination resistor value  $R_T$  can be as low as 0Ω.

The proportional, differential output voltages can then be used to drive a wideband RF transformer or a fast, low-noise, low-distortion operational amplifier to convert the differential voltage into a single-ended output.

The MAX5195 analog outputs can also be configured in single-ended mode. For more details on different output configurations, see the *Applications Information* section.

## Applications Information

### Differential Coupling Using a Wideband RF Transformer

A wideband RF transformer such as the TTWB1010 (1:1 turns ratio) from Coilcraft can be used to convert the MAX5195 differential output signal to a single-ended signal (Figure 6). As long as the generated output spectrum is within the passband of the transformer, a differentially coupled transformer provides the best distortion performance. Additionally, the transformer helps to reject noise and even-order harmonics, provides electrical isolation, and is capable of delivering more power to the load.

### Single-Ended Unbuffered Output Configuration

Figure 7a shows an unbuffered single-ended output, which is suitable for applications requiring a unipolar voltage output. The nominal termination resistor load of 27.4Ω (referred to AV<sub>CC</sub>) results in a differential output

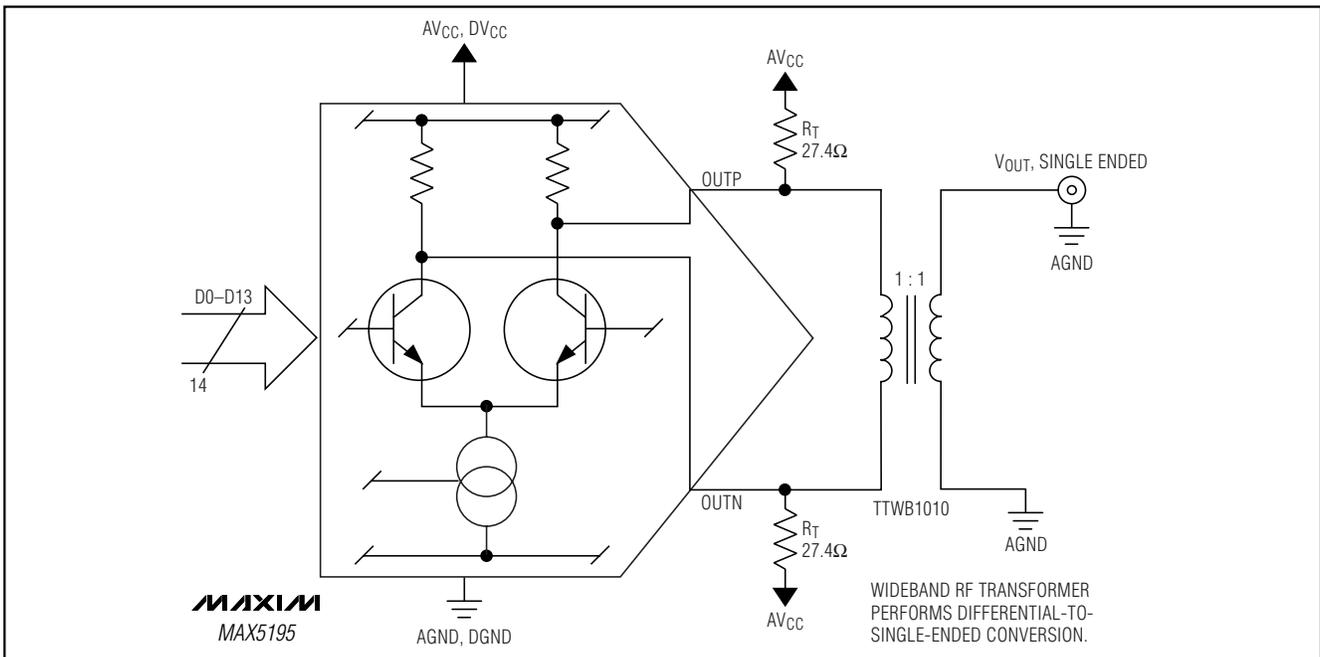


Figure 6. Differential Coupling Using a Wideband RF Transformer

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**MAX5195**

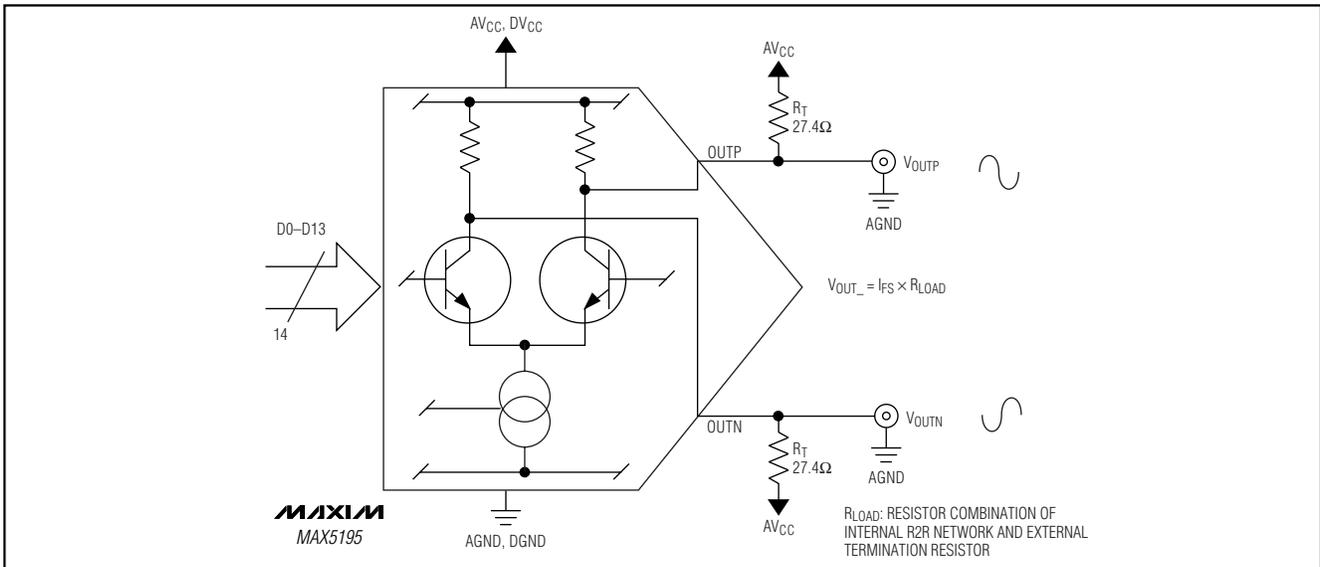


Figure 7a. Single-Ended Unbuffered Output Configuration

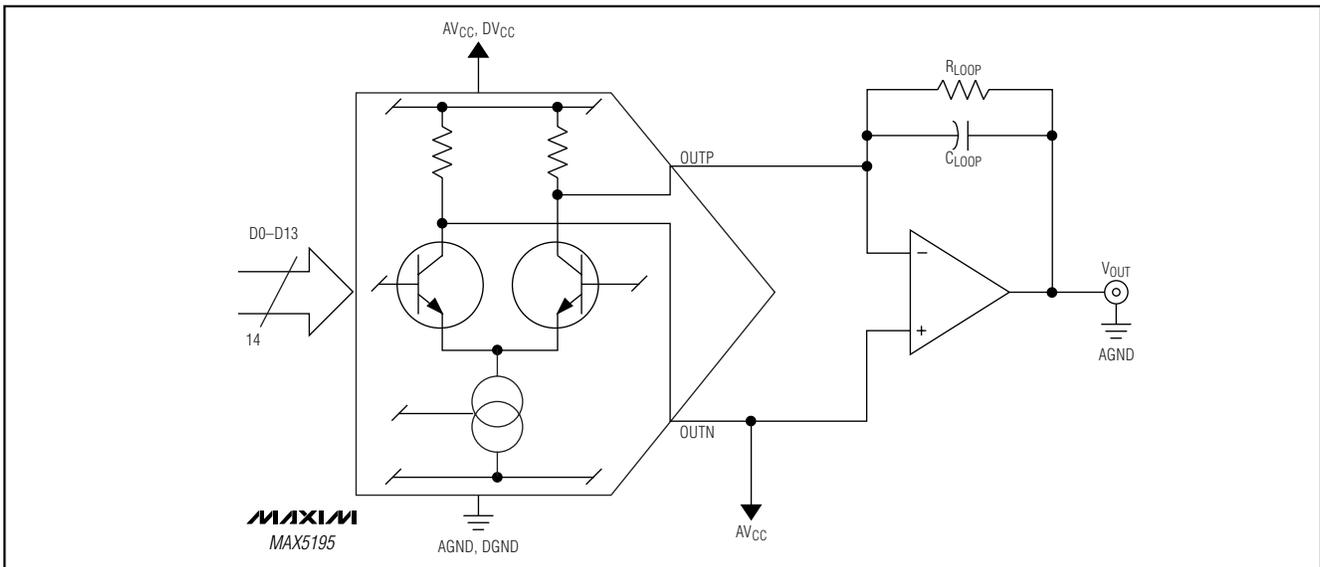


Figure 7b. Single-Ended Buffered Output Configuration

swing of 1V<sub>P-P</sub> (0.5V<sub>P-P</sub> single ended) when applying a full-scale current of 20mA.

Alternatively, an external unity-gain amplifier can be used to buffer the outputs. This circuit works as an I-V amplifier (Figure 7b), in which OUTP is held at AV<sub>CC</sub> by the inverting terminal of the buffer amplifier. OUTN should then be connected to AV<sub>CC</sub> to provide a DC-current path for the current switched to OUTP. The

amplifier's maximum output swing and the MAX5195 full-scale current determine the value of R<sub>LOOP</sub>. An optional roll-off capacitor (C<sub>LOOP</sub>) in the feedback loop helps to ease dV/dt requirements at the input of the operational amplifier. It is recommended that the amplifier's power-supply rails be higher than the resistor's output reference voltage AV<sub>CC</sub> due to its positive and negative output swing around AV<sub>CC</sub>.

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## Grounding, Bypassing, and Power-Supply Considerations

Grounding and power-supply decoupling can strongly influence the performance of the MAX5195. Unwanted digital crosstalk can couple through the input, reference, power supply, and ground connections, thus affecting dynamic performance. Proper grounding and power-supply decoupling guidelines for high-speed, high-frequency applications should be closely followed. This reduces EMI and internal crosstalk, which can also affect the dynamic performance of the MAX5195.

Use of a multilayer printed circuit (PC) board with separate ground and power-supply planes is recommended. High-speed signals should be run on lines directly above the ground plane. Since the MAX5195 has separate analog and digital ground buses (AGND and DGND, respectively), the PC board should have separate analog and digital ground sections with only one

point connecting the two planes. Digital signals should run above the digital ground plane and analog signals above the analog ground plane. Digital signals should be kept as far away from sensitive analog inputs, reference input lines, and clock inputs. Digital signal paths should be kept short and run lengths matched to avoid propagation delay mismatch.

The MAX5195 has two separate power-supply inputs for analog (AVCC) and digital (DVCC). Each AVCC input should be decoupled with parallel ceramic chip capacitors of 10 $\mu$ F in parallel with 0.1 $\mu$ F and 47pF with these capacitors as close to the supply pins as possible and their opposite ends with the shortest possible connection to the ground plane (Figure 8). The DVCC pins should also have separate 10 $\mu$ F in parallel with 0.1 $\mu$ F and 47pF capacitors adjacent to their respective pins.

Try to minimize the analog and digital load capacitances for proper operation.

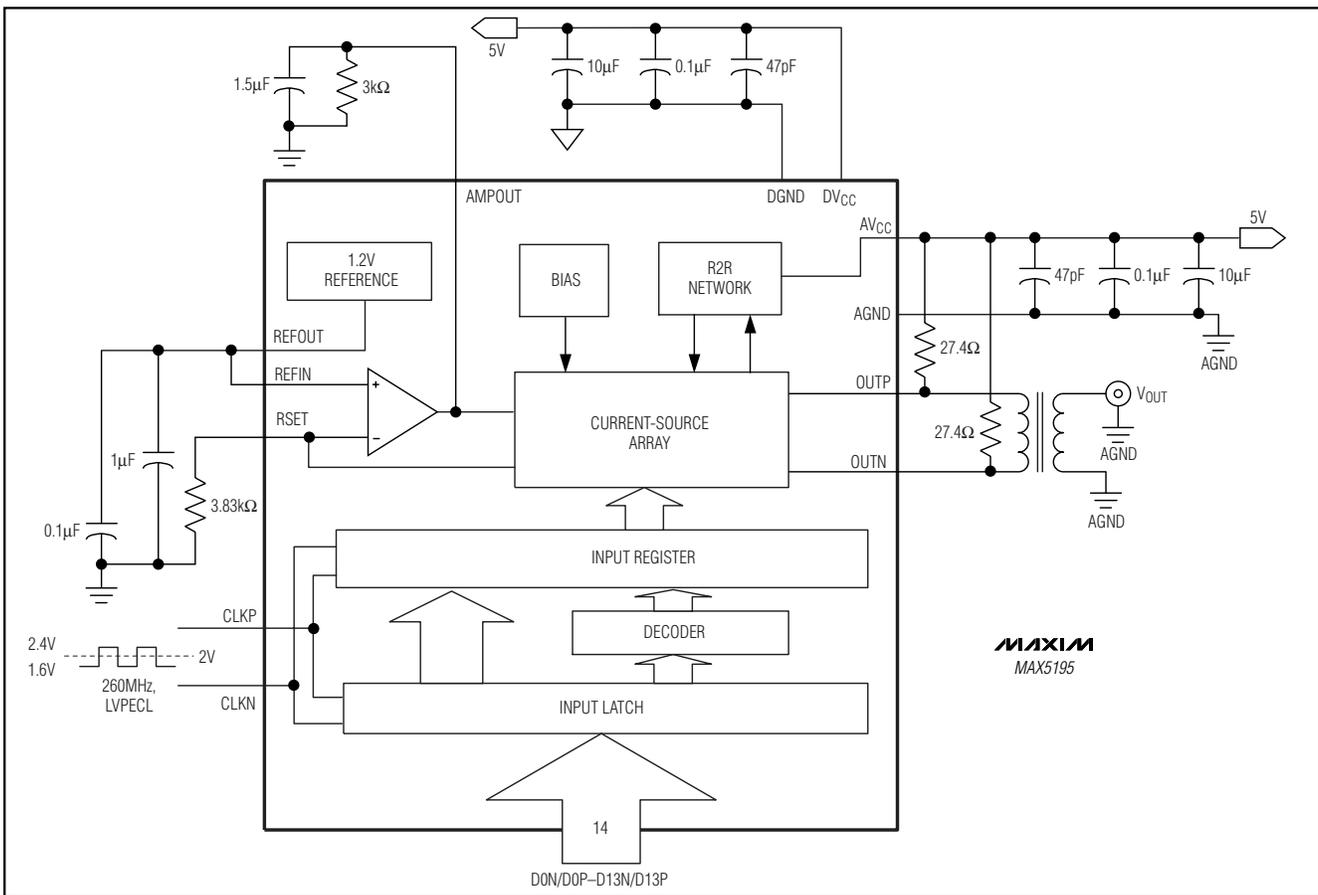


Figure 8. Decoupling and Bypassing Techniques for MAX5195—Typical Operating Circuit

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The power-supply voltages should also be decoupled at the point where they enter the PC board with tantalum or electrolytic capacitors. Ferrite beads with additional decoupling capacitors forming a  $\pi$  network can also improve performance.

The analog and digital power-supply inputs AVCC and DVCC of the MAX5195 allow a 4.75V to 5.25V supply voltage range.

### Enhanced Thermal Dissipation QFN-EP Package

The MAX5195 is packaged in a thermally enhanced 48-pin QFN-EP package, providing greater design flexibility, increased thermal efficiency, and a low thermal junction-case ( $\theta_{jc}$ ) resistance of  $\approx 2^{\circ}\text{C}/\text{W}$ . In this package, the data converter die is attached to an EP lead frame. The back of the lead frame is exposed at the package bottom surface (the PC board side of the package, Figure 9). This allows the package to be attached to the PC board with standard infrared (IR) flow soldering techniques. A specially created land pattern on the PC board, matching the size of the EP (5.5mm  $\times$  5.5mm), guarantees proper attachment of the chip, and can also be used for heat-sinking purposes. Designing thermal vias\* into the land area and implementing large ground planes in the PC board design further enhance the thermal conductivity between board and package. To remove heat from a 48-pin QFN-EP package effectively, an array of 3  $\times$  3 (or

\*Connect the land pattern to internal or external copper planes.

greater) vias ( $\leq 0.3\text{mm}$  diameter per via hole and 1.2mm pitch between via holes) is recommended. A smaller via array can be used as well, but results in an increased  $\theta_{ja}$ .

Note that efficient thermal management for the MAX5195 is strongly dependent on PC board and circuit design, component placement, and installation; therefore, exact performance figures cannot be provided. For more information on proper design techniques and recommendations to enhance the thermal performance of parts such as the MAX5195, refer to Amkor Technology's website at [www.amkor.com](http://www.amkor.com).

### Static Performance Parameter Definitions

#### Integral Nonlinearity (INL)

Integral nonlinearity is the deviation of the values on an actual transfer function from either a best-straight-line fit (closest approximation to the actual transfer curve) or a line drawn between the endpoints of the transfer function, once offset and gain errors have been nullified. For a DAC, the deviations are measured every individual step.

#### Differential Nonlinearity (DNL)

Differential nonlinearity is the difference between an actual step height and the ideal value of 1LSB. A DNL error specification of less than 1LSB guarantees no missing codes and a monotonic transfer function.

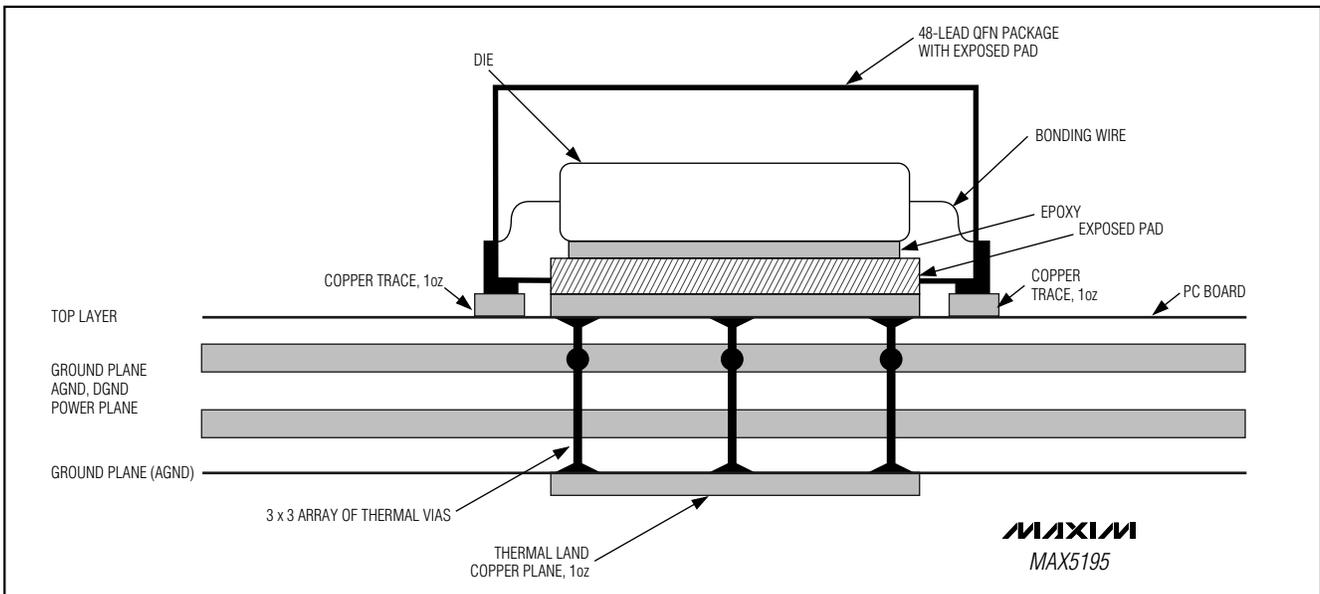


Figure 9. MAX5195 Exposed Paddle/PC Board Cross Section

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## Offset Error

The offset error is the difference between the ideal and the actual offset point. For a DAC, the offset point is the step value when the digital input is at midscale. This error affects all codes by the same amount.

## Gain Error

A gain error is the difference between the ideal and the actual full-scale output voltage on the transfer curve, after nullifying the offset error. This error alters the slope of the transfer function and corresponds to the same percentage error in each step.

## Glitch Energy

Glitch impulses are caused by asymmetrical switching times in the DAC architecture, which generates undesired output transients. The amount of energy that appears at DAC's output is measured over time and is usually specified in the pV-s range.

## Dynamic Performance Parameter Definitions

### Signal-to-Noise Ratio (SNR)

For a waveform perfectly reconstructed from digital samples, the theoretical maximum SNR is the ratio of the full-scale analog output (RMS value) to the RMS quantization error (residual error). The ideal, theoretical minimum can be derived from the DAC's resolution (N bits):

$$\text{SNR}_{\text{dB}} = 6.02_{\text{dB}} \times N + 1.76_{\text{dB}}$$

However, noise sources such as thermal noise, reference noise, clock jitter, etc., affect the ideal reading. SNR is therefore computed by taking the ratio of the RMS signal to the RMS noise, which includes all spectral components minus the fundamental, the first four harmonics, and the DC offset.

## Spurious-Free Dynamic Range

SFDR is the ratio of RMS amplitude of the carrier frequency (maximum signal components) to the RMS value of the next largest distortion component. SFDR is measured in dBc, with respect to the carrier frequency amplitude.

## Multitone Power Ratio (MTPR)

A series of equally spaced ones is applied to the DAC with one tone removed from the center of the range. MTPR is defined as the worst-case distortion (usually a 3rd-order harmonic product of the fundamental frequencies), which appears as the largest spur at the frequency of the missing tone in the sequence. This test can be performed with any number of input tones; however, four and eight tones are among the most common test conditions for CDMA- and GSM/EDGE-type applications.

## Intermodulation Distortion (IMD)

The two-tone IMD is the ratio expressed in dBc of either input tone to the worst 3rd-order (or higher) IMD products. Note that 2nd-order IMD products usually fall at frequencies, which can be easily removed by digital filtering. Therefore, they are not as critical as 3rd-order IMDs. The two-tone IMD performance of the MAX5195 was tested with the two individual input tone levels set to -9dBFS and -12dBFS.

## Chip Information

TRANSISTOR COUNT: 15,000

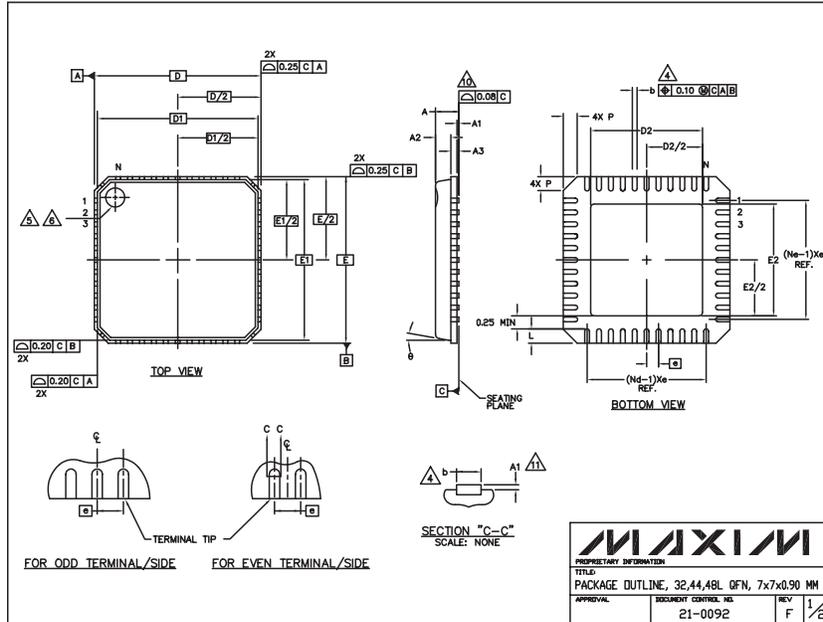
PROCESS: SiGe

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## Package Information

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages).)

MAX5195



### NOTES:

- DIE THICKNESS ALLOWABLE IS 0.305mm MAXIMUM(.012 INCHES MAXIMUM)
- DIMENSIONING & TOLERANCES CONFORM TO ASME Y14.5M. - 1994.
- N IS THE NUMBER OF TERMINALS.  
Nd IS THE NUMBER OF TERMINALS IN X-DIRECTION & Ne IS THE NUMBER OF TERMINALS IN Y-DIRECTION.
- DIMENSION b APPLIES TO PLATED TERMINAL AND IS MEASURED BETWEEN 0.20 AND 0.25mm FROM TERMINAL TIP.
- THE PIN #1 IDENTIFIER MUST EXIST ON THE TOP SURFACE OF THE PACKAGE BY USING INDENTATION MARK OR INK/ LASER MARKED. OF PACKAGE BODY.
- EXACT SHAPE AND SIZE OF THIS FEATURE IS OPTIONAL.
- ALL DIMENSIONS ARE IN MILLIMETERS.
- PACKAGE WARPAGE MAX 0.08mm.
- APPLIED FOR EXPOSED PAD AND TERMINALS.  
EXCLUDE EMBEDDED PART OF EXPOSED PAD FROM MEASURING.
- MEETS JEDEC MO220.
- THIS PACKAGE OUTLINE APPLIES TO ANVIL SINGULATION (STEPPED SIDES) AND TO SAW SINGULATION (STRAIGHT SIDES) QFN STYLES.

PITCH VARIATION C				PITCH VARIATION C				PITCH VARIATION D			
MIN.	NOM.	MAX.	N <sub>d</sub>	MIN.	NOM.	MAX.	N <sub>d</sub>	MIN.	NOM.	MAX.	N <sub>e</sub>
0.65	BSC		3	0.50	BSC		3	0.50	BSC		3
0.32			3	0.44			3	0.48			3
			3	0.11			3	0.12			3
			3	0.11			3	0.12			3
0.35	0.55	0.75	4	0.35	0.55	0.75	4	0.30	0.40	0.50	4
0.23	0.28	0.35	4	0.18	0.23	0.30	4	0.18	0.23	0.30	4



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