



## 8 BIT MICROPOWER MULTIPLYING D/A CONVERTER

### GENERAL DESCRIPTION

The ALD1801 is an 8-bit monolithic current output digital to analog converter designed to provide low power, low operating voltage and simple operation. It offers industry pin configuration of DAC-08 types, and is intended for a wide range of digital to analog conversion and control applications in +5V single power supply and  $\pm 5V$  dual power supply systems, as well as +3V to +12V battery operated systems. Device characteristics are specified for +5V single supply and 3.3V dual supply systems.

The ALD1801 is manufactured with Advanced Linear Devices' enhanced CMOS silicon gate CMOS process and has been designed to be also used as a linear cell element in Advanced Linear Devices' "Function-Specific" ASIC, as it is fully compatible in design, operation, and manufacture with all other linear elements in Advanced Linear Devices' product family.

The ALD1801 is designed with matching between reference and full scale currents. Digital inputs are standard CMOS logic inputs to provide ease of interface. Output currents can be directly converted to a voltage output by using a pair of resistors. When used with ALD's rail-to-rail output operational amplifiers such as the ALD1702, full scale output of 0 to +5V can be easily achieved with single +5V power supply.

### ORDERING INFORMATION

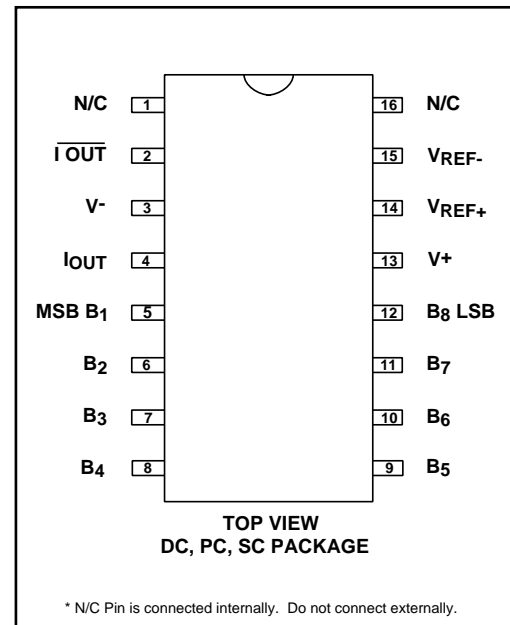
Operating Temperature Range		
-55°C to +125°C	0°C to +70°C	0°C to +70°C
16-Pin CERDIP Package	16-Pin Small Outline Package(SOIC)	16-Pin Plastic Dip Package
ALD1801A DC	ALD1801A SC	ALD1801A PC
ALD1801B DC	ALD1801B SC	ALD1801B PC
ALD1801 DC	ALD1801 SC	ALD1801 PC

\* Contact factory for industrial temperature range

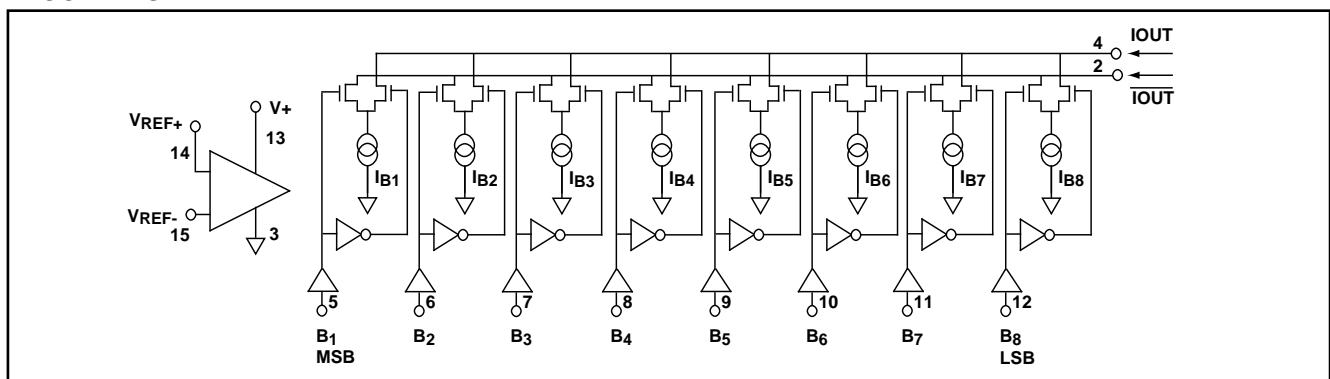
### FEATURES

- Low voltage 3V to 12V operation
- Low power 1.8mW max @ 3.3V
- Single supply operation (5V or 3.3V)
- Direct CMOS logic interface
- Complementary current outputs
- Nonlinearity to 0.1% max over temperature range
- High input impedance
- Low full scale current
- High output impedance

### PIN CONFIGURATION



### BLOCK DIAGRAM



# OPERATING ELECTRICAL CHARACTERISTICS

$T_A = 25^{\circ}\text{C}$   $V_S = \pm 2.5\text{V}$  or  $V_S = +5.0\text{V}$  unless otherwise specified

Parameter	Symbol	1801A			1801B			1801			Unit	Test Conditions
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max		
Supply Voltage	$V_S$	$\pm 1.5$		$\pm 6.0$	$\pm 1.5$		$\pm 6.0$	$\pm 1.5$		$\pm 6.0$	V	Dual Supply Single Supply
Resolution		8			8			8			Bits	
Monotonicity		8			8			8			Bits	
Nonlinearity	$N_L$			$\pm 0.1$			$\pm 0.19$			$\pm 0.39$	% of Full Scale	
Settling Time	$t_S$		2.5	5.0		2.5	5.0		2.5	5.0	$\mu\text{s}$	To 1/2 LSB with all bits turned on/off
Propagation Delay	$t_d$		1.5	2.5		1.5	2.5		1.5	2.5	$\mu\text{s}$	Each Bit
			1.5	2.5		1.5	2.5		1.5	2.5	$\mu\text{s}$	All Bits
Full Scale Tempco	$T_C$		$\pm 10$	$\pm 50$		$\pm 10$	$\pm 50$		$\pm 10$	$\pm 50$	ppm/ $^{\circ}\text{C}$	
Output Compliance	$V_{OC}$	V- $+1.5$		V+ $+0.2$	V- $+1.5$		V+ $+0.2$	V- $+1.5$		V+ $+0.2$	V	
Output Impedance		50			50			50			$\text{M}\Omega$	Output Within Compliance limits
Full Scale Current Range	$I_{FS}$		100			100			100		$\mu\text{A}$	$R_{OUT} = R_{OUT} = 50\text{K}\Omega$ $V_{REF} = 2.5\text{V}$ ; $R_{REF} = 25\text{K}\Omega$
Full Scale Symmetry	$I_{FSS}$			$\pm 2.5$			$\pm 2.5$			$\pm 2.5$	$\mu\text{A}$	
Zero Scale Current	$I_{ZS}$			10			10			10	nA	
Logic Input Level <sup>1</sup> Logic "0" Logic "1"	$V_{IL}$ $V_{IH}$	2.1		-1.1	2.1		-1.1	2.1		-1.1	V	Supply = $\pm 2.5\text{V}$
Logic Swing Logic Threshold Range	$V_{LS}$	-2.8		2.8	-2.8		2.8	-2.8		2.8	V	Supply = $\pm 2.5\text{V}$
		-1.5		1.5	-1.5		1.5	-1.5		1.5	V	Supply = $\pm 2.5\text{V}$
Reference Bias Current	$I_{RB}$			0.1			0.1			0.1	nA	
Power Supply Current	$+I_S$ $-I_S$		500 700	800 1000		500 700	800 1000		500 700	800 1000	$\mu\text{A}$	Full Scale Output = $100\mu\text{A}$
Power Dissipation	$P_D$			4.5			4.5			4.5	mW	Supply = $\pm 2.5\text{V}$
Compensation												Not Required

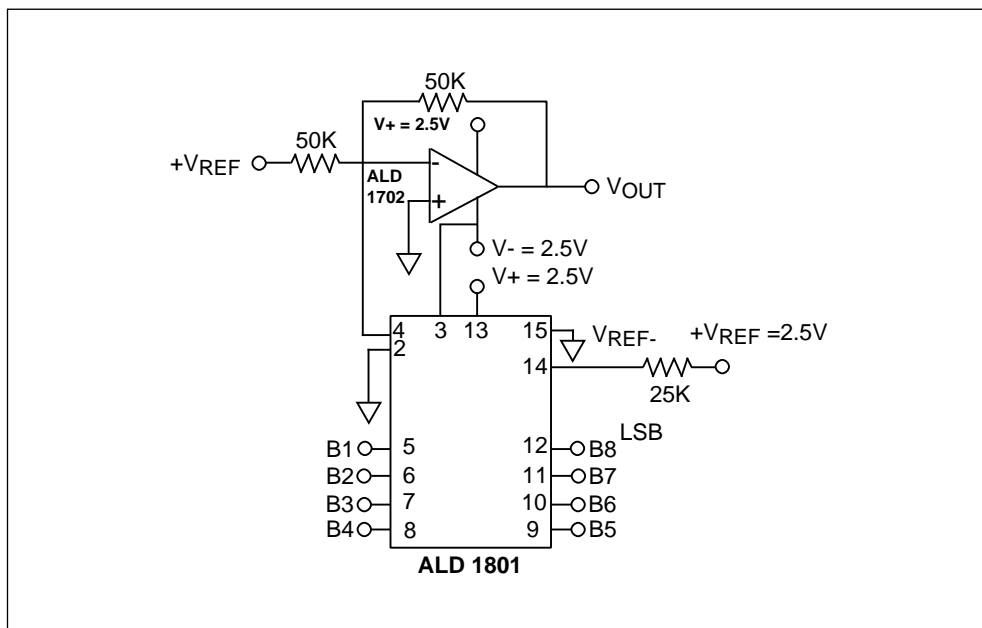
Notes: 1. Contact ALD for  $\pm 1.0\text{V}/\pm 1.25\text{V}$  operation  
2. Logic levels of  $V_{IL}$  0.4V and  $V_{IH}$  4.6V for single supply applications.

# OPERATING ELECTRICAL CHARACTERISTICS

T<sub>A</sub> = 25°C V<sub>S</sub> = ±1.65V or V<sub>S</sub> = +3.3V unless otherwise specified

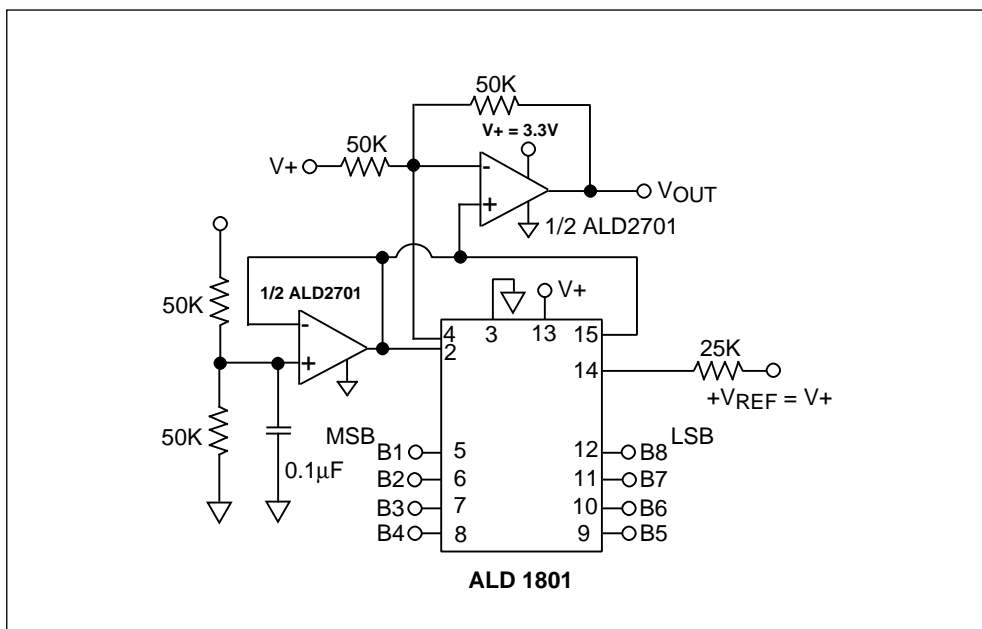
Parameter	Symbol	1801A			1801B			1801			Unit	Test Conditions
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max		
Resolution		8			8			8			Bits	
Monotonicity		8			8			8			Bits	
Nonlinearity	N <sub>L</sub>			±0.1			±0.19			±0.39	% of Full Scale	
Settling Time	t <sub>S</sub>		4.0	10.0		4.0	10.0		4.0	10.0	μs	To 1/2 LSB with all bits turned on/off
Propagation Delay	t <sub>d</sub>		1.5	4.0		1.5	4.0		1.5	4.0	μs	Each Bits
			1.5	4.0		1.5	4.0		1.5	4.0	μs	All Bits
Full Scale Tempco	T <sub>C</sub>		±10	±50		±10	±50		±10	±50	ppm/°C	
Output Compliance	V <sub>OC</sub>	V- +1.5		V+ +0.2	V- +1.5		V+ +0.2	V- +1.5		V+ +0.2	V	
Output Impedance		50			50			50			MΩ	Output Within Compliance limits
Full Scale Current Range	I <sub>FS</sub>		50			50			50		μA	R <sub>OUT</sub> = R <sub>OUT</sub> = 100KΩ V <sub>REF</sub> = 2.5V; R <sub>REF</sub> = 50KΩ
Full Scale Symmetry	I <sub>FSS</sub>			±2.5			±2.5			±2.5	μA	
Zero Scale Current	I <sub>ZS</sub>			10			10			10	nA	
Reference Bias Current	I <sub>RB</sub>			0.1			0.1			0.1	nA	
Power Supply Current	+I <sub>S</sub> - I <sub>S</sub>		350 450	500 600		350 450	500 600		350 450	500 600	μA	Full Scale Output = 50μA
Power Dissipation	P <sub>D</sub>			1.8			1.8			1.8	mW	

# **DUAL SUPPLY $\pm 2.5V$ RATIOMETRIC VOLTAGE OUTPUT DAC**



	B1	B2	B3	B4	B5	B6	B7	B8	V <sub>OUT</sub>
Zero Scale	0	0	0	0	0	0	0	0	-2.500
LSB	0	0	0	0	0	0	0	1	-2.480
Half Scale -LSB	0	1	1	1	1	1	1	1	-0.019
Half Scale	1	0	0	0	0	0	0	0	0.000
Half Scale +LSB	1	0	0	0	0	0	0	1	0.019
Full Scale	1	1	1	1	1	1	1	1	2.480

# **SINGLE SUPPLY 3.3V RATIOMETRIC VOLTAGE OUTPUT DAC**



	B1	B2	B3	B4	B5	B6	B7	B8	V <sub>OUT</sub>
Zero Scale	0	0	0	0	0	0	0	0	0.000
Half Scale	1	0	0	0	0	0	0	0	1.650
Full Scale	1	1	1	1	1	1	1	1	3.287

## APPLICATIONS NOTES:

The ALD1801 is an 8 bit multiplying D/A converter. It has been designed to operate with standard single or split power supplies of 5V or  $\pm 5V$ . Functionality extends down to 3V or  $\pm 1.5V$  power supply, making it ideal for lithium battery or rechargeable battery operated systems where power efficiency and performance are important design parameters.

The ALD1801 features ultra low quiescent bias current which depends on the operating current in the internal current steering circuit. A high gain internal operational amplifier is fully compensated for stable operation without any need for external capacitor compensation. The operational amplifier is placed in a negative feedback loop to generate the reference current for ratio matched transistors. It is trimmed to provide nonlinearity as specified. In some applications this feature can be used along with the multiplying nature of the ALD1801 to obtain 9 or 10 bit digital to analog conversion with external switches.

The ALD1801 is a multiplying D/A converter in which the output is a current that is a function of an 8 bit digital input word multiplied by the reference current. The reference current may be a fixed reference current or a varying input current. If a fixed reference voltage or a varying low impedance voltage output source is used, a fixed value resistor (referred to as  $R_{REF}$ ) can be used to convert the voltage into a reference current for most applications.

$R_{REF}$  is a precision fixed resistor without trimming. Trimming can be accomplished by adjusting  $R_{REF}$  through either connecting a potentiometer in series with a fixed resistor or by substituting the fixed resistor with a multi-turn potentiometer. The recommended nominal value of  $R_{REF}$  is 25K $\Omega$ .

The ALD1801 can operate from single power supply or dual supplies up to  $\pm 6.6V$ . Symmetrical supplies are not required in the case of dual supply operation. However,  $V_{REF-}$  input voltage must be set at 1V or higher above the  $V_-$  voltage. Due to the internal operational amplifier feedback,  $V_{REF+}$  input terminal would be set at the same potential as  $V_{REF-}$  input terminal, with the input reference current determined by: Input reference current

$$I_{REF} = \{ (V_{REF+}) - (V_{REF-}) \} / R_{REF}$$

The ALD1801 is fabricated in CMOS technology and provides direct logic interface to all CMOS logic families including logic levels of the CD4000 and 74C logic families operating at logic voltage levels other than 5V. It is primarily designed to operate in a power supply environment where interface takes place between digital logic circuitry and analog circuitry. Both types of circuitry operate with the same power supplies.

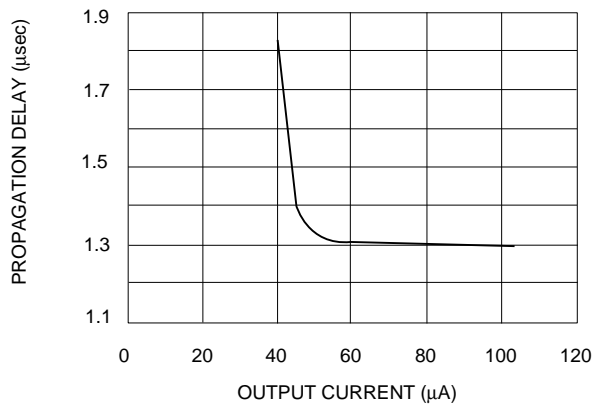
The nonlinearity and monotonicity of the ALD1801 applies over the full rated operating temperature. The device has been developed with minimal temperature drift, typically at  $\pm 10\text{ppm}/^\circ\text{C}$ . A single array of matched and tracked resistor networks of nominal 50K $\Omega$  can be used for all the resistors required for the D/A converter. As an example,  $R_{REF}$  can be set to 25K $\Omega$  by connecting two 50K $\Omega$  resistors in parallel where output resistors are set at 50K $\Omega$ .

Due to the very low quiescent and reference currents used, layout of the circuit board to minimize any parasitic capacitance is important in getting high frequency operation, as the settling time is due in large part to the output currents charging and discharging the node capacitances at the output. As the internal bias current levels is adaptive to the reference current, the switching speed of the device depends on the reference current selected. Characterization of the settling time has been performed at full scale current set at 100 $\mu\text{A}$  and device operation at single 5V supply. Faster operation can be obtained by using short leads, minimizing output capacitance, load resistor values, and by adequate bypass capacitors placed on the board at the supply and reference nodes.

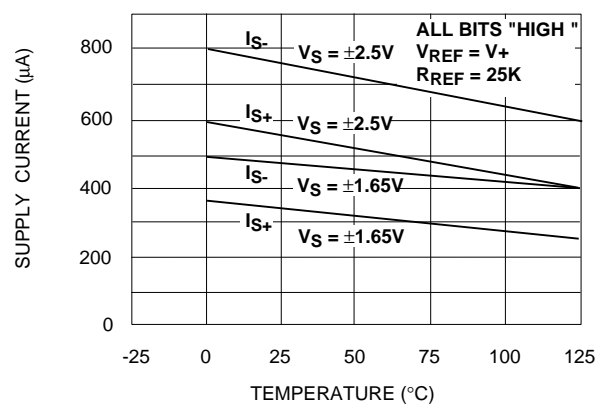
Both  $I_O$  and  $I_{\bar{O}}$  outputs can be used simultaneously. If one of the outputs is not used, then it must be connected to ground or a potential where the sum of  $I_O$  and  $I_{\bar{O}}$  can maintain a constant value. Due to internal leakage currents that vary with temperature, it is recommended that  $I_{FS}$  of 50 $\mu\text{A}$  to 100 $\mu\text{A}$  be used so that 1/2LSB bit current is set at as high a level as possible. The temperature coefficient of the reference resistor  $R_{REF}$  and output resistors  $R_{OUT}$  and  $R_{\bar{O}UT}$  should match to minimize temperature drift.

## TYPICAL PERFORMANCE CHARACTERISTICS

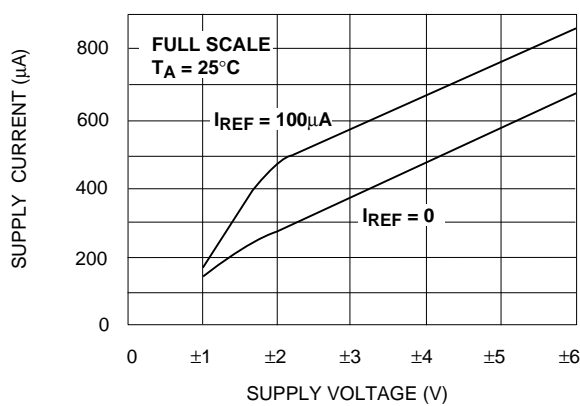
PROPAGATION DELAY AS A FUNCTION OF FULL SCALE OUTPUT CURRENT



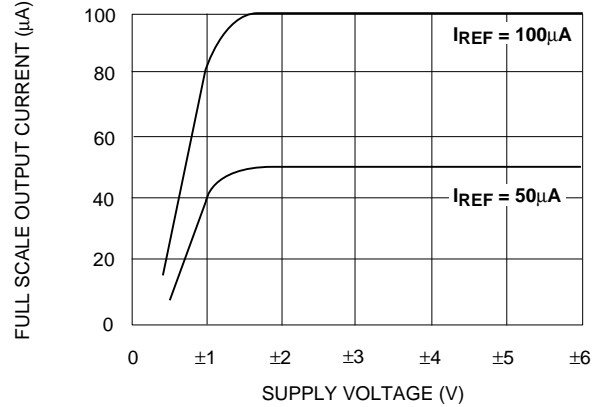
SUPPLY CURRENT AS A FUNCTION OF TEMPERATURE



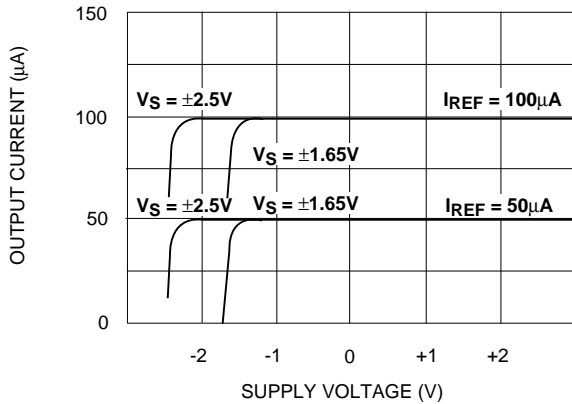
SUPPLY CURRENT AS A FUNCTION OF SUPPLY VOLTAGE



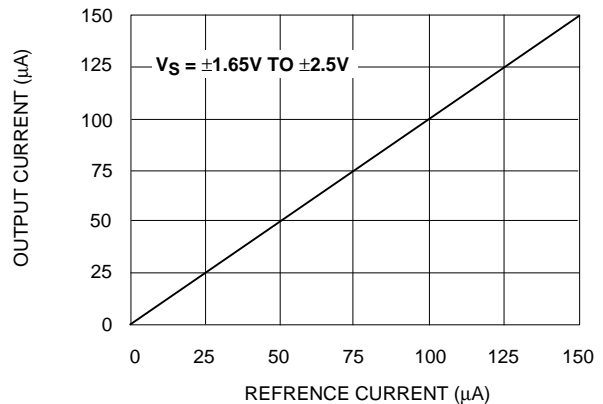
FULL SCALE OUTPUT CURRENT AS A FUNCTION OF SUPPLY VOLTAGE



FULL SCALE OUTPUT CURRENT AS A FUNCTION OF OUTPUT VOLTAGE (COMPLIANCE)



FULL SCALE OUTPUT CURRENT AS A FUNCTION OF REFERENCE CURRENT



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