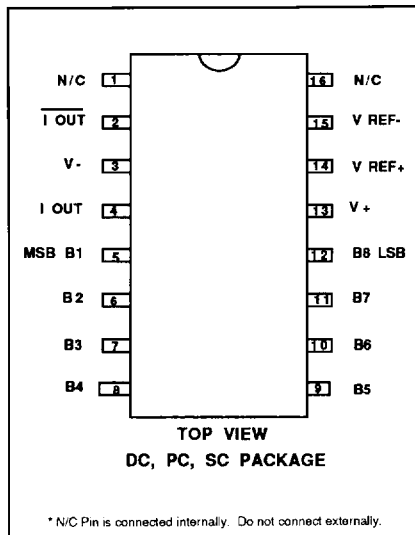# 8 BIT MICROPOWER MULTIPLYING D/A CONVERTER

GENERAL DESCRIPTION

The ALD 1801 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 ±5V dual power supply systems, as well as +3V to +12V battery operated systems. All device characteristics are specified for +5V single supply or ±2.5V dual supply systems.

The ALD 1801 is manufactured with Advanced Linear Devices' enhanced ACMOS 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 ALD 1801 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 ALD 1702, full scale output of 0 to +5V can be easily achieved with single +5V power supply.
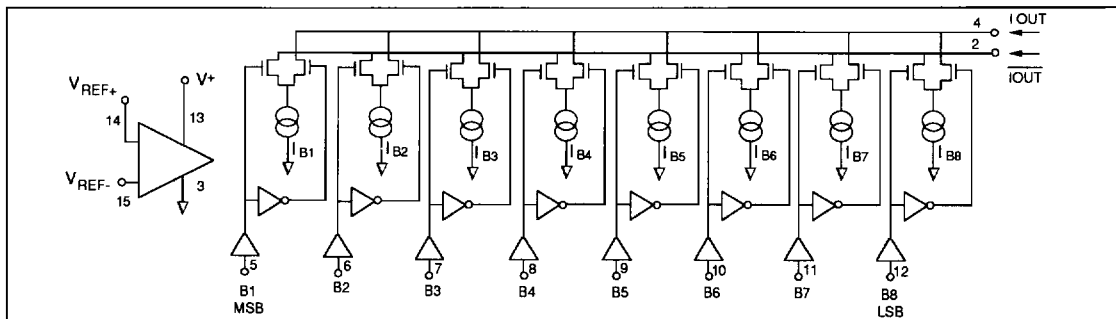
PIN CONFIGURATION

N/C	1	16	N/C
I OUT	2	15	V REF-
V -	3	14	V REF+
I OUT	4	13	V +
MSB B1	5	12	B8 LSB
B2	6	11	B7
B3	7	10	B6
B4	8	9	B5

TOP VIEW
DC, PC, SC PACKAGE

* N/C Pin is connected internally. Do not connect externally.

ORDERING INFORMATION

	Operating Temperature Range		
	-55°C to +125°C	0°C to +70°C	0°C to +70°C
Nonlinearity	16-Pin CERDIP Package	16-Pin Small Outline Package (SOIC)	16-Pin Plastic Dip Package
±0.1%	1801A DC	1801A SC	1801A PC
±0.19%	1801B DC	1801B SC	1801B PC
±0.39%	1801 DC	1801 SC	1801 PC

FEATURES

- Low voltage 3V to 12V operation
- Low power 1.2mW max @ 3V
- Single supply operation (5V)
- 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

BLOCK DIAGRAM

Tel: (408) 720-8737   Fax: (408) 720-8297

ADLDS002

DC AND OPERATING ELECTRICAL CHARACTERISTICS
$T_A = 25°C$ $V_S = ±2.5V$ or $V_S = +5.0V$ unless otherwise specified

Parameter	Symbol	1801A			1801B			1801			Unit	
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max		
Supply Voltage	V_S	±1.5		±6.0	±1.5		±6.0	±1.5		±6.0	V	Single supply Dual supply
Resolution		8			8			8			Bits	
Monotonicity		8			8			8			Bits	
Nonlinearity	N_L			±0.1			±0.19			±0.39	% of full scale	
Settling Time	t_s		2.5	5.0		2.5	5.0		2.5	5.0	µs	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	µs	each bit
			1.5	2.5		1.5	2.5		1.5	2.5	µs	all bits
Full Scale Tempco	T_c		±10	±50		±10	±50		±10	±50	ppm/°C	
Output Compliance	V_{oc}	Vss +1.5		Vdd +0.2	Vss +1.5		Vdd +0.2	Vss +1.5		Vdd +0.2	V	
Output Impedance		50			50			50			MΩ	output within compliance limits
Full Scale Current Range	I_{FS}		100			100			100		µA	Rout=Rout =50kΩ Vref= 2.5V; Rref= 25kΩ
Full Scale Symmetry	I_{FSS}			±2.5			±2.5			±2.5	µA	
Zero Scale Current	I_{ZS}			10			10			10	nA	
Logic Input Level[2] Logic "0" Logic "1"	V_{IL} V_{IH}	2.1		-1.1	2.1		-1.1	2.1		-1.1	V	Supply = ±2.5V
Logic Swing Logic Threshold Range	V_{LS}	-2.8 -1.5		2.8 1.5	-2.8 -1.5		2.8 1.5	-2.8 -1.5		2.8 1.5	V V	Supply = ±2.5V Supply = ±2.5V
Reference Bias Current	I_{RB}			0.1			0.1			0.1	nA	
Power Supply Current	I_{DD} $-I_{DD}$		500 700	800 1000		500 700	800 1000		500 700	800 1000	µA	Full scale output = 100µA
Power Dissipation	P_D			4.5			4.5			4.5	mW	Supply = ±2.5V
Compensation												Not required

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

DUAL SUPPLY ±2.5V
RATIOMETRIC VOLTAGE OUTPUT DAC

	B1	B2	B3	B4	B5	B6	B7	B8	Vout
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	Vout
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

DC AND OPERATING ELECTRICAL CHARACTERISTICS
$T_A = 25°C$ $V_S = \pm 1.65V$ or $V_S = 3.3V$ unless otherwise specified

Parameter	Symbol	1801A			1801B			1801			Unit	
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max		
Resolution		8			8			8			Bits	
Monotonicity		8			8			8			Bits	
Nonlinearity	NL			±0.1			±0.19			±0.39	% of full scale	
Settling Time	ts		4.0	10.0		4.0	10.0		4.0	10.0	µs	to1/2 LSB with all bits turned on/off
Propagation Delay	td		1.5 1.5	4.0 4.0		1.5 1.5	4.0 4.0		1.5 1.5	4.0 4.0	µs µs	each bit all bits
Full Scale Tempco	Tc		±10	±50		±10	±50		±10	±50	ppm/°C	
Output Compliance	Voc	Vss +1.5		Vdd +0.2	Vss +1.5		Vdd +0.2	Vss +1.5		Vdd +0.2	V	
Output Impedance		50			50			50			MΩ	output within compliance limits
Full Scale Current Range	IFS		50			50			50		µA	Rout=R̄o̅u̅t̅ = 100kΩ Vref= 2.5V, Rref= 50kΩ
Full Scale Symmetry	IFSS			±2.5			±2.5			±2.5	µA	
Zero Scale Current	Izs			10			10			10	nA	
Reference Bias Current	IRB			0.1			0.1			0.1	nA	
Power Supply Current	+Idd -Idd		350 450	500 600		350 450	500 600		350 450	500 600	µA	Full scale output = 50µA
Power Dissipation	PD			1.8			1.8			1.8	mW	

Notes: 1. Contact ALD for ±1.0V/±1.25V operation
      2. Logic levels of VIL 0.4V and VIH 4.6V for single supply applications

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 5 V or ±5 V. Functionality extends down to 3 V or ±1.5 V 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 Rref) can be used to convert the voltage into a reference current for most applications.

Rref is a precision fixed resistor without trimming. Trimming can be accomplished by adjusting Rref 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 Rref is 25kΩ.

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

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 5 V. 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.
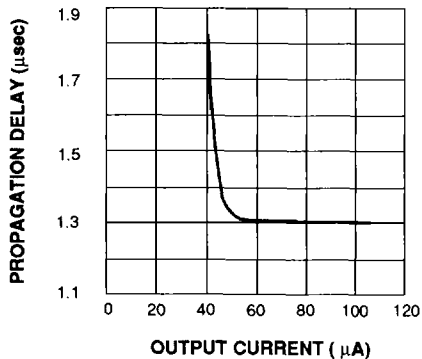
The nonlinearity and monotonicity of the ALD1801 applies over the full rated operating temperature. The device has been developed with minimal temperature drift, typically at ±10ppm/° C. A single array of matched and tracked resistor networks of nominal 50kΩ can be used for all the resistors required for the D/A converter. As an example, Rref can be set to 25kΩ by connecting two 50kΩ resistors in parallel where output resistors are set at 50kΩ.

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 100µA and device operation at single 5 V 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.
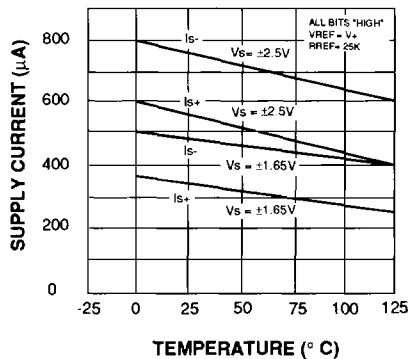
Both Io and $\overline{\text{Io}}$ outputs can be used simultaneously. If one of the outputs is not used, then it must be connected to ground or a potential where the sum of Io and $\overline{\text{Io}}$ can maintain a constant value. Due to internal leakage currents that vary with temperature, it is recommended that IFS of 50µA to 100µA be used so that 1/2 LSB bit current is set at as high a level as possible. The temperature coefficient of the reference resistor RREF and output resistors ROUT and $\overline{\text{ROUT}}$ should match to minimize temperature drift.
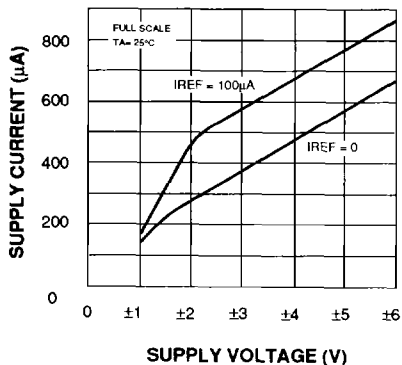
TYPICAL PERFORMANCE CHARACTERISTICS

### PROPAGATION DELAY AS A FUNCTION OF FULL SCALE OUTPUT CURRENT

PROPAGATION DELAY (μsec) vs OUTPUT CURRENT (μA)

SUPPLY CURRENT AS A FUNCTION OF TEMPERATURE

SUPPLY CURRENT (μA) vs TEMPERATURE (°C)

ALL BITS "HIGH"
VREF = V+
RREF= 25K

Is- Vs= ±2.5V
Is+ Vs = ±2.5V
Is- Vs = ±1.65V
Is+ Vs = ±1.65V

SUPPLY CURRENT AS A FUNCTION OF SUPPLY VOLTAGE

SUPPLY CURRENT (μA) vs SUPPLY VOLTAGE (V)

FULL SCALE
TA= 25°C

IREF = 100μA
IREF = 0

FULL SCALE OUTPUT CURRENT AS A FUNCTION OF SUPPLY VOLTAGE

FULL SCALE OUTPUT CURRENT (μA) vs SUPPLY VOLTAGE (V)

IREF = 100μA
IREF = 50μA
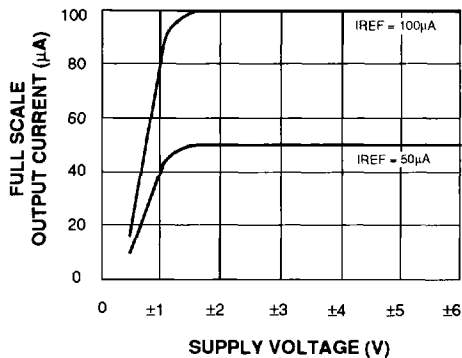
FULL SCALE OUTPUT CURRENT AS A FUNCTION OF OUTPUT VOLTAGE (COMPLIANCE)

OUTPUT CURRENT (μA) vs OUTPUT VOLTAGE (V)

Vs = ±2.5V
Vs = ±1.65V
I REF = 100μA
Vs = ±2.5V
Vs = ±1.65V
I REF = 50μA
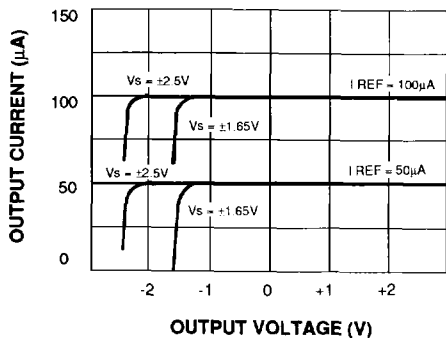
FULL SCALE OUTPUT CURRENT AS A FUNCTION OF REFERENCE CURRENT

OUTPUT CURRENT (μA) vs REFERENCE CURRENT (μA)

Vs = ±1.65V to ±2.5V