



**Complete High Speed 12-Bit Monolithic D/A Converter**

**DAC-4565**

*0.54*

**Features**

- Nonlinearity 1/2 LSB — 0.012%
- Differential Nonlinearity — 0.012% (13 Bits)
- Settles to 1/2 LSB in 200 nS
- On Chip Bandgap Voltage Reference
- Linearity Guaranteed Over Temperature
- Low Power: 225mW Including Reference
- Direct Interface to All Major Logic Families
- Includes Trimmed Application Resistors

- The DAC-4565S grade guarantees linearity and monotonicity over the -55°C to +125°C range and is available fully processed to MIL-STD-883, Level B.

**Highlights**

- The DAC-4565 is a monolithic 12-Bit DAC that has on board the self-contained voltage-reference and application resistors.
- The device incorporates interdigitizing of the elements forming the currents of the 3 MSB's of the DAC. Interdigitizing minimizes the effects of thin film sputtering, thermal and diffusion gradients in the most critical portions of the design. Excellent linearity distributions are achieved prior to trimming, thus insuring optimal stability of nonlinearity over temperature as well as stability versus time.
- The thin film resistors have a trim tab which is distant from the main body of the resistor. This resistor geometry insures near perfect nonlinearity after trim as well as minimizes damage due to laser trimming.
- The internal reference is laser trimmed to 10.00 Volts with a ±1.0% maximum error. The reference voltage is available externally and can source typically 10mA beyond that required for the reference and bipolar offset resistors.
- The DAC-4565 contains SiCr thin film application resistors which can be used with either an external op amp, creating a precision voltage output DAC, or as input resistors for a successive approximation A/D converter. The resistors are inherently matched and are laser trimmed to guarantee minimum full scale and bipolar offset errors.

**Description**

The DAC-4565 is a fast 12-bit digital-to-analog converter. Inside the 24 pin DIP package are all of the circuit functions required for a complete DAC: a stable bandgap voltage reference, a reference amplifier and resistors, twelve laser trimmed binary weighted current sources, twelve high speed precision current steering switches, and laser trimmed span and bipolar offset application resistors.

The high performance and flexibility of the DAC-4565 were achieved through circuit design and layout, a thin film resistor process, and interactive computer-controlled laser trimming. The DAC-4565 settles to 1/2 LSB in 200nS, typical, with a maximum settling time of 400nS. Accuracy is specified at a **maximum** of 1/2 LSB for all grades.

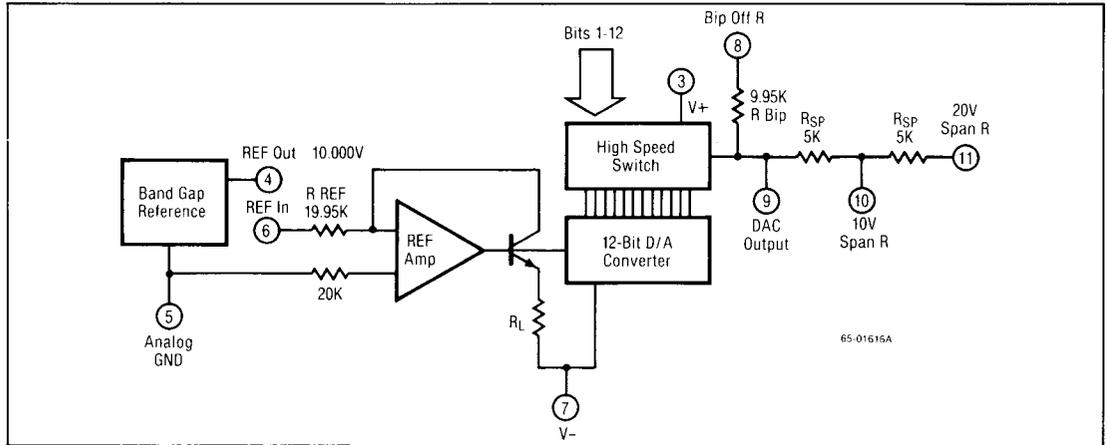
High speed and accuracy coupled with inherent high output impedance make the DAC-4565 the ideal DAC for high speed display drivers, high speed control systems, and with the RC4805 high speed latching comparator, for analog-to-digital converters.

The bandgap voltage reference is laser trimmed to optimize both temperature drift and absolute output voltage. The current sourcing capability of the DAC-4565 reference (10mA typ) allows the reference to drive peripheral circuit elements in addition to the DAC. Typical reference drift is better than 15ppm/°C, (S and J grade).

The DAC-4565 is available in three performance grades. The DAC-4565J and DAC-4565D grades are specified over 0°C to +70°C, while the DAC-4565S grade is specified over the -55°C to +125°C temperature range.

*2722*  
*73*  
*3733*  
*1000*  
*DOP*  
*211*

## Functional Block Diagram



## Absolute Maximum Rating

- Power Supply Voltage .....  $\pm 18V$
- Logic Inputs .....  $-1.0V$  to  $+18V$
- Analog Common to
  - Digital Common .....  $\pm 1.0V$
- Voltage on DAC
  - Output (Pin 9) .....  $-3.0V$  to  $+18V$
- Reference Input to
  - Analog Common .....  $\pm 12V$
- Bipolar Offset to
  - Analog Common .....  $\pm 12V$
  - 10V Span R to Analog Common .....  $\pm 12V$
  - 20V Span R to Analog Common .....  $\pm 24V$
- Ref Out ..... Indefinite Short to Either
  - Common, Momentary
  - Short to V+

## Thermal Characteristics

	24-Lead Sidebrazed DIP
Max. Junction Temp.	175°C
Max. $P_D$ $T_A < 50^\circ C$	1042mW
Therm. Res. $\theta_{JC}$	60°C/W
Therm. Res. $\theta_{JA}$	120°C/W
For $T_A > 50^\circ C$ Derate at	8.38mW per °C

## Connection Information

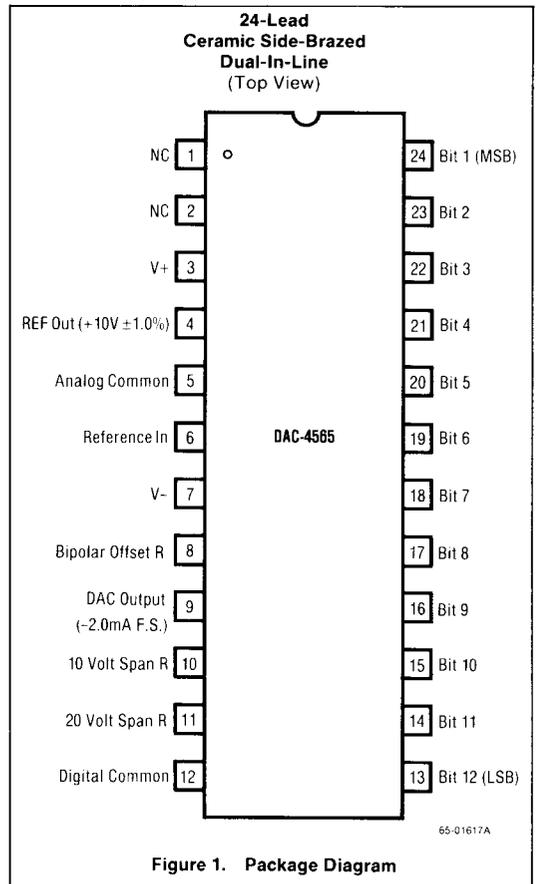


Figure 1. Package Diagram

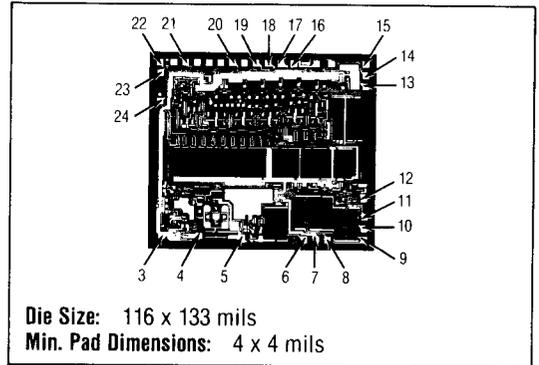
# Complete High Speed 12-Bit Monolithic D/A Converter

## DAC-4565

### Ordering Information

Part Number	Package	Operating Temperature Range
DAC-4565SDM	Sidebrazed	-55°C to +125°C
DAC-4565JDC	Sidebrazed	0°C to +70°C
DAC-4565DDC	Sidebrazed	0°C to +70°C

### Mask Pattern



### Electrical Characteristics $T_A = +25^\circ\text{C}$ , $V_+ = +15\text{V}$ , $V_- = -15\text{V}$ (unless otherwise noted)

Parameter	Test Conditions	DAC-4565S/J			DAC-4565D			Units
		Min	Typ	Max	Min	Typ	Max	
Resolution		12	12	12	12	12	12	Bits
Monotonicity		12	12	12	12	12	12	Bits
Nonlinearity			$\pm 1/4$	$\pm 1/2$		$\pm 1/4$	$\pm 1/2$	LSB
Differential Nonlinearity	Deviation from ideal step size		$\pm 0.3$	$\pm 0.75$		$\pm 0.3$	$\pm 0.75$	LSB
Full Scale Current	Unipolar (All bits on) Internal Reference (Full temperature)	-1.6	-2.0	-2.4	-1.6	-2.0	-2.4	mA
	Bipolar (Figure 3 $R_2 = 50\Omega$ fixed) All bits on or off (Full temperature)	$\pm 0.8$	$\pm 1.0$	$\pm 1.2$	$\pm 0.8$	$\pm 1.0$	$\pm 1.2$	
Output Resistance		1.0	10		1.0	10	$M\Omega$	
Output Compliance	$R_0 > 10M\Omega$ typ (Full temperature)	-1.5		+10	-1.5		+10	V
Output Capacitance			25			25		pF
Offset Unipolar Zero Scale			0.001	0.0025		0.002	0.01	% of F.S.
	Bipolar (Figure 3 $R_2 = 50\Omega$ Fixed)		0.05	0.15		0.10	0.30	
Settling Time to 1/2 LSB	All bits on to off or off to on		200	400		200	400	nS

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**Electrical Characteristics( Cont'd)**

T<sub>A</sub> = +25° C, V<sub>+</sub> = +15V, V<sub>-</sub> = -15V (unless otherwise noted)

Parameter	Test Conditions	DAC-4565S/J			DAC-4565D			Units
		Min	Typ	Max	Min	Typ	Max	
Full Scale Transition 10% to 90% Delay Plus Rise Time			40			40		nS
90% to 10% Delay Plus Fall Time			40			40		
Logic Input Levels Logic "0"	(Full temperature)			0.8			0.8	V
Logic "1"	(Full temperature)	2.0			2.0			
Logic Input Currents	V <sub>IN</sub> = 0V to 18V (Full temperature)			40			40	μA
Reference Input Current	V <sub>REF</sub> = 10.000V	0.4	0.5	0.6	0.4	0.5	0.6	mA
Input Resistance		15	20	25	15	20	25	kΩ
Power Supply Range	(Full temperature)	±13.5	±15	±16.5	±13.5	±15	±16.5	V
Power Supply Current	V <sub>+</sub> = +13.5 to +16.5		3.0	5.0		3.0	5.0	mA
	V <sub>-</sub> = -13.5 to -16.5		-10	-18		-10	-18	
Power Dissipation			195	345		195	345	mW
Power Supply Sensitivity	V <sub>+</sub> = +15V, ±10%		3.0	10		7.0	20	ppm of F.S./%
	V <sub>-</sub> = -15V, ±10%		15	25		20	35	
Reference Output Voltage		9.90	10	10.1	9.7	10	10.3	V
Reference Output Current	(Available for External Loads)	5.0	10		5.0	10		mA
External Adjustments	(Gain Error with Fixed 50Ω Resistor for R <sub>2</sub> (Figure 4))		±0.1	±0.25		±0.1	±0.50	% of F.S.
Bipolar Zero Error with Fixed 50Ω Resistor for R <sub>1</sub>	(Figure 5)		±0.05	±0.15		±0.05	±1.0	% of F.S.
Gain Adjustment Range		±0.25			±0.50			% of F.S.
Bipolar Zero Adjustment Range		±0.15			±0.3			% of F.S.
Programmable Output Range	(See Figures 4, 5, 6)	0		5.0	0		5.0	V
		-2.5		+2.5	-2.5		+2.5	
		0		10	0		10	
		-5.0		+5.0	-5.0		+5.0	
		-10		+10	-10		+10	

# Complete High Speed 12-Bit Monolithic D/A Converter

## DAC-4565

### Electrical Characteristics

DAC-4565S = -55°C to +125°C, DAC-4565J/D = 0°C to +70°C (unless otherwise noted)

Parameter	Test Conditions	DAC-4565S/J			DAC-4565D			Units
		Min	Typ	Max	Min	Typ	Max	
Resolution		12	12	12	12	12	12	Bits
Monotonicity		12	12	12	12	12	12	Bits
Nonlinearity			±1/2	±3/4		±1/2	±3/4	LSB
Differential Nonlinearity	Deviation from ideal Step size	Monotonicity Guaranteed						
Temperature Coefficients Unipolar Zero			1.0	2.0		1.0	2.0	ppm/°C
Bipolar Zero			5.0	10		10		ppm/°C
Differential Nonlinearity			2.0			2.0		ppm/°C
Gain with Internal Reference	Full Scale	15	30			40		ppm/°C
with External Reference								
Power Supply Current	V+ = +13.5V to +16.5V		4.0	7.0		4.0	7.0	mA
	V- = -13.5V to -16.5V		-12	-18		-12	-18	mA

### Connecting the DAC-4565 for Buffered Voltage Output

The standard current to voltage conversion connections using an operational amplifier are shown in Figure 2. If a low offset voltage operational amplifier (OP-07, OP-27, OP-37) is used, excellent performance can be obtained in most applications without trimming. If a fixed 50Ω resistor is substituted for the 100Ω trimmer of Figure 2, unipolar zero will be typically much less than ±1/2 LSB and full scale accuracy will be within 0.1% (0.25% max). Substituting a 50Ω resistor for the 100Ω bipolar offset trimmer (R1) of Figure 3 will give a bipolar zero error typically within ±2.0 LSB.

The configuration of Figure 2 will provide a unipolar 0V to +10V output range. In this mode, the bipolar terminal, pin 8, should be grounded if not used for trimming.

### Unipolar Configurations

#### Step 1 — Gain Adjust

Turn all bits on and adjust 100Ω gain trimmer R1 until the output is 9.9976 (Full scale should be

adjusted to 1 LSB less than 10.000 Volts). If a 10.2375V full scale is desired (exactly 2.5mV/bit), insert a 120Ω resistor in series with the gain resistor at pin 10 to the op amp output.

In most cases a zero trim is not needed, due to the extremely low zero scale output current. Pin 8 should be connected to pin 9 for unipolar operation.

### Bipolar Configurations

These configurations will yield ±5.0V, ±10V, or ±2.5V, with positive full scale occurring with all bits on (all 1's).

#### Step 1 — Offset Adjust

Turn off all bits. Adjust 100Ω trimmer R1 to give -5.000, -10.000, or -2.500 Volts, depending upon the configuration.

#### Step 2 — Gain Adjust

Turn on all bits and adjust trimmer R2 to give a reading of 4.9976, 9.9952, or 2.4988 Volts depending upon configuration.

If a precision op amp such as the OP-07, OP-27 or OP-37 is used no separate trimming of the



operational amplifier is required or recommended.

## 0V to 5.0V Range

A 0V to 5V output can be achieved by modifying the configuration of Figure 2. Tie pin 11 to pin 9 rather than to ground and adjust full scale to 4.9988 Volts.

## Internal/External Reference Use

The DAC-4565 has an internal bandgap voltage reference which is trimmed for both temperature coefficient and absolute accuracy. The reference is buffered with an internal operational amplifier and is capable of driving a minimum of 5.0mA in addition to the 0.5mA to REF<sub>IN</sub> and 1.0mA to Bipolar Offset for the DAC. The reference is typically trimmed to ±0.2% but specified to 1.0% (J, S grades) max error. Testing and specifying of absolute unipolar and bipolar full scale is done using the internal reference. For noise performance of the reference (see Figure 6.).

## Digital Input Considerations

The DAC-4565 uses a positive true straight binary code for unipolar outputs (all 1's give full scale output) and an offset binary code for bipolar output ranges. In the bipolar mode, all 0's give -F.S., with only the MSB on give 0.00 Volts, and with all 1's, +F.S. is achieved.

The threshold of the digital input circuitry is set at 1.4 Volts independent of supply voltage. The bit lines are compatible with TTL, DTL, CMOS, and unbuffered CMOS.

## Application of Analog and Digital Commons

The DAC-4565 separates analog and digital grounds to optimize accuracy and noise. 200mV difference between the two grounds can be tolerated without degradation in performance.

## Output Voltage Compliance

The Raytheon DAC-4565 has a minimum output voltage compliance range of -1.5V to +10V and is independent of both the positive and negative supply. The output can be modeled as a 25pF capacitance shunted by a 10MΩ resistance

across the output current source to ground. This is a dramatic improvement over competitive DAC-4565 designs which have a 8KΩ output impedance. The DAC-4565's output current varies insignificantly as a function of output voltage.

More significantly, the errors introduced by the input errors of the external output operational amplifier are not magnified by a low output impedance. The output system error from the op amp is equal to:

$$(V_{ERR} \text{ in op amp}) \left( \frac{R_{SPAN} + R_{IN}}{R_{IN}} \right)$$

and defaults to only the inherent input errors of the op amp.

## Settling Time

The internally compensated reference amplifier and differential bit switch are optimized for fast settling operation. Worst case settling time occurs when all bits are switched and is specified as 400nS maximum. Note: The settling time specification is for the output current, not for a voltage. When using an external op amp as a current to voltage converter the settling time will usually be dominated by the speed performance of the operational amplifier. When using the DAC in a successive approximation A/D application, care in the selection of the comparator is critical in determining accuracy and speed. Raytheon recommends the use of the RM4805 comparator to optimize A/D performance. Please refer to the 4805 application notes for further details on speed and accuracy characteristics of successive approximation A/D converters.

## Direct Unbuffered Voltage Output for Cable Driving

The high output impedance and compliance range allow for direct current to voltage conversion using the bipolar and span resistors. The circuit configurations of Figure 6 yield complementary unipolar coding (10V to 0V) as well as ±1.0V bipolar coding. The 10MΩ output impedance of the Raytheon DAC-4565 allows for direct current to voltage conversion without any degradation of linearity performance.





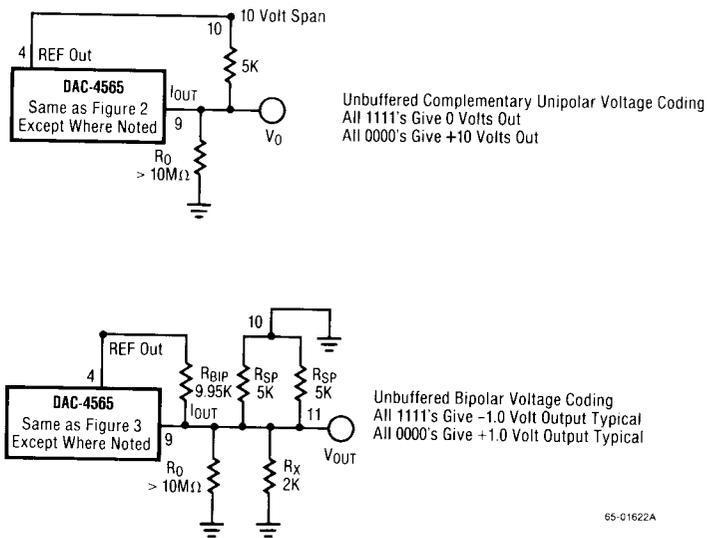


Figure 5. Unbuffered Voltage Output Configurations

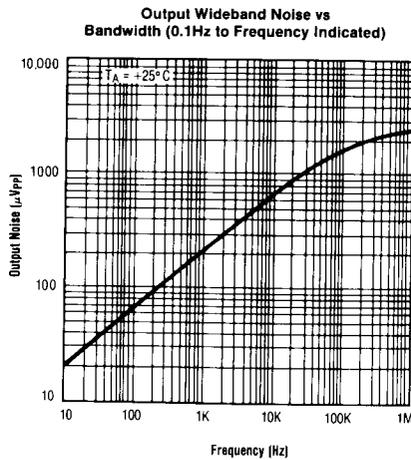
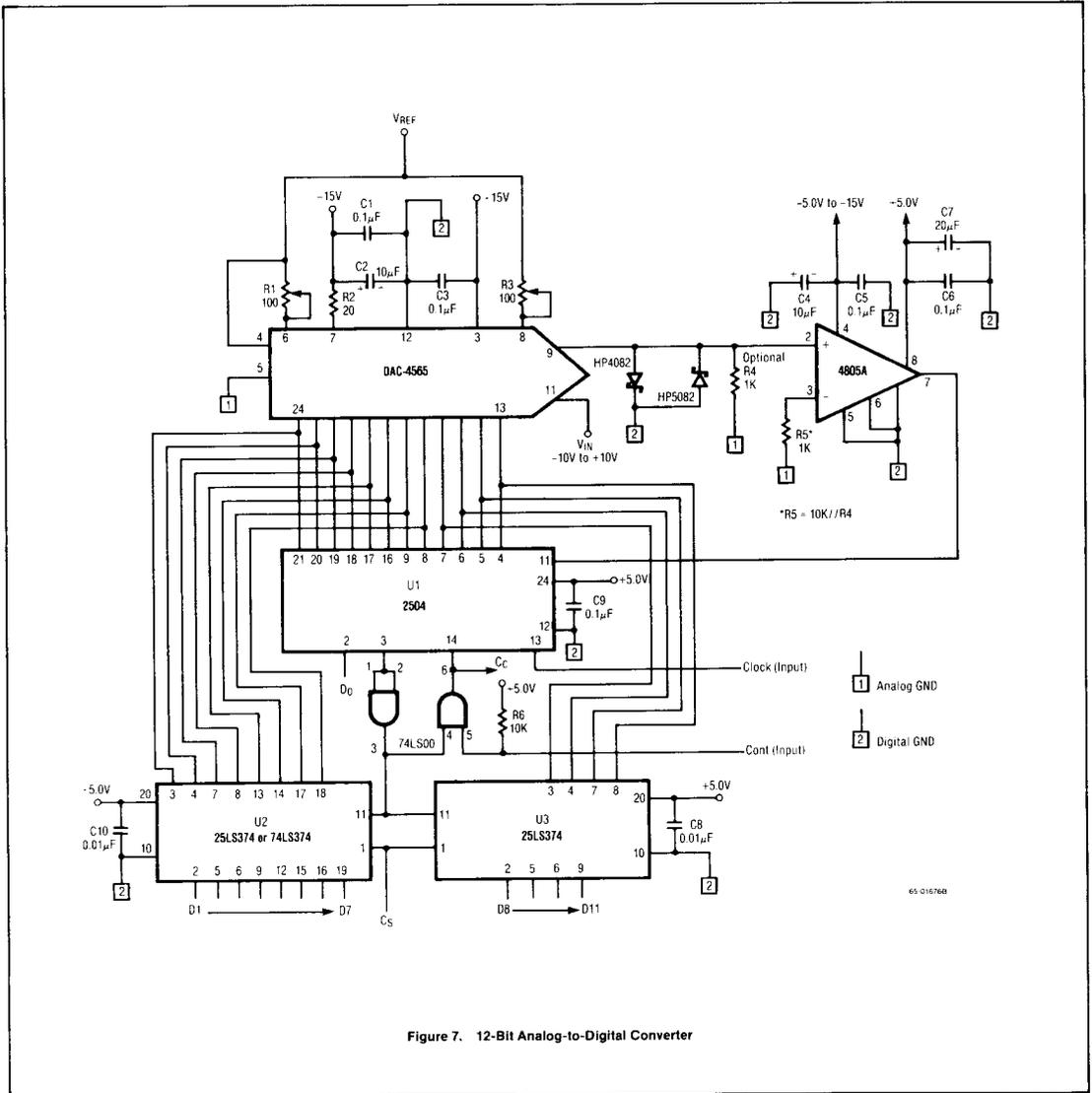


Figure 6.

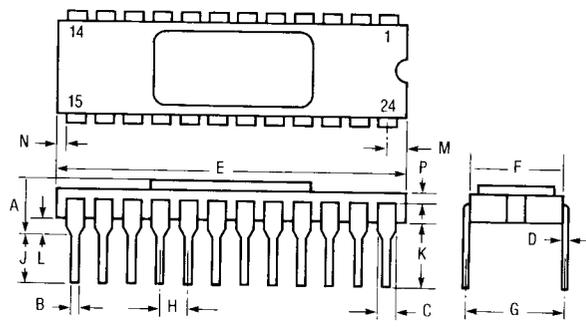


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**DAC-4565**

## Packaging Information

**24-Lead  
Ceramic Side-Brazed  
Dual In-Line**



Dimension	Inches		Millimeters	
	Min	Max	Min	Max
A		0.200		5.08
B	0.015	0.023	0.38	0.58
C	0.045	0.060	1.14	1.52
D	0.008	0.012	0.20	0.31
E	1.150	1.220	29.20	31.01
F	0.280	0.310	7.11	7.87
G	0.290	0.320	7.37	8.13
H	0.100BSC		2.54BSC	
J	0.125		3.18	
K	0.150		3.05	5.08
L	0.015	0.060	0.38	1.52
M	0.030	0.065	0.76	1.65
N	0.005		0.13	
P	0.005		0.13	

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