

16-Ch/Dual 8-Ch High-Performance CMOS Analog Multiplexers

DESCRIPTION

The DG406 is a 16 channel single-ended analog multiplexer designed to connect one of sixteen inputs to a common output as determined by a 4-bit binary address. The DG407 selects one of eight differential inputs to a common differential output. Break-before-make switching action protects against momentary shorting of inputs.

An on channel conducts current equally well in both directions. In the off state each channel blocks voltages up to the power supply rails. An enable (EN) function allows the user to reset the multiplexer/demultiplexer to all switches off for stacking several devices. All control inputs, address (A_x) and enable (EN) are TTL compatible over the full specified operating temperature range.

Applications for the DG406, DG407 include high speed data acquisition, audio signal switching and routing, ATE systems, and avionics. High performance and low power dissipation make them ideal for battery operated and remote instrumentation applications.

Designed in the 44 V silicon-gate CMOS process, the absolute maximum voltage rating is extended to 44 V, allowing operation with ± 20 V supplies. Additionally single (12 V) supply operation is allowed. An epitaxial layer prevents latchup.

For applications information please request documents 70601 and 70604.

FEATURES

- Low on-resistance - $R_{DS(on)}$: 50 Ω
- Low charge injection - Q: 15 pC
- Fast transition time - t_{TRANS} : 200 ns
- Low power: 0.2 mW
- Single supply capability
- 44 V supply max. rating

BENEFITS

- Higher accuracy
- Reduced glitching
- Improved data throughput
- Reduced power consumption
- Increased ruggedness
- Wide supply ranges: ± 5 V to ± 20 V

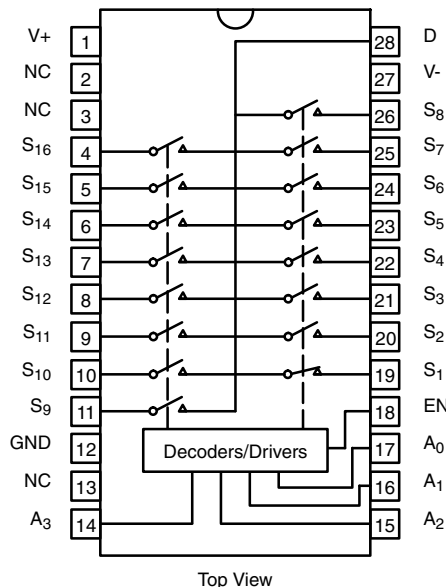
APPLICATIONS

- Data acquisition systems
- Audio signal routing
- Medical instrumentation
- ATE systems
- Battery powered systems
- High-rel systems
- Single supply systems

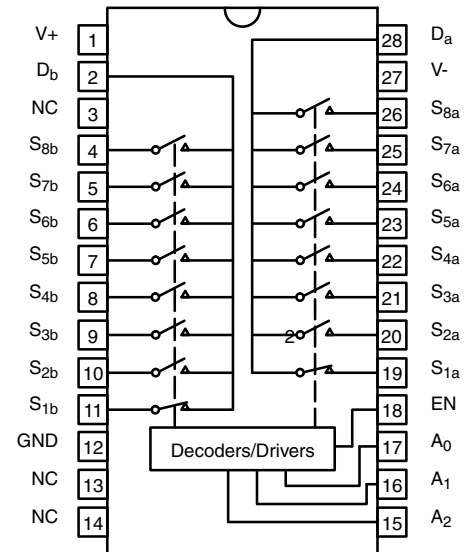


RoHS*
COMPLIANT

FUNCTIONAL BLOCK DIAGRAM AND PIN CONFIGURATION

DG406
Dual-In-Line and SOIC Wide-Body


Top View

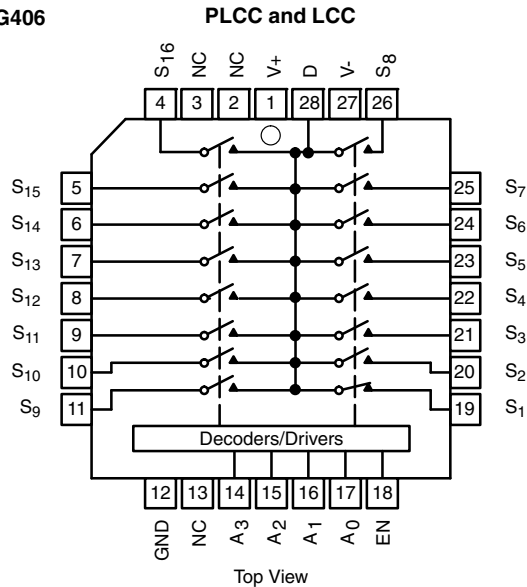
DG407
Dual-In-Line and SOIC Wide-Body


Top View

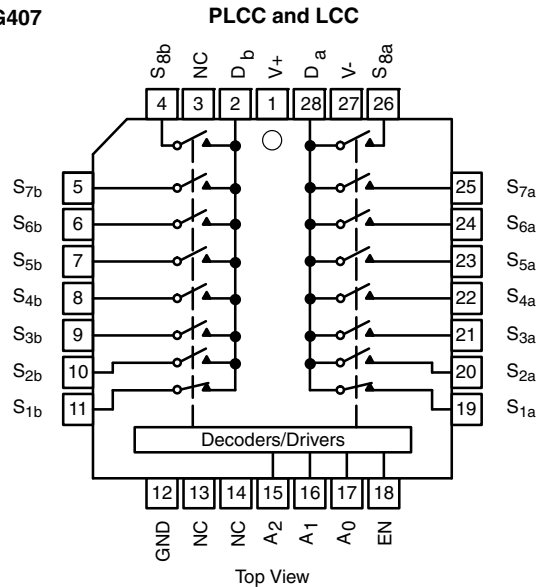
* Pb containing terminations are not RoHS compliant, exemptions may apply

FUNCTIONAL BLOCK DIAGRAM AND PIN CONFIGURATION

DG406



DG407



| TRUTH TABLE (DG406) | | | | | |
|---------------------|----------------|----------------|----------------|----|-----------|
| A ₃ | A ₂ | A ₁ | A ₀ | EN | On Switch |
| X | X | X | X | 0 | None |
| 0 | 0 | 0 | 0 | 1 | 1 |
| 0 | 0 | 0 | 1 | 1 | 2 |
| 0 | 0 | 1 | 0 | 1 | 3 |
| 0 | 0 | 1 | 1 | 1 | 4 |
| 0 | 1 | 0 | 0 | 1 | 5 |
| 0 | 1 | 0 | 1 | 1 | 6 |
| 0 | 1 | 1 | 0 | 1 | 7 |
| 0 | 1 | 1 | 1 | 1 | 8 |
| 1 | 0 | 0 | 0 | 1 | 9 |
| 1 | 0 | 0 | 1 | 1 | 10 |
| 1 | 0 | 1 | 0 | 1 | 11 |
| 1 | 0 | 1 | 1 | 1 | 12 |
| 1 | 1 | 0 | 0 | 1 | 13 |
| 1 | 1 | 0 | 1 | 1 | 14 |
| 1 | 1 | 1 | 0 | 1 | 15 |
| 1 | 1 | 1 | 1 | 1 | 16 |

| TRUTH TABLE (DG407) | | | | |
|---------------------|----------------|----------------|----|----------------|
| A ₂ | A ₁ | A ₀ | EN | On Switch Pair |
| X | X | X | 0 | None |
| 0 | 0 | 0 | 1 | 1 |
| 0 | 0 | 1 | 1 | 2 |
| 0 | 1 | 0 | 1 | 3 |
| 0 | 1 | 1 | 1 | 4 |
| 1 | 0 | 0 | 1 | 5 |
| 1 | 0 | 1 | 1 | 6 |
| 1 | 1 | 0 | 1 | 7 |
| 1 | 1 | 1 | 1 | 8 |

Logic "0" = $V_{AL} \leq 0.8 V$
 Logic "1" = $V_{AH} \geq 2.4 V$
 X = Do not Care

| ORDERING INFORMATION (DG406) | | |
|------------------------------|----------------------|--------------------------|
| Temp. Range | Package | Part Number |
| - 40 °C to 85 °C | 28-Pin Plastic DIP | DG406DJ DG406DJ-E3 |
| | 28-Pin PLCC | DG406DN DG406DN-T1-E3 |
| | 28-Pin Widebody SOIC | DG406DW DG406DW-E3 |

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|------------------------------|----------------------|--------------------------|
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| | 28-Pin PLCC | DG407DN DG407DN-T1-E3 |
| | 28-Pin Widebody SOIC | DG407DW DG407DW-E3 |



| ABSOLUTE MAXIMUM RATINGS | | | |
|---|----------------------------------|--|-------------|
| Parameter | | Limit | Unit |
| Voltages Referenced to V- | V+ | 44 | V |
| | GND | 25 | |
| Digital Inputs ^a , V _S , V _D | | (V-) - 2 to (V+) + 2 V or 20 mA, whichever occurs first | |
| Current (Any terminal) | | 30 | mA |
| Peak Current, S or D (Pulsed at 1 ms, 10 % duty cycle max.) | | 100 | |
| Storage Temperature | (AK, AZ Suffix) | - 65 to 150 | °C |
| | (DJ, DN Suffix) | - 65 to 125 | |
| Power Dissipation (Package) ^b | 28-Pin Plastic DIP ^b | 625 | mW |
| | 28-Pin CerDIP ^d | 1.2 | W |
| | 28-Pin Plastic PLCC ^c | 450 | mW |
| | LCC-28 ^e | 1.35 | W |
| | 28-Pin Widebody SOIC | 450 | mW |

Notes:

- a. Signals on SX, DX or INX exceeding V+ or V- will be clamped by internal diodes. Limit forward diode current to maximum current ratings.
- b. All leads soldered or welded to PC board.
- c. Derate 6 mW/°C above 75°C.
- d. Derate 12 mW/°C above 75°C.
- e. Derate 13.5 mW/°C above 75°C .



| SPECIFICATIONS ^a | | | | | | | | | | |
|---|---------------------|--|--------------------|-------------------|-------------------------------|-------------------|------------------------------|-------------------|---------------|---------|
| Parameter | Symbol | Test Conditions Unless Otherwise Specified $V_+ = 15\text{ V}$, $V_- = -15\text{ V}$ $V_{AL} = 0.8\text{ V}$, $V_{AH} = 2.4\text{ V}^f$ | Temp. ^b | Typ. ^c | A Suffix - 55 °C to 125 °C | | D Suffix - 40 °C to 85 °C | | Unit | |
| | | | | | Min. ^d | Max. ^d | Min. ^d | Max. ^d | | |
| Analog Switch | | | | | | | | | | |
| Analog Signal Range ^e | V_{ANALOG} | | Full | | - 15 | 15 | - 15 | 15 | V | |
| Drain-Source On-Resistance | $R_{DS(on)}$ | $V_D = \pm 10\text{ V}$, $I_S = -10\text{ mA}$ sequence each switch on | Room Full | 50 | | 100 125 | | 100 125 | Ω | |
| $R_{DS(on)}$ Matching Between Channels ^g | $\Delta R_{DS(on)}$ | $V_D = \pm 10\text{ V}$ | Room | 5 | | | | | % | |
| Source Off Leakage Current | $I_{S(off)}$ | $V_{EN} = 0\text{ V}$ $V_D = \pm 10\text{ V}$ $V_S = \pm 10\text{ V}$ | Room Full | 0.01 | - 0.5 - 50 | 0.5 50 | - 0.5 - 5 | 0.5 5 | nA | |
| Drain Off Leakage Current | $I_{D(off)}$ | | DG406 | Room Full | 0.04 | - 1 - 200 | 1 200 | - 1 - 40 | | 1 40 |
| | | | DG407 | Room Full | 0.04 | - 1 - 100 | 1 100 | - 1 - 20 | | 1 20 |
| Drain On Leakage Current | $I_{D(on)}$ | | DG406 | Room Full | 0.04 | - 1 - 200 | 1 200 | - 1 - 40 | | 1 40 |
| | | DG407 | Room Full | 0.04 | - 1 - 100 | 1 100 | - 1 - 20 | 1 20 | | |
| Digital Control | | | | | | | | | | |
| Logic High Input Voltage | V_{INH} | | Full | | 2.4 | | 2.4 | | V | |
| Logic Low Input Voltage | V_{INL} | | Full | | | 0.8 | | 0.8 | | |
| Logic High Input Current | I_{AH} | $V_A = 2.4\text{ V}$, 15 V | Full | | - 1 | 1 | - 1 | 1 | μA | |
| Logic Low Input Current | I_{AL} | $V_{EN} = 0\text{ V}$, 2.4 V , $V_A = 0\text{ V}$ | Full | | - 1 | 1 | - 1 | 1 | | |
| Logic Input Capacitance | C_{in} | $f = 1\text{ MHz}$ | Room | 7 | | | | | pF | |
| Dynamic Characteristics | | | | | | | | | | |
| Transition Time | t_{TRANS} | see figure 2 | Room Full | 200 | | 350 450 | | 350 450 | ns | |
| Break-Before-Make Interval | t_{OPEN} | see figure 4 | Room Full | 50 | 25 10 | | 25 10 | | | |
| Enable Turn-On Time | $t_{ON(EN)}$ | see figure 3 | Room Full | 150 | | 200 400 | | 200 400 | | |
| Enable Turn-Off Time | $t_{OFF(EN)}$ | | Room Full | 70 | | 150 300 | | 150 300 | | |
| Charge Injection | Q | $V_S = 0\text{ V}$, $C_L = 1\text{ nF}$, $R_S = 0\ \Omega$ | Room | 15 | | | | | pC | |
| Off Isolation ^h | OIRR | $V_{EN} = 0\text{ V}$, $R_L = 1\text{ k}\Omega$ $f = 100\text{ kHz}$ | Room | - 69 | | | | | dB | |
| Source Off Capacitance | $C_{S(off)}$ | $V_{EN} = 0\text{ V}$, $V_S = 0\text{ V}$, $f = 1\text{ MHz}$ | Room | 8 | | | | | pF | |
| Drain Off Capacitance | $C_{D(off)}$ | $V_{EN} = 0\text{ V}$ $V_D = 0\text{ V}$ $f = 1\text{ MHz}$ | Room | 130 | | | | | | |
| | | | DG407 | Room | 65 | | | | | |
| Drain On Capacitance | $C_{D(on)}$ | | DG406 | Room | 140 | | | | | |
| | | | DG407 | Room | 70 | | | | | |
| Power Supplies | | | | | | | | | | |
| Positive Supply Current | I_+ | $V_{EN} = V_A = 0\text{ or }5\text{ V}$ | Room Full | 13 | | 30 75 | | 30 75 | μA | |
| Negative Supply Current | I_- | | Room Full | - 0.01 | - 1 - 10 | | - 1 - 10 | | | |
| Positive Supply Current | I_+ | $V_{EN} = 2.4\text{ V}$, $V_A = 0\text{ V}$ | Room Full | 50 | | 500 900 | | 500 700 | | |
| Negative Supply Current | I_- | | Room Full | - 0.01 | - 20 - 20 | | - 20 - 20 | | | |



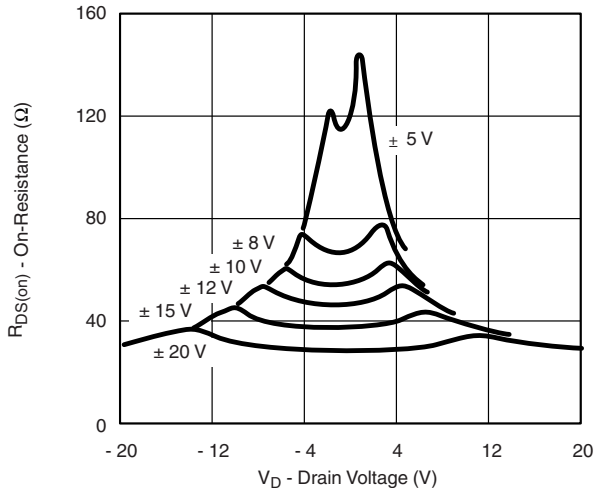
| SPECIFICATIONS ^a (for Single Supply) | | | | | | | | | |
|--|----------------------|---|--------------------|-------------------|-------------------------------|-------------------|------------------------------|-------------------|------|
| Parameter | Symbol | Test Conditions Unless Otherwise Specified V ₊ = 12 V, V ₋ = 0 V V _{AL} = 0.8 V, V _{AH} = 2.4 V ^f | Temp. ^b | Typ. ^c | A Suffix - 55 °C to 125 °C | | D Suffix - 40 °C to 85 °C | | Unit |
| | | | | | Min. ^d | Max. ^d | Min. ^d | Max. ^d | |
| Analog Switch | | | | | | | | | |
| Analog Signal Range ^e | V _{ANALOG} | | Full | | 0 | 12 | 0 | 12 | V |
| Drain-Source On-Resistance | R _{DS(on)} | V _D = 3 V, 10 V, I _S = - 1 mA sequence each switch on | Room | 90 | | 120 | | 120 | Ω |
| R _{DS(on)} Matching Between Channels ^g | ΔR _{DS(on)} | | Room | 5 | | | | | % |
| Source Off Leakage Current | I _{S(off)} | V _{EN} = 0 V V _D = 10 V or 0.5 V V _S = 0.5 V or 10 V V _S = V _D = ± 10 sequence each switch on | Room | 0.01 | | | | | nA |
| Drain Off Leakage Current | I _{D(off)} | | DG406 | Room | 0.04 | | | | |
| | | | DG407 | Room | 0.04 | | | | |
| Drain On Leakage Current | I _{D(on)} | | DG406 | Room | 0.04 | | | | |
| | | | DG407 | Room | 0.04 | | | | |
| Dynamic Characteristics | | | | | | | | | |
| Switching Time of Multiplexer | t _{OPEN} | V _{S1} = 8 V, V _{S8} = 0 V, V _{IN} = 2.4 V | Room | 300 | | 450 | | 450 | ns |
| Enable Turn-On Time | t _{ON(EN)} | V _{INH} = 2.4 V, V _{INL} = 0 V V _{S1} = 5 V | Room | 250 | | 600 | | 600 | |
| Enable Turn-Off Time | t _{OFF(EN)} | | Room | 150 | | 300 | | 300 | |
| Charge Injection | Q | C _L = 1 nF, V _S = 6 V, R _S = 0 | Room | 20 | | | | | pC |
| Power Supplies | | | | | | | | | |
| Positive Supply Current | I ₊ | V _{EN} = 0 V or 5 V, V _A = 0 V or 5 V | Room | 13 | | 30 | | 30 | μA |
| Negative Supply Current | I ₋ | | Full | Full | - 0.01 | - 20 | - 20 | - 20 | |

Notes:

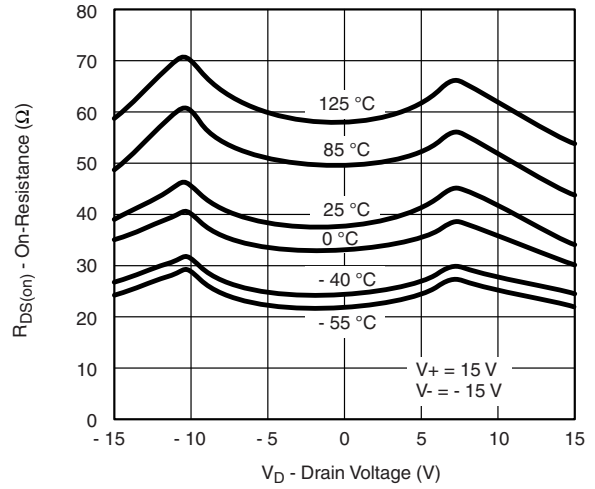
- a. Refer to PROCESS OPTION FLOWCHART.
- b. Room = 25 °C, Full = as determined by the operating temperature suffix.
- c. Typical values are for DESIGN AID ONLY, not guaranteed nor subject to production testing.
- d. The algebraic convention whereby the most negative value is a minimum and the most positive a maximum, is used in this data sheet.
- e. Guaranteed by design, not subject to production test.
- f. V_{IN} = input voltage to perform proper function.
- g. ΔR_{DS(on)} = R_{DS(on)} max. - R_{DS(on)} min.
- h. Worst case isolation occurs on Channel 4 due to proximity to the drain pin.

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.

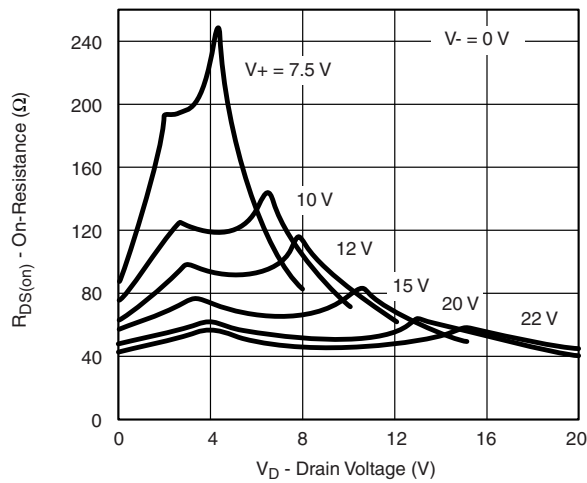
TYPICAL CHARACTERISTICS (T_A = 25 °C, unless otherwise noted)



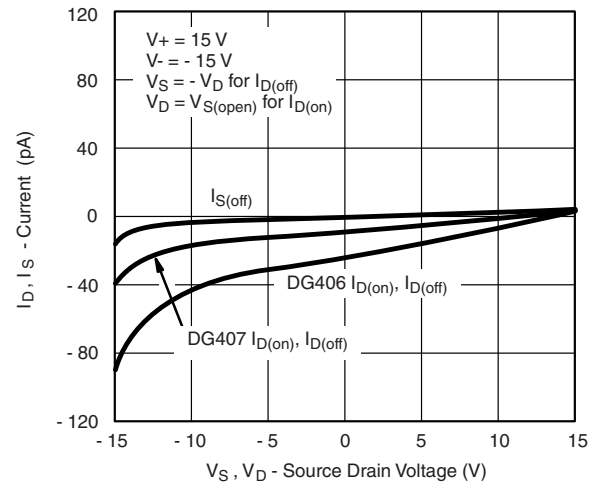
R_{DS(on)} vs. V_D and Supply



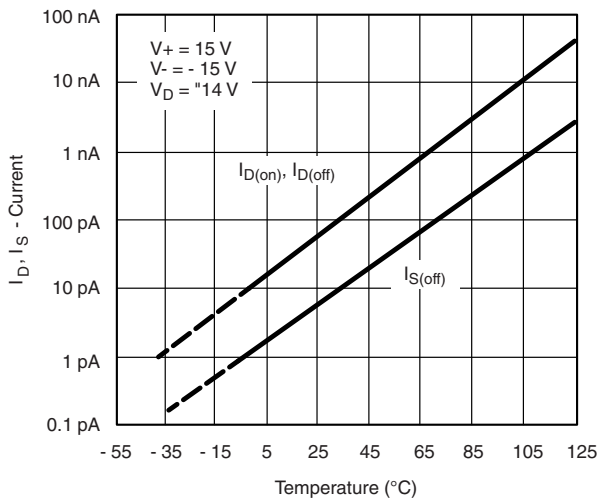
R_{DS(on)} vs. V_D and Temperature



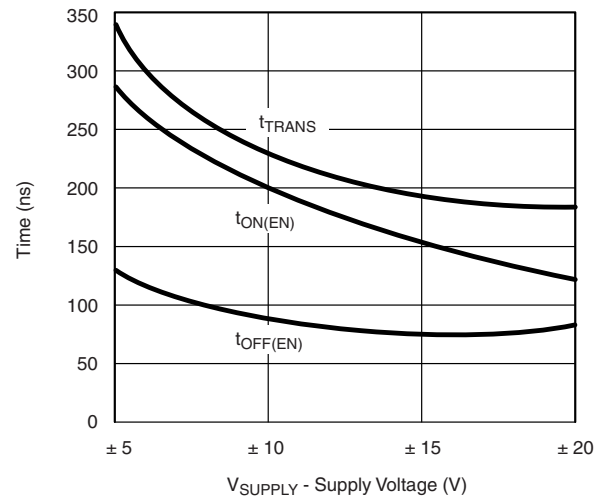
R_{DS(on)} vs. V_D and Supply



I_D, I_S Leakage Currents vs. Analog Voltage

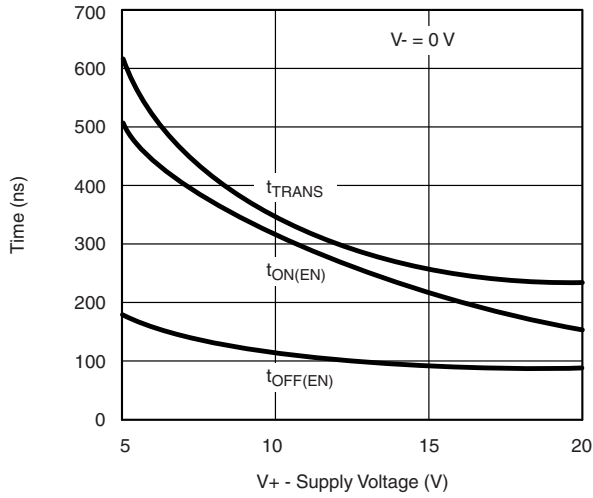


I_D, I_S Leakages vs. Temperature

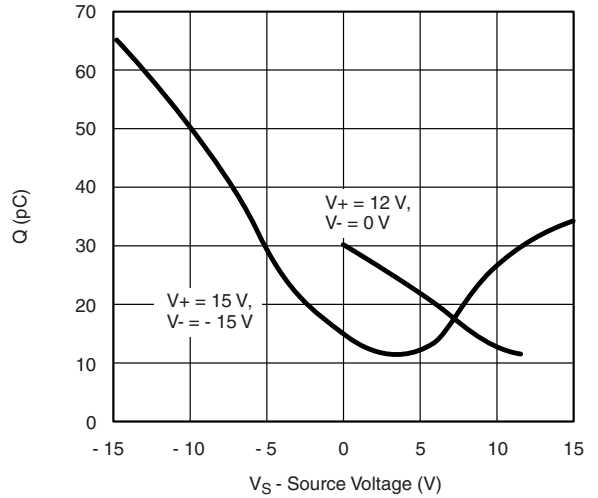


Switching Times vs. Bipolar Supplies

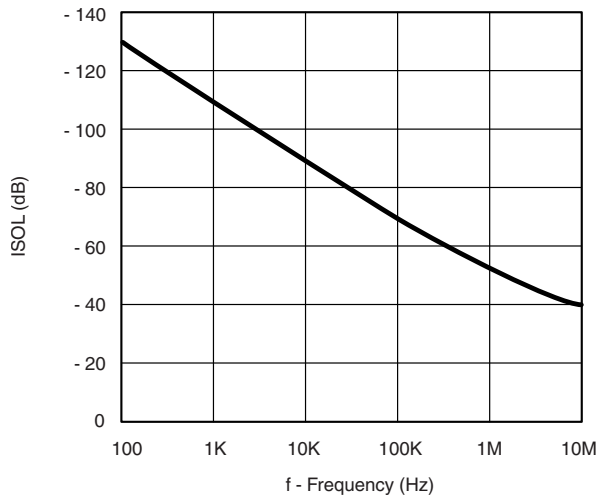
TYPICAL CHARACTERISTICS ($T_A = 25^\circ\text{C}$, unless otherwise noted)



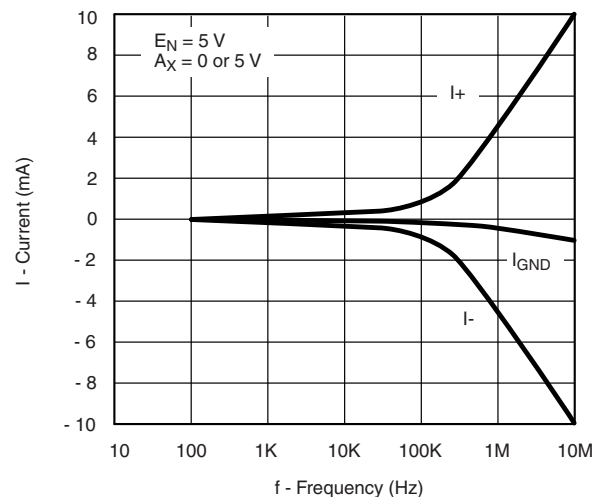
Switching Times vs. Single Supply



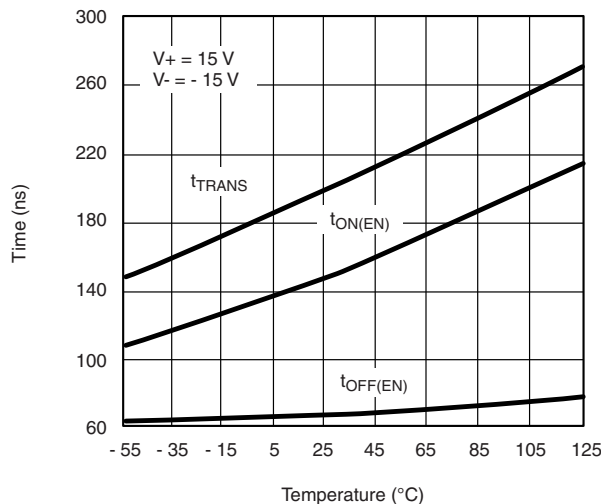
Charge Injection vs. Analog Voltage



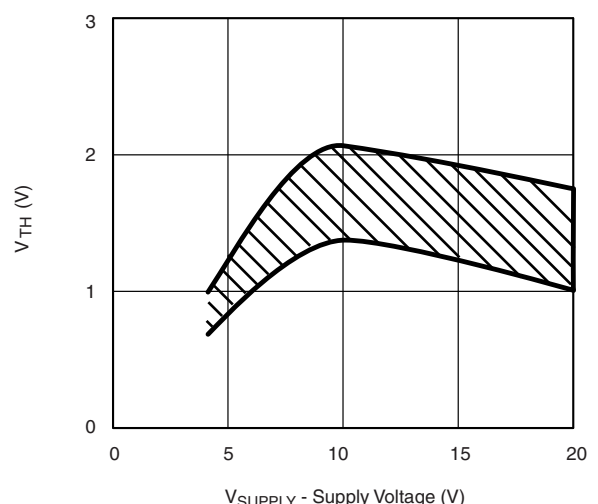
Off-Isolation vs. Frequency



Supply Currents vs. Switching Frequency



t_{ON}/t_{OFF} vs. Temperature



Switching Threshold vs. Supply Voltage

SCHEMATIC DIAGRAM (Typical Channel)

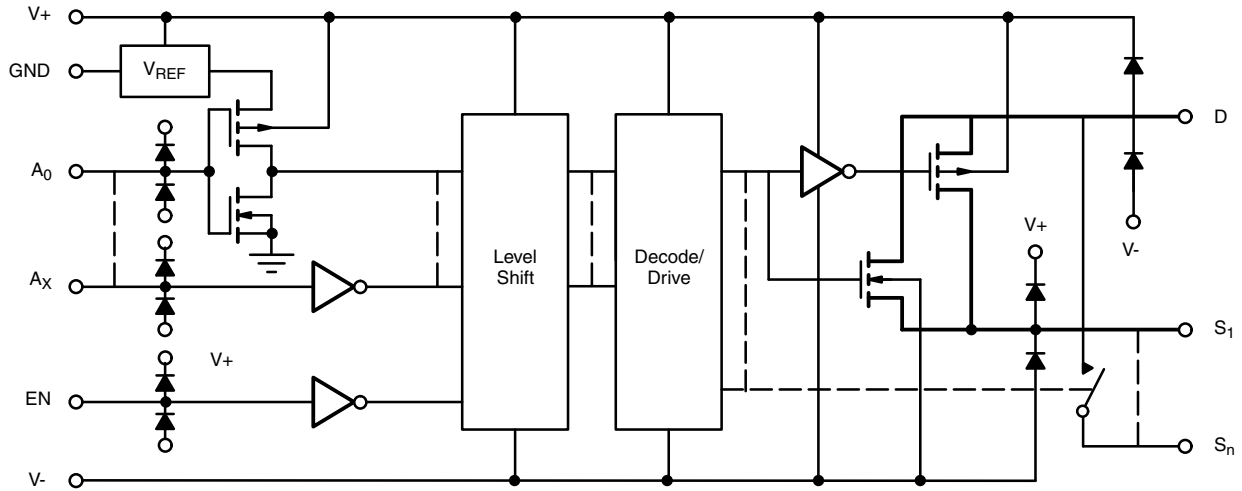
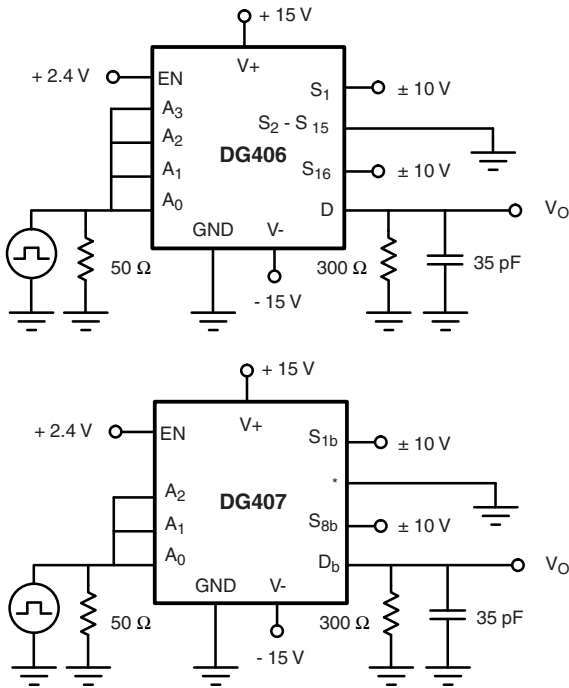


Figure 1.

TEST CIRCUITS



* = S_{1a} - S_{8a}, S_{2b} S_{±7b}, D_a

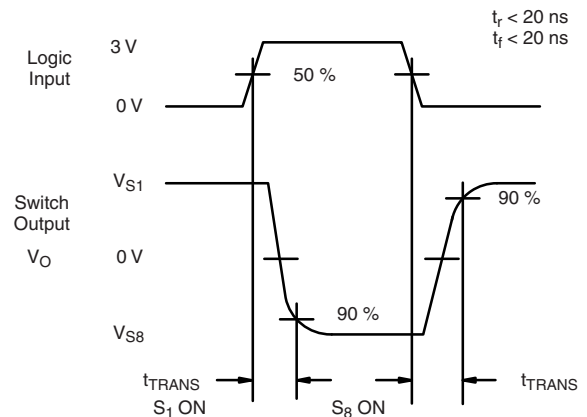


Figure 2. Transition Time

TEST CIRCUITS

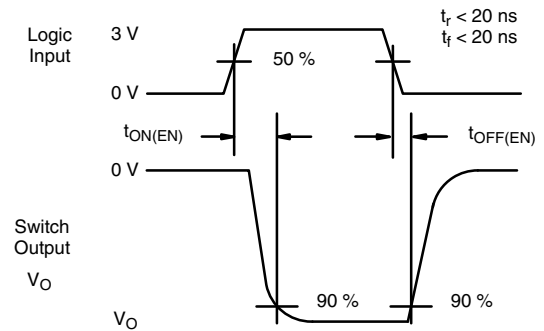
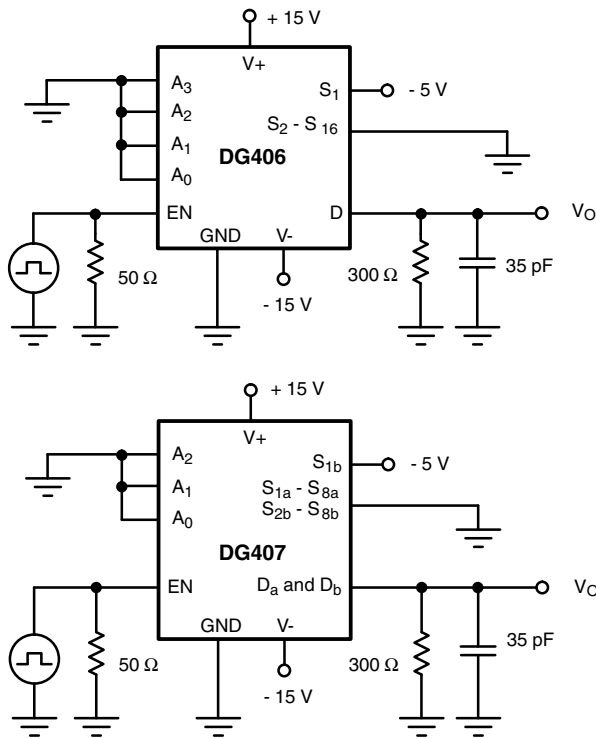


Figure 3. Enable Switching Time

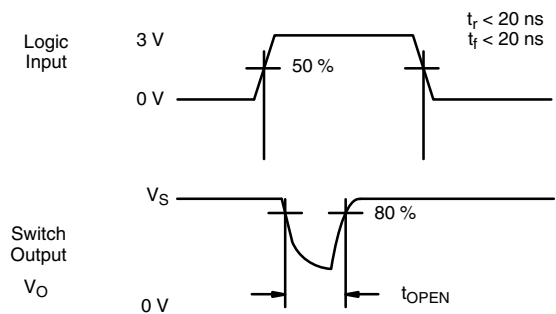
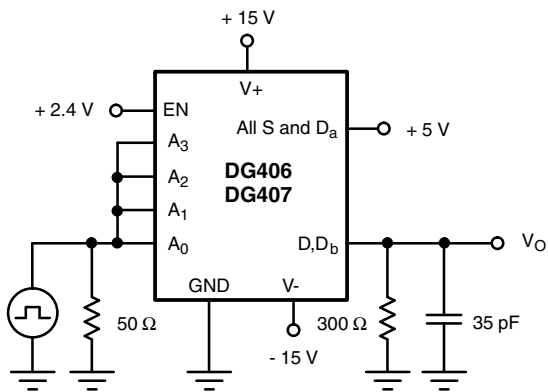


Figure 4. Break-Before-Make Interval

APPLICATIONS HINTS

Sampling speed is limited by two consecutive events: the transition time of the multiplexer, and the settling time of the sampled signal at the output.

t_{TRANS} is given on the data sheet. Settling time at the load depends on several parameters: $R_{DS(on)}$ of the multiplexer, source impedance, the multiplexer and load capacitances, charge injection of the multiplexer and accuracy desired.

The settling time for the multiplexer alone can be derived from the model shown in figure 5. Assuming a low impedance signal source like that presented by an op amp or a buffer amplifier, the settling time of the RC network for a given accuracy is equal to $n\tau$:

| % ACCURACY | # BITS | N |
|------------|--------|----|
| 0.25 | 8 | 6 |
| 0.012 | 12 | 9 |
| 0.0017 | 15 | 11 |

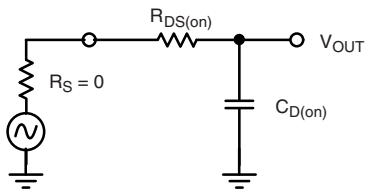


Figure 5. Simplified Model of One Multiplexer Channel

The maximum sampling frequency of the multiplexer is:

$$f_s = \frac{1}{N(t_{SETTLING} + t_{TRANS})} \tag{1}$$

where N = number of channels to scan

$$t_{SETTLING} = n\tau = n \times R_{DS(on)} \times C_{D(on)}$$

For the DG406 then, at room temp and for 12-bit accuracy, using the maximum limits:

$$f_s = \frac{1}{16 (9 \times 100 \Omega \times 10^{-12}F) + 300 \times 10^{-12}s} \tag{2}$$

or

$$f_s = 694 \text{ kHz} \tag{3}$$

From the sampling theorem, to properly recover the original signal, the sampling frequency should be more than twice the maximum component frequency of the original signal. This assumes perfect bandlimiting. In a real application sampling at three to four times the filter cutoff frequency is a good practice.

Therefore from equation 2 above:

$$f_c = \frac{1}{4} \times f_s = 173 \text{ kHz} \tag{4}$$

From this we can see that the DG406 can be used to sample 16 different signals whose maximum component frequency can be as high as 173 kHz. If for example, two channels are used to double sample the same incoming signal then its cutoff frequency can be doubled.

The block diagram shown in Figure 6 illustrates a typical data acquisition front end suitable for low-level analog signals. Differential multiplexing of small signals is preferred since this method helps to reject any common mode noise. This is especially important when the sensors are located at a distance and it may eliminate the need for individual amplifiers. A low $R_{DS(on)}$, low leakage multiplexer like the DG407 helps to reduce measurement errors. The low power dissipation of the DG407 minimizes on-chip thermal gradients which can cause errors due to temperature mismatch along the parasitic thermocouple paths. Please refer to Application Note AN203 for additional information.

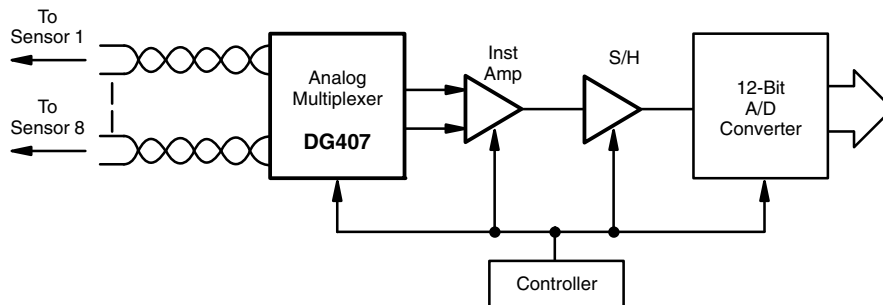
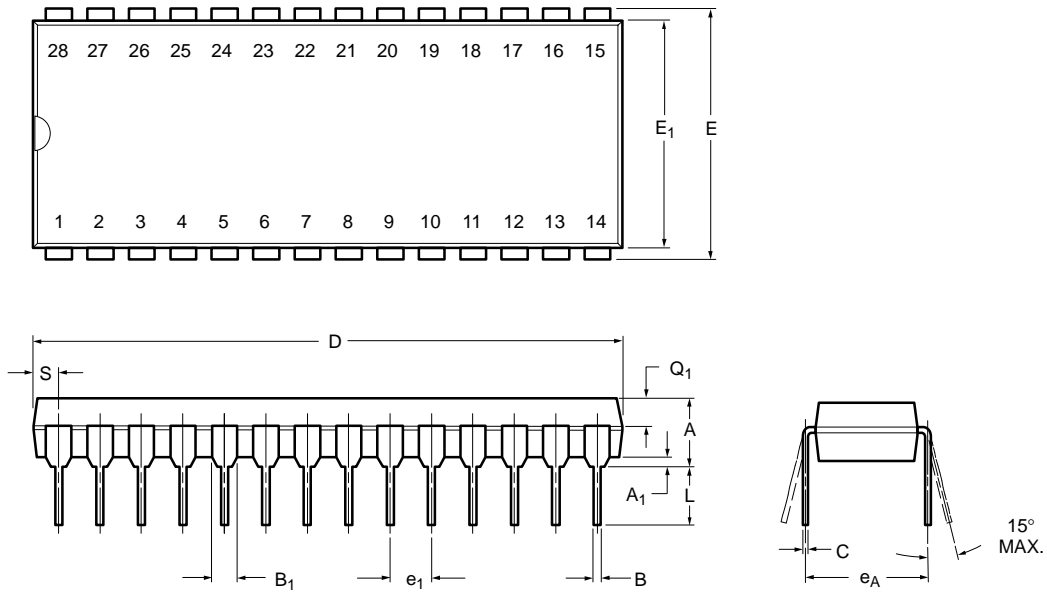


Figure 6. Measuring low-level analog signals is more accurate when using a differential multiplexing technique

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PDIP: 28-LEAD

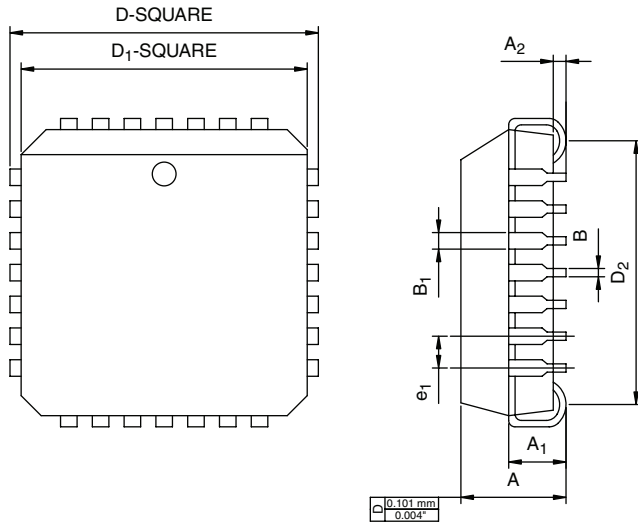


| Dim | MILLIMETERS | | INCHES | |
|----------------------|-------------|-------|--------|--------|
| | Min | Max | Min | Max |
| A | 2.29 | 5.08 | 0.090 | 0.200 |
| A₁ | 0.39 | 1.77 | 0.015 | 0.070 |
| B | 0.38 | 0.56 | 0.015 | 0.022 |
| B₁ | 0.89 | 1.65 | 0.035 | 0.065 |
| C | 0.204 | 0.30 | 0.008 | 0.012 |
| D | 35.10 | 39.70 | 1.380 | 1.565 |
| E | 15.24 | 15.88 | 0.600 | 0.625 |
| E₁ | 13.21 | 14.73 | 0.520 | 0.580 |
| e₁ | 2.29 | 2.79 | 0.090 | 0.110 |
| e_A | 14.99 | 15.49 | 0.590 | 0.610 |
| L | 2.60 | 5.08 | 0.100 | 0.200 |
| Q₁ | 0.95 | 2.345 | 0.0375 | 0.0925 |
| S | 0.995 | 2.665 | 0.0375 | 0.105 |

ECN: S-03946—Rev. F, 09-Jul-01
DWG: 5488



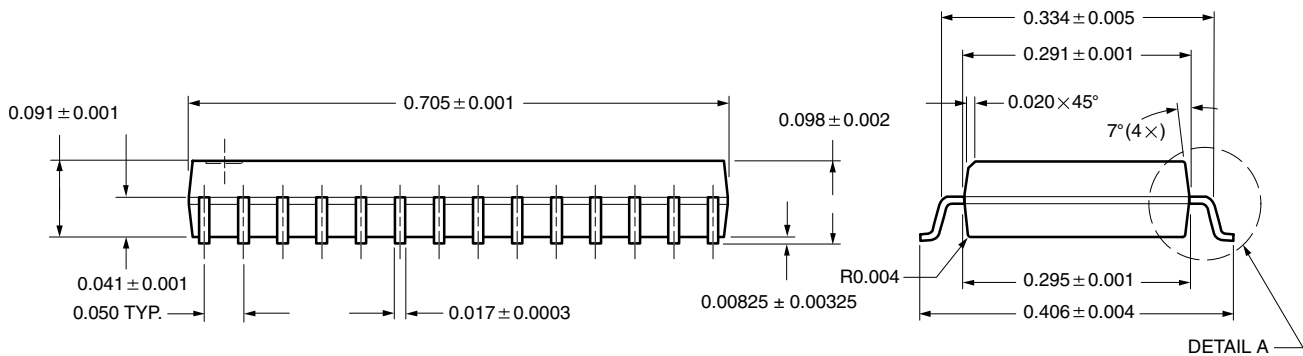
PLCC: 28-LEAD



| DIM. | MILLIMETERS | | INCHES | |
|--|-------------|--------|-----------|-------|
| | MIN. | MAX. | MIN. | MAX. |
| A | 4.20 | 4.57 | 0.165 | 0.180 |
| A ₁ | 2.29 | 3.04 | 0.090 | 0.120 |
| A ₂ | 0.51 | - | 0.020 | - |
| B | 0.331 | 0.553 | 0.013 | 0.021 |
| B ₁ | 0.661 | 0.812 | 0.026 | 0.032 |
| D | 12.32 | 12.57 | 0.485 | 0.495 |
| D ₁ | 11.430 | 11.582 | 0.450 | 0.456 |
| D ₂ | 9.91 | 10.92 | 0.390 | 0.430 |
| e ₁ | 1.27 BSC | | 0.050 BSC | |
| ECN: T09-0766-Rev. D, 28-Sep-09 DWG: 5491 | | | | |



SOIC (WIDE-BODY): 28-LEADS



All Dimensions In Inches

ECN: E11-2209-Rev. D, 01-Aug-11
DWG: 5850



28-LEAD LCC



| Dim | MILLIMETERS | | INCHES | |
|----------------------|-------------|-------|-----------|-------|
| | Min | Max | Min | Max |
| A | 1.37 | 2.24 | 0.054 | 0.088 |
| A₁ | 1.63 | 2.54 | 0.064 | 0.100 |
| B | 0.56 | 0.71 | 0.022 | 0.028 |
| D | 11.23 | 11.63 | 0.442 | 0.458 |
| E | 11.23 | 11.63 | 0.442 | 0.458 |
| e | 1.27 BSC | | 0.050 BSC | |
| L | 1.14 | 1.40 | 0.045 | 0.055 |
| L₁ | 1.96 | 2.36 | 0.077 | 0.093 |

ECN: S-03946—Rev. B, 09-Jul-01
DWG: 5319



CERDIP: 28-LEAD



| Dim | MILLIMETERS | | INCHES | |
|---|-------------|-------|-----------|-------|
| | Min | Max | Min | Max |
| A | 4.06 | 5.92 | 0.160 | 0.232 |
| A₁ | 0.38 | 1.52 | 0.015 | 0.060 |
| B | 0.38 | 0.51 | 0.015 | 0.020 |
| B₁ | 1.14 | 1.65 | 0.045 | 0.065 |
| C | 0.20 | 0.30 | 0.008 | 0.012 |
| D | 36.58 | 37.08 | 1.440 | 1.460 |
| E | 15.24 | 15.88 | 0.600 | 0.625 |
| E₁ | 12.95 | 13.46 | 0.510 | 0.530 |
| e₁ | 2.54 BSC | | 0.100 BSC | |
| e_A | 15.24 BSC | | 0.600 BSC | |
| L | 3.18 | 3.81 | 0.125 | 0.150 |
| L₁ | 3.81 | 5.08 | 0.150 | 0.200 |
| Q₁ | 1.27 | 2.16 | 0.050 | 0.085 |
| S | 1.52 | 2.29 | 0.060 | 0.090 |
| ∞ | 0° | 15° | 0° | 15° |
| ECN: S-03946—Rev. E, 09-Jul-01 DWG: 5434 | | | | |



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