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# 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
- Material categorization:
  For definitions of compliance please see www.vishay.com/doc?99912

Pb-free Available

RoHS* Available

HALOGEN FREE

**Note**

* This datasheet provides information about parts that are RoHS-compliant and/or parts that are non-RoHS-compliant. For example, parts with lead (Pb) terminations are not RoHS-compliant. Please see the information/tables in this datasheet for details.

## BENEFITS

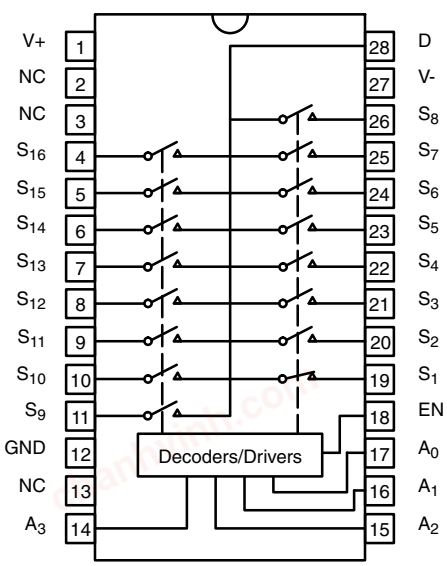
- Higher accuracy
- Reduced glitching
- Improved data throughput
- Reduced power consumption
- Increased ruggedness
- Wide supply ranges: ± 5 V to ± 20 V

## APPLICATIONS

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

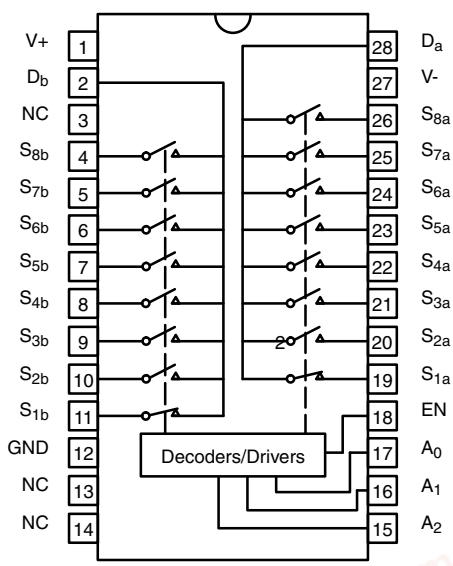
## FUNCTIONAL BLOCK DIAGRAM AND PIN CONFIGURATION

**DG406** Dual-In-Line and SOIC Wide-Body




Top View

**DG407** Dual-In-Line and SOIC Wide-Body




Top View



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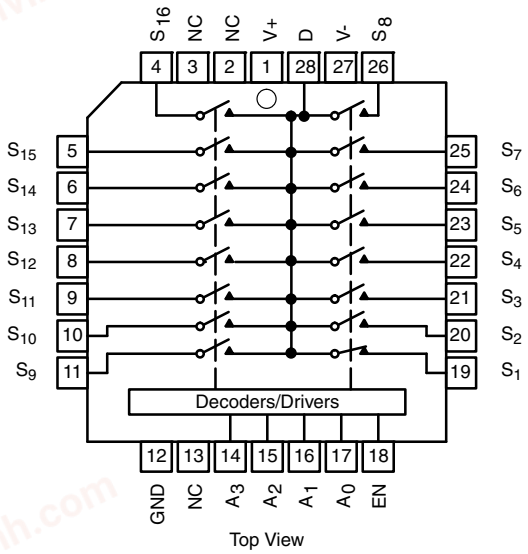
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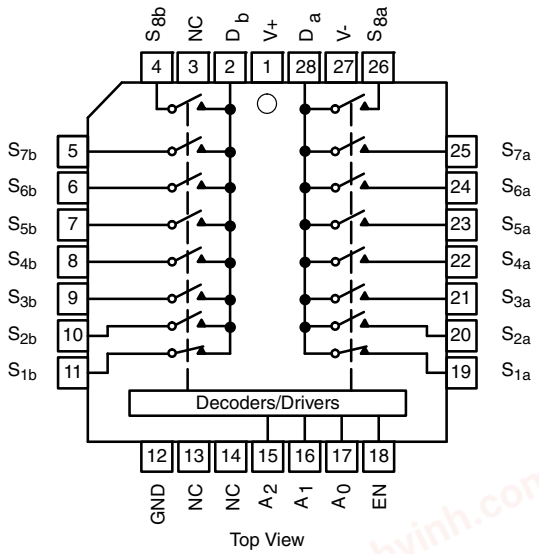
## FUNCTIONAL BLOCK DIAGRAM AND PIN CONFIGURATION

DG406 PLCC and LCC




Top View

DG407 PLCC and LCC




Top View

**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 |

**Notes**

- 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, DG406DW-T1-E3 |

**ORDERING INFORMATION** (DG407)

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| -40 °C to 85 °C | 28-Pin Plastic DIP | DG407DJ, DG407DJ-E3 |
| | 28-Pin PLCC | DG407DN, DG407DN-T1-E3 |
| | 28-Pin Widebody SOIC | DG407DW, DG407DW-E3, DG407DW-T1-E3 |

**Note**

- -T1 indicates Tape and Reel, -E3 indicates Lead-Free and RoHS Compliant, NO -E3 indicates standard Tin/Lead finish.


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| ABSOLUTE MAXIMUM RATINGS | | | |
|---|---|---|---|
| **PARAMETER** | | **LIMIT** | **UNIT** |
| Voltages Referenced to V- | V+ to V -[f] | 44 | V |
| | GND to V- | -25 | |
| Digital Inputs[a], $V_S$, $V_D$ | | (V-) - 2 to (V+) + 2 V<br>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 Plastic PLCC[c] | 450 | |
| | 28-Pin Widebody SOIC | 450 | |

**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.
f. Also applies when V- = GND



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## SPECIFICATIONS[a]

| PARAMETER | SYMBOL | TEST CONDITIONS UNLESS OTHERWISE SPECIFIED V+ = 15 V, V- = -15 V $V_{AL}$ = 0.8 V, $V_{AH}$ = 2.4 V[f] | | TEMP.[b] | TYP.[c] | D SUFFIX -40 °C TO 85 °C MIN.[d] | D SUFFIX -40 °C TO 85 °C MAX.[d] | UNIT |
|---|---|---|---|---|---|---|---|---|
| **Analog Switch** | | | | | | | | |
| Analog Signal Range[e] | $V_{ANALOG}$ | | | Full | - | -15 | 15 | V |
| Drain-Source On-Resistance | $R_{DS(on)}$ | $V_D$ = ± 10 V, $I_S$ = -10 mA sequence each switch on | | Room | 50 | - | 100 | Ω |
| | | | | Full | 50 | - | 125 | |
| $R_{DS(on)}$ Matching Between Channels[g] | $\Delta R_{DS(on)}$ | $V_D$ = ± 10 V | | Room | 5 | - | - | % |
| Source Off Leakage Current | $I_{S(off)}$ | $V_{EN}$ = 0 V, $V_D$ = ± 10 V, $V_S$ = ± 10 V | | Room | 0.01 | -0.5 | 0.5 | nA |
| | | | | Full | 0.01 | -5 | 5 | |
| Drain Off Leakage Current | $I_{D(off)}$ | | DG406 | Room | 0.04 | -1 | 1 | |
| | | | | Full | 0.04 | -40 | 40 | |
| | | | DG407 | Room | 0.04 | -1 | 1 | |
| | | | | Full | 0.04 | -20 | 20 | |
| Drain On Leakage Current | $I_{D(on)}$ | $V_S$ = $V_D$ = ± 10 sequence each switch on | DG406 | Room | 0.04 | -1 | 1 | |
| | | | | Full | 0.04 | -40 | 40 | |
| | | | DG407 | Room | 0.04 | -1 | 1 | |
| | | | | Full | 0.04 | -20 | 20 | |
| **Digital Control** | | | | | | | | |
| Logic High Input Voltage | $V_{INH}$ | | | Full | - | 2.4 | - | V |
| Logic Low Input Voltage | $V_{INL}$ | | | Full | - | - | 0.8 | |
| Logic High Input Current | $I_{AH}$ | $V_A$ = 2.4 V, 15 V | | Full | - | -1 | 1 | µA |
| Logic Low Input Current | $I_{AL}$ | $V_{EN}$ = 0 V, 2.4 V, $V_A$ = 0 V | | Full | - | -1 | 1 | |
| Logic Input Capacitance | $C_{in}$ | f = 1 MHz | | Room | 7 | - | - | pF |
| **Dynamic Characteristics** | | | | | | | | |
| Transition Time | $t_{TRANS}$ | see figure 2 | | Room | 200 | - | 350 | ns |
| | | | | Full | - | - | 450 | |
| Break-Before-Make Interval | $t_{OPEN}$ | see figure 4 | | Room | 50 | 25 | - | |
| | | | | Full | - | 10 | - | |
| Enable Turn-On Time | $t_{ON(EN)}$ | see figure 3 | | Room | 150 | - | 200 | |
| | | | | Full | - | - | 400 | |
| Enable Turn-Off Time | $t_{OFF(EN)}$ | | | Room | 70 | - | 150 | |
| | | | | Full | - | - | 300 | |
| Charge Injection | Q | $V_S$ = 0 V, $C_L$ = 1 nF, $R_S$ = 0 Ω | | Room | 15 | - | - | pC |
| Off Isolation[h] | OIRR | $V_{EN}$ = 0 V, $R_L$ = 1 kΩ f = 100 kHz | | Room | -69 | - | - | dB |
| Source Off Capacitance | $C_{S(off)}$ | $V_{EN}$ = 0 V, $V_S$ = 0 V, f = 1 MHz | | Room | 8 | - | - | pF |
| Drain Off Capacitance | $C_{D(off)}$ | $V_{EN}$ = 0 V, $V_D$ = 0 V, f = 1 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 or 5 V | | Room | 13 | - | 30 | µA |
| | | | | Full | - | - | 75 | |
| Negative Supply Current | I- | | | Room | -0.01 | -1 | - | |
| | | | | Full | - | -10 | - | |
| Positive Supply Current | I+ | $V_{EN}$ = 2.4 V, $V_A$ = 0 V | | Room | 50 | - | 500 | |
| | | | | Full | | - | 700 | |
| Negative Supply Current | I- | | | Room | -0.01 | -20 | - | |
| | | | | Full | -0.01 | -20 | - | |


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| 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] | D SUFFIX -40 °C TO 85 °C MIN.[d] | D SUFFIX -40 °C TO 85 °C MAX.[d] | UNIT |
| **Analog Switch** | | | | | | | | |
| Analog Signal Range[e] | $V_{ANALOG}$ | | | Full | - | 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 | Ω |
| $R_{DS(on)}$ Matching Between Channels[g] | $\Delta R_{DS(on)}$ | | | 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 | | Room | 0.01 | - | - | nA |
| Drain Off Leakage Current | $I_{D(off)}$ | | DG406 | Room | 0.04 | - | - | |
| | | | DG407 | Room | 0.04 | - | - | |
| Drain On Leakage Current | $I_{D(on)}$ | $V_S$ = $V_D$ = ± 10 V sequence each switch 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 | ns |
| Enable Turn-On Time | $t_{ON(EN)}$ | $V_{INH}$ = 2.4 V, $V_{INL}$ = 0 V, $V_{S1}$ = 5 V | | Room | 250 | - | 600 | |
| Enable Turn-Off Time | $t_{OFF(EN)}$ | | | Room | 150 | - | 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 | µA |
| | | | | Full | - | - | 75 | |
| Negative Supply Current | I- | | | Room | -0.01 | -20 | - | |
| | | | | Full | -0.01 | -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. $\Delta R_{DS(on)} = R_{DS(on)}$ max. - $R_{DS(on)}$ min.
h. Worst case isolation occurs on Channel 4 due to proximity to the drain pin.

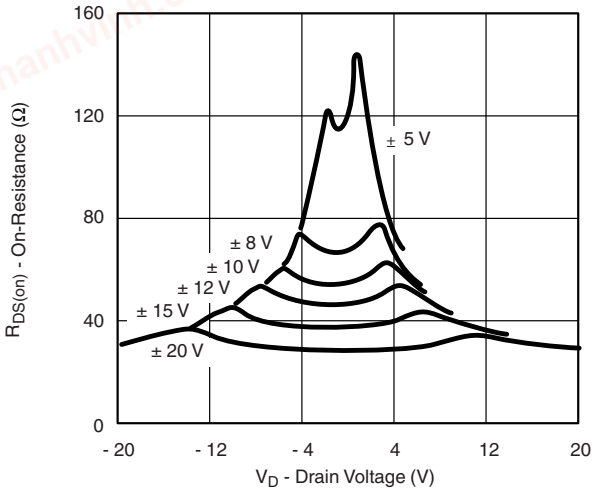
*Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure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


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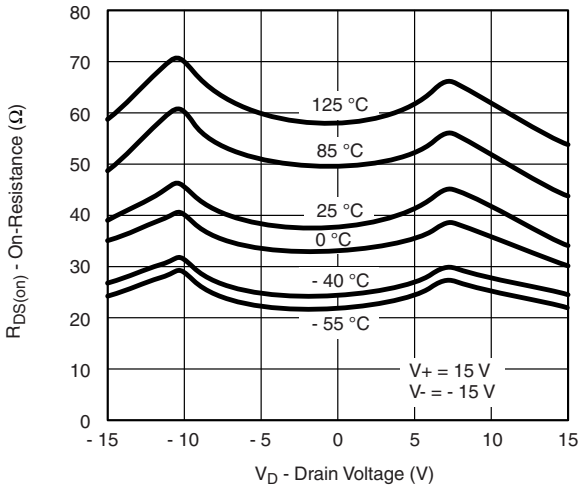
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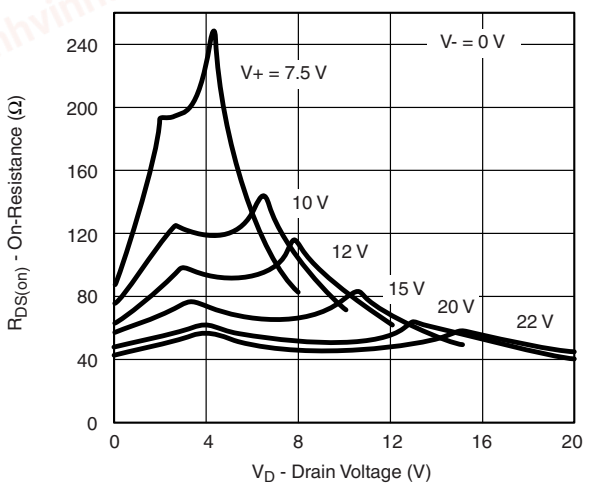
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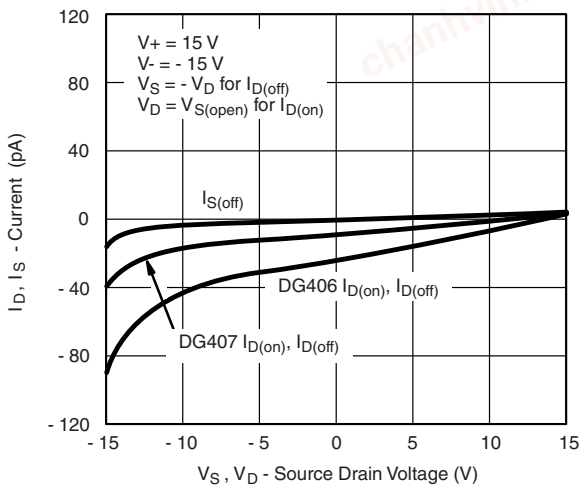

$R_{DS(on)}$ vs. $V_D$ and Supply



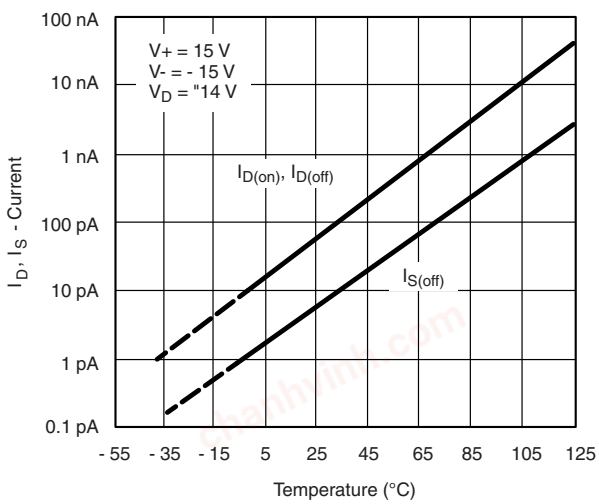

$R_{DS(on)}$ vs. $V_D$ and Temperature



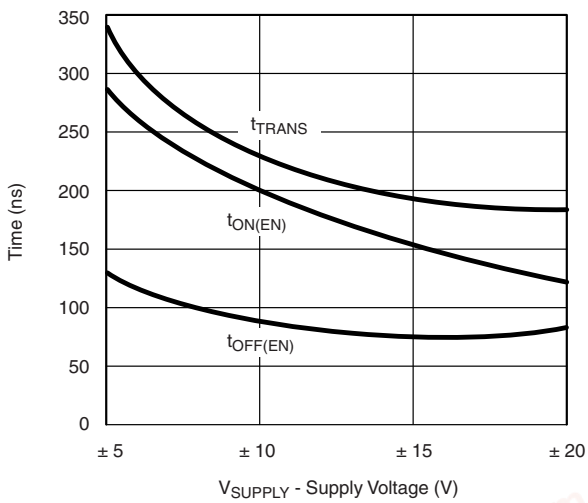

$R_{DS(on)}$ vs. $V_D$ and Supply




$I_D$ , $I_S$ Leakage Currents vs. Analog Voltage




$I_D$, $I_S$ Leakages vs. Temperature



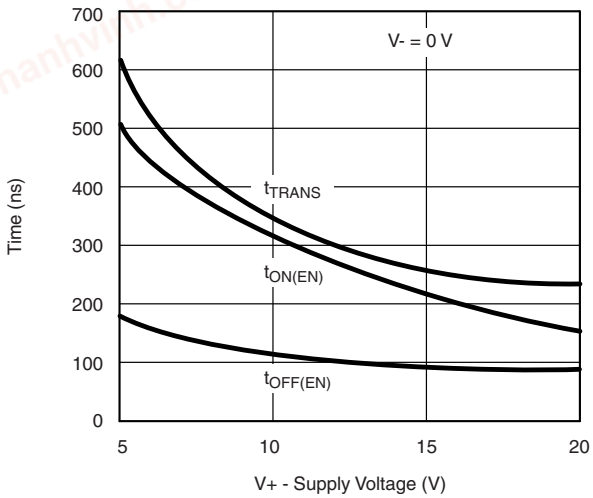

Switching Times vs. Bipolar Supplies


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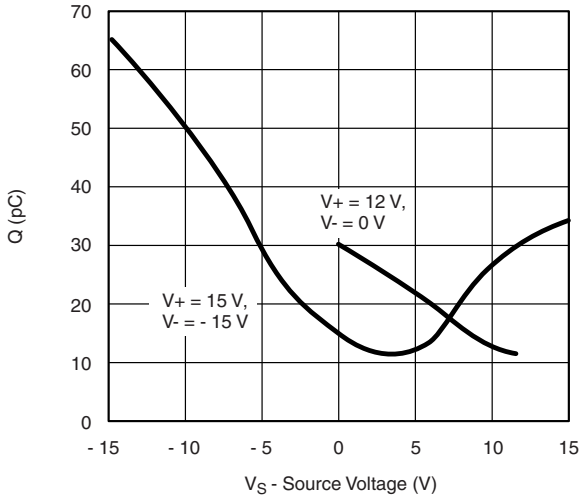
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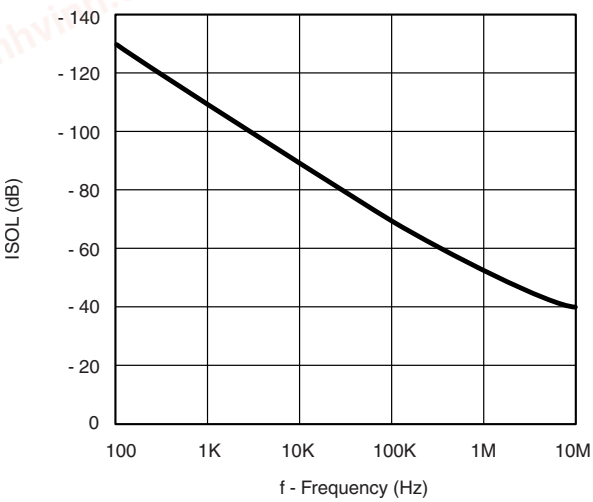
## TYPICAL CHARACTERISTICS ($T_A$ = 25 °C, unless otherwise noted)



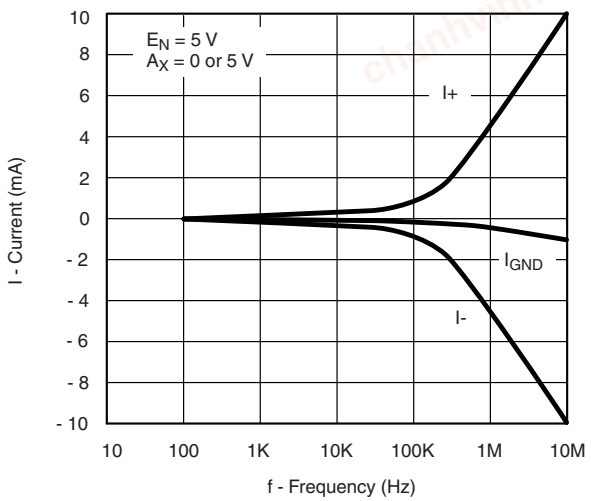

Switching Times vs. Single Supply



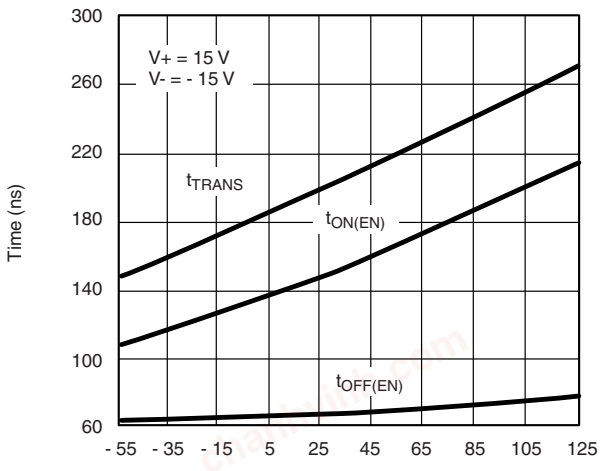

Charge Injection vs. Analog Voltage



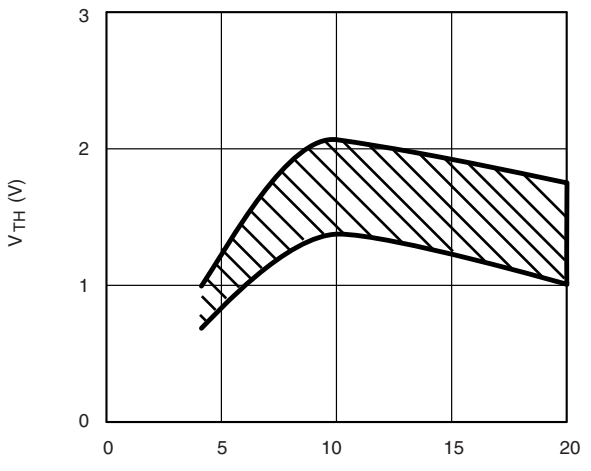

Off-Isolation vs. Frequency




Supply Currents vs. Switching Frequency




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




Switching Threshold vs. Supply Voltage


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## SCHEMATIC DIAGRAM (Typical Channel)

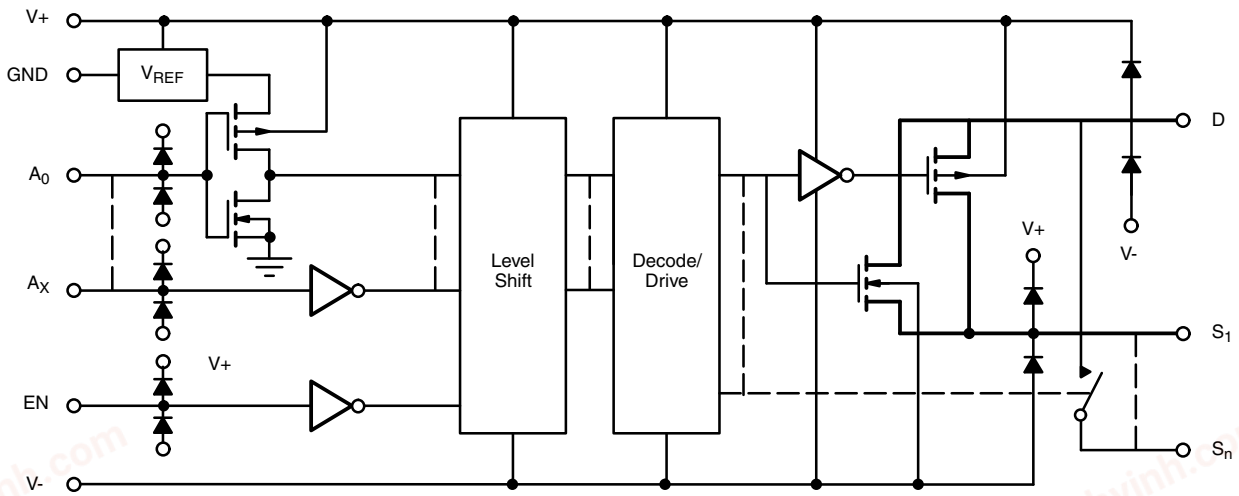
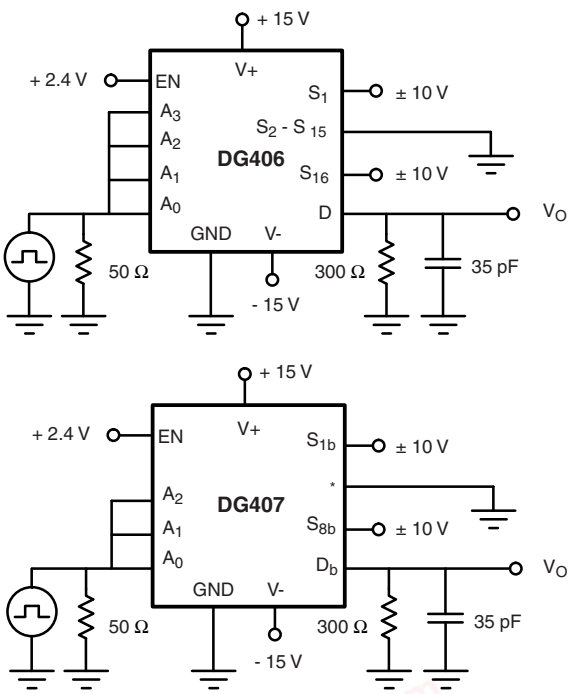



Fig. 1

## TEST CIRCUITS




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

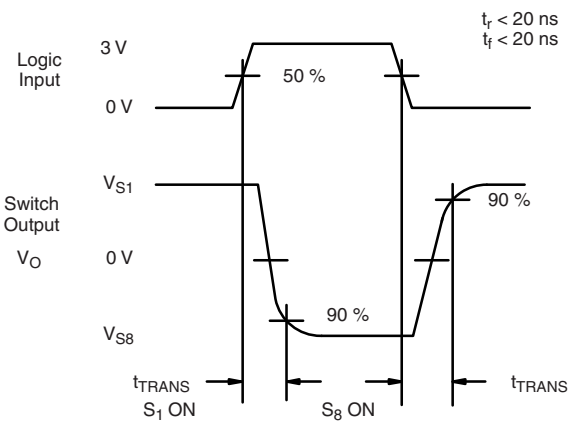


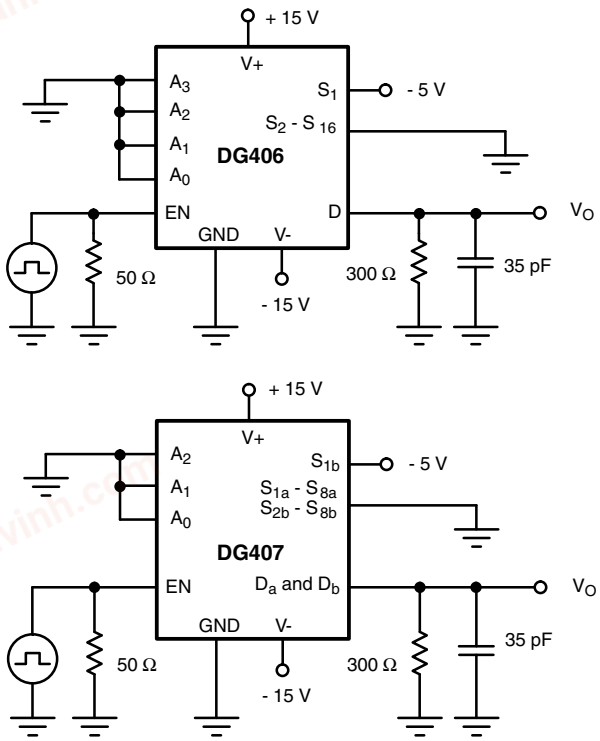

Fig. 2 - Transition Time


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## TEST CIRCUITS



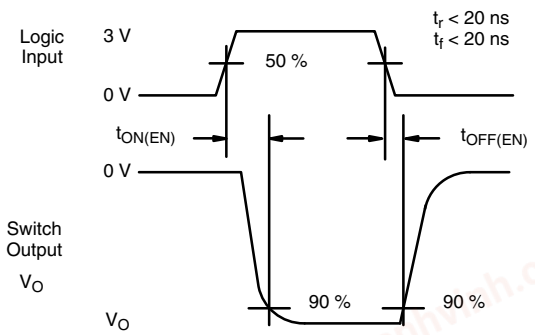
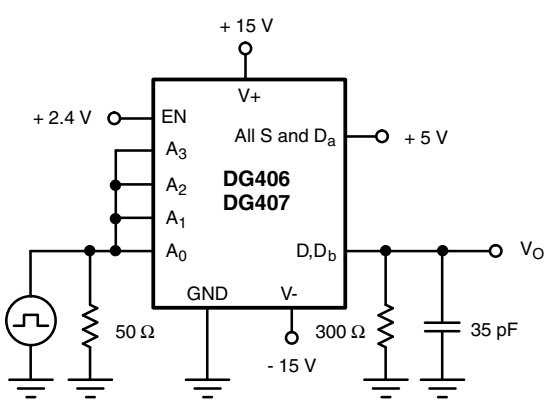




Fig. 3 - Enable Switching Time



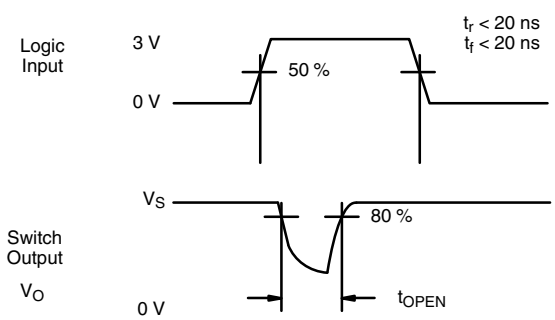




Fig. 4 - Break-Before-Make Interval


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## 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, 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 nτ:

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

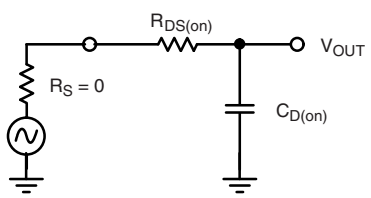



Fig. 5 - Simplified Model of One Multiplexer Channel

The maximum sampling frequency of the multiplexer is:

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

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:

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

or

$$f_s = 694\ \text{kHz} \quad (3)$$

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:

$$f_c = \frac{1}{4} \times f_s = 173\ \text{kHz} \quad (4)$$

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.

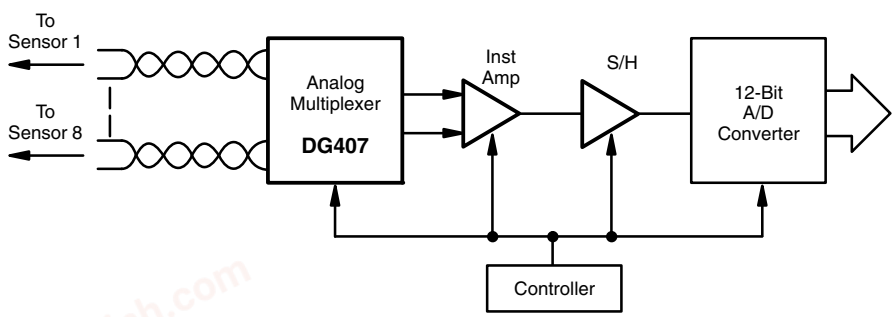



Fig. 6 - Measuring Low-Level Analog Signals is more accurate when using a Differential Multiplexing Technique

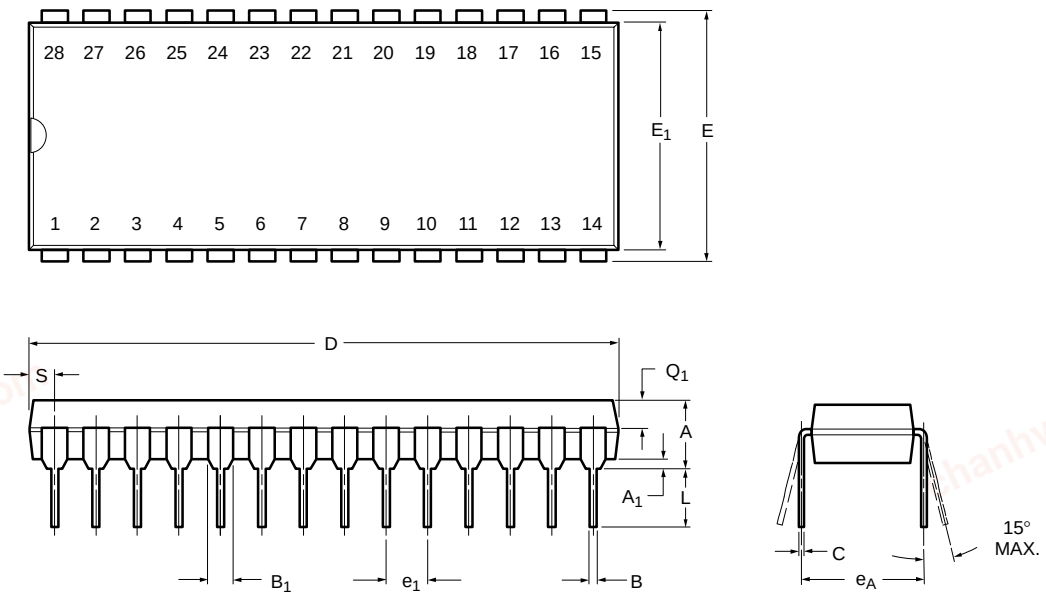
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## PDIP: 28-LEAD



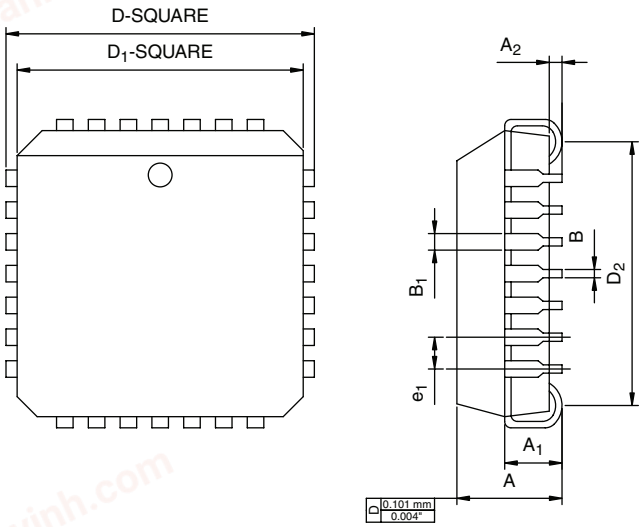

| Dim | MILLIMETERS | | INCHES | |
|---|---|---|---|---|
| | Min | Max | Min | Max |
| **A** | 2.29 | 5.08 | 0.090 | 0.200 |
| **$A_1$** | 0.39 | 1.77 | 0.015 | 0.070 |
| **B** | 0.38 | 0.56 | 0.015 | 0.022 |
| **$B_1$** | 0.89 | 1.65 | 0.035 | 0.065 |
| **C** | 0.204 | 0.30 | 0.008 | 0.012 |
| **D** | 35.10 | 39.70 | 1.380 | 1.565 |
| **E** | 15.24 | 15.88 | 0.600 | 0.625 |
| **$E_1$** | 13.21 | 14.73 | 0.520 | 0.580 |
| **$e_1$** | 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 |
| **$Q_1$** | 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<br>DWG: 5488 | | | | |

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# Package Information

Vishay Siliconix

## PLCC: 28-LEAD

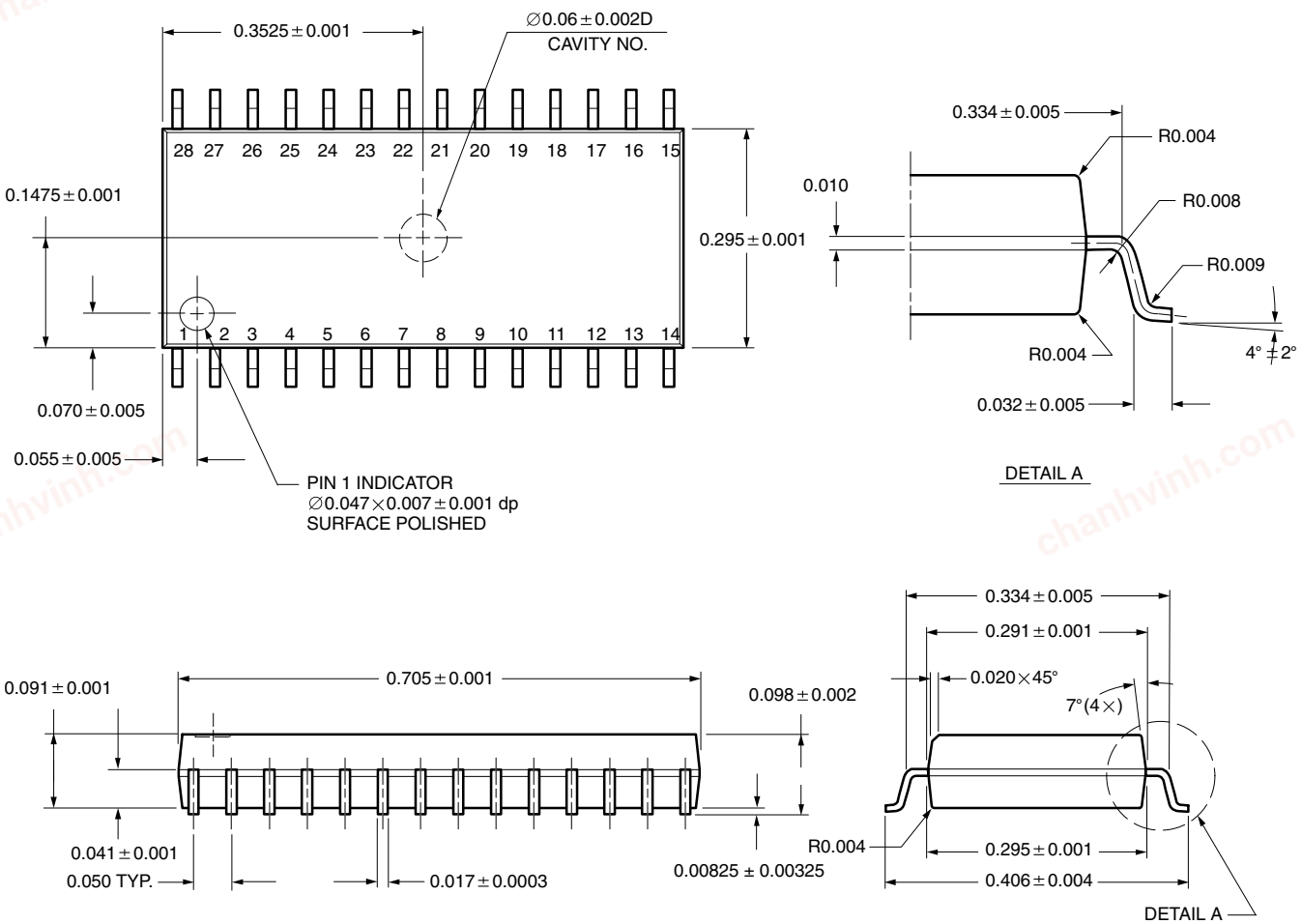



| DIM. | MILLIMETERS | | INCHES | |
|---|---|---|---|---|
| | MIN. | MAX. | MIN. | MAX. |
| A | 4.20 | 4.57 | 0.165 | 0.180 |
| $A_1$ | 2.29 | 3.04 | 0.090 | 0.120 |
| $A_2$ | 0.51 | - | 0.020 | - |
| B | 0.331 | 0.553 | 0.013 | 0.021 |
| $B_1$ | 0.661 | 0.812 | 0.026 | 0.032 |
| D | 12.32 | 12.57 | 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<br>DWG: 5491 | | | | |

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## SOIC (WIDE-BODY): 28-LEADS




All Dimensions In Inches

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



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