



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

### FEATURES

- Low On-Resistance— $r_{DS(on)}$ : 50  $\Omega$
- 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:  $\pm 5$  V to  $\pm 20$  V

### APPLICATIONS

- Data Acquisition Systems
- Audio Signal Routing
- Medical Instrumentation
- ATE Systems
- Battery Powered Systems
- High-Rel Systems
- Single Supply Systems

### 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 ( $A_n$ ) and enable (EN) are TTL compatible over the full specified operating temperature range.

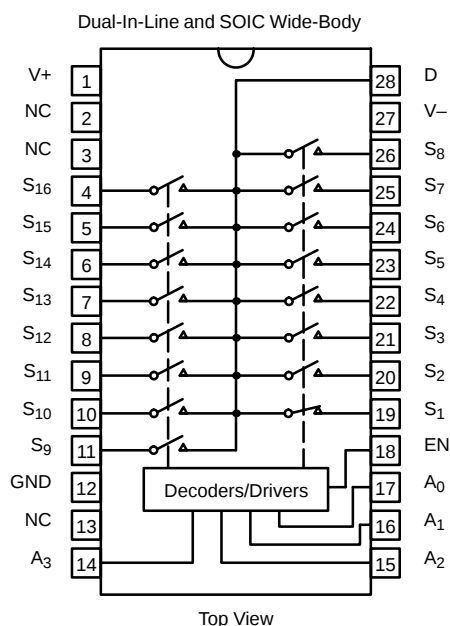
Applications for the DG406/407 include high speed data acquisition, audio signal switching and routing, ATE systems, and avionics. High performance and low power dissipation make them ideal for battery operated and remote instrumentation applications. For additional application information order Faxback document numbers 70601 and 70604.

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

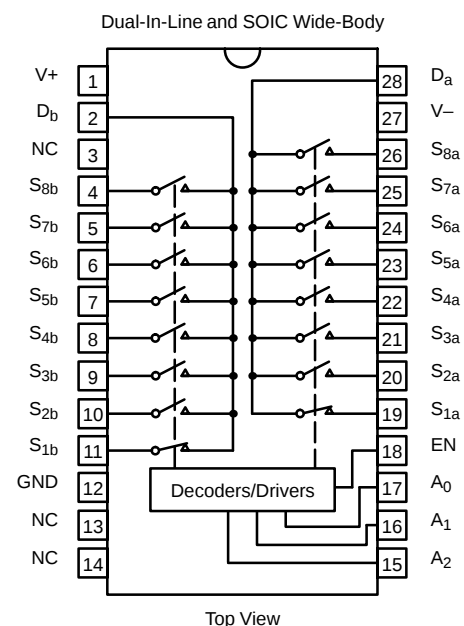
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### FUNCTIONAL BLOCK DIAGRAM AND PIN CONFIGURATION

DG406



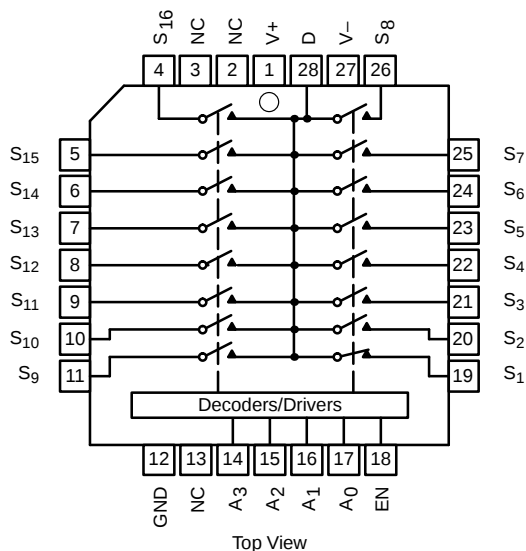
DG407



**FUNCTIONAL BLOCK DIAGRAM AND PIN CONFIGURATION**

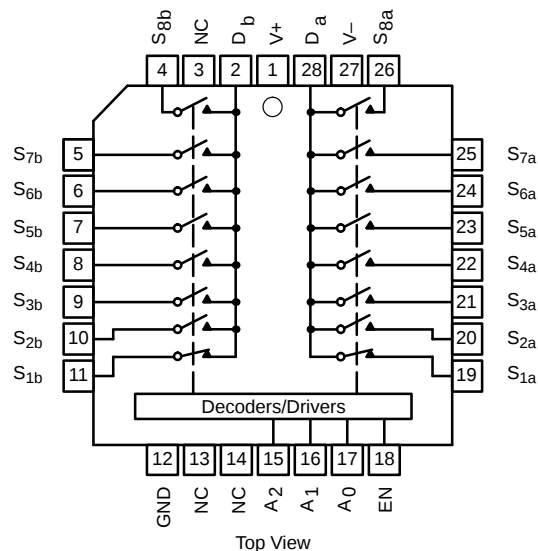
**DG406**

PLCC and LCC



**DG407**

PLCC and LCC



**TRUTH TABLE — DG406**

| A <sub>3</sub> | A <sub>2</sub> | A <sub>1</sub> | A <sub>0</sub> | 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 <sub>2</sub> | A <sub>1</sub> | A <sub>0</sub> | 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" =  $V_{AL} \leq 0.8\text{ V}$   
 Logic "1" =  $V_{AH} \geq 2.4\text{ V}$   
 X = Don't Care

**ORDERING INFORMATION — DG406**

| Temp Range   | Package              | Part Number                     |
|--------------|----------------------|---------------------------------|
| -40 to 85°C  | 28-Pin Plastic DIP   | DG406DJ                         |
|              | 28-Pin PLCC          | DG406DN                         |
|              | 28-Pin Widebody SOIC | DG406DW                         |
| -55 to 125°C | 28-Pin CerDIP        | DG406AK/883,<br>5962-9562301QXA |
|              | LCC-28               | DG406AZ/883,<br>5962-9562301Q3A |

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|              | LCC-28               | DG407AZ/883,<br>5962-9562302Q3A |



## ABSOLUTE MAXIMUM RATINGS

Voltages Referenced to V–

V+ ..... 44 V

GND ..... 25 V

Digital Inputs<sup>a</sup>, V<sub>S</sub>, V<sub>D</sub> ..... (V–) –2 V 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 mA

Storage Temperature (AK, AZ Suffix) ..... –65 to 150°C  
(DJ, DN Suffix) ..... –65 to 125°C

Power Dissipation (Package)<sup>b</sup>

28-Pin Plastic DIP<sup>c</sup> ..... 625 mW

28-Pin CerDIP<sup>d</sup> ..... 1.2 W

28-Pin Plastic PLCC<sup>c</sup> ..... 450 mW

LCC-28<sup>e</sup> ..... 1.35 W

28-Pin Widebody SOIC ..... 450 mW

Notes:

a. Signals on S<sub>X</sub>, D<sub>X</sub> or I<sub>NX</sub> 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<sup>a</sup>

| Parameter                                                  | Symbol               | Test Conditions<br>Unless Otherwise Specified<br><br>V <sub>+</sub> = 15 V, V <sub>–</sub> = –15 V<br>V <sub>AL</sub> = 0.8 V, V <sub>AH</sub> = 2.4 V <sup>f</sup> |  | Temp <sup>b</sup> | Typ <sup>c</sup> | A Suffix<br>–55 to 125°C |                  | D Suffix<br>–40 to 85°C |                  | Unit    |         |
|------------------------------------------------------------|----------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|-------------------|------------------|--------------------------|------------------|-------------------------|------------------|---------|---------|
|                                                            |                      |                                                                                                                                                                     |  |                   |                  | Min <sup>d</sup>         | Max <sup>d</sup> | Min <sup>d</sup>        | Max <sup>d</sup> |         |         |
| Analog Switch                                              |                      |                                                                                                                                                                     |  |                   |                  |                          |                  |                         |                  |         |         |
| Analog Signal Range <sup>e</sup>                           | V <sub>ANALOG</sub>  |                                                                                                                                                                     |  | Full              |                  | –15                      | 15               | –15                     | 15               | V       |         |
| Drain-Source On-Resistance                                 | r <sub>DS(on)</sub>  | V <sub>D</sub> = ±10 V, I <sub>S</sub> = –10 mA<br>Sequence Each Switch On                                                                                          |  | Room<br>Full      | 50               |                          | 100<br>125       |                         | 100<br>125       | Ω       |         |
| r <sub>DS(on)</sub> Matching Between Channels <sup>g</sup> | Δr <sub>DS(on)</sub> | V <sub>D</sub> = ±10 V                                                                                                                                              |  | Room              | 5                |                          |                  |                         |                  | %       |         |
| Source Off Leakage Current                                 | I <sub>S(off)</sub>  | V <sub>EN</sub> = 0 V<br>V <sub>D</sub> = ±10 V<br>V <sub>S</sub> = ∓10 V                                                                                           |  | Room<br>Full      | 0.01             | –0.5<br>–50              | 0.5<br>50        | –0.5<br>–5              | 0.5<br>5         | nA      |         |
| Drain Off Leakage Current                                  | I <sub>D(off)</sub>  |                                                                                                                                                                     |  | DG406             | Room<br>Full     | 0.04                     | –1<br>–200       | 1<br>200                | –1<br>–40        |         | 1<br>40 |
|                                                            |                      |                                                                                                                                                                     |  | DG407             | Room<br>Full     | 0.04                     | –1<br>–100       | 1<br>100                | –1<br>–20        |         | 1<br>20 |
| Drain On Leakage Current                                   | I <sub>D(on)</sub>   | V <sub>S</sub> = V <sub>D</sub> = ±10 V<br>Sequence Each Switch On                                                                                                  |  | DG406             | Room<br>Full     | 0.04                     | –1<br>–200       | 1<br>200                | –1<br>–40        |         | 1<br>40 |
|                                                            |                      |                                                                                                                                                                     |  | DG407             | Room<br>Full     | 0.04                     | –1<br>–100       | 1<br>100                | –1<br>–20        | 1<br>20 |         |
| Digital Control                                            |                      |                                                                                                                                                                     |  |                   |                  |                          |                  |                         |                  |         |         |
| Logic High Input Voltage                                   | V <sub>INH</sub>     |                                                                                                                                                                     |  | Full              |                  | 2.4                      |                  | 2.4                     |                  | V       |         |
| Logic Low Input Voltage                                    | V <sub>INL</sub>     |                                                                                                                                                                     |  | Full              |                  |                          | 0.8              |                         | 0.8              |         |         |
| Logic High Input Current                                   | I <sub>AH</sub>      | V <sub>A</sub> = 2.4 V, 15 V                                                                                                                                        |  | Full              |                  | –1                       | 1                | –1                      | 1                | μA      |         |
| Logic Low Input Current                                    | I <sub>AL</sub>      | V <sub>EN</sub> = 0 V, 2.4 V, V <sub>A</sub> = 0 V                                                                                                                  |  | Full              |                  | –1                       | 1                | –1                      | 1                |         |         |
| Logic Input Capacitance                                    | C <sub>in</sub>      | f = 1 MHz                                                                                                                                                           |  | Room              | 7                |                          |                  |                         |                  | pF      |         |
| Dynamic Characteristics                                    |                      |                                                                                                                                                                     |  |                   |                  |                          |                  |                         |                  |         |         |
| Transition Time                                            | t <sub>TRANS</sub>   | See Figure 2                                                                                                                                                        |  | Room<br>Full      | 200              |                          | 350<br>450       |                         | 350<br>450       | ns      |         |
| Break-Before-Make Interval                                 | t <sub>OPEN</sub>    | See Figure 4                                                                                                                                                        |  | Room<br>Full      | 50               | 25<br>10                 |                  | 25<br>10                |                  |         |         |
| Enable Turn-On Time                                        | t <sub>ON(EN)</sub>  | See Figure 3                                                                                                                                                        |  | Room<br>Full      | 150              |                          | 200<br>400       |                         | 200<br>400       |         |         |
| Enable Turn-Off Time                                       | t <sub>OFF(EN)</sub> |                                                                                                                                                                     |  | Room<br>Full      | 70               |                          | 150<br>300       |                         | 150<br>300       |         |         |
| Charge Injection                                           | Q                    | C <sub>L</sub> = 1 nF, V <sub>S</sub> = 0 V, R <sub>S</sub> = 0 Ω                                                                                                   |  | Room              | 15               |                          |                  |                         |                  | pC      |         |
| Off Isolation <sup>h</sup>                                 | OIRR                 | V <sub>EN</sub> = 0 V, R <sub>L</sub> = 1 kΩ<br>f = 100 kHz                                                                                                         |  | Room              | –69              |                          |                  |                         |                  | dB      |         |
| Source Off Capacitance                                     | C <sub>S(off)</sub>  | V <sub>EN</sub> = 0 V, V <sub>S</sub> = 0 V, f = 1 MHz                                                                                                              |  | Room              | 8                |                          |                  |                         |                  | pF      |         |
| Drain Off Capacitance                                      | C <sub>D(off)</sub>  | V <sub>EN</sub> = 0 V, V <sub>D</sub> = 0 V<br>f = 1 MHz                                                                                                            |  | Room              | 130              |                          |                  |                         |                  |         |         |
|                                                            |                      |                                                                                                                                                                     |  | DG407             | Room             | 65                       |                  |                         |                  |         |         |
| DG406                                                      | Room                 |                                                                                                                                                                     |  | 140               |                  |                          |                  |                         |                  |         |         |
| DG407                                                      | Room                 |                                                                                                                                                                     |  | 70                |                  |                          |                  |                         |                  |         |         |

**SPECIFICATIONS<sup>a</sup>**

| Parameter               | Symbol | Test Conditions<br>Unless Otherwise Specified<br><br>V+ = 15 V, V− = −15 V<br>V <sub>AL</sub> = 0.8 V, V <sub>AH</sub> = 2.4 V <sup>f</sup> | Temp <sup>b</sup> | Typ <sup>c</sup> | A Suffix<br>−55 to 125°C |                  | D Suffix<br>−40 to 85°C |                  | Unit |
|-------------------------|--------|---------------------------------------------------------------------------------------------------------------------------------------------|-------------------|------------------|--------------------------|------------------|-------------------------|------------------|------|
|                         |        |                                                                                                                                             |                   |                  | Min <sup>d</sup>         | Max <sup>d</sup> | Min <sup>d</sup>        | Max <sup>d</sup> |      |
| Power Supplies          |        |                                                                                                                                             |                   |                  |                          |                  |                         |                  |      |
| Positive Supply Current | I+     | V <sub>EN</sub> = V <sub>A</sub> = 0 or 5 V                                                                                                 | Room Full         | 13               |                          | 30<br>75         |                         | 30<br>75         | μA   |
| Negative Supply Current | I−     |                                                                                                                                             | Room Full         | −0.01            | −1<br>−10                |                  | −1<br>−10               |                  |      |
| Positive Supply Current | I+     | V <sub>EN</sub> = 2.4 V, V <sub>A</sub> = 0 V                                                                                               | Room Full         | 50               |                          | 500<br>900       |                         | 500<br>700       |      |
| Negative Supply Current | I−     |                                                                                                                                             | Room Full         | −0.01            | −20<br>−20               |                  | −20<br>−20              |                  |      |

**SPECIFICATIONS<sup>a</sup> FOR SINGLE SUPPLY**

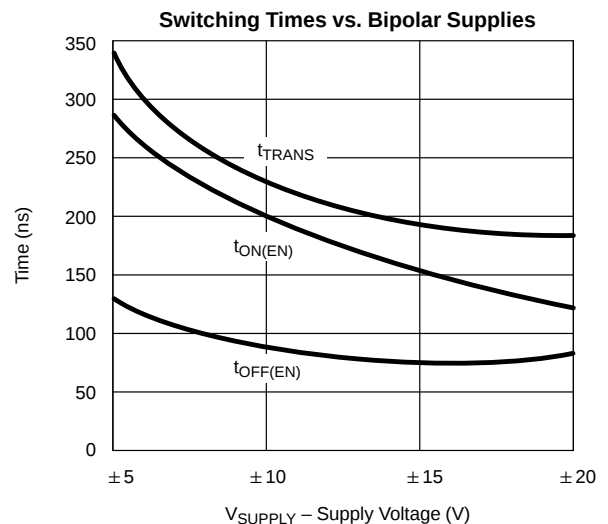
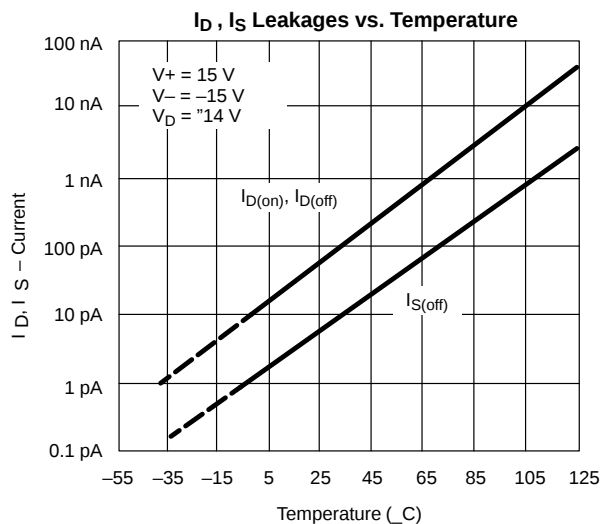
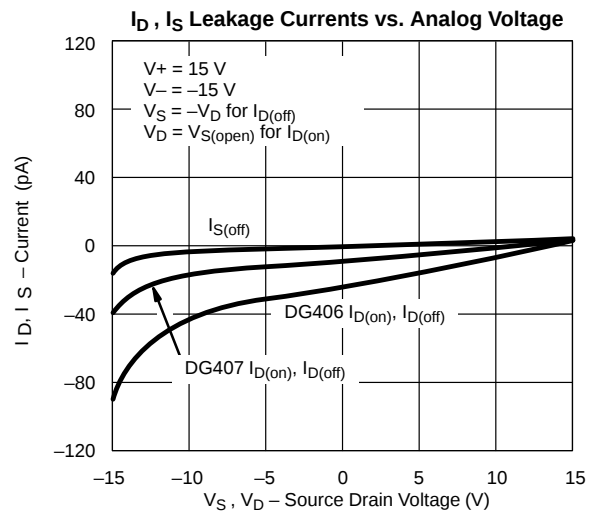
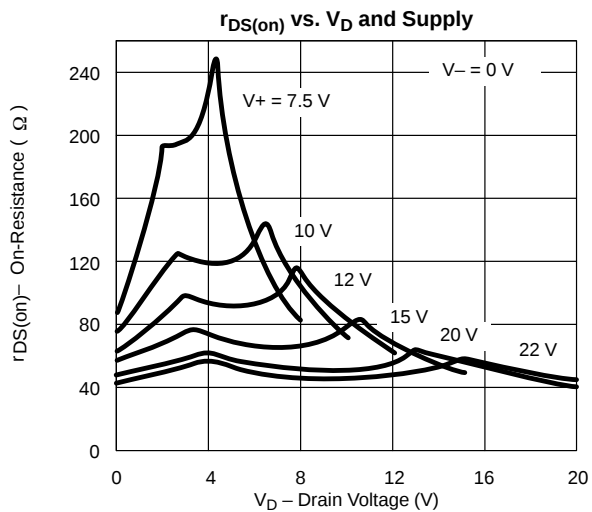
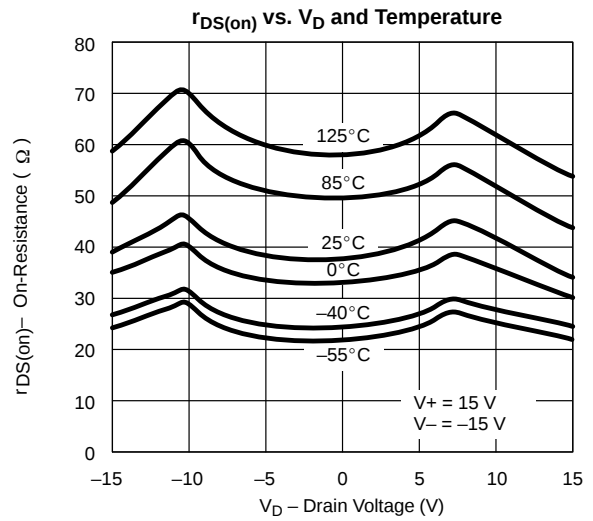
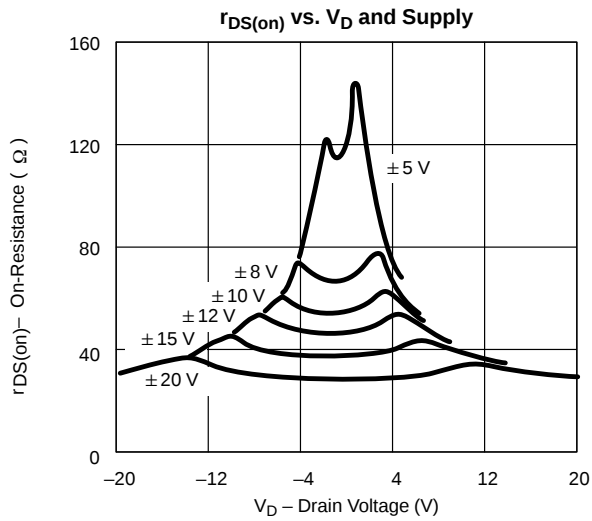
| Parameter                                      | Symbol   | Test Conditions<br>Unless Otherwise Specified<br><br>V+ = 12 V, V− = 0 V<br>VAL = 0.8 V, VAH = 2.4 V <sup>f</sup> | Temp <sup>b</sup> | Typ <sup>c</sup> | A Suffix<br>−55 to 125°C |                  | D Suffix<br>−40 to 85°C |                  | Unit |
|------------------------------------------------|----------|-------------------------------------------------------------------------------------------------------------------|-------------------|------------------|--------------------------|------------------|-------------------------|------------------|------|
|                                                |          |                                                                                                                   |                   |                  | Min <sup>d</sup>         | Max <sup>d</sup> | Min <sup>d</sup>        | Max <sup>d</sup> |      |
| Analog Switch                                  |          |                                                                                                                   |                   |                  |                          |                  |                         |                  |      |
| Analog Signal Range <sup>e</sup>               | VANALOG  |                                                                                                                   | Full              |                  | 0                        | 12               | 0                       | 12               | V    |
| Drain-Source On-Resistance                     | rDS(on)  | VD = 3 V, 10 V, IS = − 1 mA<br>Sequence Each Switch On                                                            | Room              | 90               |                          | 120              |                         | 120              | Ω    |
| rDS(on) Matching Between Channels <sup>g</sup> | ΔrDS(on) |                                                                                                                   | Room              | 5                |                          |                  |                         |                  | %    |
| Source Off Leakage Current                     | IS(off)  | VEN = 0 V<br>VD = 10 V or 0.5 V<br>VS = 0.5 V or 10 V                                                             | Room              | 0.01             |                          |                  |                         |                  | nA   |
| Drain Off Leakage Current                      | ID(off)  |                                                                                                                   | DG406             | Room             | 0.04                     |                  |                         |                  |      |
|                                                |          |                                                                                                                   | DG407             | Room             | 0.04                     |                  |                         |                  |      |
| Drain On Leakage Current                       | ID(on)   | DG406                                                                                                             | Room              | 0.04             |                          |                  |                         |                  |      |
|                                                |          | DG407                                                                                                             | Room              | 0.04             |                          |                  |                         |                  |      |
| Dynamic Characteristics                        |          |                                                                                                                   |                   |                  |                          |                  |                         |                  |      |
| Switching Time of Multiplexer                  | tTRANS   | VS1 = 8 V, VS8 = 0 V, VIN = 2.4 V                                                                                 | Room              | 300              |                          | 450              |                         | 450              | ns   |
| Enable Turn-On Time                            | tON(EN)  | VINH = 2.4 V, VINL = 0 V<br>VS1 = 5 V                                                                             | Room              | 250              |                          | 600              |                         | 600              |      |
| Enable Turn-Off Time                           | tOFF(EN) |                                                                                                                   | Room              | 150              |                          | 300              |                         | 300              |      |
| Charge Injection                               | Q        | CL = 1 nF, VS = 6 V, RS = 0                                                                                       | Room              | 20               |                          |                  |                         |                  | pC   |
| Power Supplies                                 |          |                                                                                                                   |                   |                  |                          |                  |                         |                  |      |
| Positive Supply Current                        | I+       | VEN = 0 V or 5 V, VA = 0 V or 5 V                                                                                 | Room Full         | 13               |                          | 30 75            |                         | 30 75            | μA   |
| Negative Supply Current                        | I−       |                                                                                                                   | Room Full         | −0.01            | −20 −20                  |                  | −20 −20                 |                  |      |

## Notes:

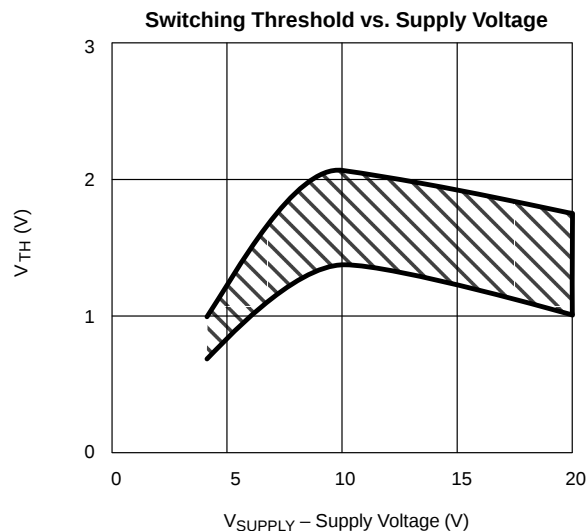
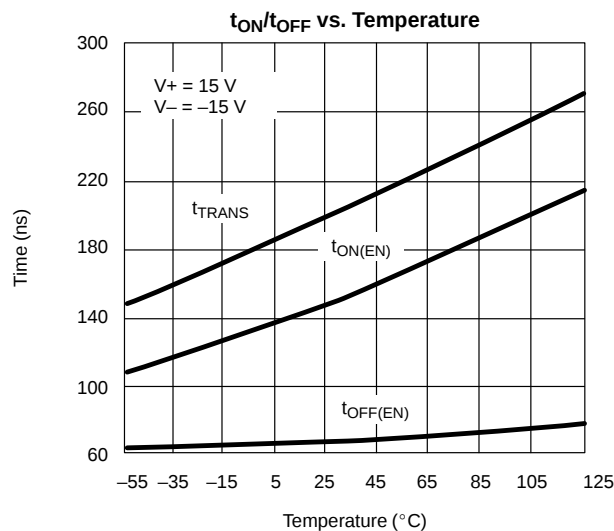
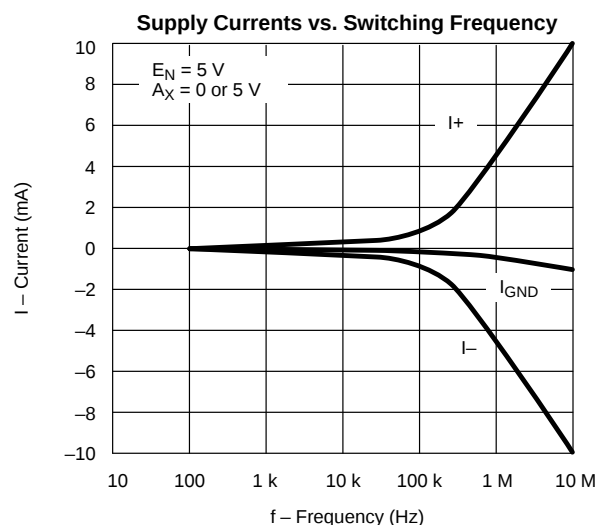
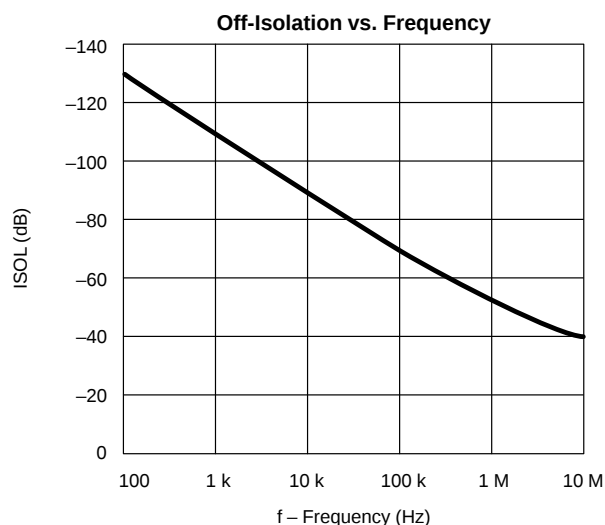
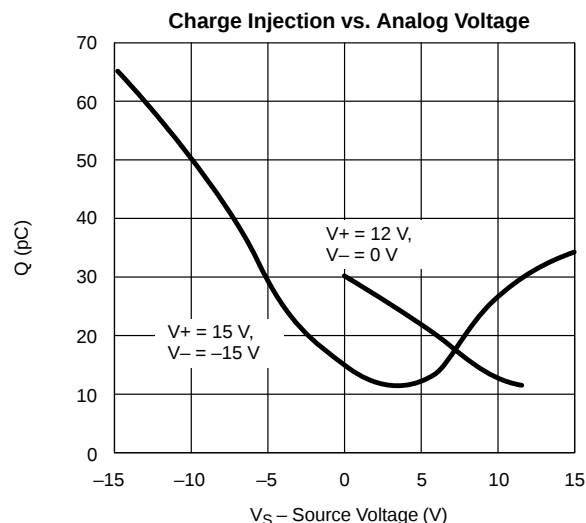
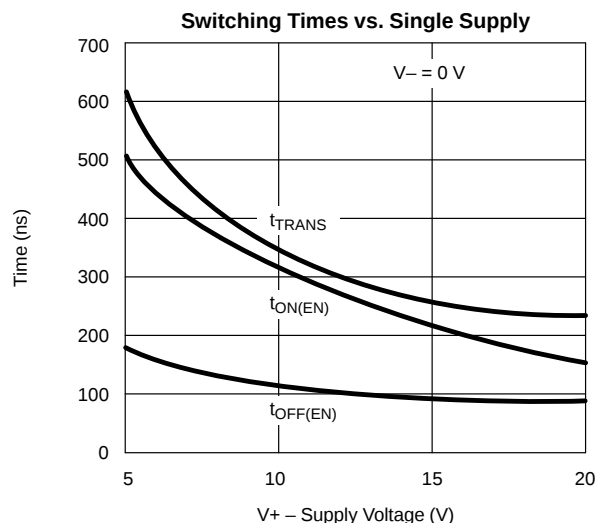
- Refer to PROCESS OPTION FLOWCHART.
- Room = 25°C, Full = as determined by the operating temperature suffix.
- Typical values are for DESIGN AID ONLY, not guaranteed nor subject to production testing.
- The algebraic convention whereby the most negative value is a minimum and the most positive a maximum,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



**TYPICAL CHARACTERISTICS (25°C UNLESS NOTED)**



**TYPICAL CHARACTERISTICS (25°C UNLESS NOTED)**



**SCHEMATIC DIAGRAM (TYPICAL CHANNEL)**

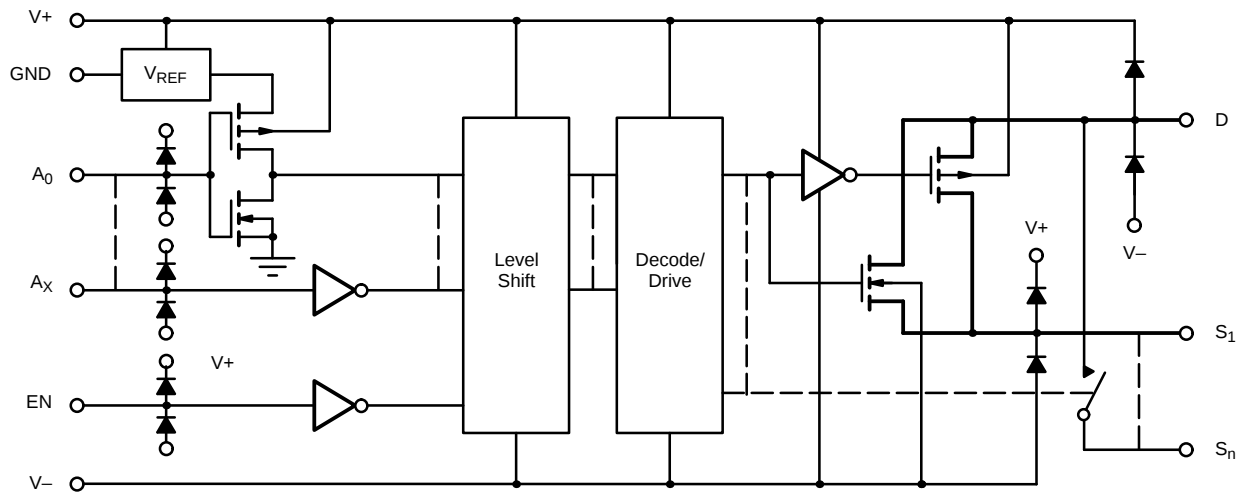


FIGURE 1.

**TEST CIRCUITS**

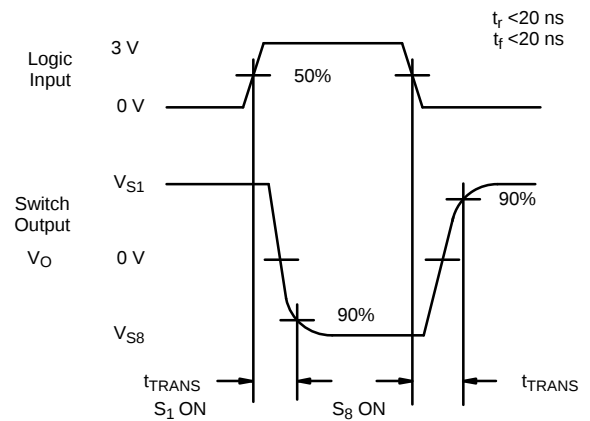
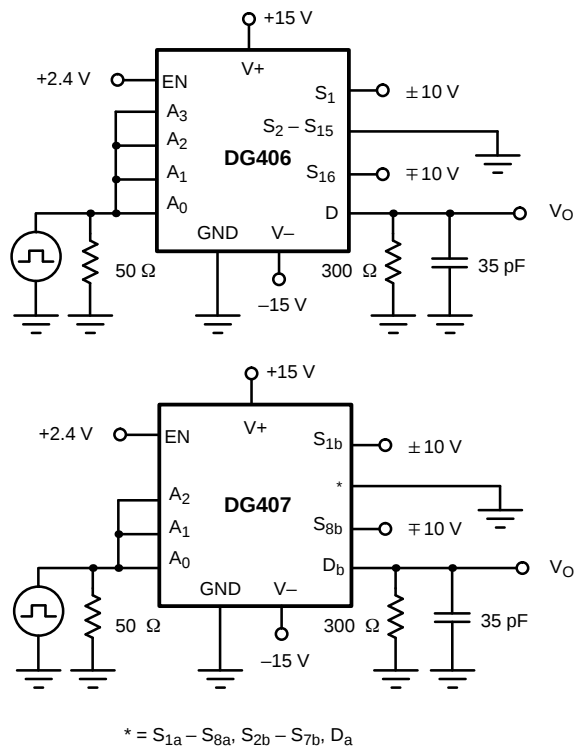
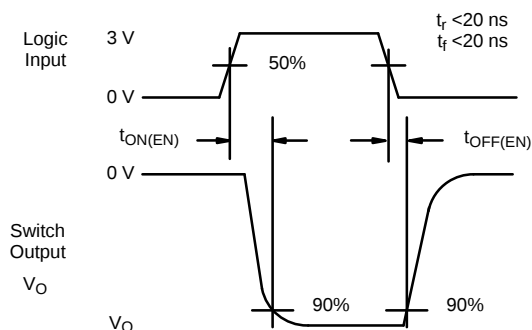
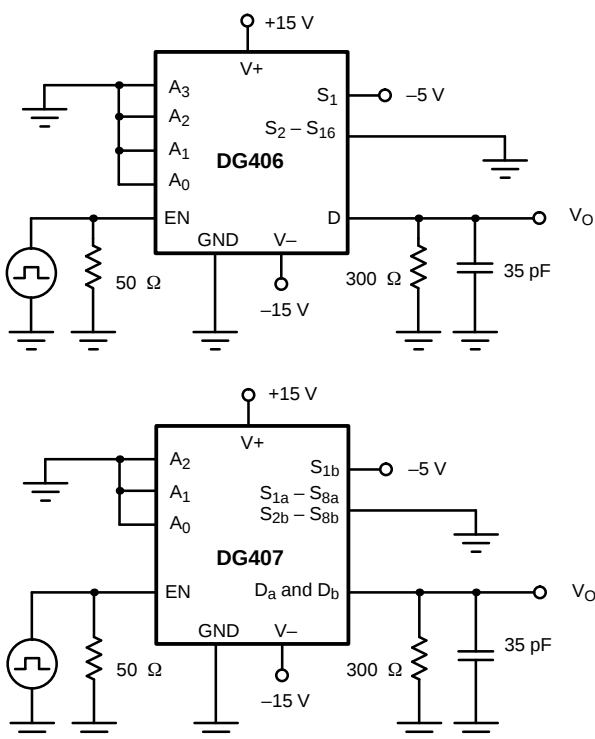
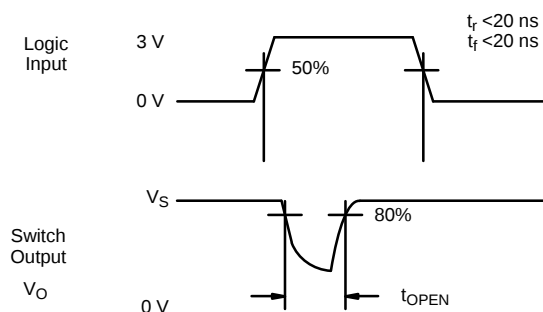
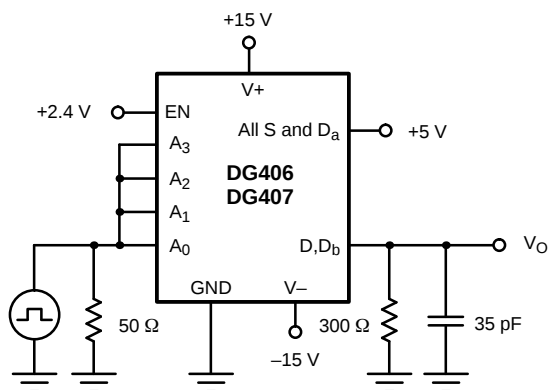


FIGURE 2. Transition Time

**TEST CIRCUITS**



**FIGURE 3.** Enable Switching Time



**FIGURE 4.** Break-Before-Make Interval

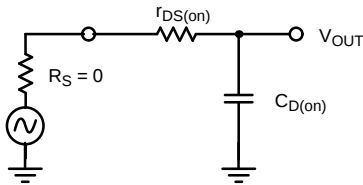
## APPLICATION HINTS

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.

$t_{\text{TRANS}}$  is given on the data sheet. Settling time at the load depends on several parameters:  $r_{\text{DS(on)}}$  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  $n\tau$ :

| % 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:

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

where  $N$  = number of channels to scan  
 $t_{\text{SETTLING}} = n\tau = n \times r_{\text{DS(on)}} \times C_{\text{D(on)}}$

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

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

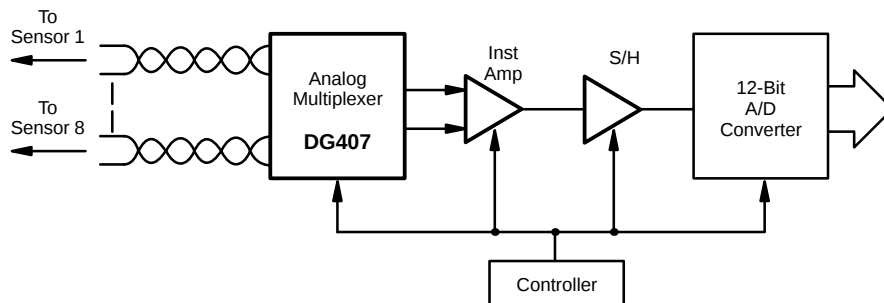
From the sampling theorem, to properly recover the original signal, the sampling frequency should be more than twice the maximum component frequency of the original signal. This assumes perfect bandlimiting. In a real application sampling at three to four times the filter cutoff frequency is a good practice.

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  $r_{\text{DS(on)}}$ , 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.