# 8-Ch/Dual 4-Ch High-Performance CMOS Analog Multiplexers

## DESCRIPTION

The DG408 is an 8-channel single-ended analog multiplexer designed to connect one of eight inputs to a common output as determined by a 3-bit binary address ($A_0$, $A_1$, $A_2$). The DG409 is a dual 4-channel differential analog multiplexer designed to connect one of four differential inputs to a common dual output as determined by its 2-bit binary address ($A_0$, $A_1$). Break-before-make switching action protects against momentary crosstalk between adjacent channels.

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 DG408/409 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. Additionally, single supply operation is also allowed. An epitaxial layer prevents latchup.

For additional information please see Technical Article TA201 (FaxBack Number 70600).

## FEATURES

- Low On-Resistance - $r_{DS(on)}$: 100 $\Omega$
- Low Charge Injection - Q: 20 pC
- Fast Transition Time - $t_{TRANS}$: 160 ns
- Low Power - $I_{SUPPLY}$: 10 µA
- Single Supply Capability
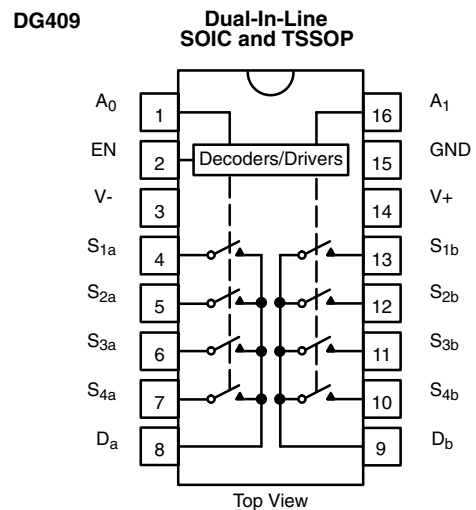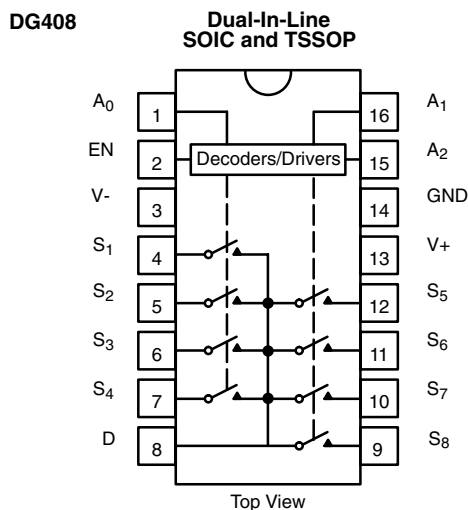- 44 V Supply Max Rating
- TTL Compatible Logic

## BENEFITS

- Reduced Switching Errors
- 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
- ATE Systems
- Battery Powered Systems
- High Rel Systems
- Single Supply Systems
- Medical Instrumentation

**Pb-free**
Available

**RoHS\***
**COMPLIANT**

## FUNCTIONAL BLOCK DIAGRAM AND PIN CONFIGURATION



DG408 — Dual-In-Line SOIC and TSSOP — Top View

| Pin | Signal | | Pin | Signal |
|---|---|---|---|---|
| 1 | $A_0$ | | 16 | $A_1$ |
| 2 | EN | | 15 | $A_2$ |
| 3 | V- | | 14 | GND |
| 4 | $S_1$ | | 13 | V+ |
| 5 | $S_2$ | | 12 | $S_5$ |
| 6 | $S_3$ | | 11 | $S_6$ |
| 7 | $S_4$ | | 10 | $S_7$ |
| 8 | D | | 9 | $S_8$ |



DG409 — Dual-In-Line SOIC and TSSOP — Top View

| Pin | Signal | | Pin | Signal |
|---|---|---|---|---|
| 1 | $A_0$ | | 16 | $A_1$ |
| 2 | EN | | 15 | GND |
| 3 | V- | | 14 | V+ |
| 4 | $S_{1a}$ | | 13 | $S_{1b}$ |
| 5 | $S_{2a}$ | | 12 | $S_{2b}$ |
| 6 | $S_{3a}$ | | 11 | $S_{3b}$ |
| 7 | $S_{4a}$ | | 10 | $S_{4b}$ |
| 8 | $D_a$ | | 9 | $D_b$ |

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

## TRUTH TABLES AND ORDERING INFORMATION

| TRUTH TABLE - DG408 | | | | |
|---|---|---|---|---|
| $A_2$ | $A_1$ | $A_0$ | EN | On Switch |
| 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 |

| TRUTH TABLE - DG409 | | | |
|---|---|---|---|
| $A_1$ | $A_0$ | EN | On Switch |
| X | X | 0 | None |
| 0 | 0 | 1 | 1 |
| 0 | 1 | 1 | 2 |
| 1 | 0 | 1 | 3 |
| 1 | 1 | 1 | 4 |

Logic "0" = $V_{AL} \leq 0.8$ V
Logic "1" = $V_{AH} \geq 2.4$ V
X = Don't Care

| ORDERING INFORMATION - DG408 | | |
|---|---|---|
| Temp Range | Package | Part Number |
| - 40 to 85 °C | 16-Pin Plastic DIP | DG408DJ<br>DG408DJ-E3 |
| | 16-Pin SOIC | DG408DY<br>DG408DY-E3<br>DG408DY-T1<br>DG408DY-T1-E3 |
| | 16-Pin TSSOP | DG408DQ<br>DG408DQ-E3<br>DG408DQ-T1<br>DG408DQ-T1-E3 |

| ORDERING INFORMATION - DG409 | | |
|---|---|---|
| Temp Range | Package | Part Number |
| - 40 to 85 °C | 16-Pin Plastic DIP | DG409DJ<br>DG409DJ-E3 |
| | 16-Pin SOIC | DG409DY<br>DG409DY-E3<br>DG409DY-T1<br>DG409DY-T1-E3 |
| | 16-Pin TSSOP | DG409DQ<br>DG409DQ-E3<br>DG409DQ-T1<br>DG409DQ-T1-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<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 Suffix) | - 65 to 150 | °C |
| | (DJ, DY Suffix) | - 65 to 125 | |
| Power Dissipation (Package)[b] | 16-Pin Plastic DIP[c] | 450 | mW |
| | 16-Pin Narrow SOIC and TSSOP[d] | 600 | |
| | 16-Pin CerDIP[e] | 900 | |
| | LCC-20[f] | 750 | |

Notes:
a. Signals on $S_X$, $D_X$ or $IN_X$ 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 7.6 mW/°C above 75 °C.
e. Derate 12 mW/°C above 75 °C.
f.  Derate 10 mW/°C above 75 °C.

## SPECIFICATIONS[a]

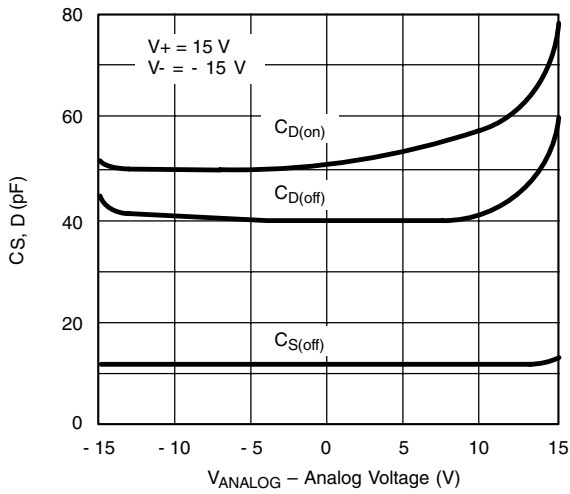| Parameter | Symbol | Test Conditions Unless Otherwise Specified V+ = 15 V, V- = - 15 V $V_{AL}$ = 0.8 V, $V_{AH}$ = 2.4 V[f] | | Temp[b] | Typ[c] | A Suffix - 55 to 125 °C | | D Suffix - 40 to 85 °C | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Min[d] | Max[d] | Min[d] | Max[d] | |
| **Analog Switch** | | | | | | | | | | |
| Analog Signal Range[e] | $V_{ANALOG}$ | | | Full | | - 15 | 15 | - 15 | 15 | V |
| Drain-Source On-Resistance | $r_{DS(on)}$ | $V_D$ = ± 10 V, $I_S$ = - 10 mA | | Room Full | 40 | | 100 125 | | 100 125 | Ω |
| $r_{DS(on)}$ Matching Between Channels[g] | $\Delta r_{DS(on)}$ | $V_D$ = ± 10 V | | Room | | | 15 | | 15 | % |
| Source Off Leakage Current | $I_{S(off)}$ | $V_S$ = ± 10 V $V_D$ = ± 10 V, $V_{EN}$ = 0 V | | Room Full | | - 0.5 - 50 | 0.5 50 | - 0.5 - 5 | 0.5 5 | nA |
| Drain Off Leakage Current | $I_{D(off)}$ | $V_D$ = ± 10 V $V_S$ = ± 10 V $V_{EN}$ = 0 V | DG408 | Room Full | | - 1 - 100 | 1 100 | - 1 - 20 | 1 20 | nA |
| | | | DG409 | Room Full | | - 1 - 50 | 1 50 | - 1 - 10 | 1 10 | |
| Drain On Leakage Current | $I_{D(on)}$ | $V_S = V_D$ = ± 10 Sequence Each Switch On | DG408 | Room Full | | - 1 - 100 | 1 100 | - 1 - 20 | 1 20 | |
| | | | DG409 | Room Full | | - 1 - 50 | 1 50 | - 1 - 10 | 1 10 | |
| **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 V, 15 V | | Full | | - 10 | 10 | - 10 | 10 | µA |
| Logic Low Input Current | $I_{AL}$ | $V_{EN}$ = 0 V, 2.4 V, $V_A$ = 0 V | | Full | | - 10 | 10 | - 10 | 10 | |
| Logic Input Capacitance | $C_{in}$ | f = 1 MHz | | Room | 8 | | | | | pF |
| **Dynamic Characteristics** | | | | | | | | | | |
| Transition Time | $t_{TRANS}$ | See Figure 2 | | Full | 160 | | 250 | | 250 | |
| Break-Before-Make Interval | $t_{OPEN}$ | See Figure 4 | | Room | | 10 | | 10 | | |
| Enable Turn-On Time | $t_{ON(EN)}$ | See Figure 3 | | Room Full | 115 | | 150 225 | | 150 | ns |
| Enable Turn-Off Time | $t_{OFF(EN)}$ | | | Room | 105 | | 150 | | 150 | |
| Charge Injection | Q | $C_L$ = 10 nF, $V_S$ = 0 V | | Room | 20 | | | | | pC |
| Off Isolation[h] | OIRR | $V_{EN}$ = 0 V, $R_L$ = 1 kΩ f = 100 kHz | | Room | - 75 | | | | | dB |
| Source Off Capacitance | $C_{S(off)}$ | $V_{EN}$ = 0 V, $V_S$ = 0 V, f = 1 MHz | | Room | 3 | | | | | |
| Drain Off Capacitance | $C_{D(off)}$ | $V_{EN}$ = 0 V $V_D$ = 0 V f = 1 MHz | DG408 | Room | 26 | | | | | pF |
| | | | DG409 | Room | 14 | | | | | |
| Drain On Capacitance | $C_{D(on)}$ | | DG408 | Room | 37 | | | | | |
| | | | DG409 | Room | 25 | | | | | |
| **Power Supplies** | | | | | | | | | | |
| Positive Supply Current | I+ | $V_{EN} = V_A$ = 0 V or 5 V | | Full | 10 | | 75 | | 75 | µA |
| Negative Supply Current | I- | | | Full | 1 | - 75 | | - 75 | | |
| Positive Supply Current | I+ | $V_{EN}$ = 2.4 V, $V_A$ = 0 V | | Room Full | 0.2 | | 0.5 2 | | 0.5 2 | mA |
| Negative Supply Current | I- | | | Full | | - 500 | | - 500 | | µA |

## 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 to 125 °C | | D Suffix - 40 to 85 °C | | Unit |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Min[d] | Max[d] | Min[d] | Max[d] | |
| **Analog Switch** | | | | | | | | | |
| Drain-Source On-Resistance[e,f] | $r_{DS(on)}$ | $V_D$ = 3 V, 10 V, $I_S$ = - 1 mA | Room | 90 | | | | | Ω |
| **Dynamic Characteristics** | | | | | | | | | |
| Switching Time of Multiplexer[e] | $t_{TRANS}$ | $V_{S1}$ = 8 V, $V_{S8}$ = 0 V, $V_{IN}$ = 2.4 V | Room | 180 | | | | | |
| Enable Turn-On Time[e] | $t_{ON(EN)}$ | $V_{INH}$ = 2.4 V, $V_{INL}$ = 0 V | Room | 180 | | | | | ns |
| Enable Turn-Off Time[e] | $t_{OFF(EN)}$ | $V_{S1}$ = 5 V | Room | 120 | | | | | |
| Charge Injection[e] | Q | $C_L$ = 1 nF, $V_S$ = 6 V, $R_S$ = 0 | Room | 5 | | | | | pC |

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.*

## TYPICAL CHARACTERISTICS  25 °C, unless otherwise noted

**Source/Drain Capacitance vs. Analog Voltage**

$V+ = 15\ V$
$V- = -15\ V$

$C_{D(on)}$
$C_{D(off)}$
$C_{S(off)}$

$C_{S, D}\ (pF)$ vs. $V_{ANALOG}$ – Analog Voltage (V)
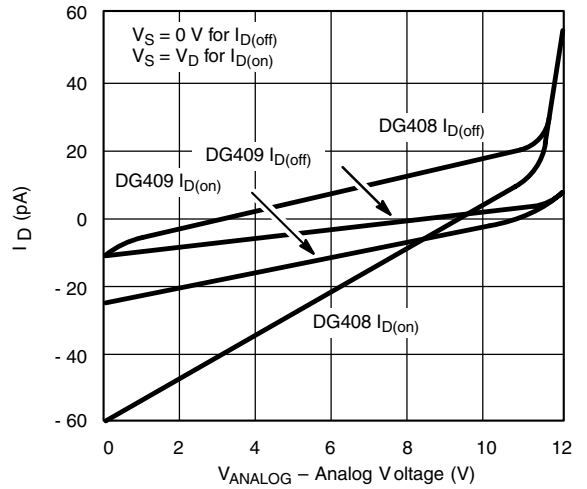
**Drain Leakage Current vs. Source/Drain Voltage (Single 12-V Supply)**

$V_S = 0\ V$ for $I_{D(off)}$
$V_S = V_D$ for $I_{D(on)}$

DG408 $I_{D(off)}$
DG409 $I_{D(off)}$
DG409 $I_{D(on)}$
DG408 $I_{D(on)}$

$I_D\ (pA)$ vs. $V_{ANALOG}$ – Analog Voltage (V)

**Drain Leakage Current vs. Source/DrainVoltage**

$V+ = 15\ V$
$V- = -15\ V$
$V_S = -V_D$ for $I_{D(off)}$
$V_D = V_{S(open)}$ for $I_{D(on)}$

DG409 $I_{D(off)}$
DG409 $I_{D(on)}$
DG408 $I_{D(on)}, I_{D(off)}$

$I_D\ (pA)$ vs. $V_D$ or $V_S$ - Drain or Source Voltage (V)
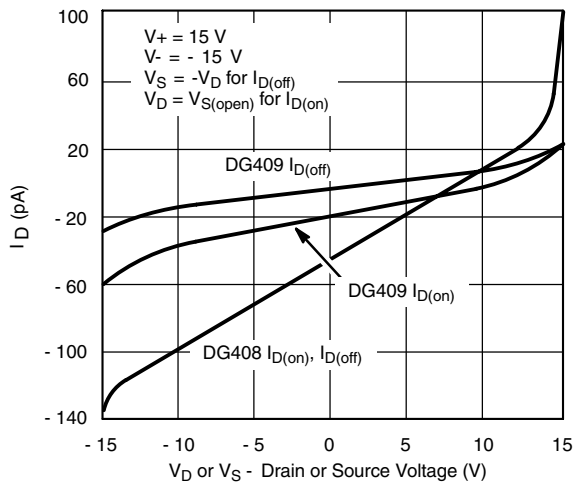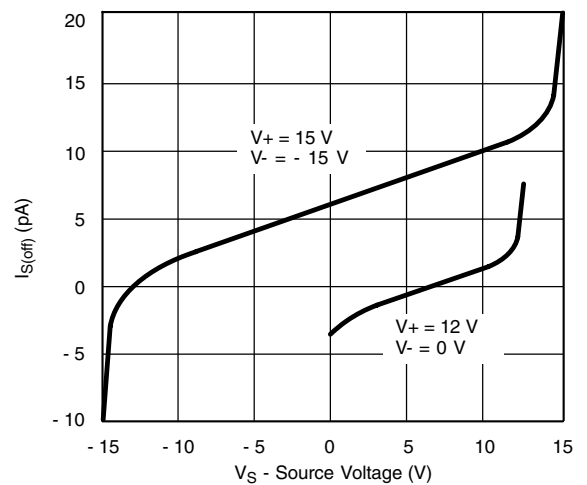
**Source Leakage Current vs. Source Voltage**

$V+ = 15\ V$
$V- = -15\ V$

$V+ = 12\ V$
$V- = 0\ V$

$I_{S(off)}\ (pA)$ vs. $V_S$ - Source Voltage (V)
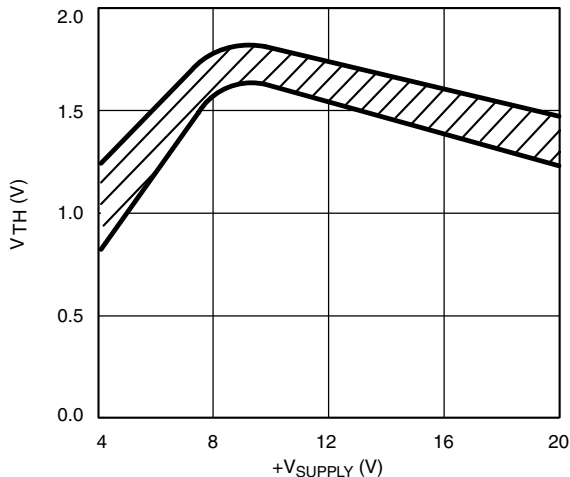
**Input Switching Threshold vs. Supply Voltage**
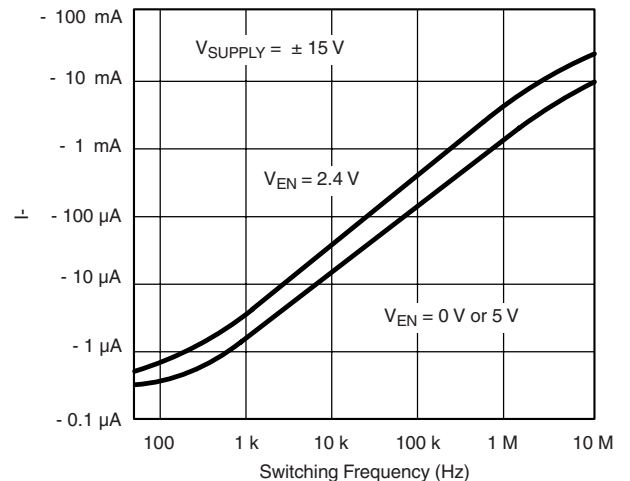
$V_{TH}\ (V)$ vs. $+V_{SUPPLY}\ (V)$

**Negative Supply Current vs. Switching Frequency**

$V_{SUPPLY} = \pm 15\ V$
$V_{EN} = 2.4\ V$
$V_{EN} = 0\ V$ or $5\ V$

$I-$ vs. Switching Frequency (Hz)

**TYPICAL CHARACTERISTICS** 25 °C, unless otherwise noted
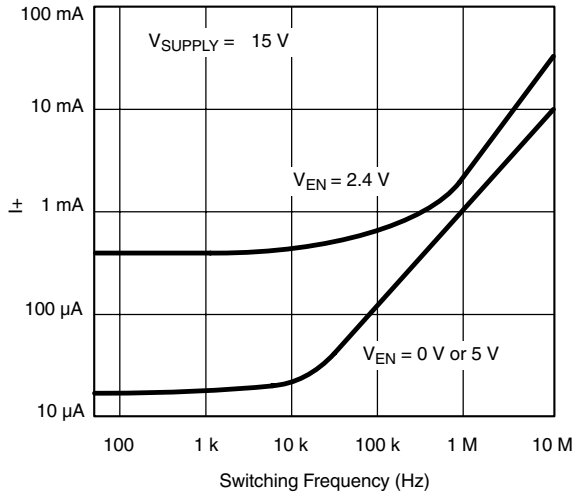
**Positive Supply Current vs. Switching Frequency**
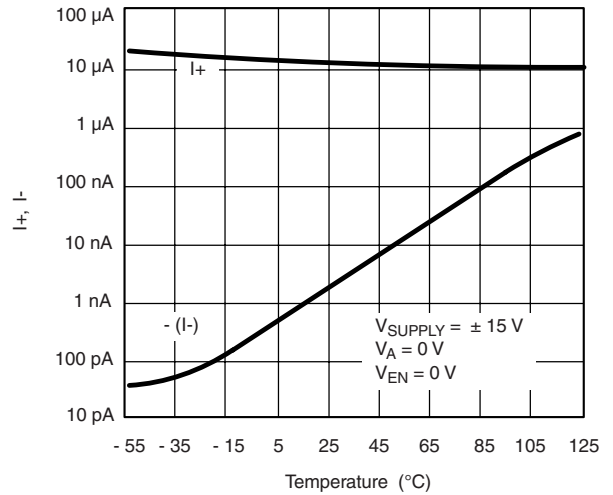
**I_SUPPLY vs. Temperature**
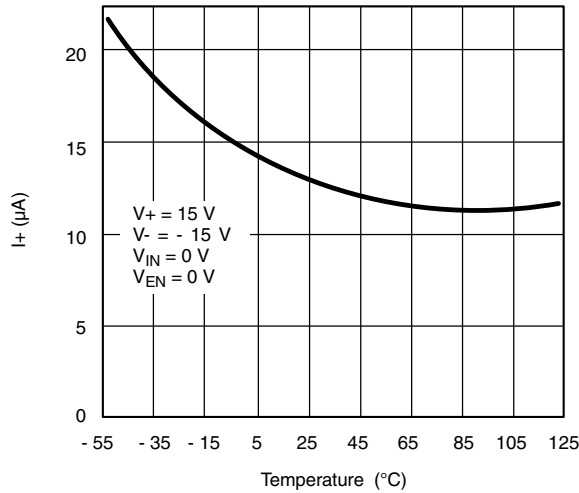
**Positive Supply Current vs. Temperature (DG408)**
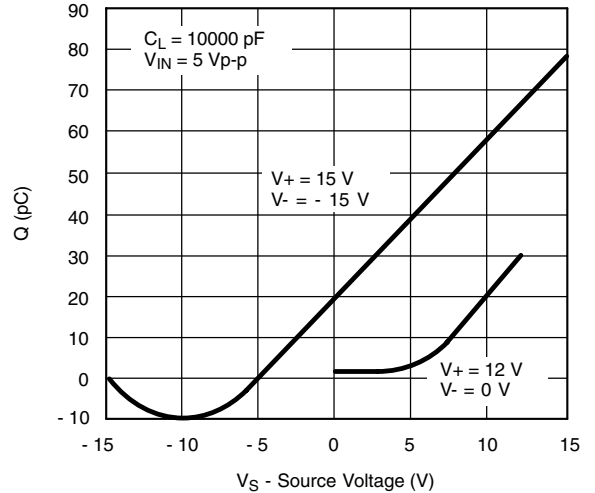
**Charge Injection vs. Analog Voltage**
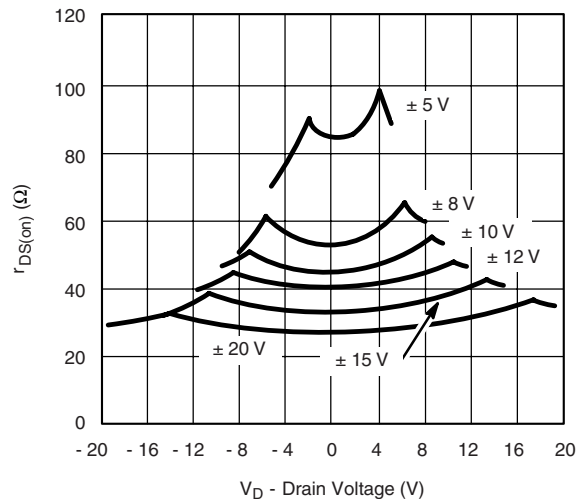
**r_DS(on) vs. V_D and Supply**
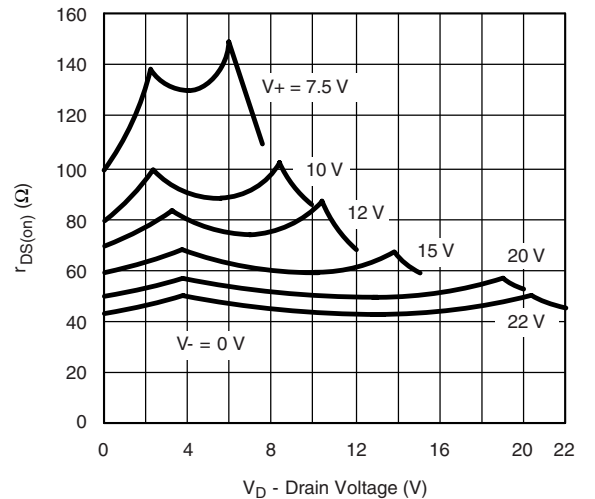
**r_DS(on) vs. V_D and Supply (Single Supply)**

# DG408/409

Vishay Siliconix

## TYPICAL CHARACTERISTICS  25 °C, unless otherwise noted
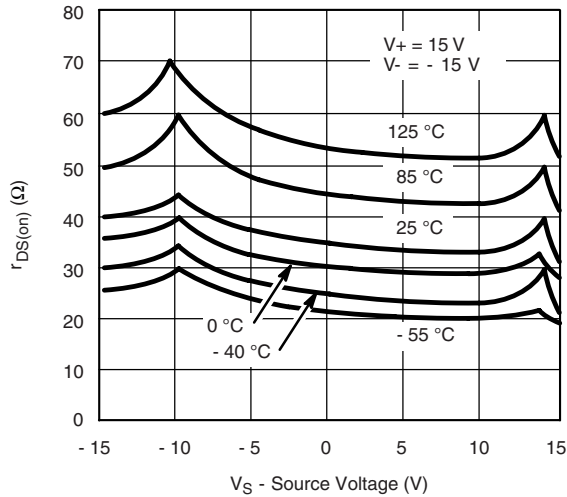


**r_DS(on) vs. V_S and Temperature**
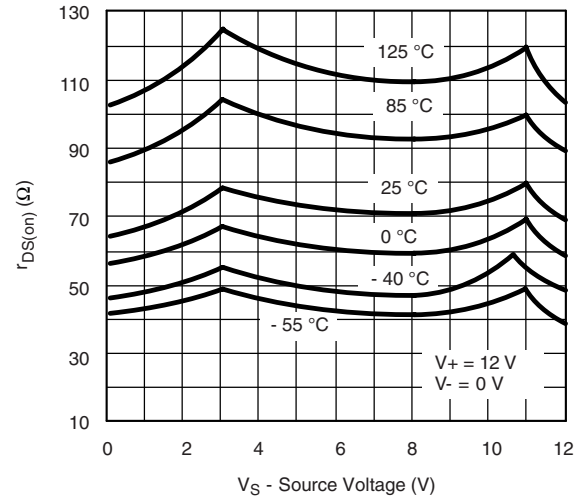


**r_DS(on) vs. V_S and Temperature (Single Supply)**
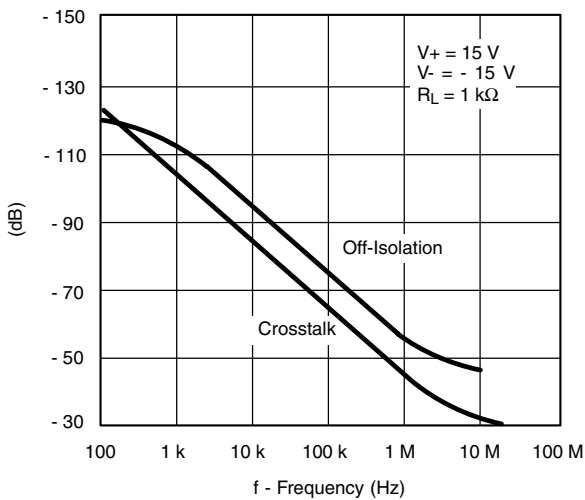


**Off Isolation and Crosstalk vs. Frequency**
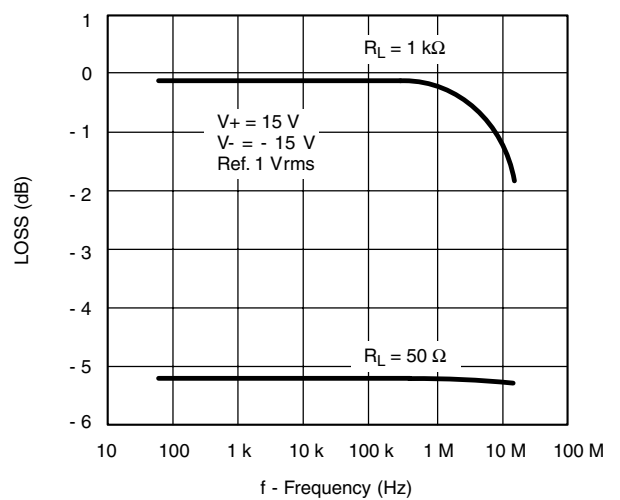


**Insertion Loss vs. Frequency**
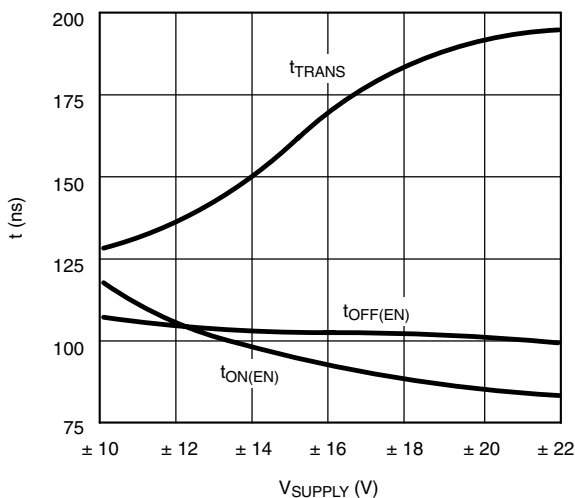


**Switching Time vs. Bipolar Supply)**
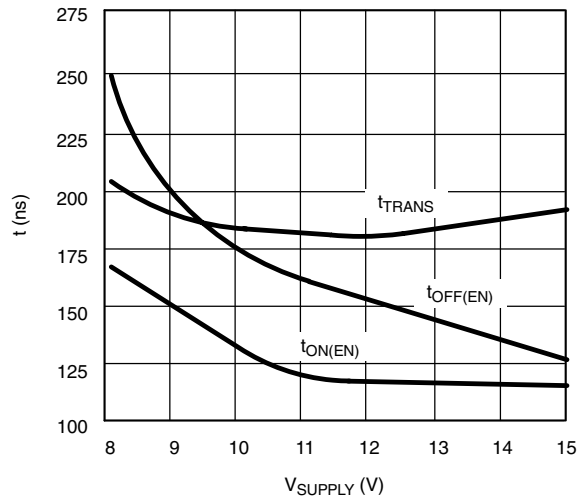


**Switching Time vs. Single Supply**

## SCHEMATIC DIAGRAM (TYPICAL CHANNEL)
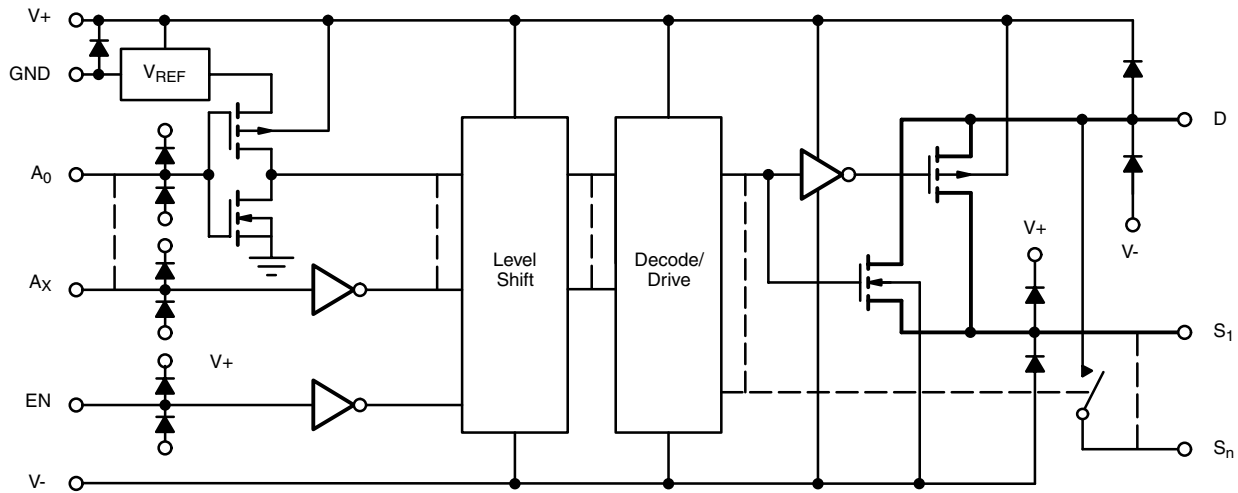


**Figure 1.**

## TEST CIRCUITS
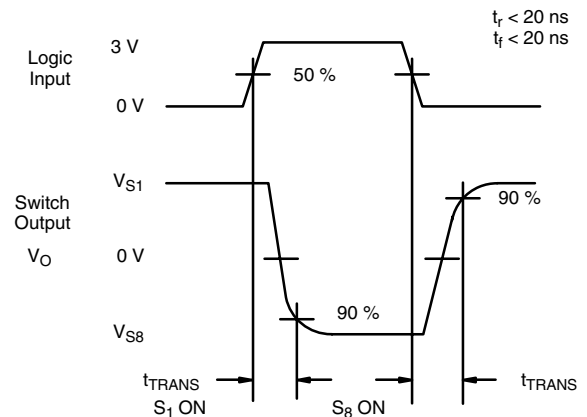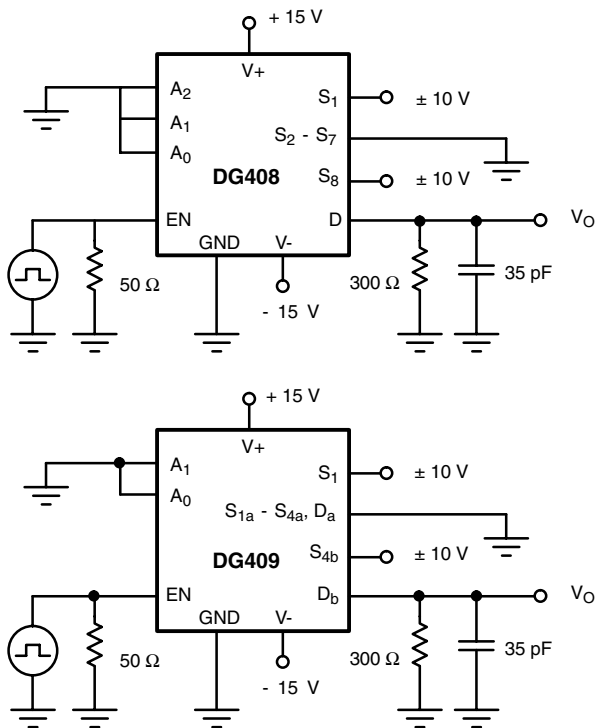


**Figure 2. Transition Time**

## TEST CIRCUITS
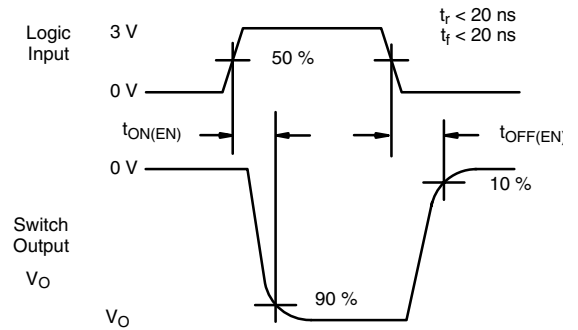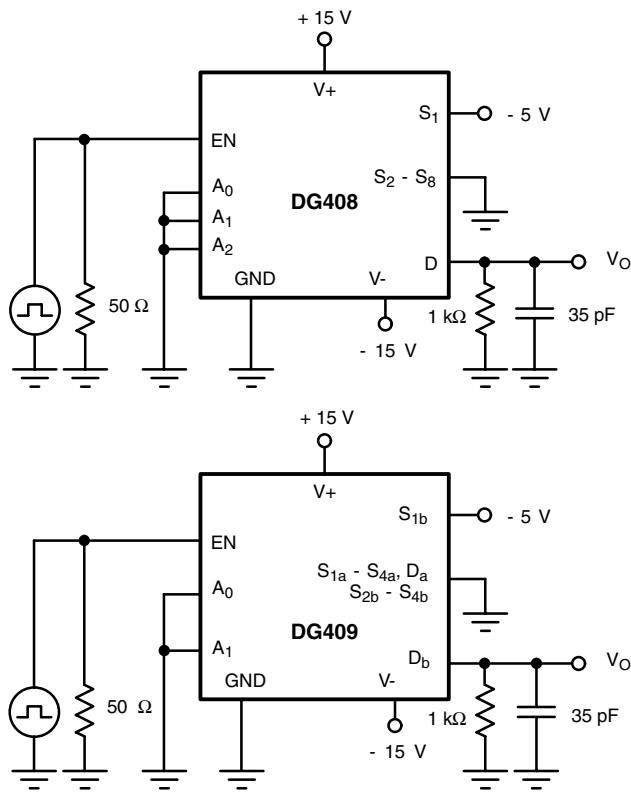


**Figure 3. Enable Switching Time**
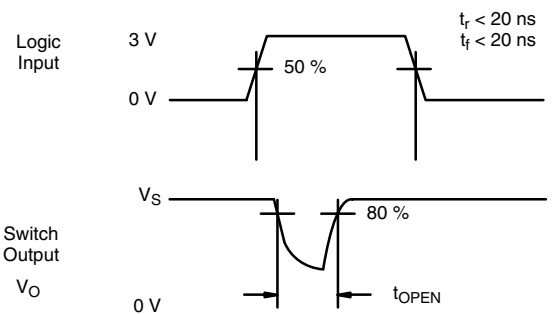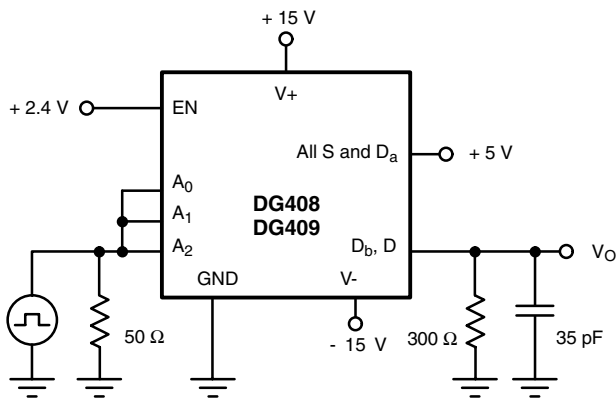


**Figure 4. Break-Before-Make Interval**
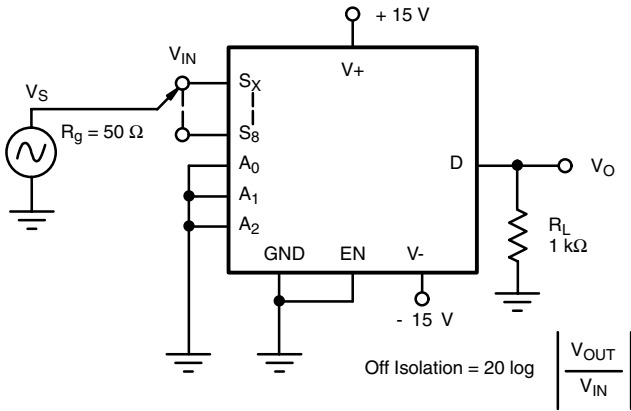
## TEST CIRCUITS
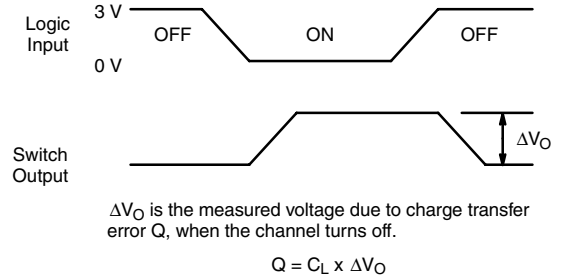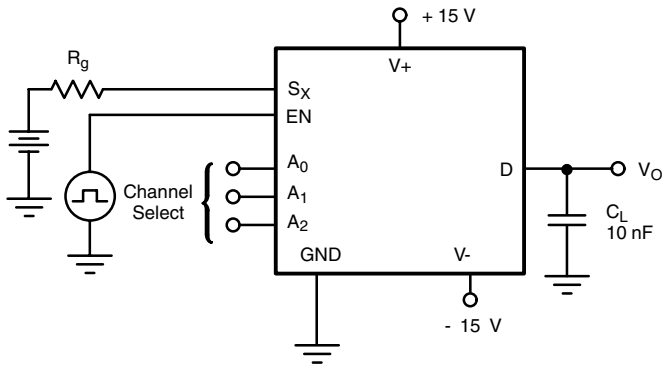


Figure 5. Charge Injection

$\Delta V_O$ is the measured voltage due to charge transfer error Q, when the channel turns off.

$$Q = C_L \times \Delta V_O$$



Off Isolation = $20 \log \left| \dfrac{V_{OUT}}{V_{IN}} \right|$

**Figure 6. Off Isolation**



Crosstalk = $20 \log \left| \dfrac{V_{OUT}}{V_{IN}} \right|$

**Figure 7. Crosstalk**



Insertion Loss = $20 \log \left| \dfrac{V_{OUT}}{V_{IN}} \right|$
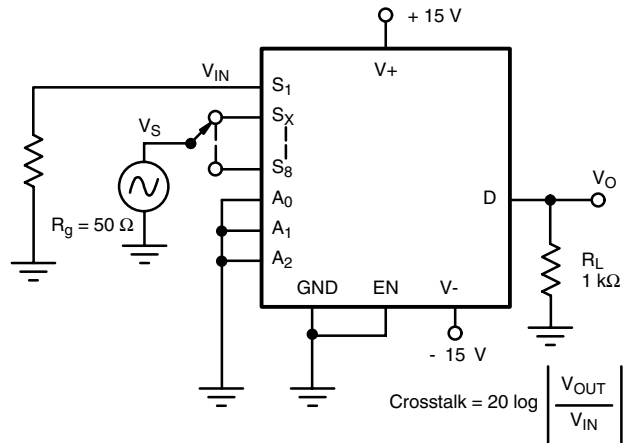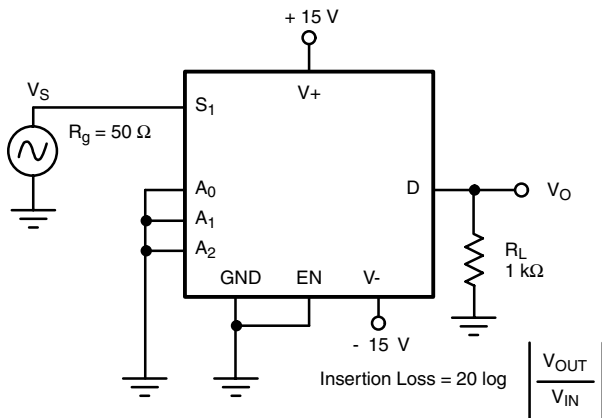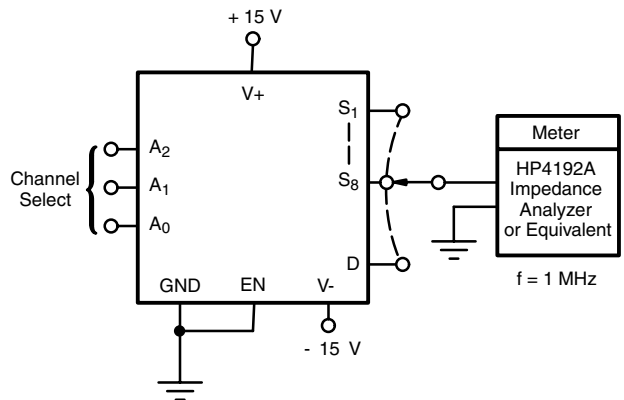
**Figure 8. Insertion Loss**



**Figure 9. Source Drain Capacitance**

## APPLICATIONS HINTS

### Overvoltage Protection

A very convenient form of overvoltage protection consists of adding two small signal diodes (1N4148, 1N914 type) in series with the supply pins (see Figure 10). This arrangement effectively blocks the flow of reverse currents. It also floats the supply pin above or below the normal V+ or V- value. In this case the overvoltage signal actually becomes the power supply of the IC. From the point of view of the chip, nothing has changed, as long as the difference VS - (V-) doesn't exceed + 44 V. The addition of these diodes will reduce the analog signal range to 1 V below V+ and 1 V above V-, but it preserves the low channel resistance and low leakage characteristics.
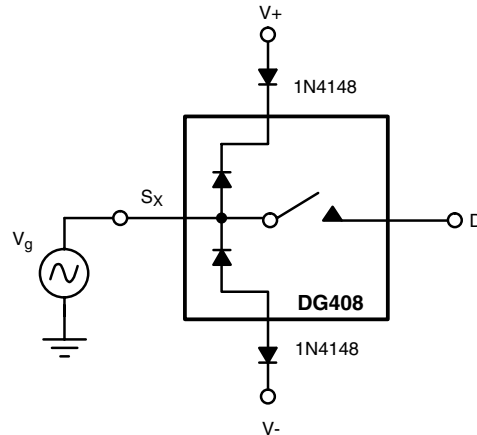
**Figure 10. Overvoltage Protection Using Blocking Diodes**

**8-Channel Sequential Multiplexer/Demultiplexer**
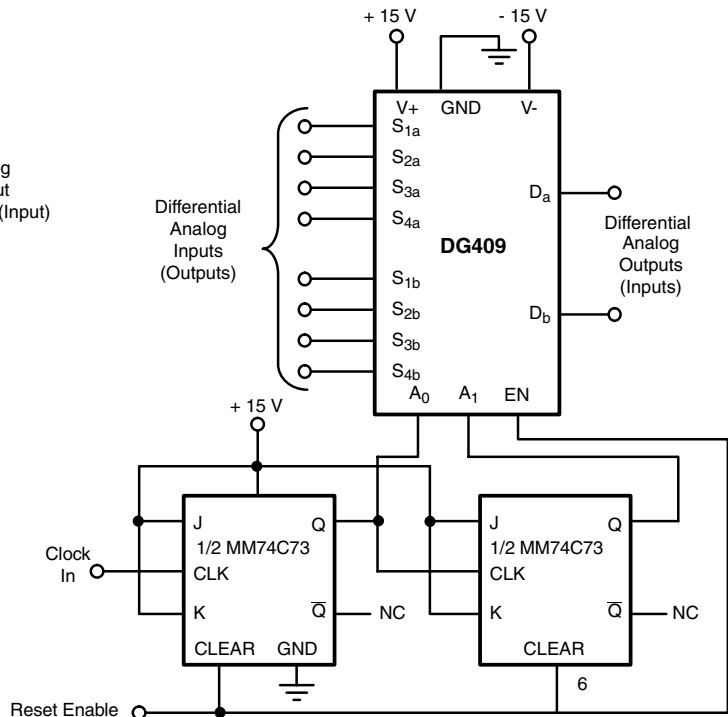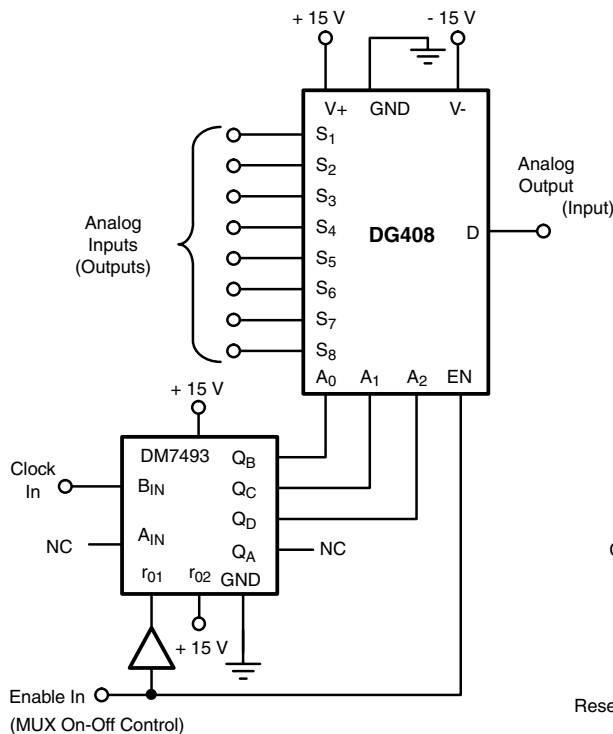
**Differential 4-Channel Sequential Multiplexer/Demultiplexer**

**Figure 11.**

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All product specifications and data are subject to change without notice.

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