



# Improved, Dual, High-Speed Analog Switches

## General Description

Maxim's redesigned DG401/DG403/DG405 analog switches now feature guaranteed low on-resistance matching between switches ( $2\Omega$  max) and guaranteed on-resistance flatness over the signal range ( $3\Omega$  max). These low on-resistance switches ( $20\Omega$  typ) conduct equally well in either direction and are guaranteed to have low charge injection ( $15\text{pC}$  max). The new design offers lower off leakage current over temperature (less than  $5\text{nA}$  at  $+85^\circ\text{C}$ ).

The DG401/DG403/DG405 are dual, high-speed switches. The single-pole/single-throw DG401 and double-pole/single-throw DG405 are normally open dual switches. The dual, single-pole/double-throw DG403 has two normally open and two normally closed switches. Switching times are  $150\text{ns}$  max for  $t_{\text{ON}}$  and  $100\text{ns}$  max for  $t_{\text{OFF}}$ , with a maximum power consumption of  $35\mu\text{W}$ . These devices operate from a single  $+10\text{V}$  to  $+30\text{V}$  supply, or bipolar supplies of  $\pm 4.5\text{V}$  to  $\pm 20\text{V}$ . Maxim's improved DG401/DG403/DG405 are fabricated with a  $44\text{V}$  silicon-gate process.

## Applications

|                              |                      |
|------------------------------|----------------------|
| Sample-and-Hold Circuits     | Test Equipment       |
| Guidance and Control Systems | Heads-Up Displays    |
| Communications Systems       | PBX, PABX            |
| Battery-Operated Systems     | Audio Signal Routing |
| Military Radios              |                      |

## New Features

- ◆ Plug-In Upgrade for Industry-Standard DG401/DG403/DG405
- ◆ Improved  $r_{\text{DS(ON)}}$  Match Between Channels ( $2\Omega$  max)
- ◆ Guaranteed  $r_{\text{FLAT(ON)}}$  Over Signal Range ( $3\Omega$  max)
- ◆ Improved Charge Injection ( $15\text{pC}$  max)
- ◆ Improved Off Leakage Current Over Temperature ( $<5\text{nA}$  at  $+85^\circ\text{C}$ )

## Existing Features

- ◆ Low  $r_{\text{DS(ON)}}$  ( $30\Omega$  max)
- ◆ Single-Supply Operation  $+10\text{V}$  to  $+30\text{V}$   
Bipolar-Supply Operation  $\pm 4.5\text{V}$  to  $\pm 20\text{V}$
- ◆ Low Power Consumption ( $35\mu\text{W}$  max)
- ◆ Rail-to-Rail Signal Handling Capability
- ◆ TTL/CMOS-Logic Compatible

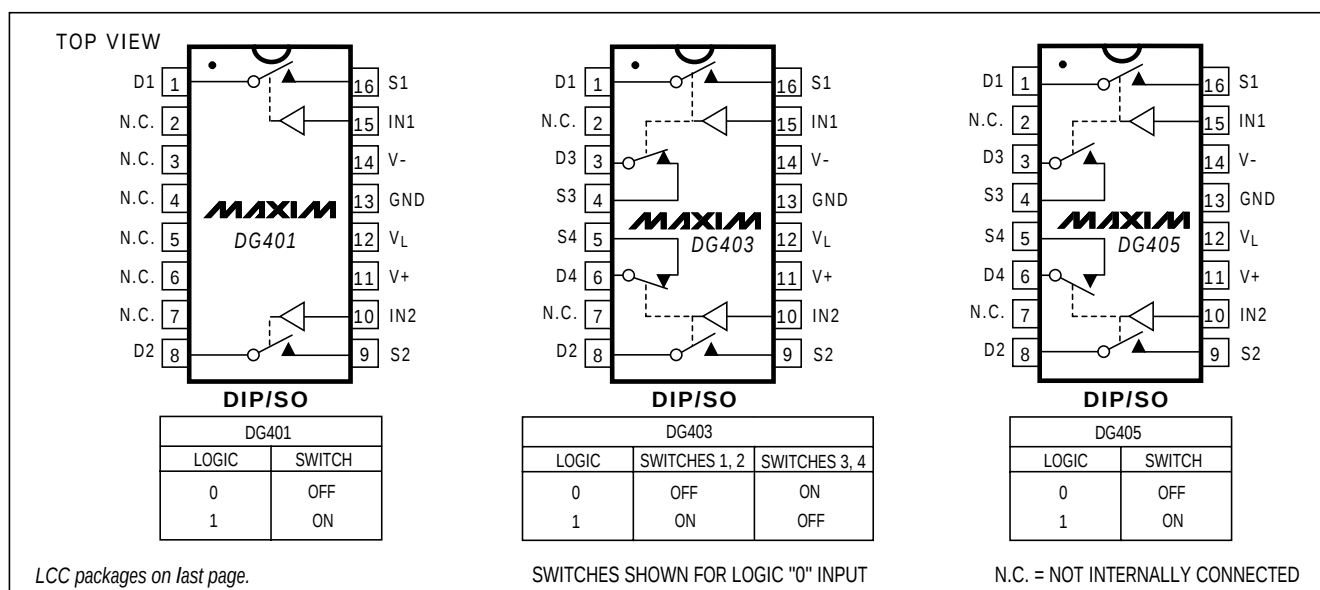
## Ordering Information

| PART     | TEMP. RANGE                              | PIN PACKAGE    |
|----------|------------------------------------------|----------------|
| DG401CJ  | $0^\circ\text{C}$ to $+70^\circ\text{C}$ | 16 Plastic DIP |
| DG401CY  | $0^\circ\text{C}$ to $+70^\circ\text{C}$ | 16 Narrow SO   |
| DG401C/D | $0^\circ\text{C}$ to $+70^\circ\text{C}$ | Dice*          |

Ordering Information continued on last page.

\*Contact factory for dice specifications.

## Pin Configurations/Functional Diagrams/Truth Tables



# Improved, Dual, High-Speed Analog Switches

## ABSOLUTE MAXIMUM RATINGS

Voltage Referenced to V-

V+ .....44V

GND .....25V

V<sub>L</sub> .....(GND - 0.3V) to (V+ + 0.3V)

Digital Inputs, V<sub>S</sub>, V<sub>D</sub> (Note 1) .....(V- - 2V) to (V+ + 2V) or 20mA  
(whichever occurs first)

Continuous Current (any terminal) .....30mA

Continuous Current, S or D .....20mA

Peak Current, S or D  
(pulsed at 1ms, 10% duty cycle max) .....100mA

Continuous Power Dissipation (T<sub>A</sub> = +70°C)

16-Pin Plastic DIP (derate 10.53mW/°C above +70°C) ...842mW

16-Pin Narrow SO (derate 8.70mW/°C above +70°C) ...696mW

16-Pin CERDIP (derate 10.00mW/°C above +70°C) .....800mW

20-Pin LCC (derate 9.09mW/°C above +70°C) .....727mW

Operating Temperature Ranges

DG40\_C\_ .....0°C to +70°C

DG40\_D\_ .....-40°C to +85°C

DG40\_A\_ .....-55°C to +125°C

Storage Temperature Range .....-65°C to +150°C

Lead Temperature (soldering, 10sec) .....+300°C

**Note 1:** Signals on S, D or IN exceeding V+ or V- are clamped by internal diodes. Limit forward current to maximum current rating.

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.

## ELECTRICAL CHARACTERISTICS

(V+ = 15V, V- = -15V, V<sub>L</sub> = +5V, GND = 0V, V<sub>INH</sub> = +2.4V, V<sub>INL</sub> = +0.8V, T<sub>A</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>, unless otherwise noted.)

| PARAMETER                                                  | SYMBOL                                   | CONDITIONS                                                                                                               | TEMP. RANGE                                           | MIN     | TYP (Note 2) | MAX   | UNITS |
|------------------------------------------------------------|------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|---------|--------------|-------|-------|
| <b>SWITCH</b>                                              |                                          |                                                                                                                          |                                                       |         |              |       |       |
| Analog Signal Range                                        | V <sub>ANALOG</sub>                      | (Note 3)                                                                                                                 |                                                       | -15     |              | +15   | V     |
| Drain-Source On-Resistance                                 | r <sub>DS(ON)</sub>                      | V+ = 13.5V, V- = -13.5V, I <sub>S</sub> = -10mA, V <sub>D</sub> = ±10V, V <sub>INH</sub> = 2.4V, V <sub>INL</sub> = 0.8V | T <sub>A</sub> = +25°C                                | C, D    | 20           | 45    | Ω     |
|                                                            |                                          |                                                                                                                          |                                                       | A       | 20           | 30    |       |
|                                                            |                                          | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub>                                                                    | C, D                                                  |         |              | 55    |       |
|                                                            |                                          |                                                                                                                          | A                                                     |         |              | 45    |       |
| Drain-Source On-Resistance Match Between Channels (Note 4) | Δr <sub>DS(ON)</sub>                     | V+ = 15V, V- = -15V, I <sub>S</sub> = -10mA, V <sub>D</sub> = ±10V                                                       | T <sub>A</sub> = +25°C                                | C, D, A | 0.5          | 2     | Ω     |
|                                                            |                                          |                                                                                                                          | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub> |         |              | 3     |       |
| On-Resistance Flatness (Note 4)                            | r <sub>FLAT(ON)</sub>                    | V+ = 15V, V- = -15V, I <sub>S</sub> = -10mA, V <sub>D</sub> = ±5V, 0V                                                    | T <sub>A</sub> = +25°C                                | C, D, A |              | 3     | Ω     |
|                                                            |                                          |                                                                                                                          | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub> |         |              | 6     |       |
| Source-Off Leakage Current (Note 7)                        | I <sub>S(OFF)</sub>                      | V+ = 16.5V, V- = -16.5V, V <sub>D</sub> = ±15.5V, V <sub>S</sub> = ±15.5V                                                | T <sub>A</sub> = +25°C                                | C, D    | -0.50        | -0.01 | nA    |
|                                                            |                                          |                                                                                                                          |                                                       | A       | -0.25        | -0.01 |       |
|                                                            |                                          | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub>                                                                    | C, D                                                  |         | -5           | 5     |       |
|                                                            |                                          |                                                                                                                          | A                                                     |         | -10          | 10    |       |
| Drain-Off Leakage Current (Note 7)                         | I <sub>D(OFF)</sub>                      | V+ = 16.5V, V- = -16.5V, V <sub>D</sub> = ±15.5V, V <sub>S</sub> = ±15.5V                                                | T <sub>A</sub> = +25°C                                | C, D    | -0.50        | -0.01 | nA    |
|                                                            |                                          |                                                                                                                          |                                                       | A       | -0.25        | -0.01 |       |
|                                                            |                                          | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub>                                                                    | C, D                                                  |         | -5           | 5     |       |
|                                                            |                                          |                                                                                                                          | A                                                     |         | -10          | 10    |       |
| Drain-On Leakage Current (Note 7)                          | I <sub>D(ON)</sub> or I <sub>S(ON)</sub> | V+ = 16.5V, V- = -16.5V, V <sub>D</sub> = ±15.5V, V <sub>S</sub> = ±15.5V                                                | T <sub>A</sub> = +25°C                                | C, D    | -1.0         | -0.04 | nA    |
|                                                            |                                          |                                                                                                                          |                                                       | A       | -0.4         | -0.04 |       |
|                                                            |                                          | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub>                                                                    | C, D                                                  |         | -10          | 10    |       |
|                                                            |                                          |                                                                                                                          | A                                                     |         | -20          | 20    |       |

# Improved, Dual, High-Speed Analog Switches

DG401/DG403/DG405

## ELECTRICAL CHARACTERISTICS (continued)

(V+ = 15V, V- = -15V, V<sub>L</sub> = +5V, GND = 0V, V<sub>INH</sub> = +2.4V, V<sub>INL</sub> = +0.8V, T<sub>A</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>, unless otherwise noted.)

| PARAMETER                             | SYMBOL                                      | CONDITIONS                                                                                                |                                                       | MIN  | TYP<br>(Note 2) | MAX | UNITS |
|---------------------------------------|---------------------------------------------|-----------------------------------------------------------------------------------------------------------|-------------------------------------------------------|------|-----------------|-----|-------|
| INPUT                                 |                                             |                                                                                                           |                                                       |      |                 |     |       |
| Input Current with Input Voltage High | I <sub>INH</sub>                            | V <sub>IN</sub> = 2.4V, all others = 0.8V                                                                 |                                                       | -1.0 | 0.005           | 1.0 | μA    |
| Input Current with Input Voltage Low  | I <sub>INL</sub>                            | V <sub>IN</sub> = 0.8V, all others = 2.4V                                                                 |                                                       | -1.0 | 0.005           | 1.0 | μA    |
| SUPPLY                                |                                             |                                                                                                           |                                                       |      |                 |     |       |
| Power-Supply Range                    |                                             |                                                                                                           |                                                       | ±4.5 |                 | ±20 | V     |
| Positive Supply Current               | I <sub>+</sub>                              | All channels on or off,<br>V <sub>+</sub> = 16.5V, V <sub>-</sub> = -16.5V,<br>V <sub>IN</sub> = 0V or 5V | T <sub>A</sub> = +25°C                                | -1.0 | 0.01            | 1.0 | μA    |
|                                       |                                             |                                                                                                           | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub> | -5.0 |                 | 5.0 |       |
| Negative Supply Current               | I <sub>-</sub>                              | All channels on or off,<br>V <sub>+</sub> = 16.5V, V <sub>-</sub> = -16.5V,<br>V <sub>IN</sub> = 0V or 5V | T <sub>A</sub> = +25°C                                | -1.0 | 0.01            | 1.0 | μA    |
|                                       |                                             |                                                                                                           | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub> | -5.0 |                 | 5.0 |       |
| Logic Supply Current                  | I <sub>L</sub>                              | All channels on or off,<br>V <sub>+</sub> = 16.5V, V <sub>-</sub> = -16.5V,<br>V <sub>IN</sub> = 0V or 5V | T <sub>A</sub> = +25°C                                | -1.0 | 0.01            | 1.0 | μA    |
|                                       |                                             |                                                                                                           | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub> | -5.0 |                 | 5.0 |       |
| Ground Current                        | I <sub>GND</sub>                            | All channels on or off,<br>V <sub>+</sub> = 16.5V, V <sub>-</sub> = -16.5V,<br>V <sub>IN</sub> = 0V or 5V | T <sub>A</sub> = +25°C                                | -1.0 | 0.01            | 1.0 | μA    |
|                                       |                                             |                                                                                                           | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub> | -5.0 |                 | 5.0 |       |
| DYNAMIC                               |                                             |                                                                                                           |                                                       |      |                 |     |       |
| Turn-On Time                          | t <sub>ON</sub>                             | Figure 2                                                                                                  | T <sub>A</sub> = +25°C                                | 100  | 150             |     | ns    |
| Turn-Off Time                         | t <sub>OFF</sub>                            | Figure 2                                                                                                  | T <sub>A</sub> = +25°C                                | 60   | 100             |     | ns    |
| Break-Before-Make Delay (Note 3)      | t <sub>D</sub>                              | DG403 only,<br>Figure 3                                                                                   | T <sub>A</sub> = +25°C                                | 10   | 20              |     | ns    |
| Charge Injection (Note 3)             | Q                                           | C <sub>L</sub> = 1.0nF, V <sub>GEN</sub> = 0V,<br>R <sub>GEN</sub> = 0Ω, Figure 4                         | T <sub>A</sub> = +25°C                                | 10   | 15              |     | pC    |
| Off Isolation (Note 5)                | OIRR                                        | R <sub>L</sub> = 100Ω, C <sub>L</sub> = 5pF,<br>f = 1MHz, Figure 5                                        | T <sub>A</sub> = +25°C                                | 72   |                 |     | dB    |
| Crosstalk (Note 6)                    |                                             | R <sub>L</sub> = 50Ω, C <sub>L</sub> = 5pF,<br>f = 1MHz, Figure 6                                         | T <sub>A</sub> = +25°C                                | 90   |                 |     | dB    |
| Source-Off Capacitance                | C <sub>S(OFF)</sub>                         | f = 1MHz, Figure 7                                                                                        | T <sub>A</sub> = +25°C                                | 12   |                 |     | pF    |
| Drain-Off Capacitance                 | C <sub>D(OFF)</sub>                         | f = 1MHz, Figure 7                                                                                        | T <sub>A</sub> = +25°C                                | 12   |                 |     | pF    |
| Channel-On Capacitance                | C <sub>D(ON)</sub><br>or C <sub>S(ON)</sub> | f = 1MHz, Figure 8                                                                                        | T <sub>A</sub> = +25°C                                | 39   |                 |     | pF    |

**Note 2:** This data sheet uses the algebraic convention, where the most negative value is a minimum and the most positive value is a maximum.

**Note 3:** Guaranteed by design.

**Note 4:**  $\Delta r_{ON} = \Delta r_{ON(max)} - \Delta r_{ON(min)}$ . On-resistance match between channels and flatness are guaranteed only with specified voltages. Flatness is defined as the difference between the maximum and minimum value of on-resistance as measured at the extremes of the specified analog signal range.

**Note 5:** Off isolation =  $20 \log (V_S/V_D)$ , V<sub>D</sub> = output, V<sub>S</sub> = input to off switch.

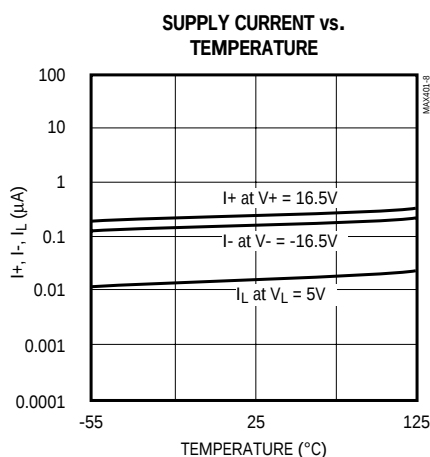
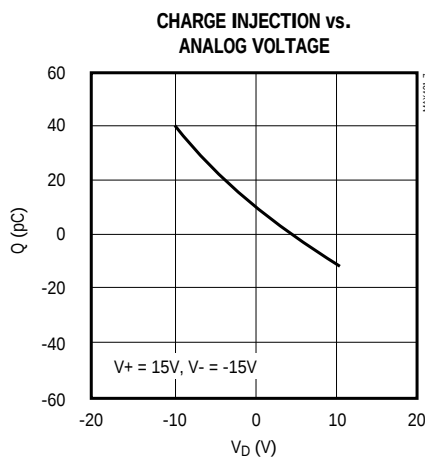
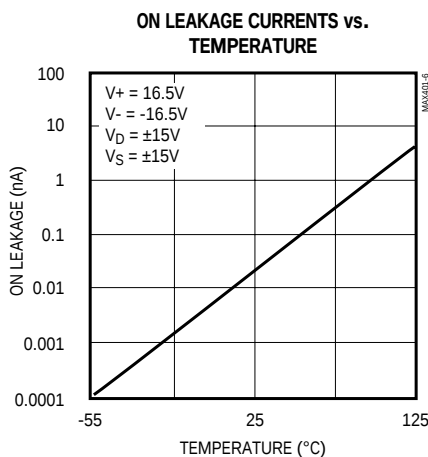
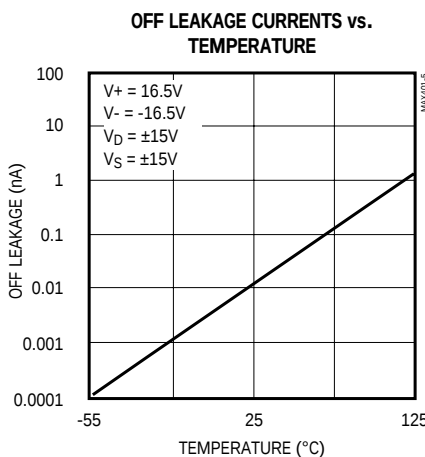
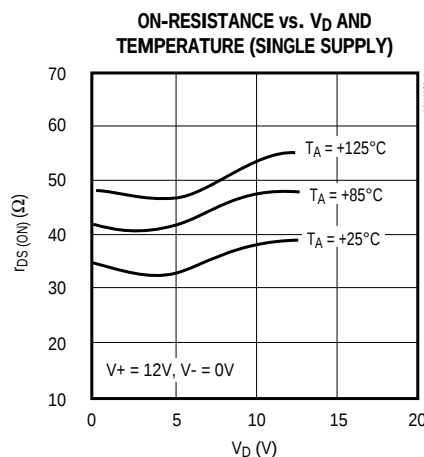
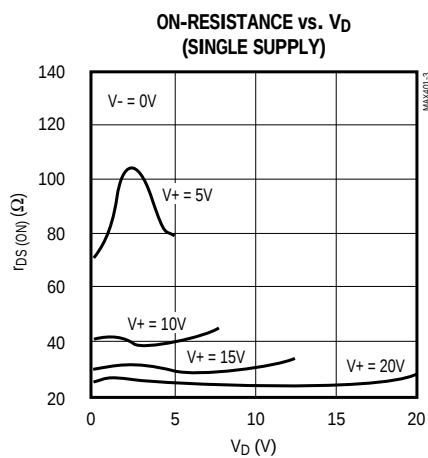
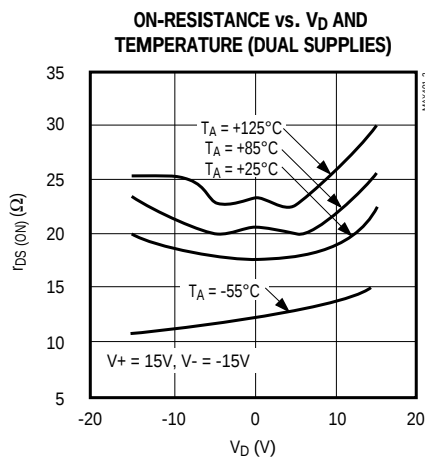
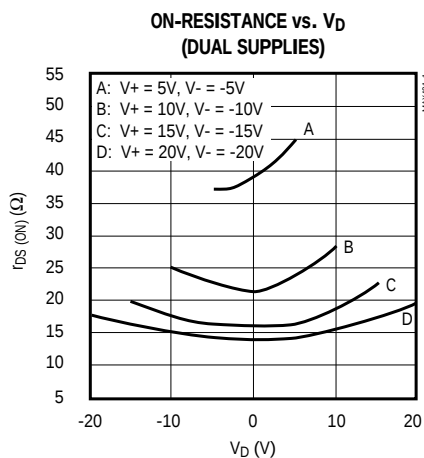
**Note 6:** Between any two switches.

**Note 7:** Leakage parameters I<sub>S(OFF)</sub>, I<sub>D(OFF)</sub>, and I<sub>D(ON)</sub> are 100% tested at the maximum rated hot temperature and guaranteed by correlation at +25°C.

# Improved, Dual, High-Speed Analog Switches

## Typical Operating Characteristics

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



# Improved, Dual, High-Speed Analog Switches

## Pin Description

| DG401       |                       | NAME           | FUNCTION                                             |
|-------------|-----------------------|----------------|------------------------------------------------------|
| DIP/SO      | LCC                   |                |                                                      |
| 1, 8        | 2, 10                 | D1, D2         | Drain (Analog Signal)                                |
| 2-7         | 1, 3-9,<br>11, 16     | N.C.           | Not internally connected                             |
| 9, 16       | 12, 20                | S2, S1         | Source (Analog Signal)                               |
| 10, 15      | 13, 19                | IN2, IN1       | Digital Logic Inputs                                 |
| 11          | 14                    | V+             | Positive Supply-Voltage Input—connected to substrate |
| 12          | 15                    | V <sub>L</sub> | Logic Supply-Voltage Input                           |
| 13          | 17                    | GND            | Ground                                               |
| 14          | 18                    | V-             | Negative Supply-Voltage Input                        |
| DG403       |                       | NAME           | FUNCTION                                             |
| DIP/SO      | LCC                   |                |                                                      |
| 1, 8, 3, 6  | 2, 10, 4, 8           | D1-D4          | Drain (Analog Signal)                                |
| 2, 7        | 1, 3, 6, 9,<br>11, 16 | N.C.           | Not internally connected                             |
| 16, 9, 4, 5 | 20, 12,<br>5, 7,      | S1-S4          | Source (Analog Signal)                               |
| 10, 15      | 13, 19                | IN2, IN1       | Digital Logic Inputs                                 |
| 11          | 14                    | V+             | Positive Supply-Voltage Input—connected to substrate |
| 12          | 15                    | V <sub>L</sub> | Logic Supply-Voltage Input                           |
| 13          | 17                    | GND            | Ground                                               |
| 14          | 18                    | V-             | Negative Supply-Voltage Input                        |
| DG405       |                       | NAME           | FUNCTION                                             |
| DIP/SO      | LCC                   |                |                                                      |
| 1, 8, 3, 6  | 2, 10, 4, 8           | D1-D4          | Drain (Analog Signal)                                |
| 2, 7        | 1, 3, 6, 9,<br>11, 16 | N.C.           | Not internally connected                             |
| 16, 9, 4, 5 | 20, 12,<br>5, 7,      | S1-S4          | Source (Analog Signal)                               |
| 10, 15      | 13, 19                | IN2, IN1       | Digital Logic Inputs                                 |
| 11          | 14                    | V+             | Positive Supply-Voltage Input—connected to substrate |
| 12          | 15                    | V <sub>L</sub> | Logic Supply-Voltage Input                           |
| 13          | 17                    | GND            | Ground                                               |
| 14          | 18                    | V-             | Negative Supply Voltage                              |

## Applications Information

### Operation with Supply Voltages

#### Other than $\pm 15V$

The DG401/DG403/DG405 switches operate with  $\pm 4.5V$  to  $\pm 20V$  bipolar supplies or with a  $+10V$  to  $+30V$  single supply. In either case, analog signals ranging from  $V+$  to  $V-$  can be switched. The *Typical Operating Characteristics* graphs illustrate typical analog-signal and supply-voltage on-resistance variations. The usual on-resistance temperature coefficient is  $0.5\%/^{\circ}C$  (typ).

### Logic Inputs

These devices operate with a single positive supply or with bipolar supplies. They maintain TTL compatibility with supplies anywhere in the  $\pm 4.5V$  to  $\pm 20V$  range as long as  $V_L = +5V$ . If  $V_L$  is connected to  $V+$  or another supply at voltages other than  $+5V$ , the devices will operate at CMOS-logic-level inputs.

### Overvoltage Protection

Proper power-supply sequencing is recommended for all CMOS devices. Do not exceed the absolute maximum ratings because stresses beyond the listed ratings may cause permanent damage to the devices. Always sequence  $V+$  on first, followed by  $V_L$ ,  $V-$ , and logic inputs. If power-supply sequencing is not possible, add two small, external signal diodes in series with supply pins for overvoltage protection (Figure 1). Adding diodes reduces the analog-signal range to  $1V$  below  $V+$  and  $1V$  below  $V-$ , without affecting low switch resistance and low leakage characteristics. Device operation is unchanged, and the difference between  $V+$  and  $V-$  should not exceed  $+44V$ .

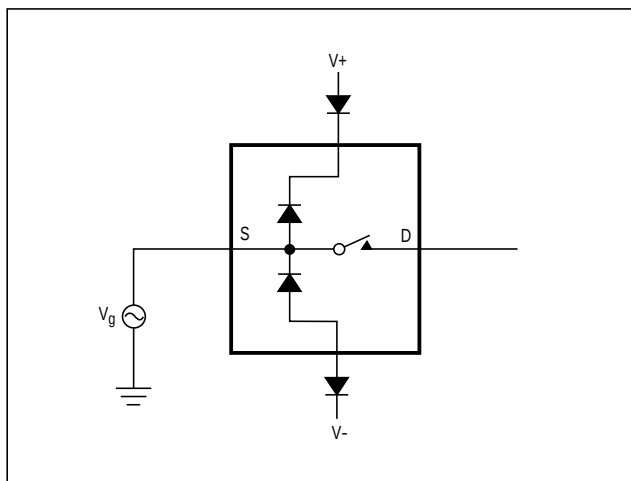


Figure 1. Overvoltage Protection Using External Blocking Diodes

# Improved, Dual, High-Speed Analog Switches

## Timing Diagrams/Test Circuits

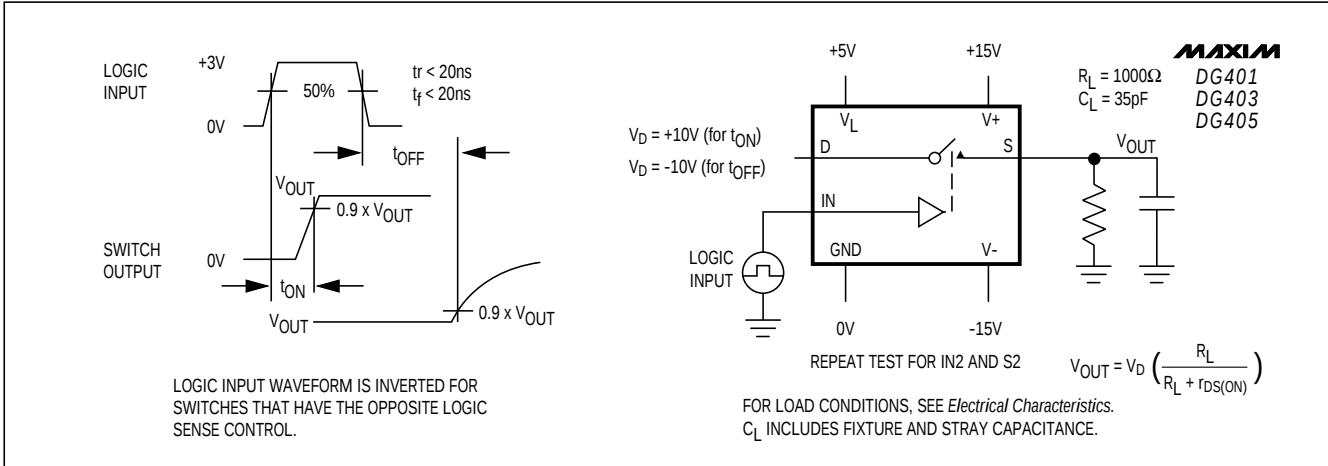


Figure 2. Switching Time

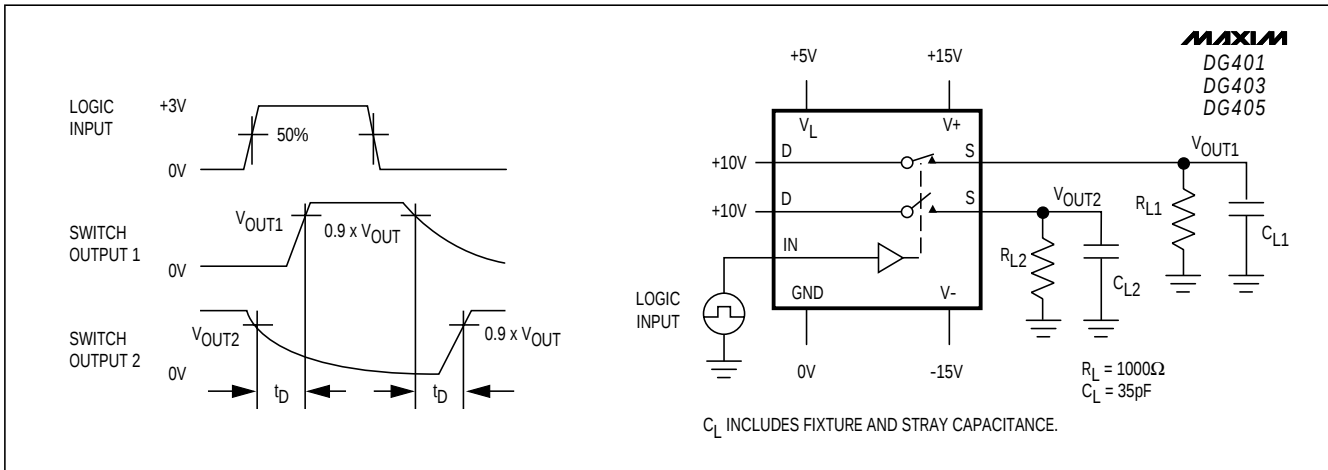


Figure 3. Break-Before-Make Interval

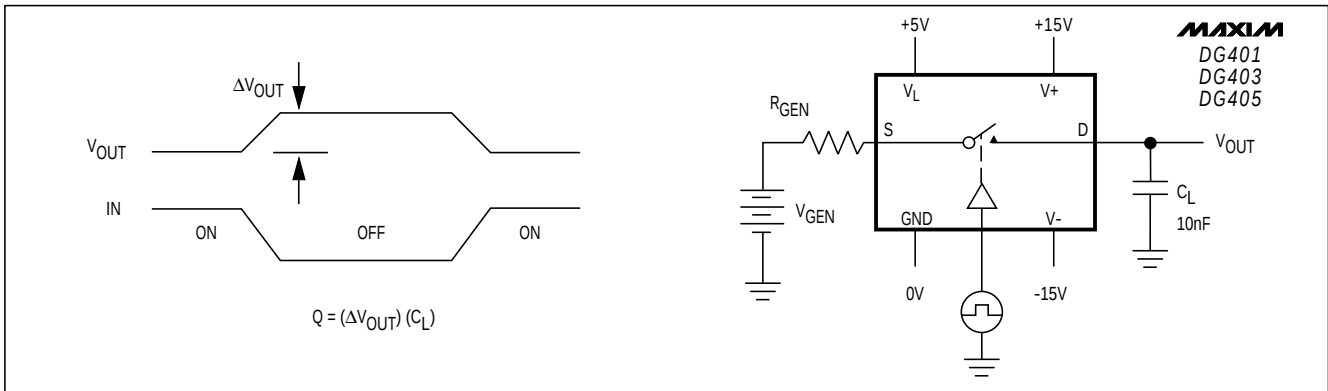


Figure 4. Charge Injection

# Improved, Dual, High-Speed Analog Switches

## Timing Diagrams/Test Circuits (continued)

DG401/DG403/DG405

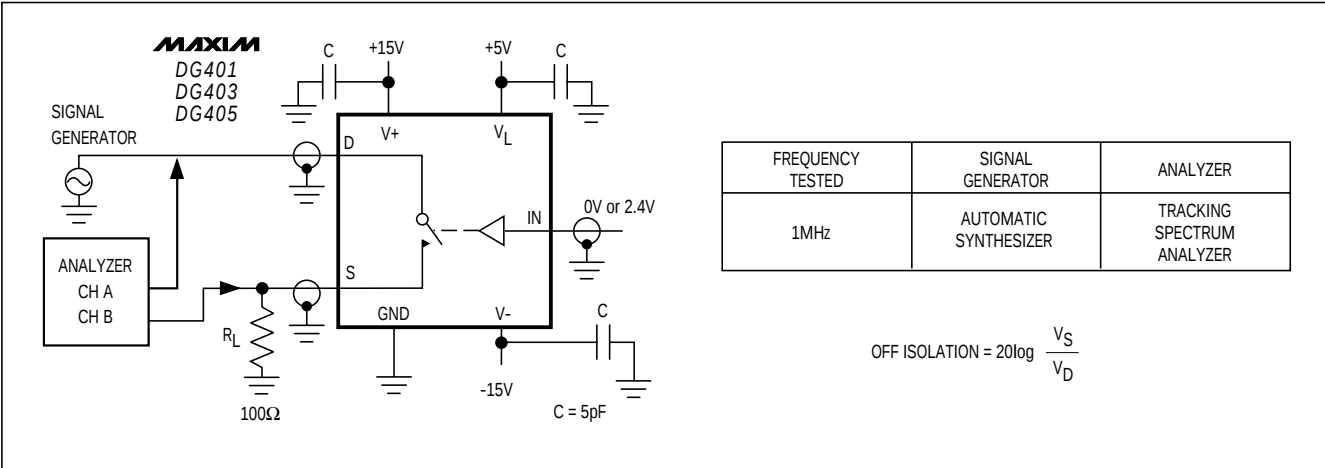


Figure 5. Off Isolation

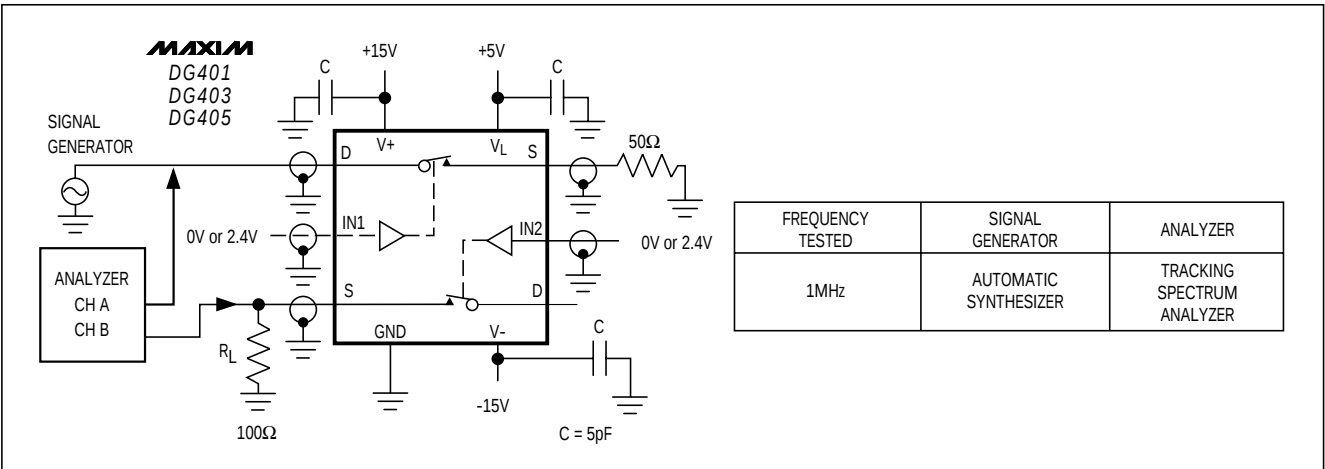


Figure 6. Crosstalk

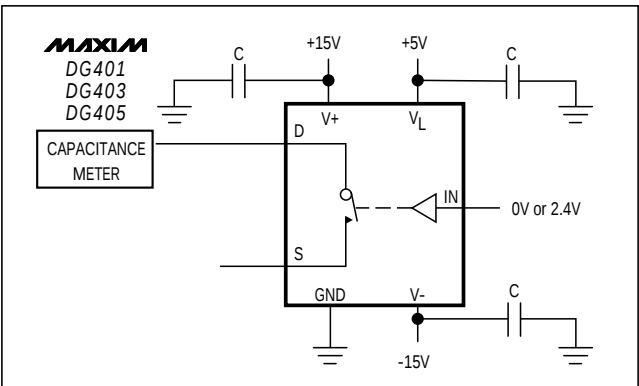


Figure 7. Channel-Off Capacitance

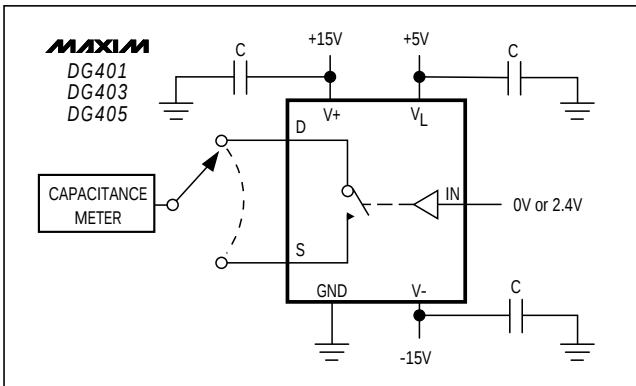


Figure 8. Channel-On Capacitance

# Improved, Dual, High-Speed Analog Switches

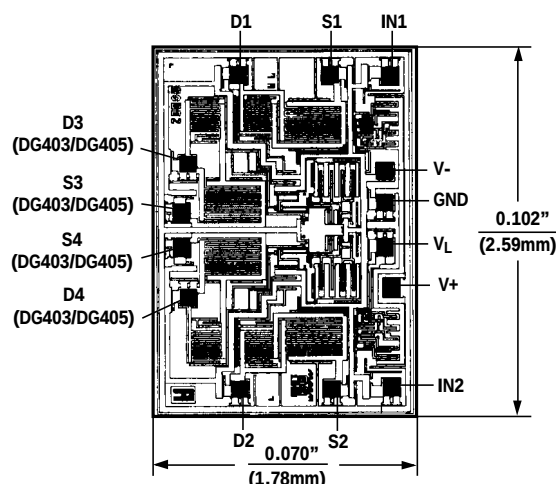
## Ordering Information (continued)

| PART           | TEMP. RANGE     | PIN PACKAGE    |
|----------------|-----------------|----------------|
| DG401DJ        | -40°C to +85°C  | 16 Plastic DIP |
| DG401DY        | -40°C to +85°C  | 16 Narrow SO   |
| DG401DK        | -40°C to +85°C  | 16 Cerdip      |
| DG401AK        | -55°C to +125°C | 16 Cerdip**    |
| DG401AZ        | -55°C to +125°C | 20 LCC**       |
| <b>DG403CJ</b> | 0°C to +70°C    | 16 Plastic DIP |
| DG403CY        | 0°C to +70°C    | 16 Narrow SO   |
| DG403C/D       | 0°C to +70°C    | Dice*          |
| DG403DJ        | -40°C to +85°C  | 16 Plastic DIP |
| DG403DY        | -40°C to +85°C  | 16 Narrow SO   |
| DG403DK        | -40°C to +85°C  | 16 Cerdip      |
| DG403AK        | -55°C to +125°C | 16 Cerdip**    |
| DG403AZ        | -55°C to +125°C | 20 LCC**       |
| <b>DG405CJ</b> | 0°C to +70°C    | 16 Plastic DIP |
| DG405CY        | 0°C to +70°C    | 16 Narrow SO   |
| DG405C/D       | 0°C to +70°C    | Dice*          |
| DG405DJ        | -40°C to +85°C  | 16 Plastic DIP |
| DG405DY        | -40°C to +85°C  | 16 Narrow SO   |
| DG405DK        | -40°C to +85°C  | 16 Cerdip      |
| DG405AK        | -55°C to +125°C | 16 Cerdip**    |
| DG405AZ        | -55°C to +125°C | 20 LCC**       |

\* Contact factory for dice specifications.

\*\*Contact factory for availability and processing to MIL-STD-883B.

## Chip Topography



TRANSISTOR COUNT: 66  
SUBSTRATE CONNECTED TO V+

Maxim cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in a Maxim product. No circuit patent licenses are implied. Maxim reserves the right to change the circuitry and specifications without notice at any time.

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## Pin Configurations (continued)

