

# DG411, DG412, DG413

## Monolithic Quad SPST, CMOS Analog Switches

August 1997

### Features

- ON-Resistance ..... <35Ω Max
- Low Power Consumption (P<sub>D</sub>) ..... <35μW
- Fast Switching Action
  - t<sub>ON</sub> ..... <175ns
  - t<sub>OFF</sub> ..... <145ns
- Low Charge Injection
- Upgrade from DG211/DG212
- TTL, CMOS Compatible
- Single or Split Supply Operation

### Applications

- Audio Switching
- Battery Operated Systems
- Data Acquisition
- Hi-Rel Systems
- Sample and Hold Circuits
- Communication Systems
- Automatic Test Equipment

### Description

The DG411 series monolithic CMOS analog switches are drop-in replacements for the popular DG211 and DG212 series devices. They include four independent single pole throw (SPST) analog switches, and TTL and CMOS compatible digital inputs.

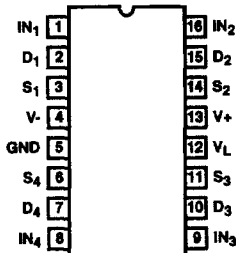
These switches feature lower analog ON resistance (<35Ω) and faster switch time (t<sub>ON</sub> < 175ns) compared to the DG211 or DG212. Charge injection has been reduced, simplifying sample and hold applications.

The improvements in the DG411 series are made possible by using a high voltage silicon-gate process. An epitaxial layer prevents the latch-up associated with older CMOS technologies. The 44V maximum voltage range permits controlling 40V<sub>p-p</sub> signals. Power supplies may be single-ended from +5V to +34V, or split from ±5V to ±20V.

The four switches are bilateral, equally matched for AC or bidirectional signals. The ON resistance variation with analog signals is quite low over a 15V analog input range. The switches in the DG411 and DG412 are identical, differing only in the polarity of the selection logic. Two of the switches in the DG413 (#1 and #4) use the logic of the DG211 and DG411 (i.e., a logic "0" turns the switch ON) and the other two switches use DG212 and DG412 positive logic. This permits independent control of turn-on and turn-off times for SPDT configurations, permitting "break-before-make" or "make-before-break" operation with a minimum of external logic.

### Pinout

DG411, DG412, DG413  
(CERDIP, PDIP, SOIC)  
TOP VIEW



### Ordering Information

| PART NUMBER    | TEMP. RANGE (°C) | PACKAGE      | PKG. NO. |
|----------------|------------------|--------------|----------|
| DG411AK/883    | -55 to 125       | 16 Ld CERDIP | F16.3    |
| DG411DJ        | -40 to 85        | 16 Ld PDIP   | E16.3    |
| DG411DY        | -40 to 85        | 16 Ld SOIC   | M16.15   |
| DG411EJ (Note) | -40 to 85        | 16 Ld PDIP   | E16.3    |
| DG411EY (Note) | -40 to 85        | 16 Ld SOIC   | M16.15   |
| DG412AK/883    | -55 to 125       | 16 Ld CERDIP | F16.3    |
| DG412DJ        | -40 to 85        | 16 Ld PDIP   | E16.3    |
| DG412DY        | -40 to 85        | 16 Ld SOIC   | M16.15   |
| DG412EJ (Note) | -40 to 85        | 16 Ld PDIP   | E16.3    |
| DG412EY (Note) | -40 to 85        | 16 Ld SOIC   | M16.15   |
| DG413AK/883    | -55 to 125       | 16 Ld CERDIP | F16.3    |
| DG413DJ        | -40 to 85        | 16 Ld PDIP   | E16.3    |
| DG413DY        | -40 to 85        | 16 Ld SOIC   | M16.15   |
| DG413EJ (Note) | -40 to 85        | 16 Ld PDIP   | E16.3    |
| DG413EY (Note) | -40 to 85        | 16 Ld SOIC   | M16.15   |

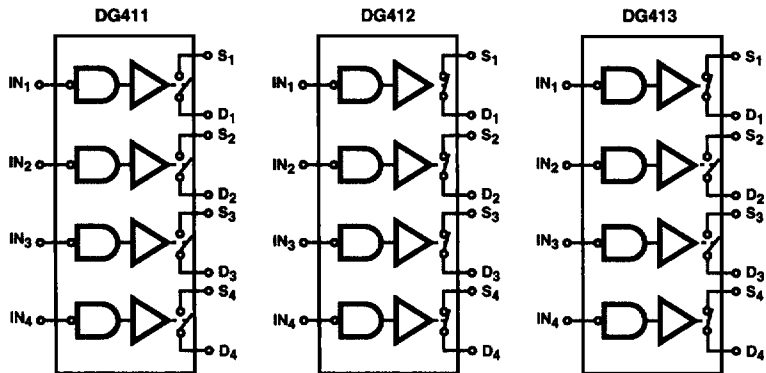
NOTE: Extended Processing Flow

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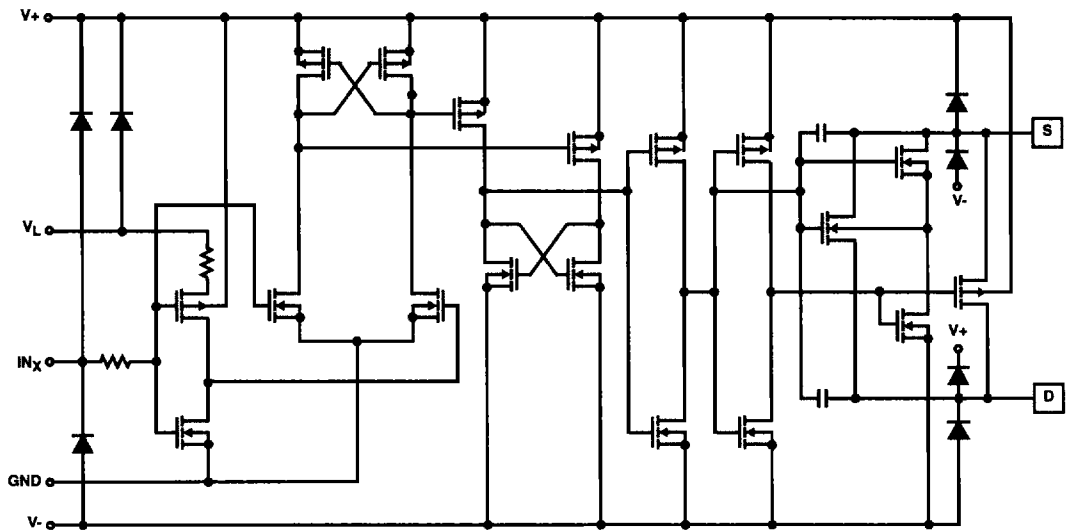
SWITCHES

## DG411, DG412, DG413

### Functional Diagrams Four SPST Switches per Package Switches Shown for Logic "1" Input



### Typical Schematic Diagram (Typical Channel)



# DG411, DG412, DG413

## Absolute Maximum Ratings

|  |  |
|--|--|
| V+ to V- .....   | 44V  |
| GND to V- .....  | 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 30mA,<br>Whichever Occurs First |
| Continuous Current (Any Terminal) .....                        | 30mA   |
| Current, S or D (Pulsed 1ms, 10% Duty Cycle) .....             | 100mA  |

## Thermal Information

|   |                                  |                      |
|---|----------------------------------|----------------------|
| Thermal Resistance (Typical, Note 2)                  | $\theta_{JA}$ (°C/W)             | $\theta_{JC}$ (°C/W) |
| PDIP Package .....                                    | 100                              | N/A                  |
| SOIC Package .....                                    | 115                              | N/A                  |
| CERDIP Package .....                                  | 75                               | 20                   |
| Maximum Junction Temperature (Plastic Packages) ..... | 150°C                            |                      |
| Maximum Junction Temperature (Ceramic Package) .....  | 175°C                            |                      |
| Maximum Storage Temperature Range .....               | -65°C to 125°C                   |                      |
| Maximum Lead Temperature (Soldering 10s) .....        | 300°C<br>(SOIC - Lead Tips Only) |                      |

## Operating Conditions

|   |               |
|---|---------------|
| Operating Voltage Range .....             | ±20V (Max)    |
| Operating Temperature Range .....         | -40°C to 85°C |
| Input Low Voltage .....                   | 0.8V (Max)    |
| Input High Voltage .....                  | 2.4V (Min)    |
| Input Rise and Fall Time .....            | ≤20ns         |
| Operating Temperature<br>(D Suffix) ..... | -40°C to 85°C |

**CAUTION:** Stresses above those listed in "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.

## NOTES:

1. 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.
2.  $\theta_{JA}$  is measured with the component mounted on an evaluation PC board in free air.

## Electrical Specifications

Test Conditions: V+ = +15V, V- = -15V, V<sub>L</sub> = 5V, V<sub>IN</sub> = 2.4V, 0.8V (Note 3),  
Unless Otherwise Specified

| PARAMETER  | TEST CONDITIONS  | (NOTE 4)<br>TEMP<br>(°C) | D SUFFIX -40°C TO 85°C |                 |                 | UNITS |
|--|--|--------------------------|------------------------|-----------------|-----------------|-------|
|  |  |                          | (NOTE 5)<br>MIN        | (NOTE 6)<br>TYP | (NOTE 5)<br>MAX |       |
| <b>DYNAMIC CHARACTERISTICS</b>   |  |                          |                        |                 |                 |       |
| Turn-ON Time, t <sub>ON</sub>  | R <sub>L</sub> = 300Ω, C <sub>L</sub> = 35pF,<br>V <sub>S</sub> = ±10V, (See Figure 7) | 25                       | -                      | 110             | 175             | ns    |
|  |  | Hot                      | -                      | -               | 220             | ns    |
| Turn-OFF Time, t <sub>OFF</sub>  |  | 25                       | -                      | 100             | 145             | ns    |
|  |  | Hot                      | -                      | -               | 160             | ns    |
| Break-Before-Make Time Delay   | DG413 Only, R <sub>L</sub> = 300Ω,<br>C <sub>L</sub> = 35pF                            | 25                       | -                      | 25              | -               | ns    |
| Charge Injection, Q  | C <sub>L</sub> = 10nF, V <sub>G</sub> = 0V, R <sub>G</sub> = 0Ω                        | 25                       | -                      | 5               | -               | pC    |
| OFF Isolation  | R <sub>L</sub> = 50Ω, C <sub>L</sub> = 5pF, f = 1MHz                                   | 25                       | -                      | 68              | -               | dB    |
| Crosstalk<br>(Channel-to-Channel)                                      |  | 25                       | -                      | 85              | -               | dB    |
| Source OFF Capacitance, C <sub>S(OFF)</sub>                            | f = 1MHz   | 25                       | -                      | 9               | -               | pF    |
| Drain OFF Capacitance, C <sub>D(OFF)</sub>                             |  | 25                       | -                      | 9               | -               | pF    |
| Channel ON Capacitance,<br>C <sub>D(ON)</sub> + C <sub>S(ON)</sub>     |  | 25                       | -                      | 35              | -               | pF    |
| <b>DIGITAL CONTROL</b>   |  |                          |                        |                 |                 |       |
| Input Current V <sub>IN</sub> Low, I <sub>IL</sub>                     | V <sub>IN</sub> Under Test = 0.8V  | Full                     | -0.5                   | 0.005           | 0.5             | μA    |
| Input Current V <sub>IN</sub> High, I <sub>IH</sub>                    | V <sub>IN</sub> Under Test = 2.4V  | Full                     | -0.5                   | 0.005           | 0.5             | μA    |
| <b>ANALOG SWITCH</b>   |  |                          |                        |                 |                 |       |
| Analogue Signal Range, V <sub>ANALOG</sub>                             | I <sub>S</sub> = ±10mA   | Full                     | -15                    | -               | 15              | V     |
| Drain-Source ON Resistance,<br>r <sub>DS(ON)</sub>                     | I <sub>S</sub> = -10mA, V <sub>D</sub> = ±8.5V,<br>V+ = 13.5V, V- = -13.5V             | 25                       | -                      | 25              | 35              | Ω     |
|  |  | Full                     | -                      | -               | 45              | Ω     |
| Switch OFF Leakage Current,<br>I <sub>S(OFF)</sub>                     | V+ = 16.5V, V <sub>D</sub> = ±15.5V<br>V- = -16.5V, V <sub>S</sub> = ±15.5V            | 25                       | -0.25                  | ±0.1            | 0.25            | nA    |
|  |  | Full                     | -5                     | -               | +5              | nA    |
| Switch OFF Leakage Current,<br>I <sub>D(OFF)</sub>                     | V <sub>D</sub> = ±15.5V<br>V <sub>S</sub> = ±15.5V                                     | 25                       | -0.25                  | ±0.1            | 0.25            | nA    |
|  |  | Full                     | -5                     | -               | +5              | nA    |
| Channel ON Leakage Current,<br>I <sub>D(ON)</sub> + I <sub>S(ON)</sub> | V <sub>S</sub> = V <sub>D</sub> = ±15.5V   | 25                       | -0.4                   | ±0.1            | 0.4             | nA    |
|  |  | Full                     | -10                    | -               | +10             | nA    |

## DG411, DG412, DG413

**Electrical Specifications** Test Conditions:  $V_+ = +15V$ ,  $V_- = -15V$ ,  $V_L = 5V$ ,  $V_{IN} = 2.4V, 0.8V$  (Note 3),  
Unless Otherwise Specified (Continued)

| PARAMETER                           | TEST CONDITIONS   | (NOTE 4)<br>TEMP<br>(°C) | D SUFFIX -40°C TO 85°C |                 |                 | UNITS   |
|-------------------------------------|---|--------------------------|------------------------|-----------------|-----------------|---------|
|                                     |   |                          | (NOTE 5)<br>MIN        | (NOTE 6)<br>TYP | (NOTE 5)<br>MAX |         |
| <b>POWER SUPPLY CHARACTERISTICS</b> |   |                          |                        |                 |                 |         |
| Positive Supply Current, $I_+$      | $V_+ = 16.5V$ , $V_- = -16.5V$<br>$V_{IN} = 0V$ or $5V$ | 25                       | -                      | 0.0001          | 1               | $\mu A$ |
|                                     |   | Hot                      | -                      | -               | 5               | $\mu A$ |
| Negative Supply Current, $I_-$      |   | 25                       | -1                     | -0.0001         | -               | $\mu A$ |
|                                     |   | Hot                      | -5                     | -               | -               | $\mu A$ |
| Logic Supply Current, $I_L$         |   | 25                       | -                      | 0.0001          | 1               | $\mu A$ |
|                                     |   | Hot                      | -                      | -               | 5               | $\mu A$ |
| Ground Current, $I_{GND}$           | 25  | -1                       | -0.0001                | -               | $\mu A$         |         |
|                                     | Hot   | -5                       | -                      | -               | $\mu A$         |         |

**Electrical Specifications** (Unipolar Supplies) Test Conditions:  $V_+ = +12V$ ,  $V_- = 0V$ ,  $V_L = 5V$ ,  $V_{IN} = 2.4V, 0.8V$  (Note 3),  
Unless Otherwise Specified

| PARAMETER                                | TEST CONDITIONS   | (NOTE 4)<br>TEMP<br>(°C) | D SUFFIX -40°C TO 85°C |                 |                 | UNITS    |
|--|---|--------------------------|------------------------|-----------------|-----------------|----------|
|  |   |                          | (NOTE 5)<br>MIN        | (NOTE 6)<br>TYP | (NOTE 5)<br>MAX |          |
| <b>DYNAMIC CHARACTERISTICS</b>           |   |                          |                        |                 |                 |          |
| Turn-ON Time, $t_{ON}$                   | $R_L = 300\Omega$ , $C_L = 35pF$ ,<br>$V_S = \pm 8V$ , (See Figure 7) | 25                       | -                      | 175             | 250             | ns       |
|  |   | Hot                      | -                      | -               | 315             | ns       |
| Turn-OFF Time, $t_{OFF}$                 |   | 25                       | -                      | 95              | 125             | ns       |
|  |   | Hot                      | -                      | -               | 140             | ns       |
| Break-Before-Make Time Delay             | DG413 Only, $R_L = 300\Omega$ ,<br>$C_L = 35pF$ , $V_S = 8V$          | 25                       | -                      | 25              | -               | ns       |
| Charge Injection, $Q$                    | $C_L = 10nF$ , $V_G = 6.0V$ ,<br>$R_G = 0\Omega$                      | 25                       | -                      | 25              | -               | pC       |
| <b>ANALOG SWITCH</b>                     |   |                          |                        |                 |                 |          |
| Analog Signal Range, $V_{ANALOG}$        |   | Full                     | 0                      | -               | 12              | V        |
| Drain-Source ON Resistance, $r_{DS(ON)}$ | $I_S = -10mA$ , $V_D = 3V, 8V$<br>$V_+ = 10.8V$                       | 25                       | -                      | 40              | 80              | $\Omega$ |
|  |   | Full                     | -                      | -               | 100             | $\Omega$ |
| <b>POWER SUPPLY CHARACTERISTICS</b>      |   |                          |                        |                 |                 |          |
| Positive Supply Current, $I_+$           | $V_+ = 13.2V$ , $V_- = 0V$<br>$V_{IN} = 0V$ or $5V$                   | 25                       | -                      | 0.0001          | 1               | $\mu A$  |
|  |   | Hot                      | -                      | -               | 5               | $\mu A$  |
| Negative Supply Current, $I_-$           |   | 25                       | -1                     | -0.0001         | -               | $\mu A$  |
|  |   | Hot                      | -5                     | -               | -               | $\mu A$  |
| Logic Supply Current, $I_L$              |   | 25                       | -                      | 0.0001          | 1               | $\mu A$  |
|  |   | Hot                      | -                      | -               | 5               | $\mu A$  |
| Ground Current, $I_{GND}$                | 25  | -1                       | -0.0001                | -               | $\mu A$         |          |
|  | Hot   | -5                       | -                      | -               | $\mu A$         |          |

**NOTES:**

3.  $V_{IN}$  = input voltage to perform proper function.
4. Hot = as determined by the operating temperature suffix.
5. The algebraic convention whereby the most negative value is a minimum and the most positive a maximum, is used in this data sheet.
6. Typical values are for DESIGN AID ONLY, not guaranteed nor subject to production testing.

Typical Performance Curves

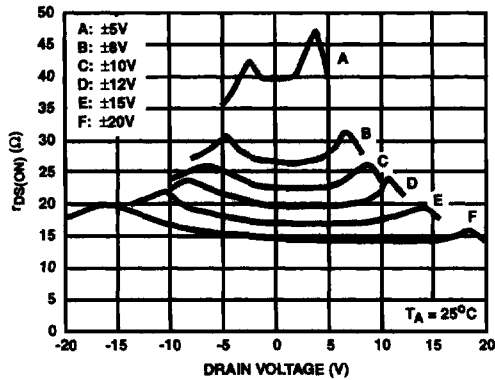


FIGURE 1. ON-RESISTANCE vs  $V_D$  AND POWER SUPPLY VOLTAGE

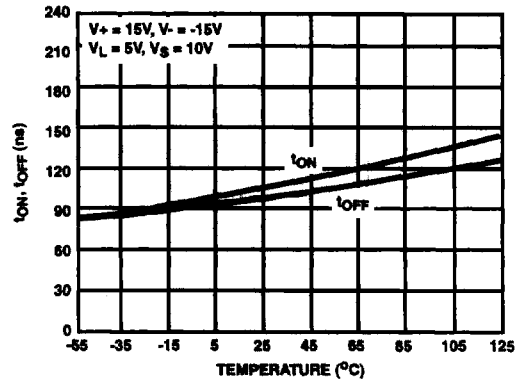


FIGURE 2. SWITCHING TIME vs TEMPERATURE

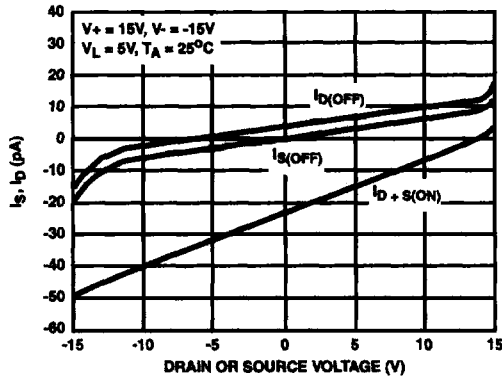


FIGURE 3. LEAKAGE CURRENT vs ANALOG VOLTAGE

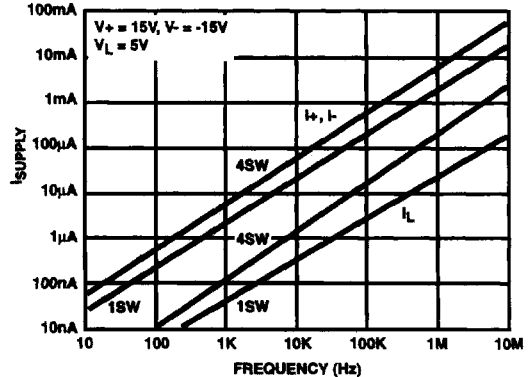


FIGURE 4. SUPPLY CURRENT vs INPUT SWITCHING FREQUENCY

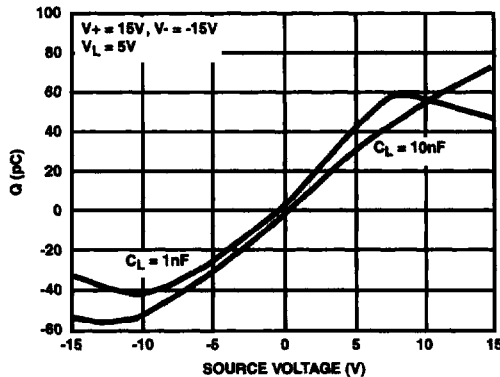


FIGURE 5. CHARGE INJECTION vs ANALOG VOLTAGE ( $V_D$ )

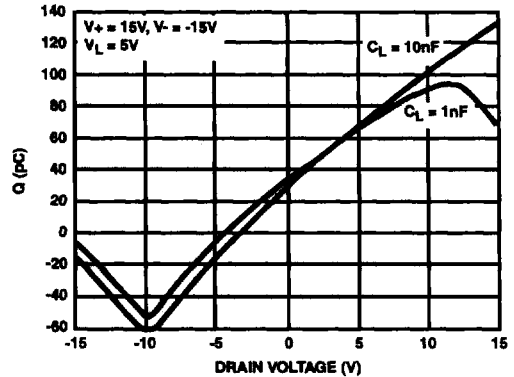


FIGURE 6. CHARGE INJECTION vs ANALOG VOLTAGE ( $V_S$ )

Pin Descriptions

| PIN | SYMBOL          | DESCRIPTION                                 |
|-----|-----------------|---|
| 1   | IN <sub>1</sub> | Logic Control for Switch 1.                 |
| 2   | D <sub>1</sub>  | Drain (Output) Terminal for Switch 1.       |
| 3   | S <sub>1</sub>  | Source (Input) Terminal for Switch 1.       |
| 4   | V-              | Negative Power Supply Terminal.             |
| 5   | GND             | Ground Terminal (Logic Common).             |
| 6   | S <sub>4</sub>  | Source (Input) Terminal for Switch 4.       |
| 7   | D <sub>4</sub>  | Drain (Output) Terminal for Switch 4.       |
| 8   | IN <sub>4</sub> | Logic Control for Switch 4.                 |
| 9   | IN <sub>3</sub> | Logic Control for Switch 3.                 |
| 10  | D <sub>3</sub>  | Drain (Output) Terminal for Switch 3.       |
| 11  | S <sub>3</sub>  | Source (Input) Terminal for Switch 3.       |
| 12  | V <sub>L</sub>  | Logic Reference Voltage.                    |
| 13  | V+              | Positive Power Supply Terminal (Substrate). |
| 14  | S <sub>2</sub>  | Source (Input) Terminal for Switch 2.       |
| 15  | D <sub>2</sub>  | Drain (Output) Terminal for Switch 2.       |
| 16  | IN <sub>2</sub> | Logic Control for Switch 2.                 |

TRUTH TABLE

| LOGIC | DG411  | DG412  | DG413       |             |
|-------|--------|--------|-------------|-------------|
|       | SWITCH | SWITCH | SWITCH 1, 4 | SWITCH 2, 3 |
| 0     | ON     | OFF    | OFF         | ON          |
| 1     | OFF    | ON     | ON          | OFF         |

NOTE: Logic "0" ≤ 0.8V. Logic "1" ≥ 2.4V.

Test Circuits and Waveforms

V<sub>O</sub> is the steady state output with the switch on. Feedthrough via switch capacitance may result in spikes at the leading and trailing edge of the output waveform.

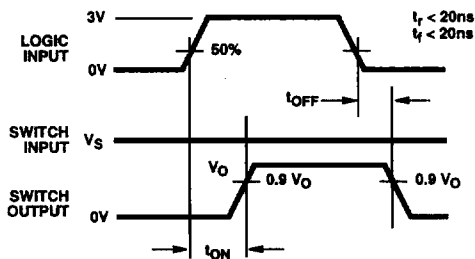
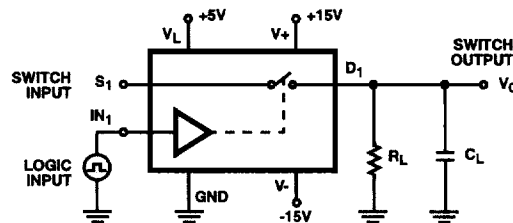


FIGURE 7A.



Repeat test for all IN and S.

For load conditions, see Specifications C<sub>L</sub> (includes fixture and stray capacitance).

$$V_O = V_S \frac{R_L}{R_L + r_{DS(ON)}}$$

FIGURE 7B.

FIGURE 7. SWITCHING TIME

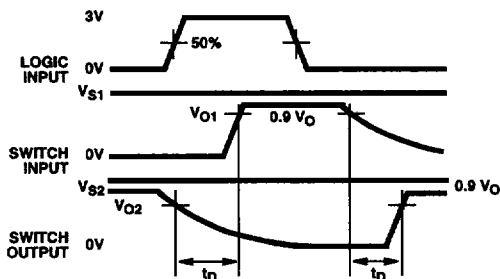
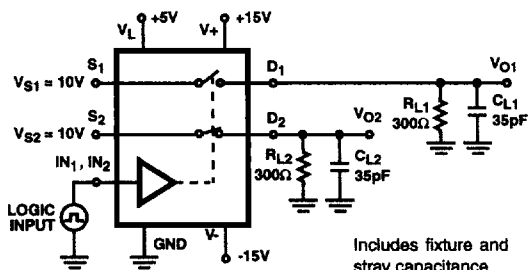


FIGURE 8A.



Includes fixture and stray capacitance.

FIGURE 8B.

FIGURE 8. BREAK-BEFORE-MAKE

Test Circuits and Waveforms (Continued)

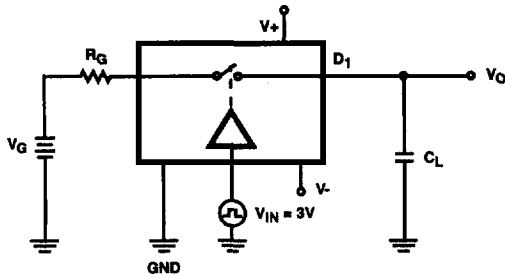


FIGURE 9A.

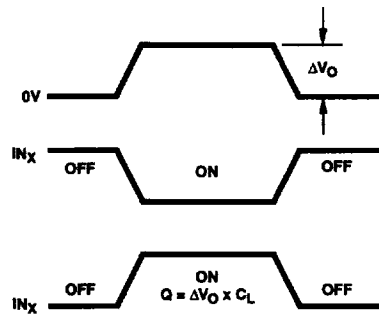


FIGURE 9B.

NOTE:  $IN_X$  dependent on switch configuration input polarity determined by sense of switch.

FIGURE 9. CHARGE INJECTION

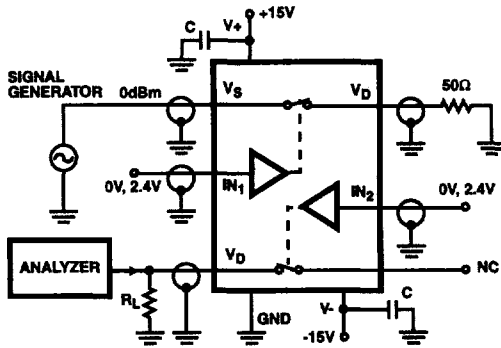


FIGURE 10. CROSSTALK

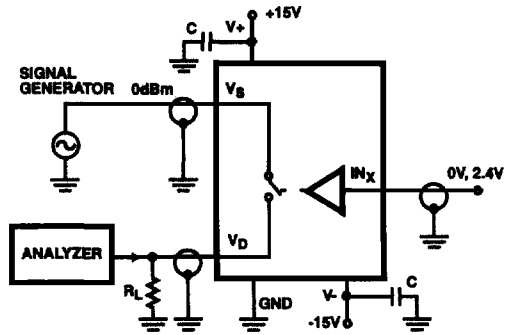


FIGURE 11. OFF ISOLATION

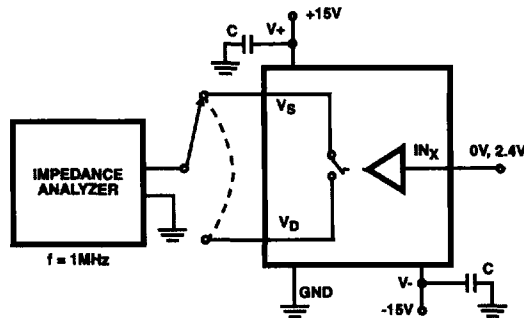


FIGURE 12. SOURCE/DRAIN CAPACITANCES

**Typical Applications**

**Single Supply Operation**

The DG411, DG412, DG413 can be operated with unipolar supplies from 5V to 44V. These devices are characterized and tested for unipolar supply operation at 12V to facilitate the majority of applications. To function properly, 12V are tied to Pin 13 and 0V are tied to Pin 4.

NOTE: Pin 12 still requires 5V for TTL compatible switching.

**Summing Amplifier**

When driving a high impedance, high capacitance load such as shown in Figure 9, where the inputs to the summing amplifier have some noise filtering, it is necessary to have shunt switches for rapid discharge of the filter capacitor, thus preventing offsets from occurring at the output.

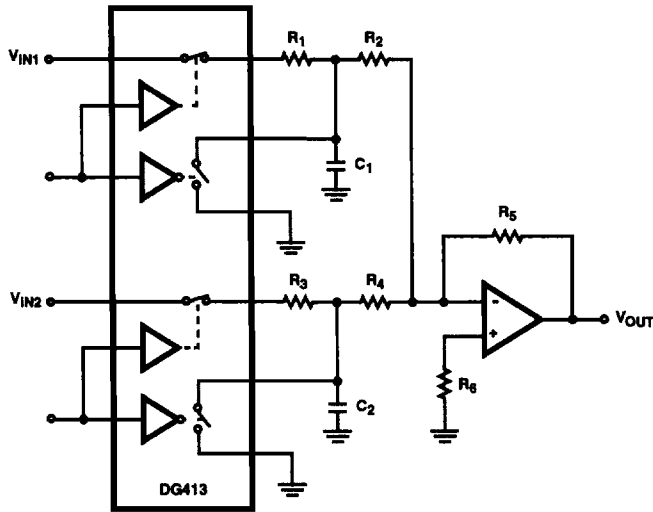


FIGURE 13. SUMMING AMPLIFIER



# DG411, DG412, DG413

## Die Characteristics

### DIE DIMENSIONS:

2760 $\mu$ m x 1780 $\mu$ m x 485 $\mu$ m  $\pm$ 25 $\mu$ m

### METALLIZATION:

Type: SiAl  
Thickness: 12k $\text{\AA}$   $\pm$ 1k $\text{\AA}$

### PASSIVATION:

Type: Nitride  
Thickness: 8k $\text{\AA}$   $\pm$ 1k $\text{\AA}$

### WORST CASE CURRENT DENSITY:

1.5 x 10<sup>5</sup> A/cm<sup>2</sup>

## Metallization Mask Layout

