

## Low-Power – High-Speed CMOS Analog Switches

### FEATURES

- $\pm 15$  V Input Range
- ON Resistance < 35  $\Omega$
- Fast Switching Action  
 $t_{ON} < 150$  ns  
 $t_{OFF} < 100$  ns
- Ultra Low Power  
 Requirements ( $P_D < 35$   $\mu$ W)
- TTL, CMOS Compatible

### BENEFITS

- Wide Dynamic Range
- Low Signal Errors and Distortion
- Break-Before-Make Switching Action
- Simple Interfacing

### APPLICATIONS

- High Performance Audio and Video Switching
- Sample and Hold Circuits
- Battery Operation

### DESCRIPTION

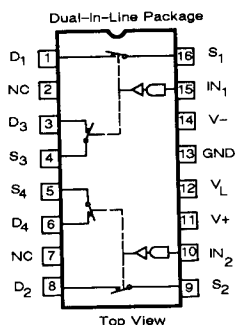
The DG400 family of monolithic analog switches were designed to provide precision, high performance switching of analog signals. Combining low power (< 35  $\mu$ W) with high speed ( $t_{ON} < 150$  ns), the DG400 series is ideally suited for portable and battery powered industrial and military applications.

Built on the Siliconix proprietary high voltage silicon gate process to achieve high voltage rating and superior switch ON/OFF performance, break-before-make is guaranteed for the SPDT configurations. An epitaxial layer prevents latchup.

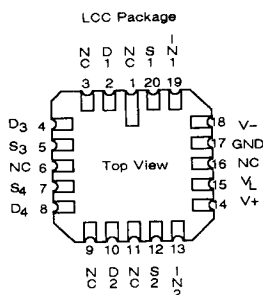
Each switch conducts equally well in both directions when ON, and blocks up to 30 volts peak-to-peak when OFF. ON resistance is very flat over the full  $\pm 15$  V analog range, rivaling JFET performance without the inherent dynamic range limitations.

The six devices in this series are differentiated by the type of switch action as shown in the functional block diagrams. Package options include the 16-pin plastic, CerDIP and LCC package. Performance grades include industrial, D suffix ( $-40$  to  $85^\circ\text{C}$ ), and military, A suffix ( $-55$  to  $125^\circ\text{C}$ ). Additionally, the DG403 and DG405 are available in the narrow body surface mount package, SO-16.

### FUNCTIONAL BLOCK DIAGRAM, PIN CONFIGURATION AND TRUTH TABLE



Order Numbers:  
CerDIP: DG405AK  
DG405AK/883  
Plastic: DG405DJ



Order Number:  
DG405AZ

### DG405

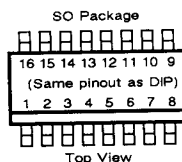
#### Two DPST Switches per Package

#### Truth Table

| LOGIC | SWITCH |
|-------|--------|
| 0     | OFF    |
| 1     | ON     |

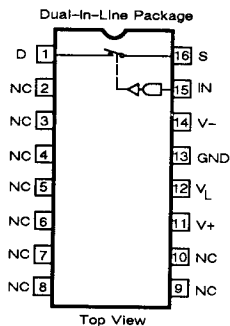
Logic "0"  $\leq 0.8$  V

Logic "1"  $\geq 2.4$  V



Order Number:  
DG405DY

**FUNCTIONAL BLOCK DIAGRAM, PIN CONFIGURATION AND TRUTH TABLE (Cont'd)**



Order Numbers:  
CerDIP: DG400AK  
DG400AK/883  
Plastic: DG400DJ

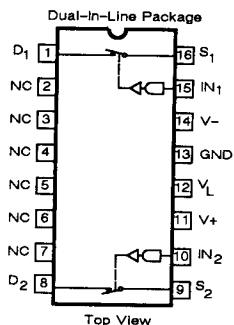
**DG400**

One SPST Switch per Package

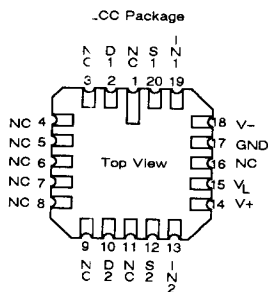
Truth Table

| LOGIC | SWITCH |
|-------|--------|
| 0     | OFF    |
| 1     | ON     |

Logic " 0 "  $\leq$  0.8 V  
Logic " 1 "  $\geq$  2.4 V



Order Numbers:  
CerDIP: DG401AK  
DG401AK/883  
Plastic: DG401DJ



Order Number:  
DG401AZ

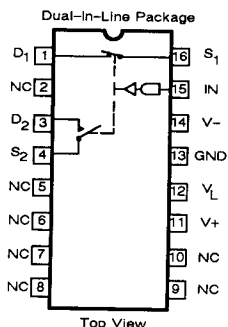
**DG401**

Two SPST Switches per Package

Truth Table

| LOGIC | SWITCH |
|-------|--------|
| 0     | OFF    |
| 1     | ON     |

Logic " 0 "  $\leq$  0.8 V  
Logic " 1 "  $\geq$  2.4 V



Order Numbers:  
CerDIP: DG402AK  
DG402AK/883  
Plastic: DG402DJ

**DG402**

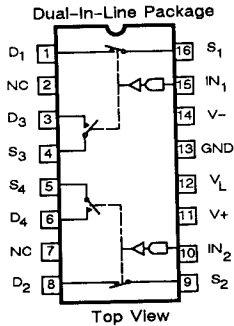
One SPDT Switch per Package

Truth Table

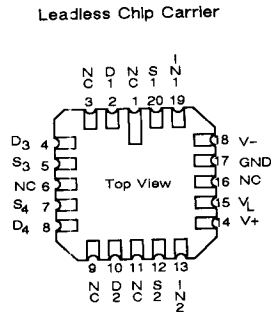
| LOGIC | SWITCH 1 | SWITCH 2 |
|-------|----------|----------|
| 0     | OFF      | ON       |
| 1     | ON       | OFF      |

Logic " 0 "  $\leq$  0.8 V  
Logic " 1 "  $\geq$  2.4 V

## FUNCTIONAL BLOCK DIAGRAM, PIN CONFIGURATION AND TRUTH TABLE (Cont'd)



Order Numbers:  
CerDIP: DG403AK  
DG403AK/883  
Plastic: DG403DJ



Order Number:  
DG403AZ

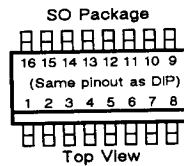
### DG403

Two SPDT Switches per Package  
Truth Table

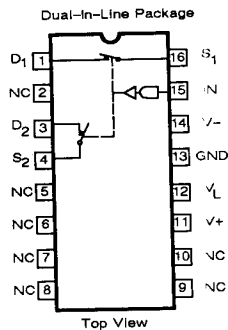
| LOGIC | SWITCH 1<br>SWITCH 2 | SWITCH 3<br>SWITCH 4 |
|-------|----------------------|----------------------|
| 0     | OFF                  | ON                   |
| 1     | ON                   | OFF                  |

Logic "0"  $\leq$  0.8 V

Logic "1"  $\geq$  2.4 V



Order Number:  
DG403DY



Order Numbers:  
CerDIP: DG404AK  
DG404AK/883  
Plastic: DG404DJ

### DG404

One DPST Switch per Package

Truth Table

| LOGIC | SWITCH |
|-------|--------|
| 0     | OFF    |
| 1     | ON     |

Logic "0"  $\leq$  0.8 V

Logic "1"  $\geq$  2.4 V

## ABSOLUTE MAXIMUM RATINGS

|                                        |                                                                |
|----------------------------------------|----------------------------------------------------------------|
| V+ to V-                               | 44 V                                                           |
| GND to V-                              | 25 V                                                           |
| VL to V-                               | (GND - 0.3 V) to 44 V                                          |
| Digital Inputs <sup>1</sup> VS, VD     | (V-) -2 V to (V+ plus 2 V)<br>or 30 mA, whichever occurs first |
| Current (Any Terminal) Continuous      | 30 mA                                                          |
| Current, S or D (Pulsed 1 ms 10% duty) | 100 mA                                                         |
| Storage Temperature                    | (A Suffix) -65 to 150°C<br>(D Suffix) -65 to 125°C             |
| Operating Temperature                  | (A Suffix) -55 to 125°C<br>(D Suffix) -40 to 85°C              |

Power Dissipation (Package) \*

|                      |        |
|----------------------|--------|
| 16-Pin Plastic DIP** | 450 mW |
| 16-Pin CerDIP***     | 900 mW |
| 20-Pin LCC****       | 750 mW |
| 16-Pin SO*****       | 600 mW |

\* All leads welded or soldered to PC board.

\*\* Derate 6 mW/°C above 75°C

\*\*\* Derate 12 mW/°C above 75°C

\*\*\*\* Derate 10 mW/°C above 75°C

\*\*\*\*\* Derate 7.6 mW/°C above 75°C

<sup>1</sup> Signals on Sx, Dx or INx exceeding V+ or V- will be clamped by internal diodes. Limit forward diode current to maximum current ratings.

**ELECTRICAL CHARACTERISTICS <sup>a</sup>**

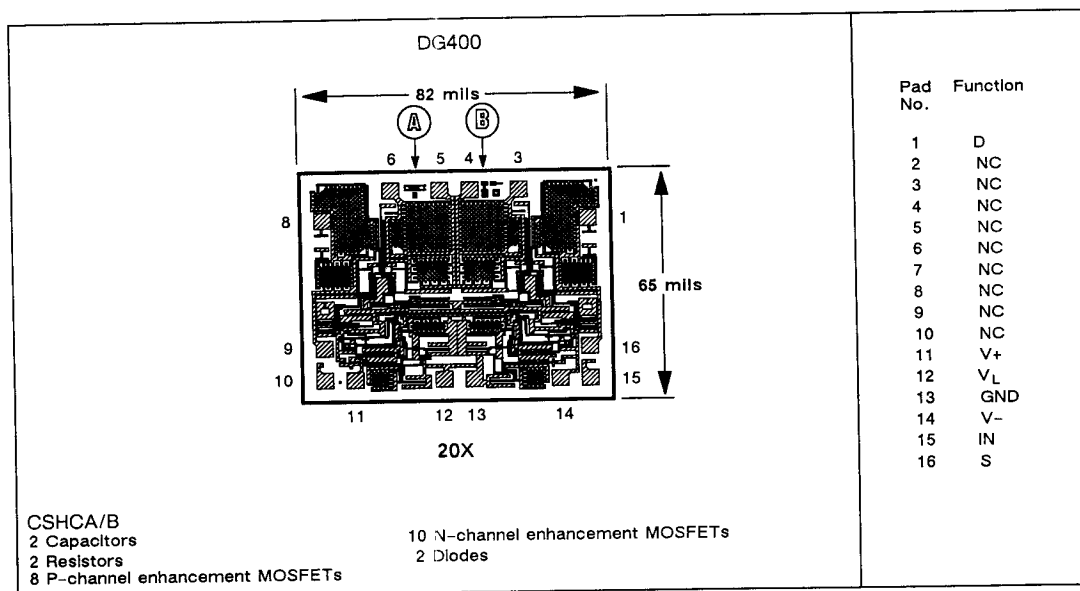
| PARAMETER                                      | SYMBOL                                     | Test Conditions<br>Unless Otherwise Specified:<br>V <sub>+</sub> = 15 V<br>V <sub>-</sub> = -15 V<br>V <sub>L</sub> = 5 V<br>GND = 0 V<br>V <sub>IN</sub> = 2.4V, 0.8 V <sup>e</sup> | LIMITS   |                  |                  |                  |                  |                  | UNIT |
|------------------------------------------------|--------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|------------------|------------------|------------------|------------------|------------------|------|
|                                                |                                            |                                                                                                                                                                                      | 1=25°C   |                  | 2=125,85°C       |                  | 3=-55,-40°C      |                  |      |
|                                                |                                            |                                                                                                                                                                                      | TEMP     | TYP <sup>d</sup> | MIN <sup>b</sup> | MAX <sup>b</sup> | MIN <sup>b</sup> | MAX <sup>b</sup> |      |
| SWITCH                                         |                                            |                                                                                                                                                                                      |          |                  |                  |                  |                  |                  |      |
| Analog Signal Range <sup>c</sup>               | V <sub>ANALOG</sub>                        |                                                                                                                                                                                      |          |                  | -15              | 15               | -15              | 15               | V    |
| Drain-Source<br>ON Resistance                  | r <sub>DS(ON)</sub>                        | V <sub>+</sub> = 13.5 V, V <sub>-</sub> = -13.5 V<br>I <sub>S</sub> = -10 mA, V <sub>D</sub> = ±10 V                                                                                 | 1<br>2,3 | 20               |                  | 35<br>45         |                  | 45<br>55         | Ω    |
| Delta Drain-Source<br>ON Resistance            | Δr <sub>DS(ON)</sub>                       | V <sub>+</sub> = 16.5 V, V <sub>-</sub> = -16.5 V<br>I <sub>S</sub> = -10 mA, V <sub>D</sub> = 5, 0, -5 V                                                                            | 1<br>2,3 | 3.0              |                  | 3.0<br>5.0       |                  | 3.0<br>5.0       |      |
| Switch OFF Leakage<br>Current                  | I <sub>S(OFF)</sub>                        | V <sub>+</sub> = 16.5 V, V <sub>-</sub> = -16.5 V<br>V <sub>D</sub> = -15.5 V, V <sub>S</sub> = 15.5 V                                                                               | 1<br>2   | -.01             | -0.25<br>-20     | 0.25<br>20       | -0.50<br>-20     | 0.50<br>20       | nA   |
|                                                | I <sub>D(OFF)</sub>                        | V <sub>D</sub> = 15.5 V, V <sub>S</sub> = -15.5 V                                                                                                                                    | 1<br>2   | -.01             | -0.25<br>-20     | 0.25<br>20       | -0.50<br>-20     | 0.50<br>20       |      |
| Channel ON<br>Leakage Current                  | I <sub>D(ON)</sub> +<br>I <sub>S(ON)</sub> | V <sub>+</sub> = 16.5 V, V <sub>-</sub> = -16.5 V<br>V <sub>D</sub> = V <sub>S</sub> = ±15.5 V                                                                                       | 1<br>2   | -0.04            | -0.4<br>-40      | 0.4<br>40        | -1.0<br>-40      | 1.0<br>40        |      |
| INPUT                                          |                                            |                                                                                                                                                                                      |          |                  |                  |                  |                  |                  |      |
| Input Current with V <sub>IN</sub><br>LOW      | I <sub>IL</sub>                            | V <sub>IN</sub> Under Test = 0.8 V<br>All Other = 2.4 V                                                                                                                              | 1,2      | .005             | -1.0             | 1.0              | -1.0             | 1.0              | μA   |
| Input Current with V <sub>IN</sub><br>HIGH     | I <sub>IH</sub>                            | V <sub>IN</sub> Under Test = 2.4 V<br>All Other = 0.8 V                                                                                                                              | 1,2      | .005             | -1.0             | 1.0              | -1.0             | 1.0              |      |
| DYNAMIC                                        |                                            |                                                                                                                                                                                      |          |                  |                  |                  |                  |                  |      |
| Turn-ON Time                                   | t <sub>ON</sub>                            | R <sub>L</sub> = 300 Ω, C <sub>L</sub> = 35 pF<br>See Figure 1A                                                                                                                      | 1        | 100              |                  | 150              |                  | 150              | ns   |
| Turn-OFF Time                                  | t <sub>OFF</sub>                           |                                                                                                                                                                                      | 1        | 60               |                  | 100              |                  | 100              |      |
| Break-Before-Make<br>Time Delay                | t <sub>D</sub>                             | R <sub>L</sub> = 300 Ω, C <sub>L</sub> = 35 pF<br>DG402/DG403                                                                                                                        | 1        | 20               | 10.0             |                  | 10.0             |                  |      |
| Charge Injection                               | Q                                          | C <sub>L</sub> = 10,000 pF<br>V <sub>gen</sub> = 0 V, R <sub>gen</sub> = 0 Ω                                                                                                         | 1        | 60               |                  | 100              |                  | 100              | pC   |
| Off Isolation                                  |                                            | R <sub>L</sub> = 100 Ω, C <sub>L</sub> = 5 pF<br>f = 1 MHz                                                                                                                           | 1        | 72               |                  |                  |                  |                  | dB   |
| Crosstalk <sup>f</sup><br>(Channel-to-Channel) |                                            | Any Other Channel Switches<br>R <sub>L</sub> = 100 Ω, C <sub>L</sub> = 5 pF<br>f = 1 MHz                                                                                             | 1        | 90               |                  |                  |                  |                  |      |
| Source-OFF Capacitance                         | C <sub>S(OFF)</sub>                        | V <sub>S</sub> = 0 V<br>f = 1 MHz                                                                                                                                                    | 1        | 12               |                  |                  |                  |                  | pF   |
| Drain-OFF Capacitance                          | C <sub>D(OFF)</sub>                        |                                                                                                                                                                                      | 1        | 12               |                  |                  |                  |                  |      |
| Drain and Source ON<br>Capacitance             | C <sub>D(ON)</sub> +<br>C <sub>S(ON)</sub> |                                                                                                                                                                                      | 1        | 39               |                  |                  |                  |                  |      |

| ELECTRICAL CHARACTERISTICS <sup>a</sup> |                  |                                                                                                                                                                                       |                                       |                  |                             |                  |                            |                  |      |
|-----------------------------------------|------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------|------------------|-----------------------------|------------------|----------------------------|------------------|------|
| PARAMETER                               | SYMBOL           | Test Conditions<br>Unless Otherwise Specified:<br>V <sup>+</sup> = 15 V<br>V <sup>-</sup> = -15 V<br>V <sub>L</sub> = 5 V<br>GND = 0 V<br>V <sub>IN</sub> = 2.4 V, 0.8 V <sup>e</sup> | LIMITS                                |                  |                             |                  |                            |                  | UNIT |
|                                         |                  |                                                                                                                                                                                       | 1=25°C<br>2=125, 85°C<br>3=-55, -40°C |                  | A<br>SUFFIX<br>-55 to 125°C |                  | D<br>SUFFIX<br>-40 to 85°C |                  |      |
|                                         |                  |                                                                                                                                                                                       | TEMP                                  | TYP <sup>d</sup> | MIN <sup>b</sup>            | MAX <sup>b</sup> | MIN <sup>b</sup>           | MAX <sup>b</sup> |      |
|                                         |                  |                                                                                                                                                                                       |                                       |                  |                             |                  |                            |                  |      |
| SUPPLY                                  |                  |                                                                                                                                                                                       |                                       |                  |                             |                  |                            |                  |      |
| Positive Supply Current                 | I <sup>+</sup>   | V <sup>+</sup> = 16.5 V, V <sup>-</sup> = -16.5 V<br>V <sub>IN</sub> = 0.0 or 5.0 V                                                                                                   | 1<br>2, 3                             | 0.01             |                             | 1<br>5           |                            | 1<br>5           | μA   |
| Negative Supply Current                 | I <sup>-</sup>   |                                                                                                                                                                                       | 1<br>2, 3                             | -0.01            | -1<br>-5                    |                  | -1<br>-5                   |                  |      |
| Logic Supply Current                    | I <sub>L</sub>   |                                                                                                                                                                                       | 1<br>2, 3                             | 0.01             |                             | 1<br>5           |                            | 1<br>5           |      |
| Ground Current                          | I <sub>GND</sub> |                                                                                                                                                                                       | 1<br>2, 3                             | -0.01            | -1<br>-5                    |                  | -1<br>-5                   |                  |      |

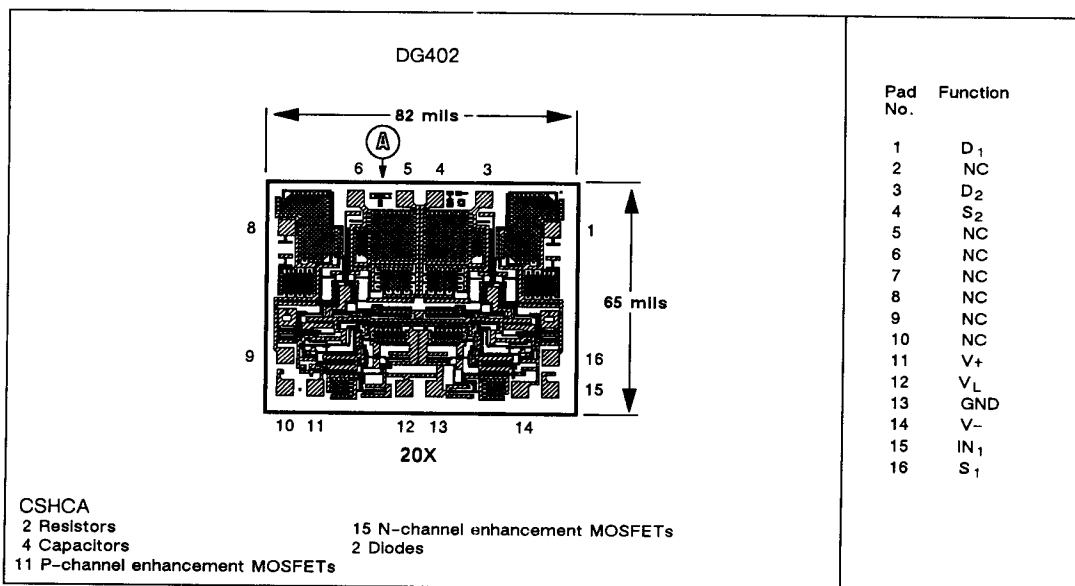
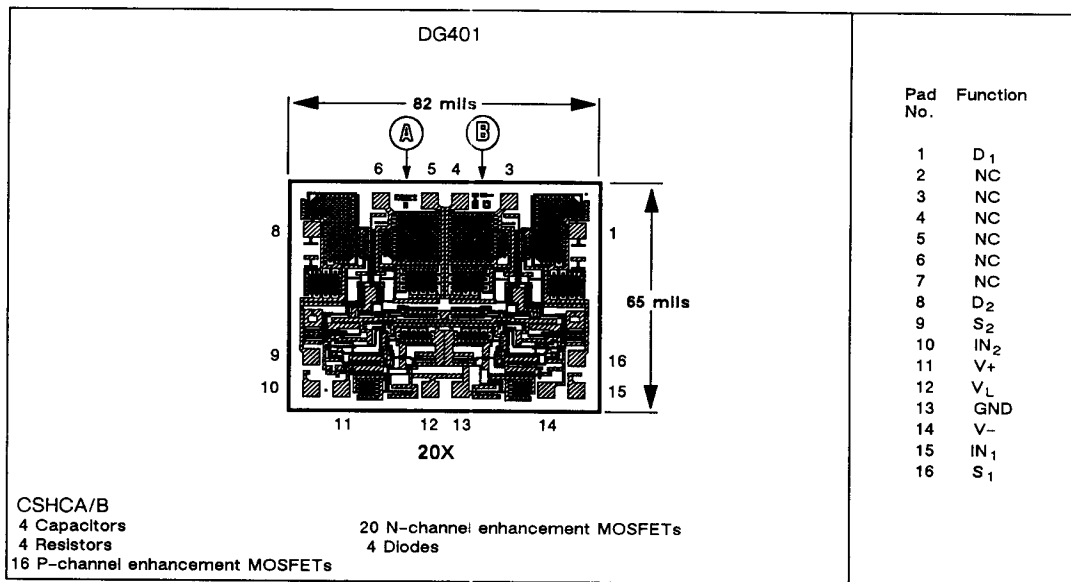
## NOTES:

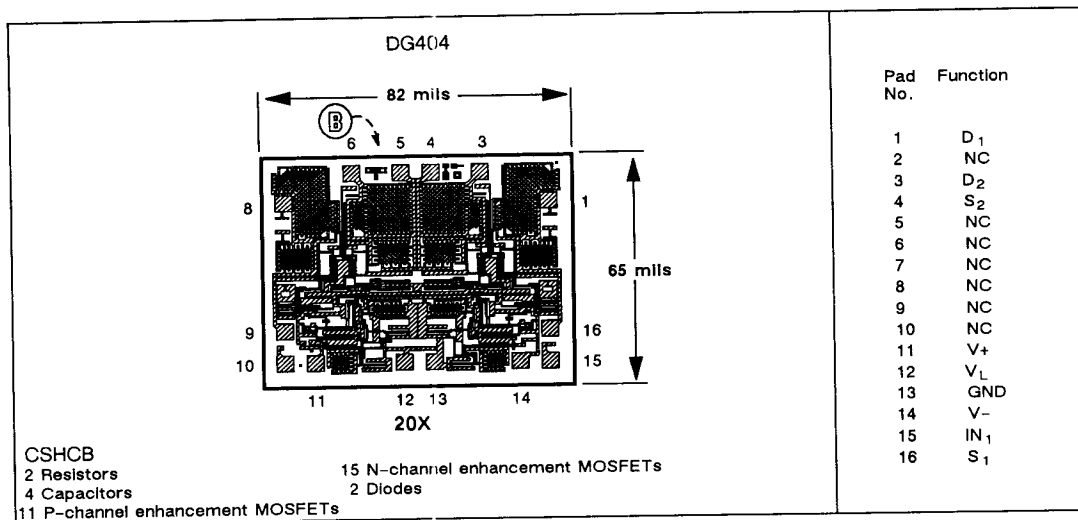
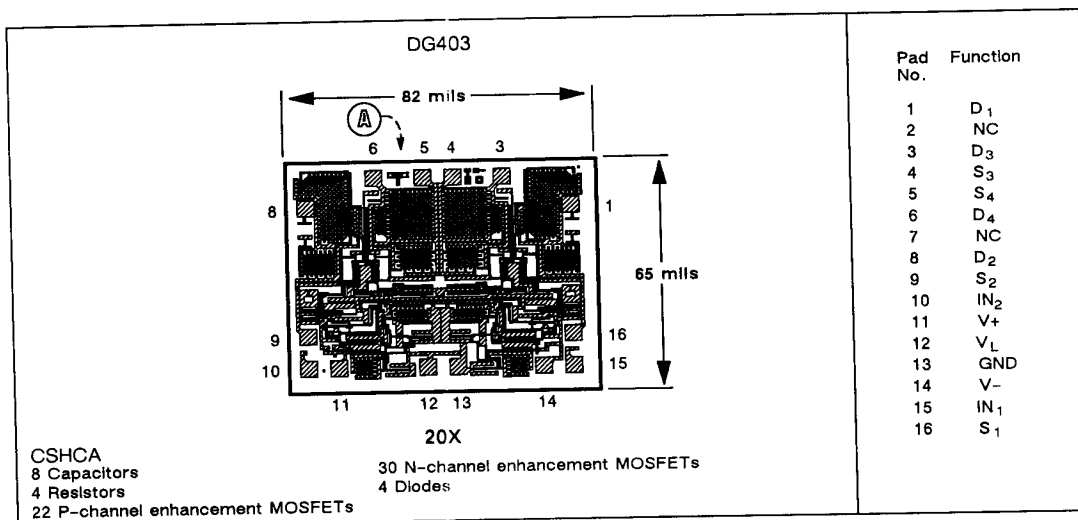
- Refer to PROCESS OPTION FLOWCHART for additional information.
- The algebraic convention whereby the most negative value is a minimum and the most positive a maximum, is used in this data sheet.
- Guaranteed by design, not subject to production test.
- Typical values are for DESIGN AID ONLY, not guaranteed nor subject to production testing.
- $V_{IN}$  = Input voltage to perform proper function.
- Crosstalk performance is improved to 110 dB (typ.) with LCC package.

## DIE TOPOGRAPHY

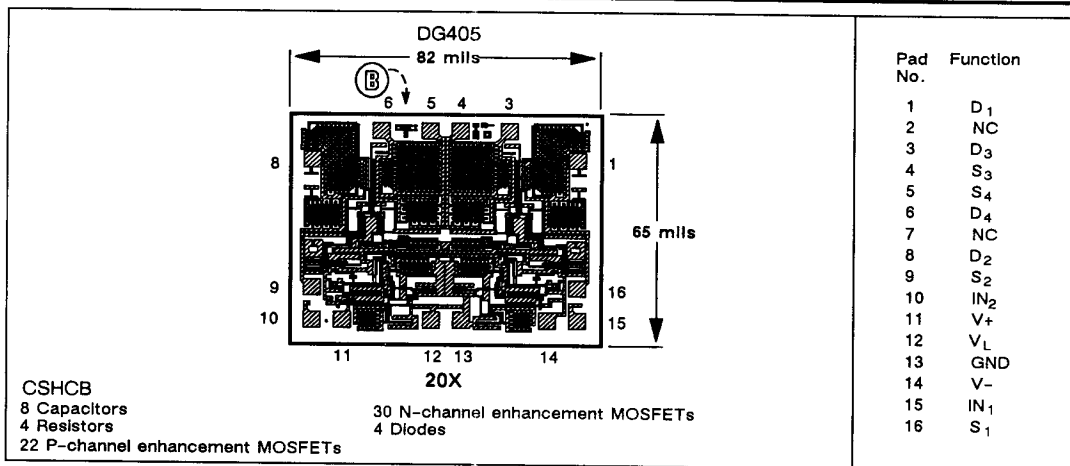


**DIE TOPOGRAPHY (Cont'd)**

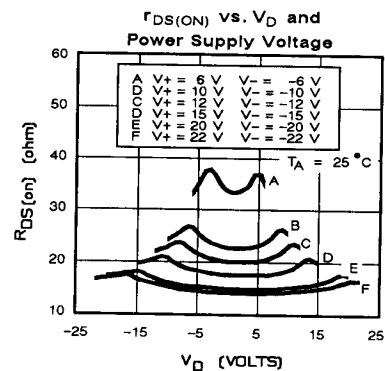
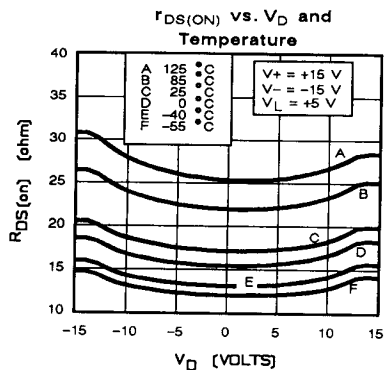
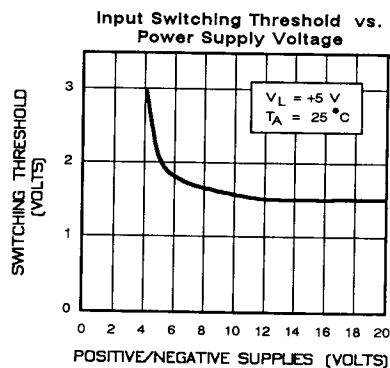
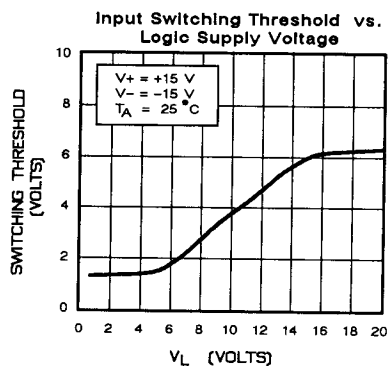




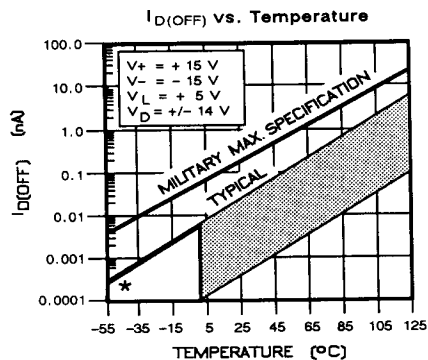
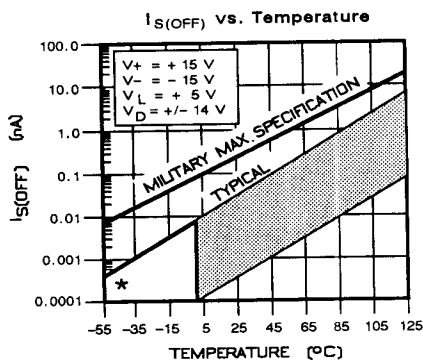
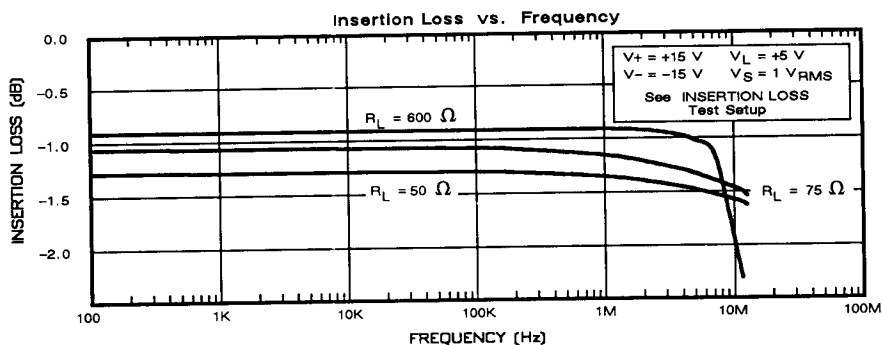
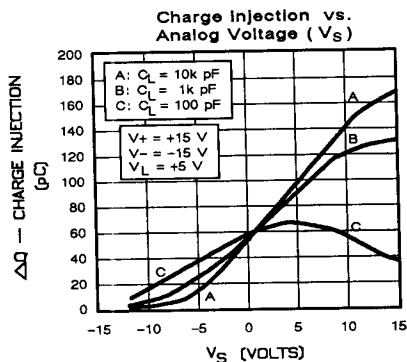
**DIE TOPOGRAPHY (Cont'd)**



**TYPICAL CHARACTERISTICS**

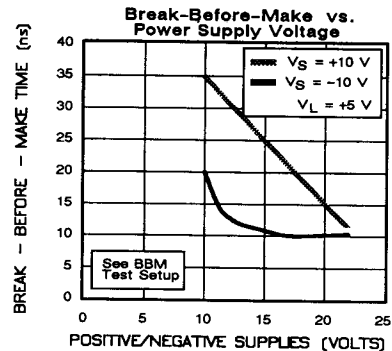
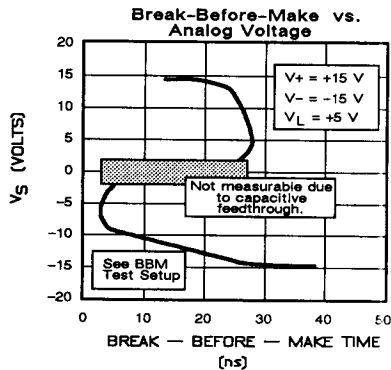
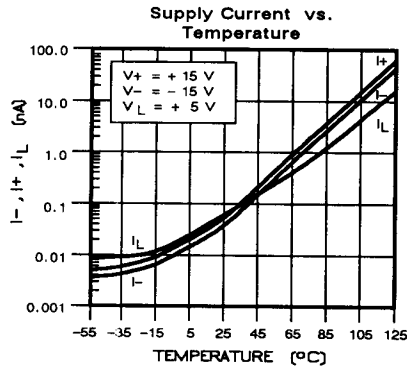
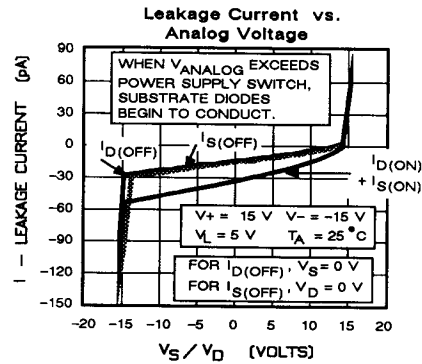
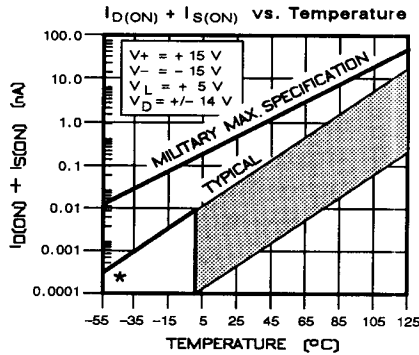


## TYPICAL CHARACTERISTICS (Cont'd)



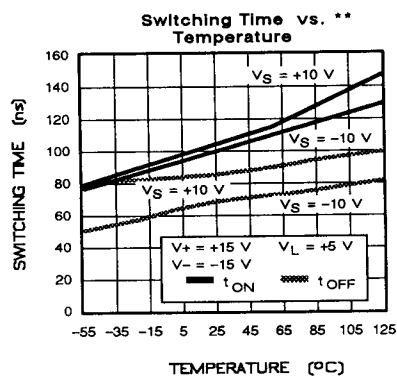
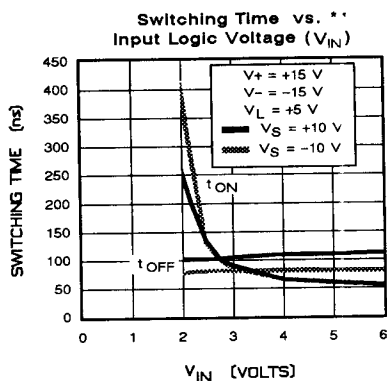
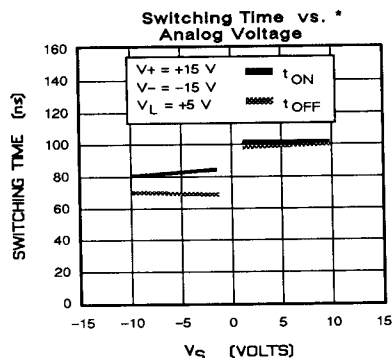
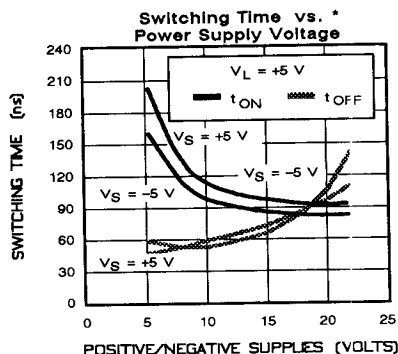
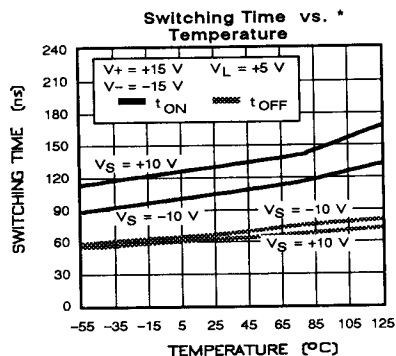
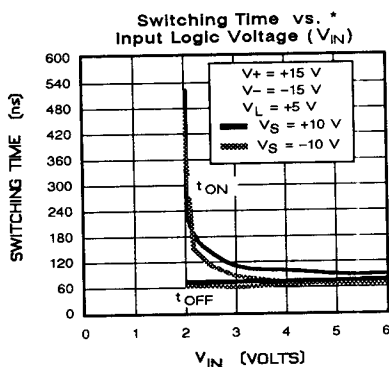
\* Leakage currents in this region are determined by extrapolation. Attempts to measure in production are limited by the ability to control humidity and leakages pin to pin below the dew point (where water condenses).

**TYPICAL CHARACTERISTICS (Cont'd)**



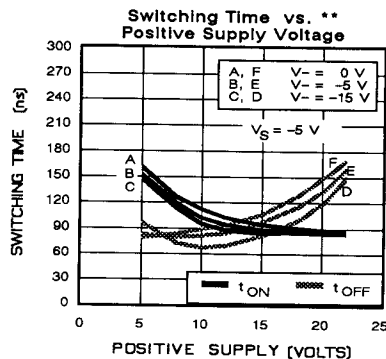
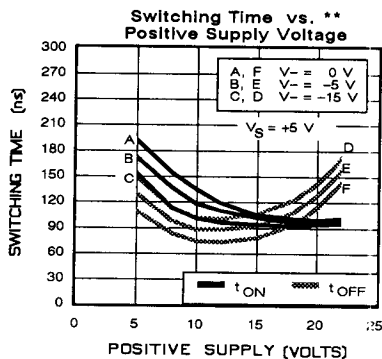
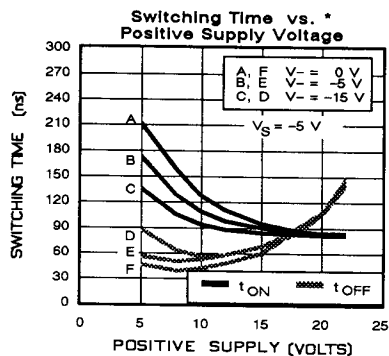
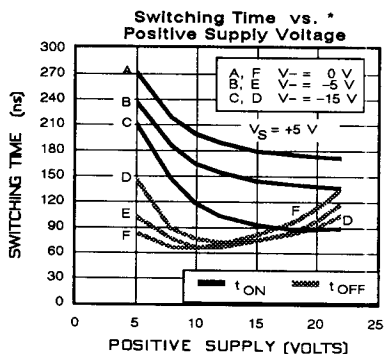
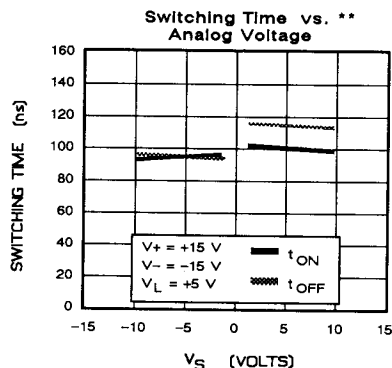
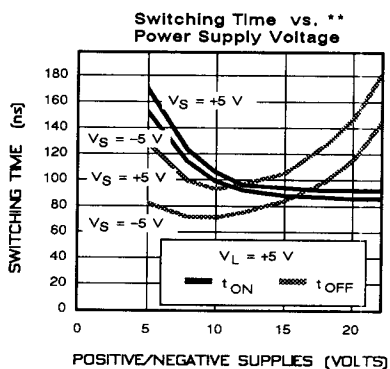
Leakage currents in this region are determined by extrapolation. Attempts to measure in production are limited by the ability to control humidity and leakages pin to pin below the dew point (where water condenses).

## TYPICAL CHARACTERISTICS (Cont'd)



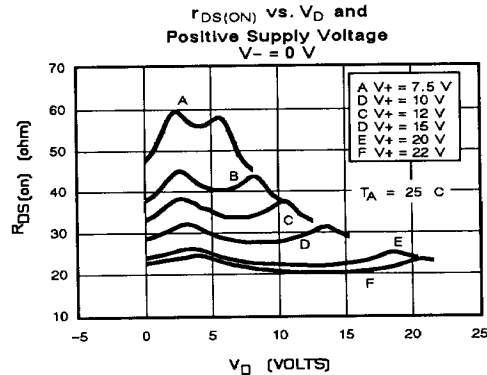
\* REFER TO FIGURE 1A FOR TEST CONDITIONS  
 \*\* REFER TO FIGURE 1B FOR TEST CONDITIONS

**TYPICAL CHARACTERISTICS (Cont'd)**



\* REFER TO FIGURE 1A FOR TEST CONDITIONS  
\*\* REFER TO FIGURE 1B FOR TEST CONDITIONS

## TYPICAL CHARACTERISTICS (Cont'd)



## SWITCHING TIME TEST CIRCUIT

$V_O$  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.

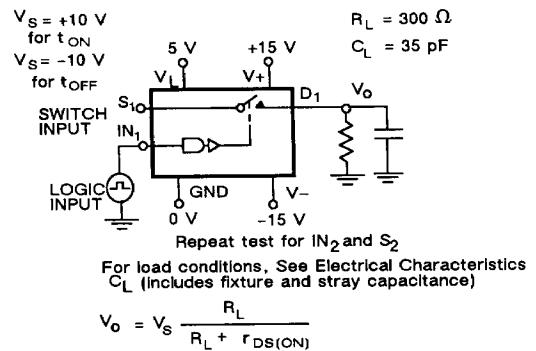
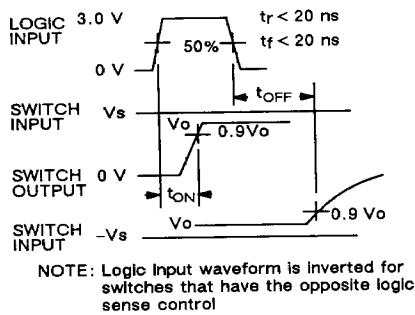
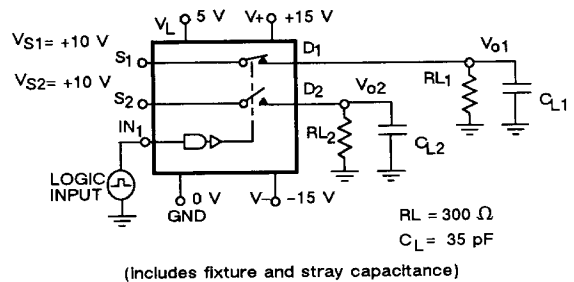
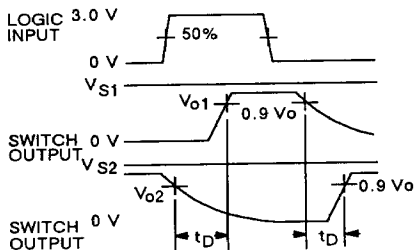
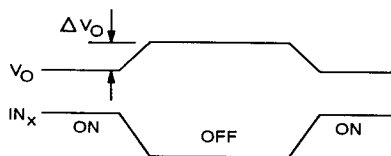
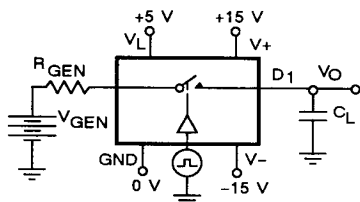


Figure 1

## BREAK-BEFORE-MAKE TEST CIRCUIT

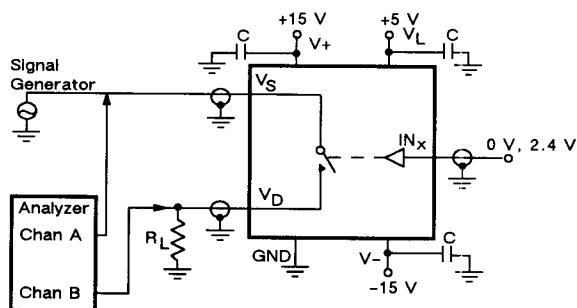


**CHARGE INJECTION TEST CIRCUIT**



$$Q = \Delta V_O C_L$$

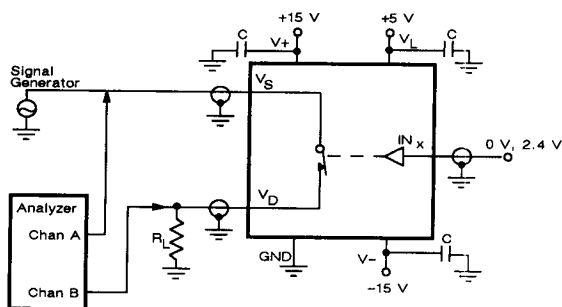
**OFF ISOLATION TEST CIRCUIT**



| FREQUENCY TESTED | SIGNAL GENERATOR              | ANALYZER                           |
|------------------|-------------------------------|------------------------------------|
| 100 Hz to 13 MHz | HP3330B Automatic Synthesizer | HP3571A Tracking Spectrum Analyzer |

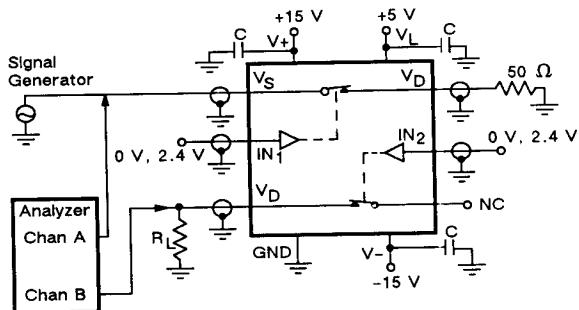
$$\text{OFF ISOLATION} = 20 \log \frac{V_D}{V_S}$$

**INSERTION LOSS TEST CIRCUIT**



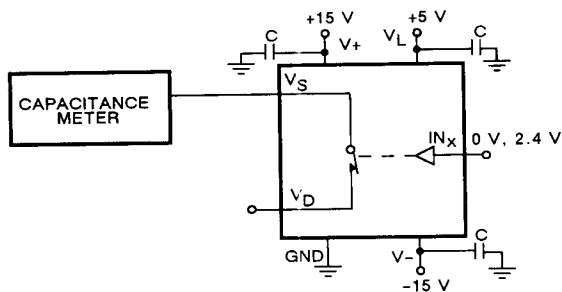
| FREQUENCY TESTED | SIGNAL GENERATOR              | ANALYZER                           |
|------------------|-------------------------------|------------------------------------|
| 100 Hz to 13 MHz | HP3330B Automatic Synthesizer | HP3571A Tracking Spectrum Analyzer |

## CROSSTALK TEST CIRCUIT



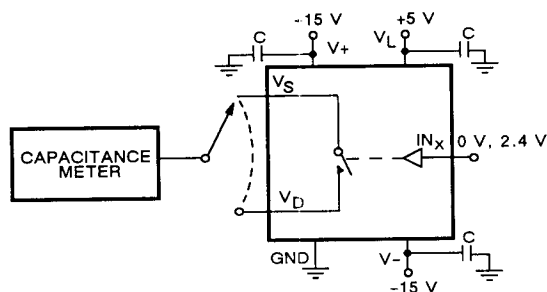
| FREQUENCY TESTED | SIGNAL GENERATOR             | ANALYZER                           |
|------------------|------------------------------|------------------------------------|
| 100 Hz to 13 MHz | HP330B Automatic Synthesizer | HP3571A Tracking Spectrum Analyzer |

## SOURCE/DRAIN ON CAPACITANCE



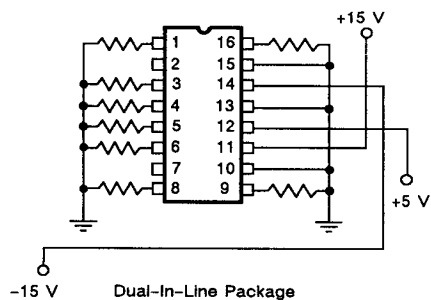
| METER                                    |
|------------------------------------------|
| HP4192A Impedance Analyzer or equivalent |

## SOURCE/DRAIN OFF CAPACITANCE

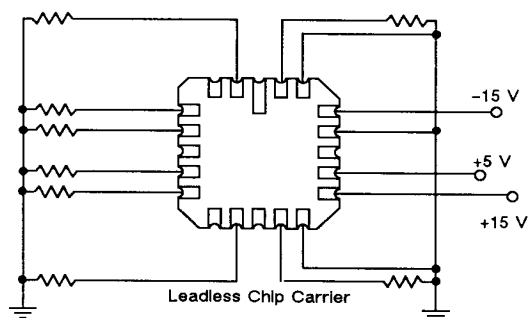


| METER                                    |
|------------------------------------------|
| HP4192A Impedance Analyzer or equivalent |

**BURN-IN CIRCUITS**

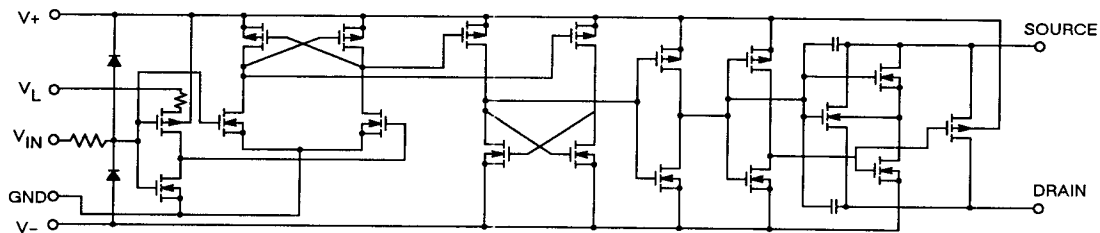


Note: All Resistors are 10 k $\Omega$  unless otherwise specified



Note: SO Package Is the same as the DIP

**SCHEMATIC DIAGRAM (Typical Channel)**



**5**

**PIN DESCRIPTION**

| SYMBOL | DESCRIPTION                       |
|--------|-----------------------------------|
| S      | An Analog Channel Input or Output |
| D      | An Analog Channel Output or Input |
| IN     | Logic Control Input               |
| V+     | Positive Supply Voltage           |
| V-     | Negative Supply Voltage           |
| GND    | Digital Ground                    |
| VL     | Logic Supply Voltage              |

## APPLICATIONS

### Stereo Source Selectors:

A single logic signal controls the status of all four switches of the device, simplifying stereo source switching. The low on-resistance ( $< 35 \Omega$ ) minimizes total harmonic distortion.

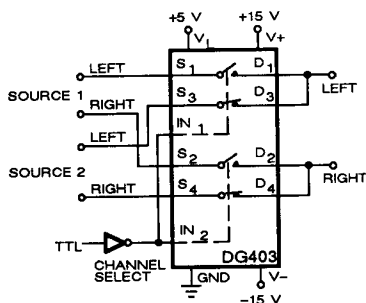
### Dual Slope Integrators:

The DG403 is well suited to configure a selectable slope integrator. One control signal selects the

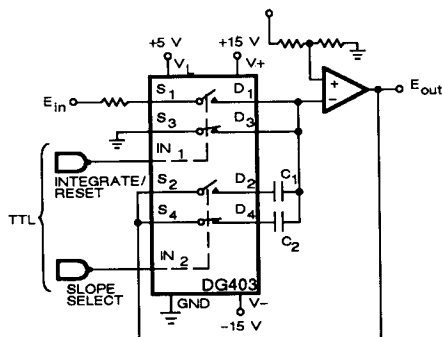
timing capacitor  $C_1$  or  $C_2$ . Another one selects  $E_{in}$  or discharges the capacitor in preparation for the next integration cycle.

### Band-Pass Switched Capacitor Filter:

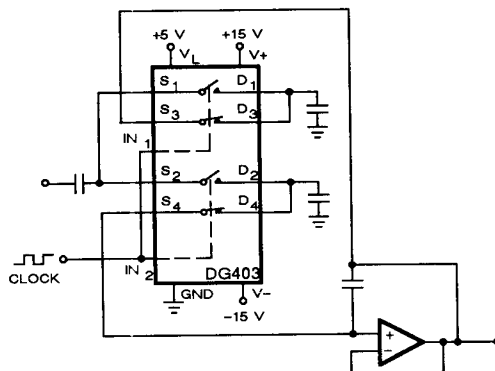
Single-pole double-throw switches are a common element for switched capacitor networks and filters. The fast switching times and low leakage of the DG403 allow for higher clock rates and consequently higher filter operating frequencies.



**Stereo Source Selector**



**Dual Slope Integrator**



**Band-Pass Switched Capacitor Filter**