

## High-Speed Drivers with Dual SPDT JFET Switches

### FEATURES

- Constant On-Resistance Over Entire Analog Range
- Low Leakage
- Low Crosstalk
- Low Crosstalk
- Rad Hardness

### BENEFITS

- Low Distortion
- Eliminates Large Signal Errors
- High Precision
- High Bandwidth Capability
- Fault Protection

### APPLICATIONS

- Audio Switching
- Video Switching
- Sample/Hold
- Guidance and Control Systems
- Aerospace

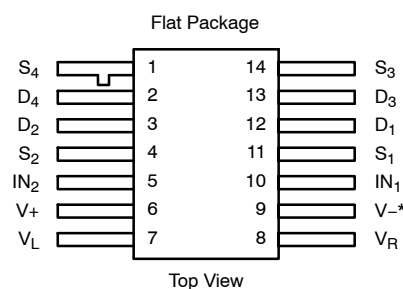
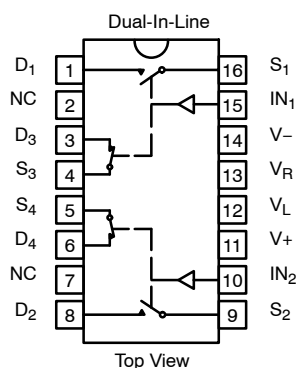
### DESCRIPTION

The DG189/190/191 are precision dual single-pole, double-throw (SPDT) analog switches designed to provide accurate switching of video and audio signals. This series is ideally suited for applications requiring a constant on-resistance over the entire analog range.

The major difference in the devices is the on-resistance (DG189—10  $\Omega$ , DG190—30  $\Omega$ , DG191—75  $\Omega$ ). Reduced errors are achieved through low leakage current ( $I_{D(on)} < 2$  nA). Applications which benefit from the flat JFET on-resistance include audio switching, video switching, and data acquisition.

To achieve fast and accurate switch performance, each device comprises four n-channel JFET transistors and a TTL compatible bipolar driver. The driver is designed to achieve break-before-make switching action, eliminating the inadvertent shorting between channels and the crosstalk which would result. In the on state, each switch conducts current equally well in either direction. In the off condition, the switches will block up to 20 V peak-to-peak, with feedthrough of less than -60 dB at 10 MHz.

### FUNCTIONAL BLOCK DIAGRAM AND PIN CONFIGURATION



Refer to JAN38510 Information, Military Section

\*Common to Substrate and Case

| TRUTH TABLE |                                   |                                   |
|-------------|-----------------------------------|-----------------------------------|
| Logic       | SW <sub>1</sub> , SW <sub>2</sub> | SW <sub>3</sub> , SW <sub>4</sub> |
| 0           | OFF                               | ON                                |
| 1           | ON                                | OFF                               |

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



| ORDERING INFORMATION |                   |                                        |
|----------------------|-------------------|----------------------------------------|
| Temp Range           | Package           | Part Number                            |
| -25 to 85°C          | 16-Pin Sidebrazed | DG189BP                                |
|                      |                   | DG190BP                                |
|                      |                   | DG191BP                                |
| -55 to 125°C         | 16-Pin Sidebrazed | DG189AP                                |
|                      |                   | DG190AP                                |
|                      |                   | DG191AP                                |
|                      |                   | DG189AP, DG189AP/883, 5962-9068901MEA  |
|                      |                   | DG190AP, DG190AP/883, JM38510/11107BEA |
|                      |                   | DG191AP, DG191AP/883, JM38510/11108BEA |
|                      | 14-Pin Flat Pack  | JM38510/11107BXA                       |
|                      |                   | JM38510/11108BXA                       |

ABSOLUTE MAXIMUM RATINGS

|                              |              |                                              |              |
|------------------------------|--------------|----------------------------------------------|--------------|
| $V_+$ to $V_-$ .....         | 36 V         | Current (S or D) DG190, DG191 .....          | 30 mA        |
| $V_+$ to $V_D$ .....         | 33 V         | Current (All Other Pins) .....               | 30 mA        |
| $V_S, V_D$ to $V_-$ .....    | -0.3 to 33 V | Storage Temperature .....                    | -65 to 150°C |
| $V_D$ to $V_D$ .....         | $\pm 22$ V   | Power Dissipation <sup>a</sup>               |              |
| $V_L$ to $V_-$ .....         | 36 V         | 16-Pin Sidebrazed <sup>b</sup> .....         | 900 mW       |
| $V_L$ to $V_{IN}$ .....      | 8 V          | 14-Pin Flat Pack <sup>c</sup> .....          | 900 mW       |
| $V_L$ to $V_R$ .....         | 8 V          |                                              |              |
| $V_{IN}$ to $V_R$ .....      | 8 V          | Notes:                                       |              |
| $V_R$ to $V_-$ .....         | 27 V         | a. All leads welded or soldered to PC Board. |              |
| $V_R$ to $V_{IN}$ .....      | 2 V          | b. Derate 12 mW/°C above 75°C                |              |
| Current (S or D) DG189 ..... | 200 mA       | c. Derate 10 mW/°C above 75°C                |              |

SCHEMATIC DIAGRAM (TYPICAL CHANNEL)

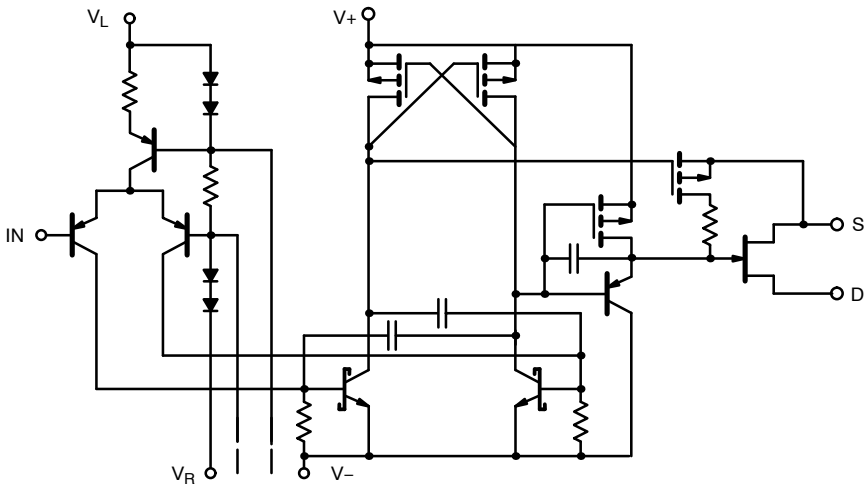


FIGURE 1.

**SPECIFICATIONS<sup>a</sup> FOR DG189**

| Parameter                             | Symbol              | Test Conditions<br>Unless Specified<br><br>V <sub>+</sub> = 15 V, V <sub>-</sub> = -15 V, V <sub>L</sub> = 5 V<br>V <sub>R</sub> = 0 V, V <sub>IN</sub> = 0.8 V or 2 V <sup>f</sup> | Temp <sup>b</sup>                         | Typ <sup>c</sup> | A Suffix<br>-55 to 125°C |                  | B Suffix<br>-25 to 85°C |                  | Unit |    |
|---------------------------------------|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------|------------------|--------------------------|------------------|-------------------------|------------------|------|----|
|                                       |                     |                                                                                                                                                                                     |                                           |                  | Min <sup>d</sup>         | Max <sup>d</sup> | Min <sup>d</sup>        | Max <sup>d</sup> |      |    |
| Analog Switch                         |                     |                                                                                                                                                                                     |                                           |                  |                          |                  |                         |                  |      |    |
| Analog Signal Range <sup>e</sup>      | V <sub>ANALOG</sub> |                                                                                                                                                                                     | Full                                      |                  | -7.5                     | 15               | -7.5                    | 15               | V    |    |
| Drain-Source On-Resistance            | r <sub>DS(on)</sub> | I <sub>S</sub> = -10 mA, V <sub>D</sub> = -7.5 V                                                                                                                                    | Room Full                                 | 7.5              |                          | 10<br>20         |                         | 15<br>25         | Ω    |    |
| Source Off Leakage Current            | I <sub>S(off)</sub> | V <sub>S</sub> = ±10 V, V <sub>D</sub> = ∓10 V<br>V <sub>+</sub> = 10 V, V <sub>-</sub> = -20 V                                                                                     | Room Hot                                  | 0.05             |                          | 10<br>1000       |                         | 15<br>300        | nA   |    |
|                                       |                     | V <sub>S</sub> = ±7.5 V, V <sub>D</sub> = ∓7.5 V                                                                                                                                    | Room Hot                                  | 0.05             |                          | 10<br>1000       |                         | 15<br>300        |      |    |
| Drain Off Leakage Current             | I <sub>D(off)</sub> | V <sub>S</sub> = ±10 V, V <sub>D</sub> = ∓10 V<br>V <sub>+</sub> = 10 V, V <sub>-</sub> = -20 V                                                                                     | Room Hot                                  | 0.04             |                          | 10<br>1000       |                         | 15<br>300        |      |    |
|                                       |                     | V <sub>S</sub> = ±7.5 V, V <sub>D</sub> = ∓7.5 V                                                                                                                                    | Room Hot                                  | 0.03             |                          | 10<br>1000       |                         | 15<br>300        |      |    |
| Channel On Leakage Current            | I <sub>D(on)</sub>  | V <sub>D</sub> = V <sub>S</sub> = ±7.5 V                                                                                                                                            | Room Hot                                  | -0.1             | -2<br>-200               |                  | -10<br>-200             |                  |      |    |
| Saturation Drain Current              | I <sub>DSS</sub>    | 2 ms Pulse Duration                                                                                                                                                                 | Room                                      | 300              |                          |                  |                         |                  | mA   |    |
| Digital Input                         |                     |                                                                                                                                                                                     |                                           |                  |                          |                  |                         |                  |      |    |
| Input Current with Input Voltage High | I <sub>INH</sub>    | V <sub>IN</sub> = 5 V                                                                                                                                                               | Room Hot                                  | <0.01            |                          | 10<br>20         |                         | 10<br>20         | μA   |    |
| Input Current with Input Voltage Low  | I <sub>INL</sub>    | V <sub>IN</sub> = 0 V                                                                                                                                                               | Full                                      | -30              | -250                     |                  | -250                    |                  |      |    |
| Dynamic Characteristics               |                     |                                                                                                                                                                                     |                                           |                  |                          |                  |                         |                  |      |    |
| Turn-On Time                          | t <sub>on</sub>     | See Switching Time Test Circuit                                                                                                                                                     |                                           | Room             | 240                      |                  | 400                     |                  | 425  | ns |
| Turn-Off Time                         | t <sub>off</sub>    |                                                                                                                                                                                     |                                           | Room             | 140                      |                  | 200                     |                  | 225  |    |
| Source-Off Capacitance                | C <sub>S(off)</sub> | f = 1 MHz                                                                                                                                                                           | V <sub>S</sub> = -5 V, I <sub>D</sub> = 0 | Room             | 21                       |                  |                         |                  |      | pF |
| Drain-Off Capacitance                 | C <sub>D(off)</sub> |                                                                                                                                                                                     | V <sub>D</sub> = -5 V, I <sub>S</sub> = 0 | Room             | 17                       |                  |                         |                  |      |    |
| Channel-On Capacitance                | C <sub>D(on)</sub>  |                                                                                                                                                                                     | V <sub>D</sub> = V <sub>S</sub> = 0 V     | Room             | 17                       |                  |                         |                  |      |    |
| Off Isolation                         | OIRR                | f = 1 MHz, R <sub>L</sub> = 75 Ω                                                                                                                                                    |                                           | Room             | >55                      |                  |                         |                  |      | dB |
| Power Supplies                        |                     |                                                                                                                                                                                     |                                           |                  |                          |                  |                         |                  |      |    |
| Positive Supply Current               | I <sub>+</sub>      | V <sub>IN</sub> = 0 V, or 5 V                                                                                                                                                       |                                           | Room             | 0.6                      |                  | 1.5                     |                  | 1.5  | mA |
| Negative Supply Current               | I <sub>-</sub>      |                                                                                                                                                                                     |                                           | Room             | -2.7                     | -5               |                         | -5               |      |    |
| Logic Supply Current                  | I <sub>L</sub>      |                                                                                                                                                                                     |                                           | Room             | 3.1                      |                  | 4.5                     |                  | 4.5  |    |
| Reference Supply Current              | I <sub>R</sub>      |                                                                                                                                                                                     |                                           | Room             | -1                       | -2               |                         | -2               |      |    |

## Notes:

- Refer to PROCESS OPTION FLOWCHART.
- Room = 25°C, Full = as determined by the operating temperature suffix.
- Typical values are for DESIGN AID ONLY, not guaranteed nor subject to production testing.
- The algebraic convention whereby the most negative value is a minimum and the most positive a maximum, is used in this data sheet.
- Guaranteed by design, not subject to production test.
- $V_{IN}$  = input voltage to perform proper function.

**SPECIFICATIONS<sup>a</sup> FOR DG190**

| Parameter                             | Symbol              | Test Conditions<br>Unless Specified<br><br>V <sub>+</sub> = 15 V, V <sub>-</sub> = -15 V, V <sub>L</sub> = 5 V<br>V <sub>R</sub> = 0 V, V <sub>IN</sub> = 0.8 V or 2 V <sup>f</sup> | Temp <sup>b</sup> | Typ <sup>c</sup> | A Suffix<br>-55 to 125°C |                  | B Suffix<br>-25 to 85°C |                  | Unit |    |
|---------------------------------------|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|------------------|--------------------------|------------------|-------------------------|------------------|------|----|
|                                       |                     |                                                                                                                                                                                     |                   |                  | Min <sup>d</sup>         | Max <sup>d</sup> | Min <sup>d</sup>        | Max <sup>d</sup> |      |    |
| Analog Switch                         |                     |                                                                                                                                                                                     |                   |                  |                          |                  |                         |                  |      |    |
| Analog Signal Range <sup>e</sup>      | V <sub>ANALOG</sub> |                                                                                                                                                                                     | Full              |                  | -7.5                     | 15               | -7.5                    | 15               | V    |    |
| Drain-Source On-Resistance            | r <sub>DS(on)</sub> | I <sub>S</sub> = -10 mA, V <sub>D</sub> = -7.5 V                                                                                                                                    | Room Full         | 18               |                          | 30<br>60         |                         | 50<br>75         | Ω    |    |
| Source Off Leakage Current            | I <sub>S(off)</sub> | V <sub>S</sub> = ± 10 V, V <sub>D</sub> = ∓ 10 V<br>V <sub>+</sub> = 10 V, V <sub>-</sub> = -20 V                                                                                   | Room Hot          | 0.06             |                          | 1<br>100         |                         | 5<br>100         | nA   |    |
|                                       |                     | V <sub>S</sub> = ± 7.5 V, V <sub>D</sub> = ∓ 7.5 V                                                                                                                                  | Room Hot          | 0.1              |                          | 1<br>100         |                         | 5<br>100         |      |    |
| Drain Off Leakage Current             | I <sub>D(off)</sub> | V <sub>S</sub> = ± 10 V, V <sub>D</sub> = ∓ 10 V<br>V <sub>+</sub> = 10 V, V <sub>-</sub> = -20 V                                                                                   | Room Hot          | 0.05             |                          | 1<br>100         |                         | 5<br>100         |      |    |
|                                       |                     | V <sub>S</sub> = ± 7.5 V, V <sub>D</sub> = ∓ 7.5 V                                                                                                                                  | Room Hot          | 0.06             |                          | 1<br>100         |                         | 5<br>100         |      |    |
| Channel On Leakage Current            | I <sub>D(on)</sub>  | V <sub>D</sub> = V <sub>S</sub> = ± 7.5 V                                                                                                                                           | Room Hot          | -0.02            | -2<br>-200               |                  | -10<br>-200             |                  |      |    |
| Digital Input                         |                     |                                                                                                                                                                                     |                   |                  |                          |                  |                         |                  |      |    |
| Input Current with Input Voltage High | I <sub>INH</sub>    | V <sub>IN</sub> = 5 V                                                                                                                                                               | Room Hot          | <0.01            |                          | 10<br>20         |                         | 10<br>20         | μA   |    |
| Input Current with Input Voltage Low  | I <sub>INL</sub>    | V <sub>IN</sub> = 0 V                                                                                                                                                               | Full              | -30              | -250                     |                  | -250                    |                  |      |    |
| Dynamic Characteristics               |                     |                                                                                                                                                                                     |                   |                  |                          |                  |                         |                  |      |    |
| Turn-On Time                          | t <sub>on</sub>     | See Switching Time Test Circuit                                                                                                                                                     |                   | Room             | 85                       |                  | 150                     |                  | 180  | ns |
| Turn-Off Time                         | t <sub>off</sub>    |                                                                                                                                                                                     |                   | Room             | 95                       |                  | 130                     |                  | 150  |    |
| Source-Off Capacitance                | C <sub>S(off)</sub> | f = 1 MHz                                                                                                                                                                           | Room              | 9                |                          |                  |                         |                  | pF   |    |
| Drain-Off Capacitance                 | C <sub>D(off)</sub> |                                                                                                                                                                                     | Room              | 6                |                          |                  |                         |                  |      |    |
| Channel-On Capacitance                | C <sub>D(on)</sub>  |                                                                                                                                                                                     | Room              | 14               |                          |                  |                         |                  |      |    |
| Off Isolation                         | OIRR                | f = 1 MHz, R <sub>L</sub> = 75 Ω                                                                                                                                                    |                   | Room             | >50                      |                  |                         |                  | dB   |    |
| Power Supplies                        |                     |                                                                                                                                                                                     |                   |                  |                          |                  |                         |                  |      |    |
| Positive Supply Current               | I <sub>+</sub>      | V <sub>IN</sub> = 0 V, or 5 V                                                                                                                                                       |                   | Room             | 0.6                      |                  | 1.5                     |                  | 1.5  | mA |
| Negative Supply Current               | I <sub>-</sub>      |                                                                                                                                                                                     |                   | Room             | -2.7                     | -5               |                         | -5               |      |    |
| Logic Supply Current                  | I <sub>L</sub>      |                                                                                                                                                                                     |                   | Room             | 3.1                      |                  | 4.5                     |                  | 4.5  |    |
| Reference Supply Current              | I <sub>R</sub>      |                                                                                                                                                                                     |                   | Room             | -1                       | -2               |                         | -2               |      |    |

## Notes:

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- Room = 25°C, Full = as determined by the operating temperature suffix.
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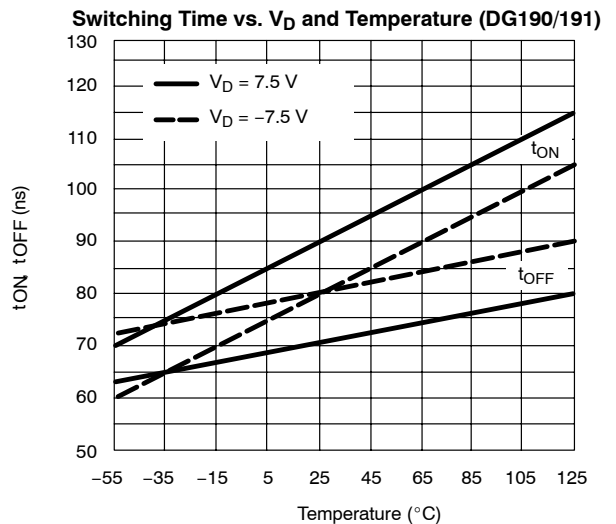
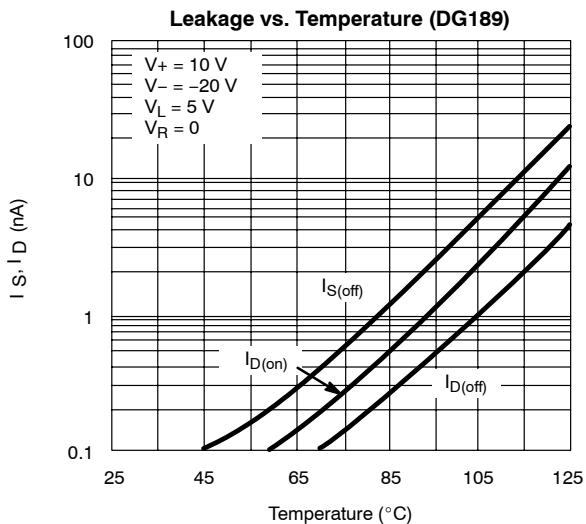
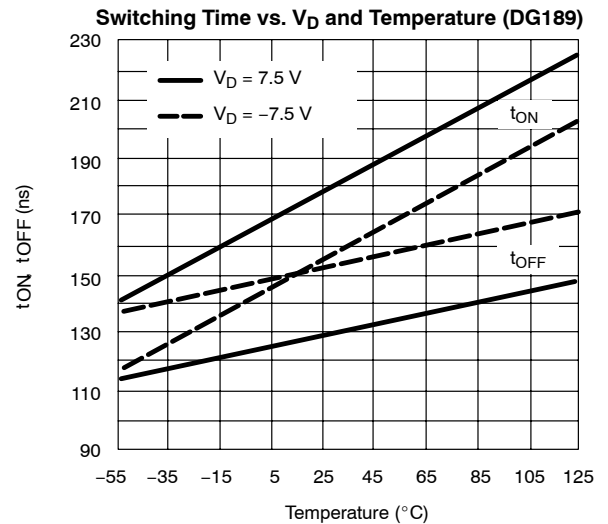
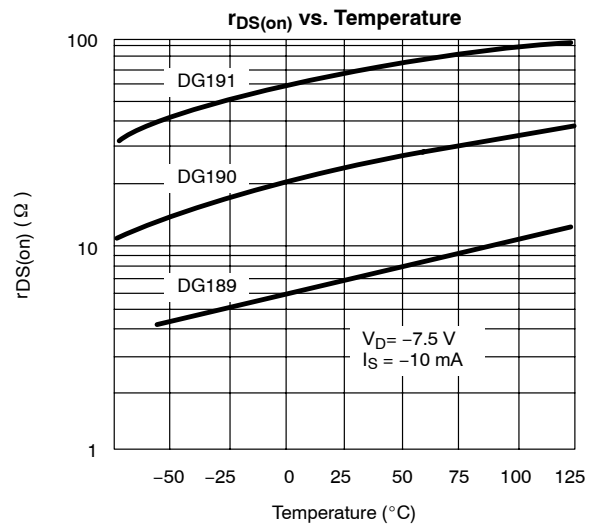
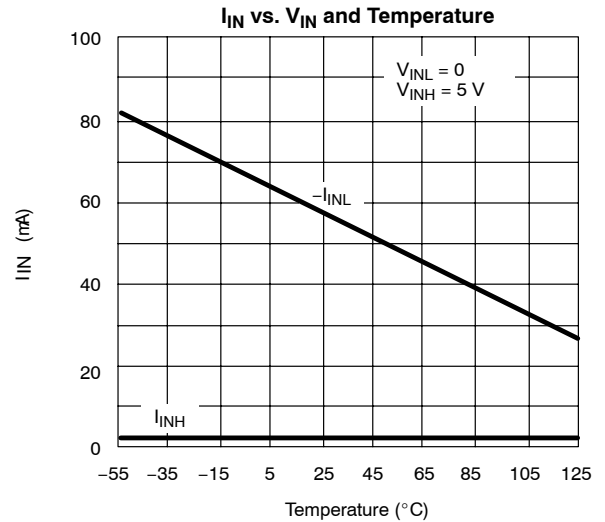
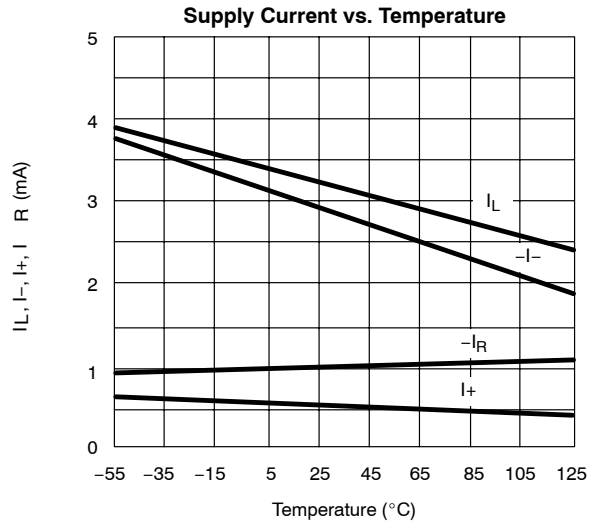
**SPECIFICATIONS<sup>a</sup> FOR DG191**

| Parameter                             | Symbol              | Test Conditions<br>Unless Specified<br><br>V <sub>+</sub> = 15 V, V <sub>-</sub> = -15 V, V <sub>L</sub> = 5 V<br>V <sub>R</sub> = 0 V, V <sub>IN</sub> = 0.8 V or 2 V <sup>f</sup> | Temp <sup>b</sup>                         | Typ <sup>c</sup> | A Suffix<br>-55 to 125°C |                  | B Suffix<br>-25 to 85°C |                  | Unit |    |
|---------------------------------------|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------|------------------|--------------------------|------------------|-------------------------|------------------|------|----|
|                                       |                     |                                                                                                                                                                                     |                                           |                  | Min <sup>d</sup>         | Max <sup>d</sup> | Min <sup>d</sup>        | Max <sup>d</sup> |      |    |
| Analog Switch                         |                     |                                                                                                                                                                                     |                                           |                  |                          |                  |                         |                  |      |    |
| Analog Signal Range <sup>e</sup>      | V <sub>ANALOG</sub> |                                                                                                                                                                                     | Full                                      |                  | -10                      | 15               | -10                     | 15               | V    |    |
| Drain-Source On-Resistance            | r <sub>DS(on)</sub> | I <sub>S</sub> = -10 mA, V <sub>D</sub> = -7.5 V                                                                                                                                    | Room Full                                 | 35               |                          | 75<br>150        |                         | 100<br>150       | Ω    |    |
| Source Off Leakage Current            | I <sub>S(off)</sub> | V <sub>S</sub> = ±10 V, V <sub>D</sub> = ∓10 V<br>V <sub>+</sub> = 10 V, V <sub>-</sub> = -20 V                                                                                     | Room Hot                                  | 0.05             |                          | 1<br>100         |                         | 5<br>100         | nA   |    |
|                                       |                     | V <sub>S</sub> = ±10 V, V <sub>D</sub> = ∓10 V                                                                                                                                      | Room Hot                                  | 0.07             |                          | 1<br>100         |                         | 5<br>100         |      |    |
| Drain Off Leakage Current             | I <sub>D(off)</sub> | V <sub>S</sub> = ±10 V, V <sub>D</sub> = ∓10 V<br>V <sub>+</sub> = 10 V, V <sub>-</sub> = -20 V                                                                                     | Room Hot                                  | 0.04             |                          | 1<br>100         |                         | 5<br>100         |      |    |
|                                       |                     | V <sub>S</sub> = ±10 V, V <sub>D</sub> = ∓10 V                                                                                                                                      | Room Hot                                  | 0.05             |                          | 1<br>100         |                         | 5<br>100         |      |    |
| Channel On Leakage Current            | I <sub>D(on)</sub>  | V <sub>D</sub> = V <sub>S</sub> = ±10 V                                                                                                                                             | Room Hot                                  | -0.03            | -2<br>-200               |                  | -10<br>-200             |                  |      |    |
| Digital Input                         |                     |                                                                                                                                                                                     |                                           |                  |                          |                  |                         |                  |      |    |
| Input Current with Input Voltage High | I <sub>INH</sub>    | V <sub>IN</sub> = 5 V                                                                                                                                                               | Room Hot                                  | <0.01            |                          | 10<br>20         |                         | 10<br>20         | μA   |    |
| Input Current with Input Voltage Low  | I <sub>INL</sub>    | V <sub>IN</sub> = 0 V                                                                                                                                                               | Full                                      | -30              | -250                     |                  | -250                    |                  |      |    |
| Dynamic Characteristics               |                     |                                                                                                                                                                                     |                                           |                  |                          |                  |                         |                  |      |    |
| Turn-On Time                          | t <sub>on</sub>     | See Switching Time Test Circuit                                                                                                                                                     |                                           | Room             | 120                      |                  | 250                     |                  | 300  | ns |
| Turn-Off Time                         | t <sub>off</sub>    |                                                                                                                                                                                     |                                           | Room             | 100                      |                  | 130                     |                  | 150  |    |
| Source-Off Capacitance                | C <sub>S(off)</sub> | f = 1 MHz                                                                                                                                                                           | V <sub>S</sub> = -5 V, I <sub>D</sub> = 0 | Room             | 9                        |                  |                         |                  |      | pF |
| Drain-Off Capacitance                 | C <sub>D(off)</sub> |                                                                                                                                                                                     | V <sub>D</sub> = -5 V, I <sub>S</sub> = 0 | Room             | 6                        |                  |                         |                  |      |    |
| Channel-On Capacitance                | C <sub>D(on)</sub>  |                                                                                                                                                                                     | V <sub>D</sub> = V <sub>S</sub> = 0 V     | Room             | 14                       |                  |                         |                  |      |    |
| Off Isolation                         | OIRR                | f = 1 MHz, R <sub>L</sub> = 75 Ω                                                                                                                                                    |                                           | Room             | >50                      |                  |                         |                  |      | dB |
| Positive Supply Current               | I <sub>+</sub>      | V <sub>IN</sub> = 0 V, or 5 V                                                                                                                                                       |                                           | Room             | 0.6                      |                  | 1.5                     |                  | 1.5  | mA |
| Negative Supply Current               | I <sub>-</sub>      |                                                                                                                                                                                     |                                           | Room             | -2.7                     | -5               |                         | -5               |      |    |
| Logic Supply Current                  | I <sub>L</sub>      |                                                                                                                                                                                     |                                           | Room             | 3.1                      |                  | 4.5                     |                  | 4.5  |    |
| Reference Supply Current              | I <sub>R</sub>      |                                                                                                                                                                                     |                                           | Room             | -1                       | -2               |                         | -2               |      |    |

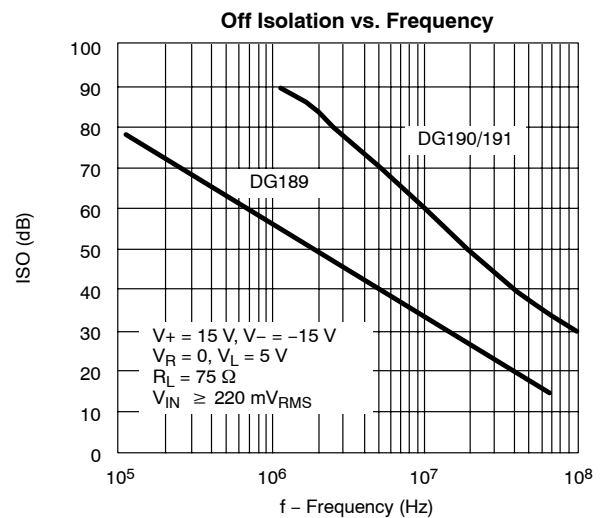
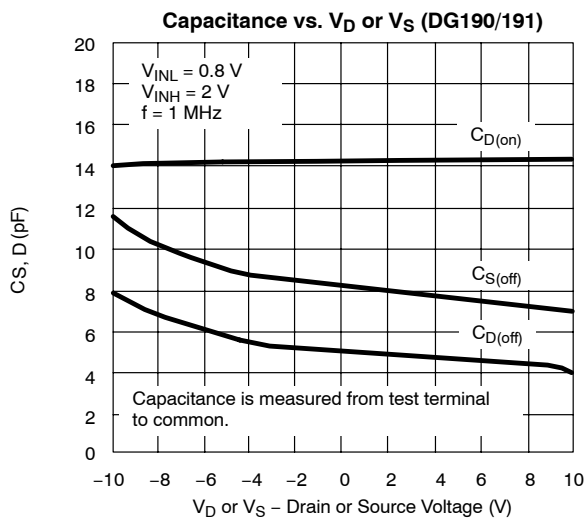
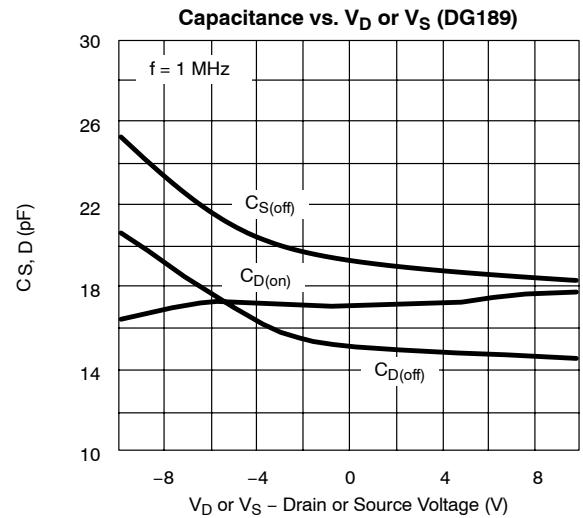
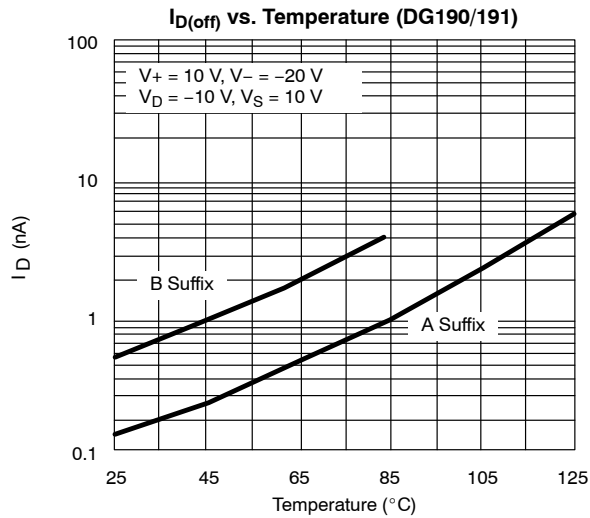
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### TYPICAL CHARACTERISTICS (25°C UNLESS NOTED)



## TYPICAL CHARACTERISTICS (25°C UNLESS NOTED)





TEST CIRCUITS

Feedthrough due to charge injection may result in spikes at the leading and trailing edge of the output waveform.

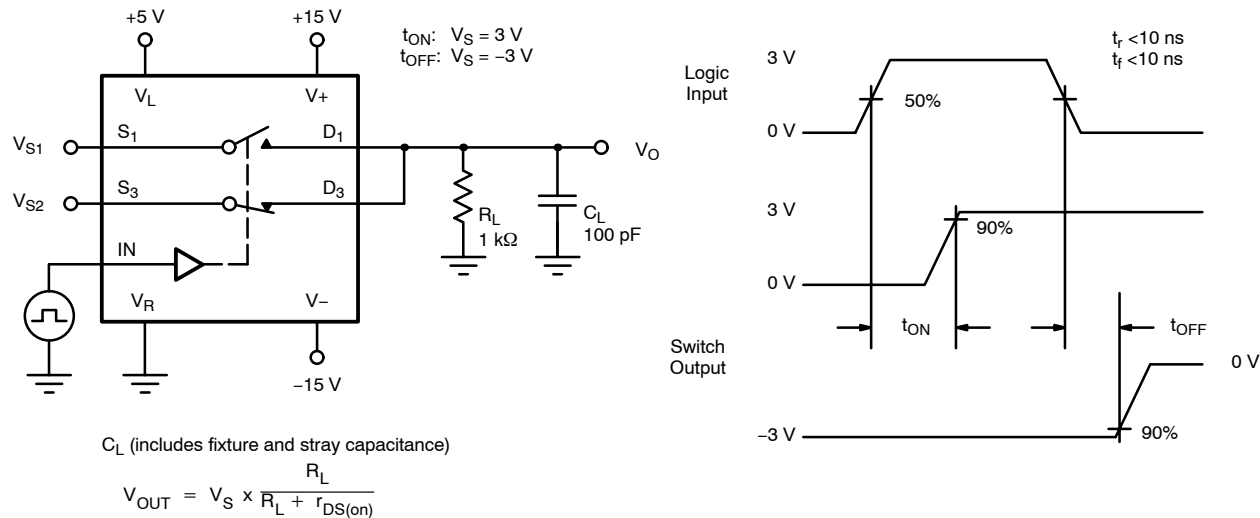


FIGURE 2. Switching Time

| APPLICATION HINTS <sup>a</sup> |                                         |                                         |                                                  |                                                         |                                                                                                  |                                                     |
|--------------------------------|-----------------------------------------|-----------------------------------------|--------------------------------------------------|---------------------------------------------------------|--------------------------------------------------------------------------------------------------|-----------------------------------------------------|
| Switch                         | V+<br>Positive<br>Supply Voltage<br>(V) | V-<br>Negative<br>Supply Voltage<br>(V) | V <sub>L</sub><br>Logic Supply<br>Voltage<br>(V) | V <sub>R</sub><br>Reference<br>Supply<br>Voltage<br>(V) | V <sub>IN</sub><br>Logic Input<br>Voltage<br>V <sub>INH(min)</sub> /V <sub>INL(max)</sub><br>(V) | V <sub>S</sub><br>Analog<br>Voltage<br>Range<br>(V) |
| DG189<br>DG190                 | 15 <sup>b</sup>                         | -15                                     | 5                                                | GND                                                     | 2.0/0.8                                                                                          | -7.5 to 15                                          |
|                                | 10                                      | -20                                     | 5                                                | GND                                                     | 2.0/0.8                                                                                          | -12.5 to 10                                         |
|                                | 12                                      | -12                                     | 5                                                | GND                                                     | 2.0/0.8                                                                                          | -4.5 to 12                                          |
| DG191                          | 15 <sup>b</sup>                         | -15                                     | 5                                                | GND                                                     | 2.0/0.8                                                                                          | -10 to 15                                           |
|                                | 10                                      | -20                                     | 5                                                | GND                                                     | 2.0/0.8                                                                                          | -15 to 10                                           |
|                                | 12                                      | -12                                     | 5                                                | GND                                                     | 2.0/0.8                                                                                          | -7 to 12                                            |

Notes:

a. Application Hints are for DESIGN AID ONLY, not guaranteed and not subject to production testing.

b. Electrical Parameter Chart based on V+ = 15 V, V<sub>L</sub> = 5 V, V<sub>R</sub> = GND



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