

## ADG508F/ADG509F/ADG528F\*

### FEATURES

- Low On Resistance (300  $\Omega$  Typ)
- Fast Switching Times
  - $t_{ON}$  250 ns Max
  - $t_{OFF}$  250 ns Max
- Low Power Dissipation (3.3 mW Max)
- Fault and Overvoltage Protection (-40 V to +55 V)
- All Switches OFF with Power Supply OFF
- Analog Output of ON Channel Clamped within Power Supplies if an Overvoltage Occurs
- Latch-Up Proof Construction
- Break before Make Construction
- TTL and CMOS Compatible Inputs

### APPLICATIONS

- Existing Multiplexer Applications (Both Fault-Protected and Nonfault-Protected)
- New Designs Requiring Multiplexer Functions

### GENERAL DESCRIPTION

The ADG508F, ADG509F, and ADG528F are CMOS analog multiplexers, the ADG508F and ADG528F comprising eight single channels and the ADG509F comprising four differential channels. These multiplexers provide fault protection. Using a series n-channel, p-channel, n-channel MOSFET structure, both device and signal source protection is provided in the event of an overvoltage or power loss. The multiplexer can withstand continuous overvoltage inputs from -40 V to +55 V. During fault conditions, the multiplexer input (or output) appears as an open circuit and only a few nanoamperes of leakage current will flow. This protects not only the multiplexer and the circuitry driven by the multiplexer, but also protects the sensors or signal sources that drive the multiplexer.

The ADG508F and ADG528F switch one of eight inputs to a common output as determined by the 3-bit binary address lines A0, A1, and A2. The ADG509F switches one of four differential inputs to a common differential output as determined by the 2-bit binary address lines A0 and A1. The ADG528F has on-chip address and control latches that facilitate microprocessor interfacing. An EN input on each device is used to enable or disable the device. When disabled, all channels are switched OFF.

### PRODUCT HIGHLIGHTS

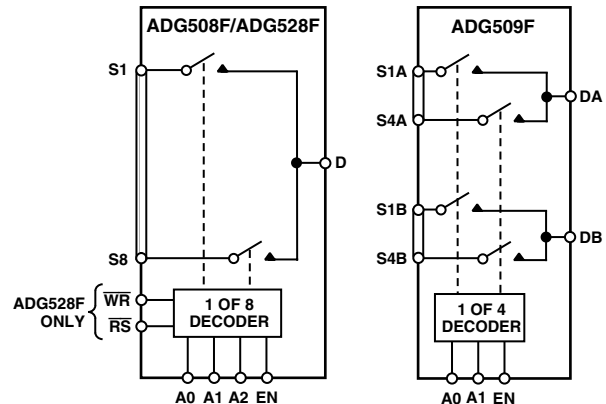
1. Fault Protection.  
The ADG508F/ADG509F/ADG528F can withstand continuous voltage inputs from -40 V to +55 V. When a fault occurs due to the power supplies being turned off, all the channels are turned off and only a leakage current of a few nanoamperes flows.

\*Patent Pending.

### REV. D

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### FUNCTIONAL BLOCK DIAGRAMS



2. ON channel turns off while fault exists.
3. Low  $R_{ON}$ .
4. Fast Switching Times.
5. Break-Before-Make Switching.  
Switches are guaranteed break-before-make so that input signals are protected against momentary shorting.
6. Trench Isolation Eliminates Latch-up.  
A dielectric trench separates the p and n-channel MOSFETs thereby preventing latch-up.

### ORDERING GUIDE

Model	Temperature Range	Package Option*
ADG508FBN	-40°C to +85°C	N-16
ADG508FBRN	-40°C to +85°C	R-16N
ADG508FBRW	-40°C to +85°C	R-16W
ADG509FBN	-40°C to +85°C	N-16
ADG509FBRN	-40°C to +85°C	R-16N
ADG509FBRW	-40°C to +85°C	R-16W
ADG528FBN	-40°C to +85°C	N-18
ADG528FBP	-40°C to +85°C	P-20A

\*N = Plastic DIP; P = Plastic Leaded Chip Carrier (PLCC); RN = 0.15" Small Outline IC (SOIC), RW = 0.3" Small Outline IC (SOIC).

# ADG508F/ADG509F/ADG528F—SPECIFICATIONS

Dual Supply ( $V_{DD} = +15\text{ V} \pm 10\%$ ,  $V_{SS} = -15\text{ V} \pm 10\%$ ,  $GND = 0\text{ V}$ , unless otherwise noted)

Parameter	B Version		Unit	Test Conditions/Comments
	+25°C	-40°C to +85°C		
<b>ANALOG SWITCH</b>				
Analog Signal Range		$V_{SS} + 3$ $V_{DD} - 1.5$	V min V max	
$R_{ON}$	300	350 400	$\Omega$ typ $\Omega$ max	$-10\text{ V} \leq V_S \leq +10\text{ V}$ , $I_S = 1\text{ mA}$ ; $V_{DD} = +15\text{ V} \pm 10\%$ , $V_{SS} = -15\text{ V} \pm 10\%$ $-10\text{ V} \leq V_S \leq +10\text{ V}$ , $I_S = 1\text{ mA}$ ; $V_{DD} = +15\text{ V} \pm 5\%$ , $V_{SS} = -15\text{ V} \pm 5\%$
$R_{ON}$ Drift	0.6		%/°C typ	$V_S = 0\text{ V}$ , $I_S = 1\text{ mA}$
$R_{ON}$ Match	5		% max	$V_S = 0\text{ V}$ , $I_S = 1\text{ mA}$
<b>LEAKAGE CURRENTS</b>				
Source OFF Leakage $I_S$ (OFF)	$\pm 0.02$ $\pm 1$	$\pm 50$	nA typ nA max	$V_D = \pm 10\text{ V}$ , $V_S = \mp 10\text{ V}$ ; Test Circuit 2
Drain OFF Leakage $I_D$ (OFF)	$\pm 0.04$		nA typ	$V_D = \pm 10\text{ V}$ , $V_S = \mp 10\text{ V}$ ; Test Circuit 3
ADG508F/ADG528F	$\pm 1$	$\pm 60$	nA max	
ADG509F	$\pm 1$	$\pm 30$	nA max	
Channel ON Leakage $I_D$ , $I_S$ (ON)	$\pm 0.04$		nA typ	$V_S = V_D = \pm 10\text{ V}$ ; Test Circuit 4
ADG508F/ADG528F	$\pm 1$	$\pm 60$	nA max	
ADG509F	$\pm 1$	$\pm 30$	nA max	
<b>FAULT</b>				
Output Leakage Current (With Overvoltage)	$\pm 0.02$ $\pm 2$	$\pm 2$	nA typ $\mu\text{A}$ max	$V_S = \pm 33\text{ V}$ , $V_D = 0\text{ V}$ , Test Circuit 3
Input Leakage Current (With Overvoltage)	$\pm 0.005$ $\pm 2$		$\mu\text{A}$ typ $\mu\text{A}$ max	$V_S = \pm 25\text{ V}$ , $V_D = \mp 10\text{ V}$ , Test Circuit 5
Input Leakage Current (With Power Supplies OFF)	$\pm 0.001$ $\pm 2$		$\mu\text{A}$ typ $\mu\text{A}$ max	$V_S = \pm 25\text{ V}$ , $V_D = V_{EN} = A0, A1, A2 = 0\text{ V}$ Test Circuit 6
<b>DIGITAL INPUTS</b>				
Input High Voltage, $V_{INH}$		2.4	V min	
Input Low Voltage, $V_{INL}$		0.8	V max	
Input Current, $I_{INL}$ or $I_{INH}$		$\pm 1$	$\mu\text{A}$ max	$V_{IN} = 0$ or $V_{DD}$
$C_{IN}$ , Digital Input Capacitance	5		pF typ	
<b>DYNAMIC CHARACTERISTICS<sup>1</sup></b>				
$t_{TRANSITION}$	200 300	400	ns typ ns max	$R_L = 1\text{ M}\Omega$ , $C_L = 35\text{ pF}$ ; $V_{S1} = \pm 10\text{ V}$ , $V_{S8} = \mp 10\text{ V}$ ; Test Circuit 7
$t_{OPEN}$	50 25	10	ns typ ns min	$R_L = 1\text{ k}\Omega$ , $C_L = 35\text{ pF}$ ; $V_S = 5\text{ V}$ ; Test Circuit 8
$t_{ON}$ (EN, $\overline{WR}$ )	200 250	400	ns typ ns max	$R_L = 1\text{ k}\Omega$ , $C_L = 35\text{ pF}$ ; $V_S = 5\text{ V}$ ; Test Circuit 9
$t_{OFF}$ (EN, $\overline{RS}$ )	200 250	400	ns typ ns max	$R_L = 1\text{ k}\Omega$ , $C_L = 35\text{ pF}$ ; $V_S = 5\text{ V}$ ; Test Circuit 9
$t_{SETT}$ , Settling Time				
0.1%		1	$\mu\text{s}$ typ	$R_L = 1\text{ k}\Omega$ , $C_L = 35\text{ pF}$ ; $V_S = 5\text{ V}$
0.01%		2.5	$\mu\text{s}$ typ	
<b>ADG528F Only</b>				
$t_W$ , Write Pulsewidth	100	120	ns min	
$t_S$ , Address, Enable Setup Time		100	ns min	
$t_H$ , Address, Enable Hold Time		10	ns min	
$t_{RS}$ , Reset Pulsewidth		100	ns min	
Charge Injection	4		pC typ	$V_S = 0\text{ V}$ , $R_S = 0\text{ }\Omega$ , $C_L = 1\text{ nF}$ ; Test Circuit 12
OFF Isolation	68 50		dB typ dB min	$R_L = 1\text{ k}\Omega$ , $C_L = 15\text{ pF}$ , $f = 100\text{ kHz}$ ; $V_S = 7\text{ V rms}$ ; Test Circuit 13
$C_S$ (OFF)	5		pF typ	
$C_D$ (OFF)				
ADG508F/ADG528F	50		pF typ	
ADG509F	25		pF typ	
<b>POWER REQUIREMENTS</b>				
$I_{DD}$	0.1	0.2	mA max	$V_{IN} = 0\text{ V}$ or $5\text{ V}$
$I_{SS}$	0.1	0.1	mA max	

## NOTES

<sup>1</sup>Guaranteed by design, not subject to production test.

Specifications subject to change without notice.

# ADG508F/ADG509F/ADG528F

**Table I. ADG508F Truth Table**

A2	A1	A0	EN	ON Switch
X	X	X	0	NONE
0	0	0	1	1
0	0	1	1	2
0	1	0	1	3
0	1	1	1	4
1	0	0	1	5
1	0	1	1	6
1	1	0	1	7
1	1	1	1	8

X = Don't Care

**Table II. ADG509F Truth Table**

A1	A0	EN	ON Switch Pair
X	X	0	NONE
0	0	1	1
0	1	1	2
1	0	1	3
1	1	1	4

X = Don't Care

**Table III. ADG528F Truth Table**

A2	A1	A0	EN	$\overline{WR}$	$\overline{RS}$	ON Switch
X	X	X	X	$\overline{f}$	1	Retains Previous Switch Condition
X	X	X	X	X	0	NONE (Address and Enable Latches Cleared)
X	X	X	0	0	1	NONE
0	0	0	1	0	1	1
0	0	1	1	0	1	2
0	1	0	1	0	1	3
0	1	1	1	0	1	4
1	0	0	1	0	1	5
1	0	1	1	0	1	6
1	1	0	1	0	1	7
1	1	1	1	0	1	8

X = Don't Care

**TIMING DIAGRAMS (ADG528F)**

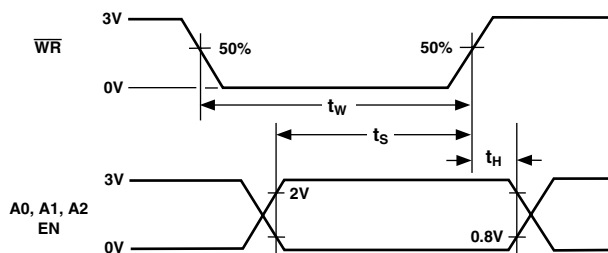


Figure 1.

Figure 1 shows the timing sequence for latching the switch address and enable inputs. The latches are level sensitive; therefore, while  $\overline{WR}$  is held low, the latches are transparent and the switches respond to the address and enable inputs. This input data is latched on the rising edge of  $\overline{WR}$ .

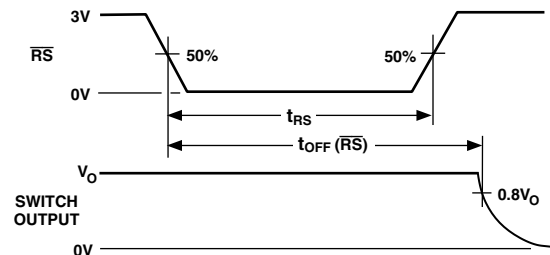


Figure 2.

Figure 2 shows the Reset Pulsewidth,  $t_{RS}$ , and the Reset Turn-off Time,  $t_{OFF}(\overline{RS})$ .

Note: All digital input signals rise and fall times are measured from 10% to 90% of 3 V.  $t_R = t_F = 20$  ns.

# ADG508F/ADG509F/ADG528F

## ABSOLUTE MAXIMUM RATINGS\*

(T<sub>A</sub> = +25°C unless otherwise noted)

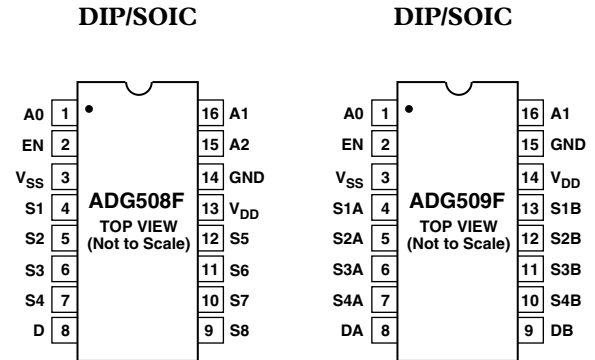
V <sub>DD</sub> to V <sub>SS</sub>	44 V
V <sub>DD</sub> to GND	-0.3 V to +25 V
V <sub>SS</sub> to GND	+0.3 V to -25 V
V <sub>EN</sub> , V <sub>A</sub> Digital Input	-0.3 V to V <sub>DD</sub> + 2 V or 20 mA, Whichever Occurs First
V <sub>S</sub> , Analog Input Overvoltage with Power ON	V <sub>SS</sub> - 25 V to V <sub>DD</sub> + 40 V
V <sub>S</sub> , Analog Input Overvoltage with Power OFF	-40 V to +55 V
Continuous Current, S or D	20 mA
Peak Current, S or D	40 mA (Pulsed at 1 ms, 10% Duty Cycle max)
Operating Temperature Range	
Industrial (B Version)	-40°C to +85°C
Storage Temperature Range	-65°C to +150°C
Junction Temperature	150°C
Plastic Package	
θ <sub>JA</sub> , Thermal Impedance	
16-Lead	117°C
18-Lead	110°C
Lead Temperature, Soldering (10 sec)	260°C
SOIC Package	
θ <sub>JA</sub> , Thermal Impedance	
Narrow Body	77°C/W
Wide Body	75°C/W
Lead Temperature, Soldering	
Vapor Phase (60 sec)	215°C
Infrared (15 sec)	220°C
PLCC Package	
θ <sub>JA</sub> , Thermal Impedance	90°C/W
Lead Temperature, Soldering	
Vapor Phase (60 sec)	215°C
Infrared (15 sec)	220°C

\*Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those listed in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability. Only one absolute maximum rating may be applied at any one time.

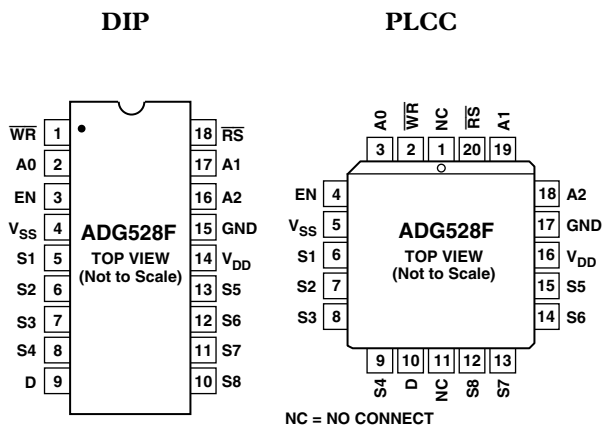
## CAUTION

ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although the ADG508F/ADG509F/ADG528F features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high-energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.

## ADG508F/ADG509F PIN CONFIGURATIONS



## ADG528F PIN CONFIGURATIONS



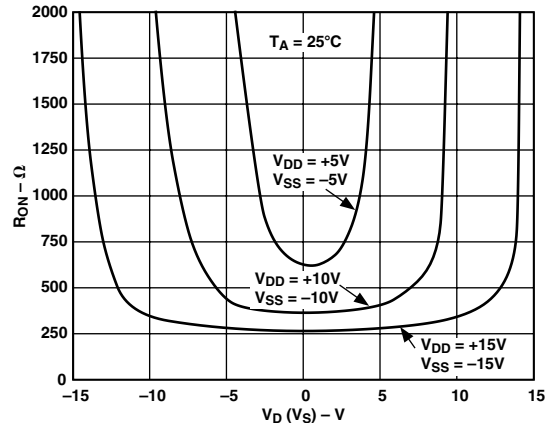
NC = NO CONNECT



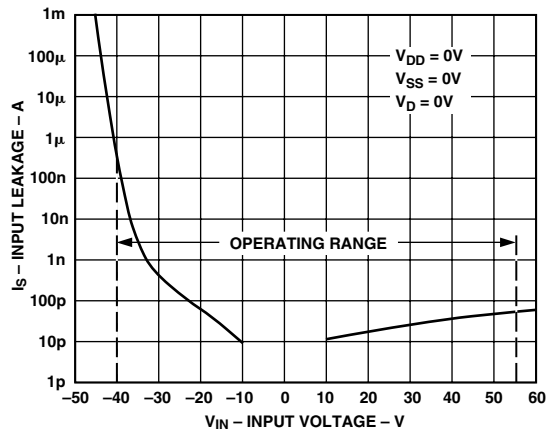
TERMINOLOGY

$V_{DD}$	Most Positive Power Supply Potential.
$V_{SS}$	Most Negative Power Supply Potential.
GND	Ground (0 V) Reference.
$R_{ON}$	Ohmic Resistance between D and S.
$R_{ON}$ Drift	Change in $R_{ON}$ when temperature changes by one degree Celsius.
$R_{ON}$ Match	Difference between the $R_{ON}$ of any two channels.
$I_S$ (OFF)	Source leakage current when the switch is off.
$I_D$ (OFF)	Drain leakage current when the switch is off.
$I_D, I_S$ (ON)	Channel leakage current when the switch is on.
$V_D$ ( $V_S$ )	Analog Voltage on Terminals D, S.
$C_S$ (OFF)	Channel input capacitance for "OFF" condition.
$C_D$ (OFF)	Channel output capacitance for "OFF" condition.
$C_D, C_S$ (ON)	"ON" Switch Capacitance.
$C_{IN}$	Digital Input Capacitance.
$t_{ON}$ (EN)	Delay time between the 50% and 90% points of the digital input and switch "ON" condition.
$t_{OFF}$ (EN)	Delay time between the 50% and 90% points of the digital input and switch "OFF" condition.
$t_{TRANSITION}$	Delay time between the 50% and 90% points of the digital inputs and the switch "ON" condition when switching from one address state to another.
$t_{OPEN}$	"OFF" time measured between 80% points of both switches when switching from one address state to another.
$V_{INL}$	Maximum input voltage for Logic "0".
$V_{INH}$	Minimum input voltage for Logic "1".
$I_{INL}$ ( $I_{INH}$ )	Input current of the digital input.
Off Isolation	A measure of unwanted signal coupling through an "OFF" channel.
Charge Injection	A measure of the glitch impulse transferred from the digital input to the analog output during switching.
$I_{DD}$	Positive Supply Current.
$I_{SS}$	Negative Supply Current.

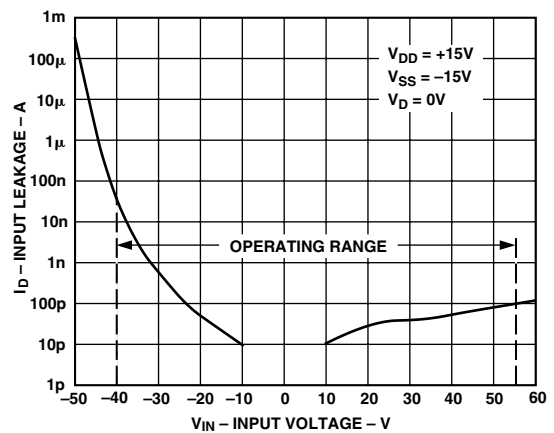
Typical Performance Characteristics



TPC 1. On Resistance as a Function of  $V_D$  ( $V_S$ )

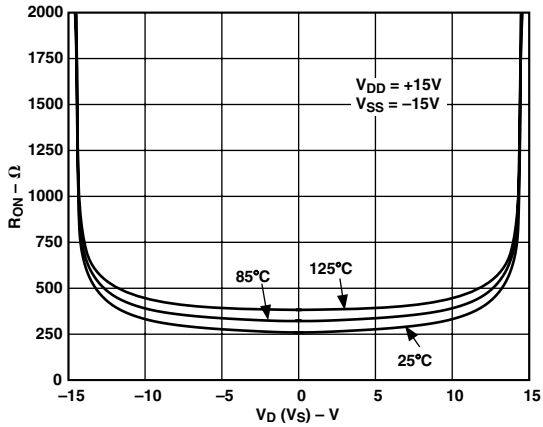


TPC 2. Input Leakage Current as a Function of  $V_S$  (Power Supplies OFF) During Overvoltage Conditions

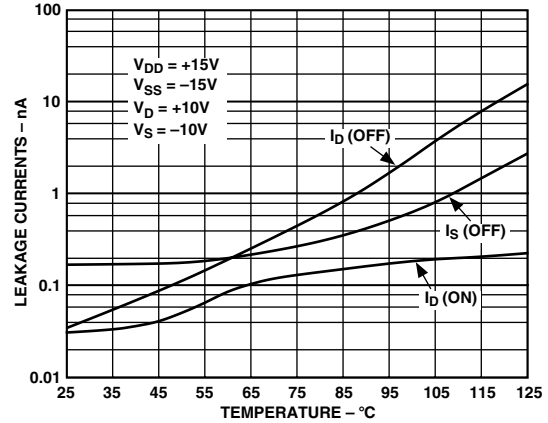


TPC 3. Output Leakage Current as a Function of  $V_S$  (Power Supplies ON) During Overvoltage Conditions

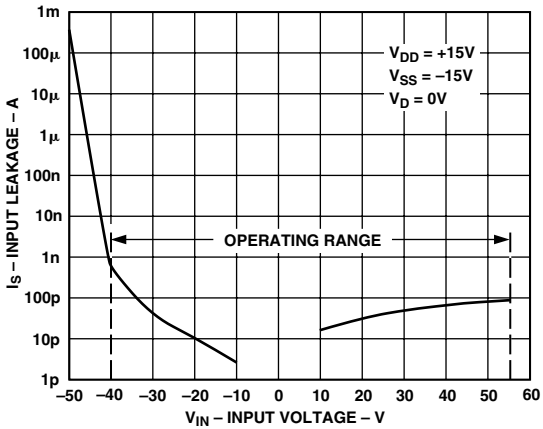
# ADG508F/ADG509F/ADG528F



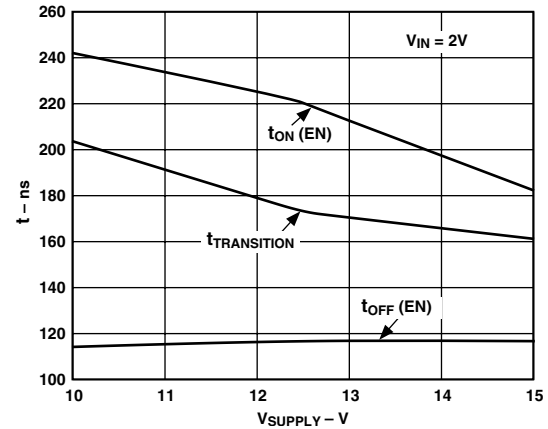
TPC 4. On Resistance as a Function of  $V_D$  ( $V_S$ ) for Different Temperatures



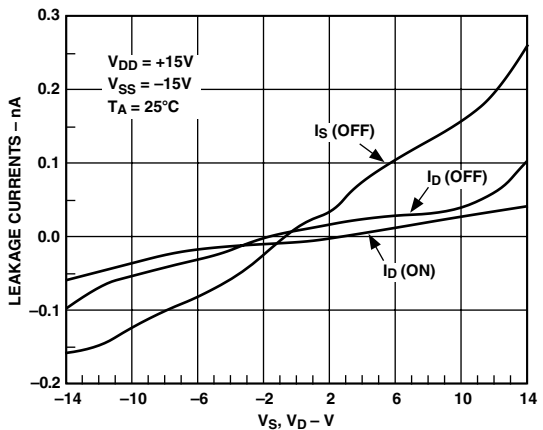
TPC 7. Leakage Currents as a Function of Temperature



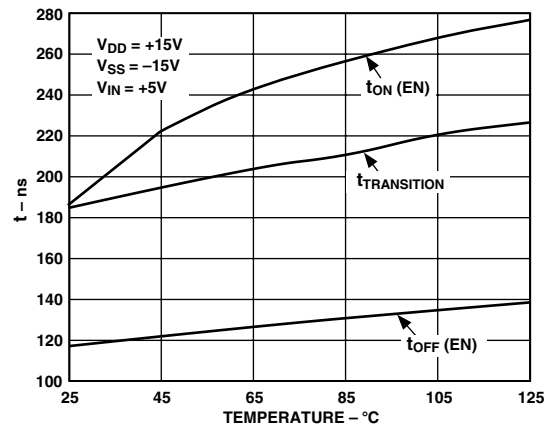
TPC 5. Input Leakage Current as a Function of  $V_S$  (Power Supplies ON) During Overvoltage Conditions



TPC 8. Switching Time vs. Power Supply



TPC 6. Leakage Currents as a Function of  $V_D$  ( $V_S$ )



TPC 9. Switching Time vs. Temperature

## THEORY OF OPERATION

The ADG508F/ADG509F/ADG528F multiplexers are capable of withstanding overvoltages from  $-40\text{ V}$  to  $+55\text{ V}$ , irrespective of whether the power supplies are present or not. Each channel of the multiplexer consists of an n-channel MOSFET, a p-channel MOSFET, and an n-channel MOSFET, connected in series. When the analog input exceeds the power supplies, one of the MOSFETs will switch off, limiting the current to submicroamp levels, thereby preventing the overvoltage from damaging any circuitry following the multiplexer. Figure 3 illustrates the channel architecture that enables these multiplexers to withstand continuous overvoltages.

When an analog input of  $V_{SS} + 3\text{ V}$  to  $V_{DD} - 1.5\text{ V}$  is applied to the ADG508F/ADG509F/ADG528F, the multiplexer behaves as a standard multiplexer, with specifications similar to a standard multiplexer, for example, the on-resistance is  $400\ \Omega$  maximum. However, when an overvoltage is applied to the device, one of the three MOSFETs will turn off.

Figures 3 to 6 show the conditions of the three MOSFETs for the various overvoltage situations. When the analog input applied to an ON channel approaches the positive power supply line, the n-channel MOSFET turns OFF since the voltage on the analog input exceeds the difference between  $V_{DD}$  and the n-channel

threshold voltage ( $V_{TN}$ ). When a voltage more negative than  $V_{SS}$  is applied to the multiplexer, the p-channel MOSFET will turn off since the analog input is more negative than the difference between  $V_{SS}$  and the p-channel threshold voltage ( $V_{TP}$ ). Since  $V_{TN}$  is nominally  $1.5\text{ V}$  and  $V_{TP}$  is typically  $3\text{ V}$ , the analog input range to the multiplexer is limited to  $-12\text{ V}$  to  $+13.5\text{ V}$  when a  $\pm 15\text{ V}$  power supply is used.

When the power supplies are present but the channel is off, again either the p-channel MOSFET or one of the n-channel MOSFETs will turn off when an overvoltage occurs.

Finally, when the power supplies are off, the gate of each MOSFET will be at ground. A negative overvoltage switches on the first n-channel MOSFET but the bias produced by the overvoltage causes the p-channel MOSFET to remain turned off. With a positive overvoltage, the first MOSFET in the series will remain off since the gate to source voltage applied to this MOSFET is negative.

During fault conditions, the leakage current into and out of the ADG508F/ADG509F/ADG528F is limited to a few microamps. This protects the multiplexer and succeeding circuitry from over stresses as well as protecting the signal sources which drive the multiplexer. Also, the other channels of the multiplexer will be undisturbed by the overvoltage and will continue to operate normally.

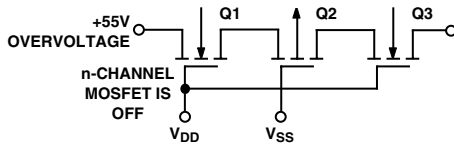


Figure 3. +55 V Overvoltage Input to the ON Channel

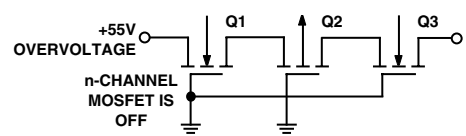


Figure 5. +55 V Overvoltage with Power OFF

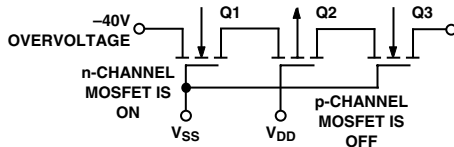


Figure 4.  $-40\text{ V}$  Overvoltage on an OFF Channel with Multiplexer Power ON

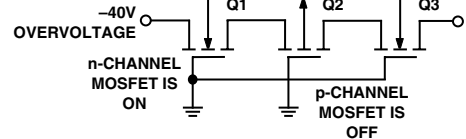
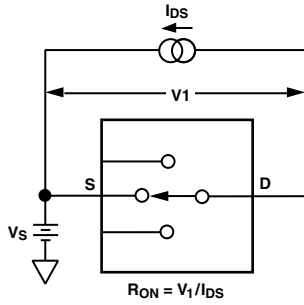


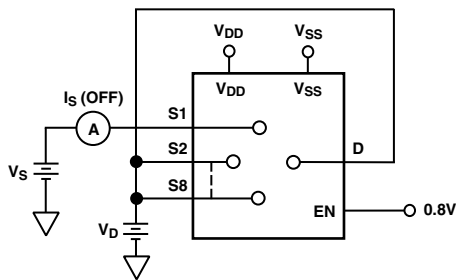
Figure 6.  $-40\text{ V}$  Overvoltage with Power OFF

# ADG508F/ADG509F/ADG528F

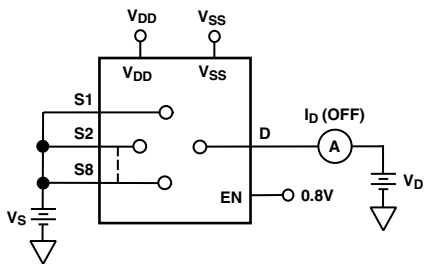
## Test Circuits



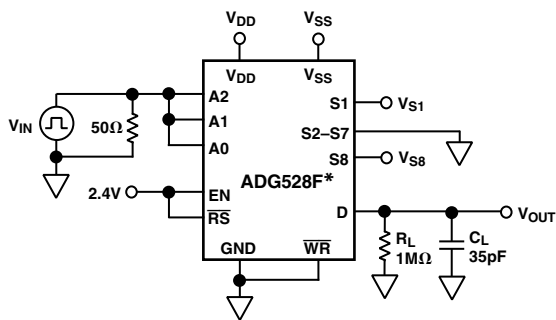
Test Circuit 1. On Resistance



Test Circuit 2.  $I_S$  (OFF)

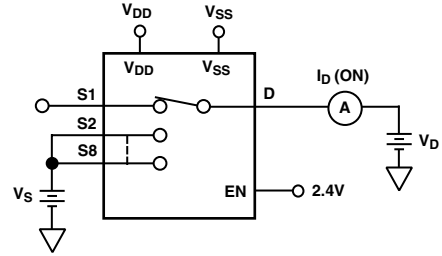


Test Circuit 3.  $I_D$  (OFF)

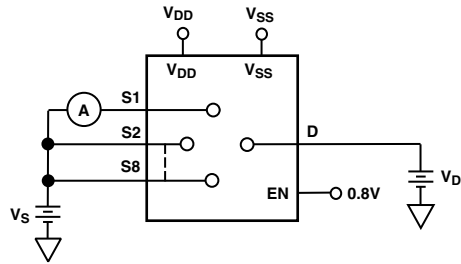


\* SIMILAR CONNECTION FOR ADG508F/ADG509F

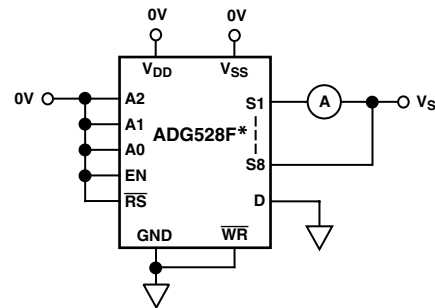
Test Circuit 7. Switching Time of Multiplexer,  $t_{TRANSITION}$



Test Circuit 4.  $I_D$  (ON)

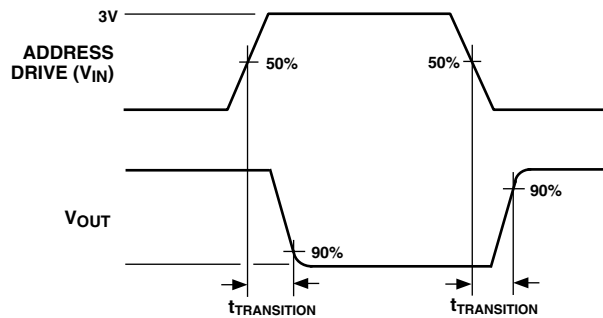


Test Circuit 5. Input Leakage Current (with Overvoltage)



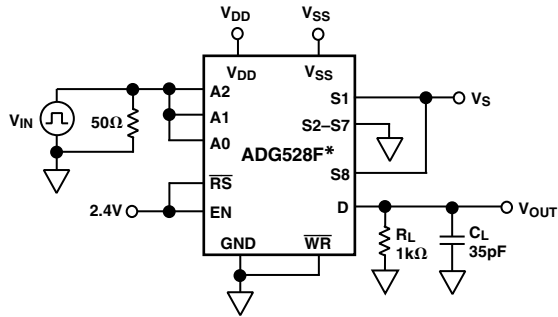
\* SIMILAR CONNECTION FOR ADG508F/ADG509F

Test Circuit 6. Input Leakage Current (with Power Supplies OFF)

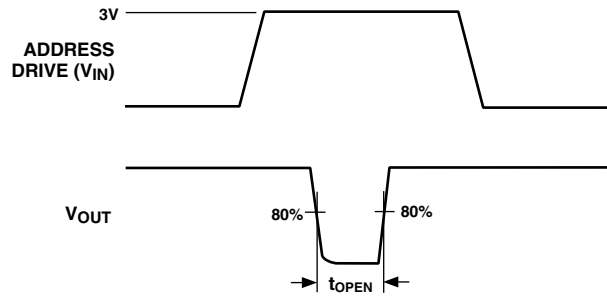




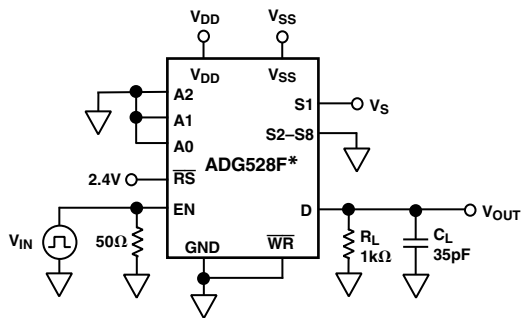
# ADG508F/ADG509F/ADG528F



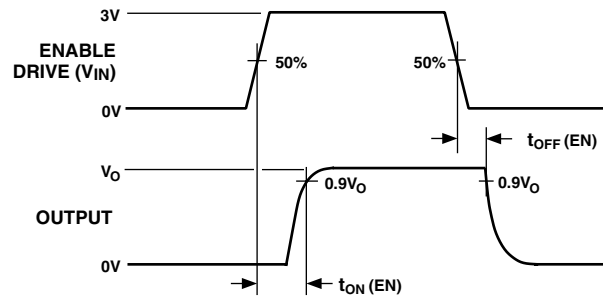
\* SIMILAR CONNECTION FOR ADG508F/ADG509F



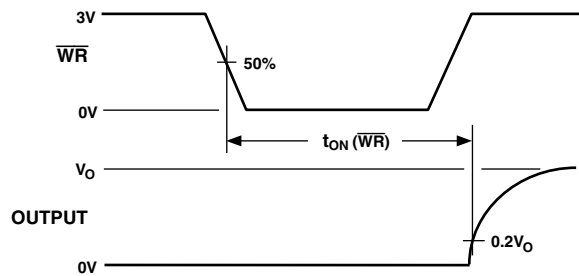
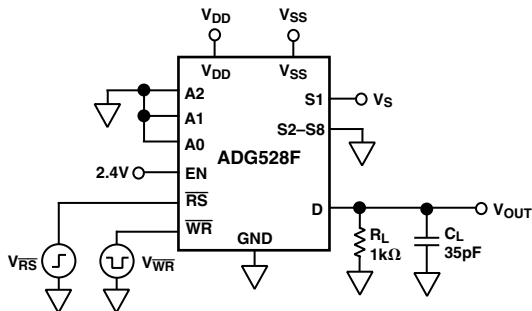
Test Circuit 8. Break-Before-Make Delay,  $t_{OPEN}$



\* SIMILAR CONNECTION FOR ADG508F/ADG509F

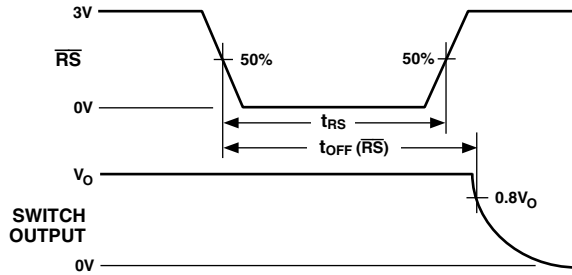
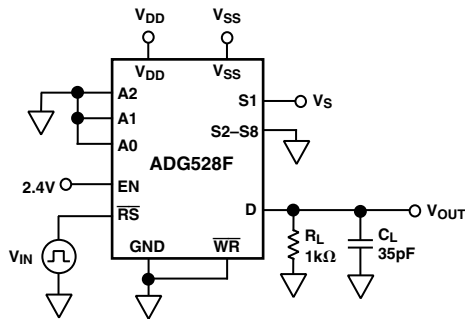


Test Circuit 9. Enable Delay,  $t_{ON}(EN)$ ,  $t_{OFF}(EN)$

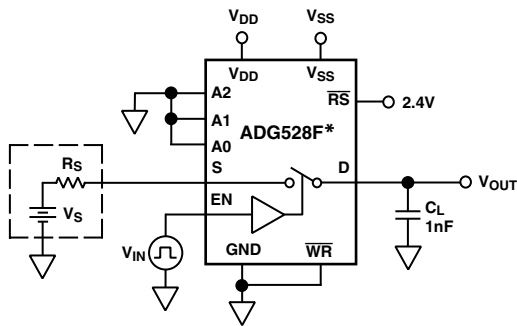


Test Circuit 10. Write Turn-On Time,  $t_{ON}(\overline{WR})$

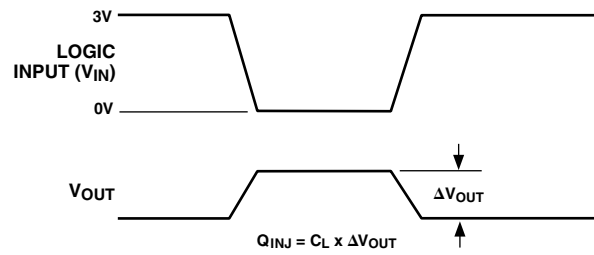
# ADG508F/ADG509F/ADG528F



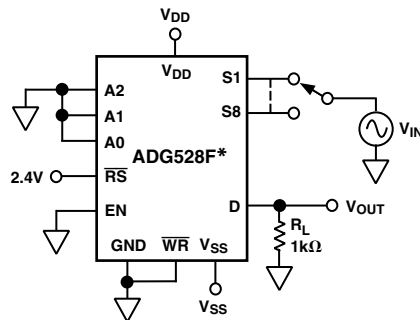
Test Circuit 11. Reset Turn-Off Time,  $t_{OFF}(\overline{RS})$



\* SIMILAR CONNECTION FOR ADG508F/ADG509F



Test Circuit 12. Charge Injection



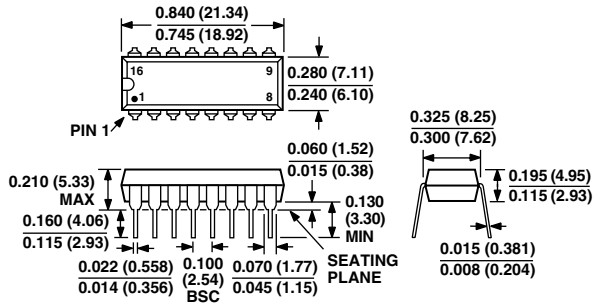
\* SIMILAR CONNECTION FOR ADG508F/ADG509F

Test Circuit 13. OFF Isolation

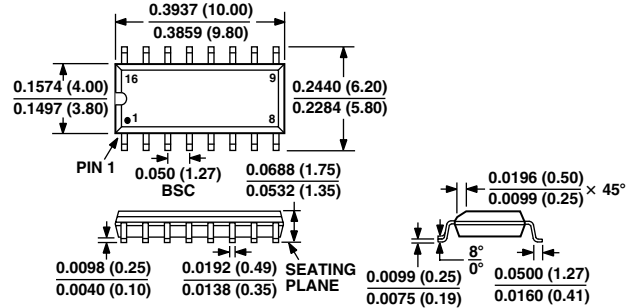
## OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).

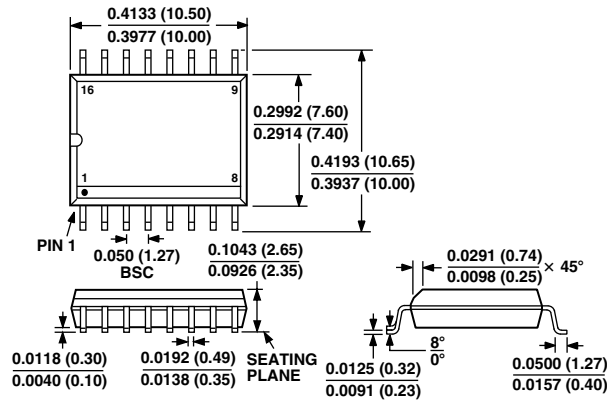
### 16-Lead Plastic (N-16)



### 16-Lead SOIC (R-16N) (Narrow Body)



### 16-Lead SOIC (R-16W) (Wide Body)

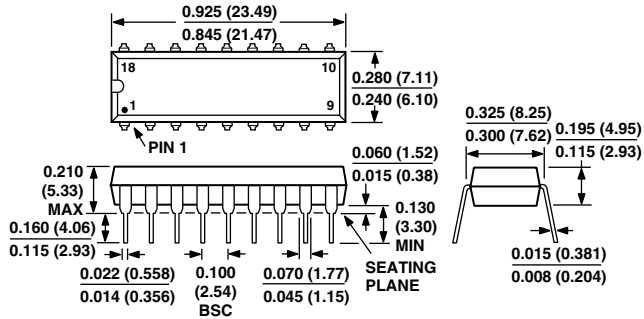


# ADG508F/ADG509F/ADG528F

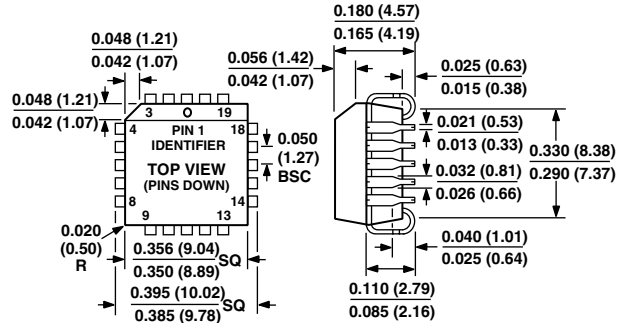
## OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).

18-Lead Plastic (N-18)



20-Lead PLCC (P-20A)



C00035c-0-4/01(D)

## ADG508F/ADG509F/ADG528F—Revision History

Location	Page
Data Sheet changed from REV. C to REV. D.	
Changes to Ordering Guide	1
Changes to Specifications table	2
MAX RATINGS changed	4
Deleted 16-Lead Cerdip from Outline Dimensions	11
Deleted 18-Lead Cerdip from Outline Dimensions	12

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