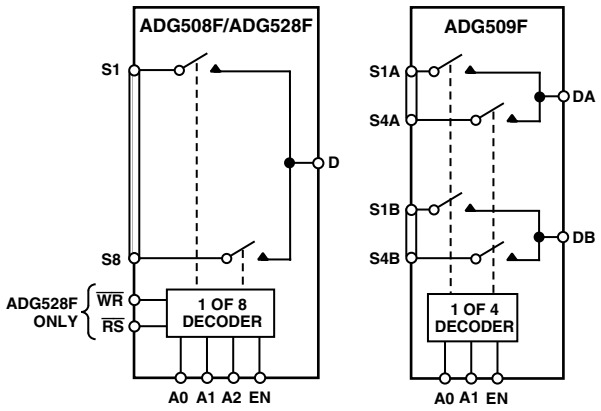
4/8 Channel Fault-Protected Analog Multiplexers

ADG508F/ADG509F/ADG528F*

FEATURES
Low On Resistance (300 Ω 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

FUNCTIONAL BLOCK DIAGRAMS



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.

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).

REV. D

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ADG508F/ADG509F/ADG528F–SPECIFICATIONS

Dual Supply (V_{DD} = +15 V ± 10%, V_{SS} = –15 V ± 10%, GND = 0 V, unless otherwise noted)

Parameter	B Version +25°C	B Version –40°C to +85°C	Unit	Test Conditions/Comments
ANALOG SWITCH				
Analog Signal Range		V_{SS} + 3	V min	
		V_{DD} – 1.5	V max	
R_{ON}	300	350	Ω typ	–10 V ≤ V_S ≤ +10 V, I_S = 1 mA; V_{DD} = +15 V ± 10%, V_{SS} = –15 V ± 10%
		400	Ω max	–10 V ≤ V_S ≤ +10 V, I_S = 1 mA; V_{DD} = +15 V ± 5%, V_{SS} = –15 V ± 5%
R_{ON} Drift	0.6		%/°C typ	V_S = 0 V, I_S = 1 mA
R_{ON} Match	5		% max	V_S = 0 V, I_S = 1 mA
LEAKAGE CURRENTS				
Source OFF Leakage I_S (OFF)	±0.02		nA typ	V_D = ±10 V, V_S = ∓10 V;
	±1	±50	nA max	Test Circuit 2
Drain OFF Leakage I_D (OFF)	±0.04		nA typ	V_D = ±10 V, V_S = ∓10 V;
ADG508F/ADG528F	±1	±60	nA max	Test Circuit 3
ADG509F	±1	±30	nA max	
Channel ON Leakage I_D, I_S (ON)	±0.04		nA typ	V_S = V_D = ±10 V;
ADG508F/ADG528F	±1	±60	nA max	Test Circuit 4
ADG509F	±1	±30	nA max	
FAULT				
Output Leakage Current	±0.02		nA typ	V_S = ±33 V, V_D = 0 V, Test Circuit 3
(With Overvoltage)	±2	±2	µA max	
Input Leakage Current	±0.005		µA typ	V_S = ±25 V, V_D = ∓10 V, Test Circuit 5
(With Overvoltage)	±2		µA max	
Input Leakage Current	±0.001		µA typ	V_S = ±25 V, V_D = V_{EN} = A0, A1, A2 = 0 V
(With Power Supplies OFF)	±2		µA max	Test Circuit 6
DIGITAL INPUTS				
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}		±1	µA max	V_{IN} = 0 or V_{DD}
C_{IN}, Digital Input Capacitance	5		pF typ	
DYNAMIC CHARACTERISTICS[1]				
$t_{TRANSITION}$	200		ns typ	R_L = 1 MΩ, C_L = 35 pF;
	300	400	ns max	V_{S1} = ±10 V, V_{S8} = ∓10 V; Test Circuit 7
t_{OPEN}	50		ns typ	R_L = 1 kΩ, C_L = 35 pF;
	25	10	ns min	V_S = 5 V; Test Circuit 8
t_{ON} (EN, $\overline{WR}$)	200		ns typ	R_L = 1 kΩ, C_L = 35 pF;
	250	400	ns max	V_S = 5 V; Test Circuit 9
t_{OFF} (EN, $\overline{RS}$)	200		ns typ	R_L = 1 kΩ, C_L = 35 pF;
	250	400	ns max	V_S = 5 V; Test Circuit 9
t_{SETT}, Settling Time				
0.1%		1	µs typ	R_L = 1 kΩ, C_L = 35 pF;
0.01%		2.5	µs typ	V_S = 5 V
ADG528F Only				
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 V, R_S = 0 Ω, C_L= 1 nF; Test Circuit 12
OFF Isolation	68		dB typ	R_L = 1 kΩ, C_L = 15 pF, f = 100 kHz;
	50		dB min	V_S = 7 V rms; Test Circuit 13
C_S (OFF)	5		pF typ	
C_D (OFF)				
ADG508F/ADG528F	50		pF typ	
ADG509F	25		pF typ	
POWER REQUIREMENTS				
I_{DD}	0.1	0.2	mA max	V_{IN} = 0 V or 5 V
I_{SS}	0.1	0.1	mA max	

NOTES
[1]Guaranteed by design, not subject to production test.

Specifications subject to change without notice.

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	↑	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)

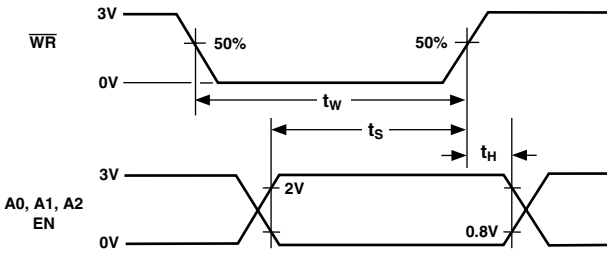


Figure 1.

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 $\overline{WR}$.

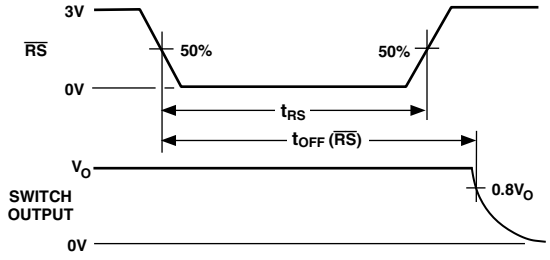


Figure 2.

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.

ABSOLUTE MAXIMUM RATINGS*

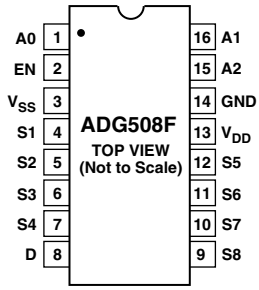
(T_A = +25°C unless otherwise noted)

V_{DD} to V_{SS} . . . . . 44 V
V_{DD} to GND . . . . . –0.3 V to +25 V
V_{SS} to GND . . . . . +0.3 V to –25 V
V_{EN}, V_A Digital Input . . . . . – 0.3 V to V_{DD} + 2 V or 20 mA, Whichever Occurs First
V_S, Analog Input Overvoltage with Power ON . . . . . V_{SS} – 25 V to V_{DD} + 40 V
V_S, Analog Input Overvoltage with Power OFF . . . . . –40 V to +55 V
Continuous Current, S or D . . . . . 20 mA
Peak Current, S or D
(Pulsed at 1 ms, 10% Duty Cycle max) . . . . . 40 mA
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_{JA}, Thermal Impedance
16-Lead . . . . . 117°C
18-Lead . . . . . 110°C
Lead Temperature, Soldering (10 sec) . . . . . 260°C
SOIC Package
θ_{JA}, 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_{JA}, Thermal Impedance . . . . . 90°C/W
Lead Temperature, Soldering
Vapor Phase (60 sec) . . . . . 215°C
Infrared (15 sec) . . . . . 220°C

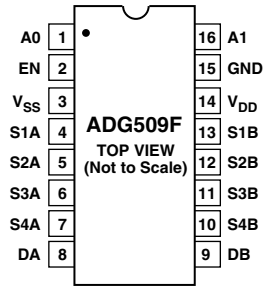
*Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those listed in the operational sections of this specification is not implied. Exposure to absolute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

ADG508F/ADG509F PIN CONFIGURATIONS

DIP/SOIC

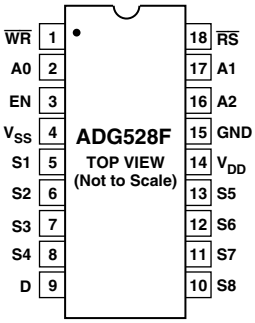


DIP/SOIC

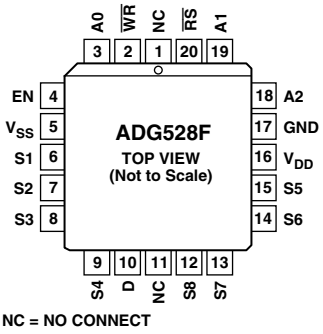


ADG528F PIN CONFIGURATIONS

DIP



PLCC



NC = NO CONNECT

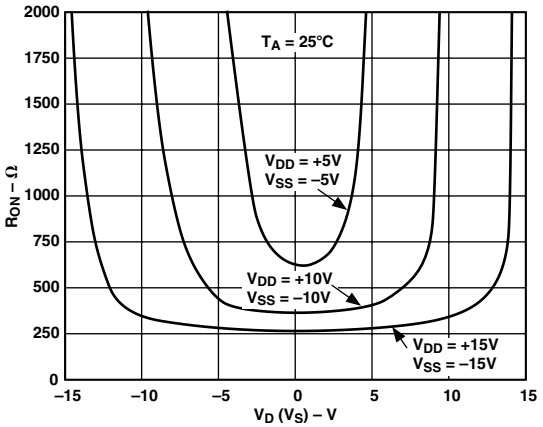
CAUTION

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.

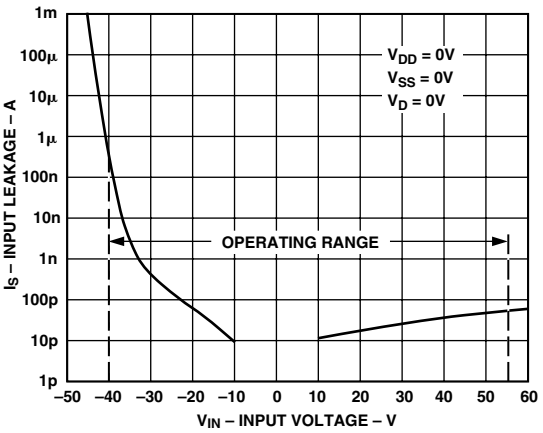
TERMINOLOGY

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.

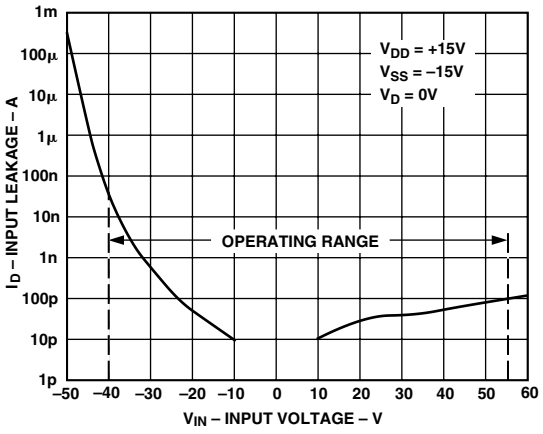
Typical Performance Characteristics



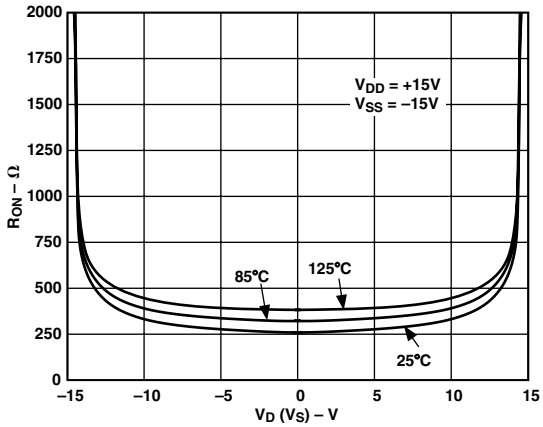
TPC 1. On Resistance as a Function of V_D (V_S)



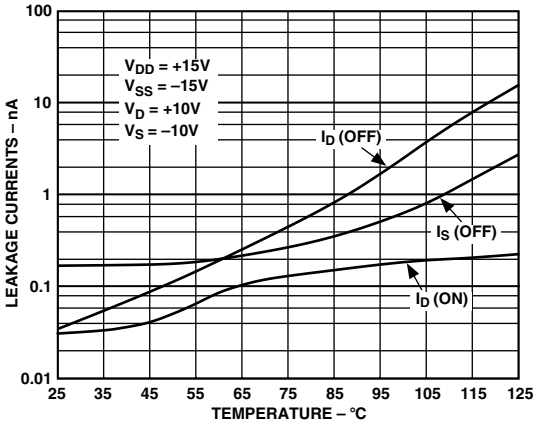
TPC 2. Input Leakage Current as a Function of V_S (Power Supplies OFF) During Overvoltage Conditions



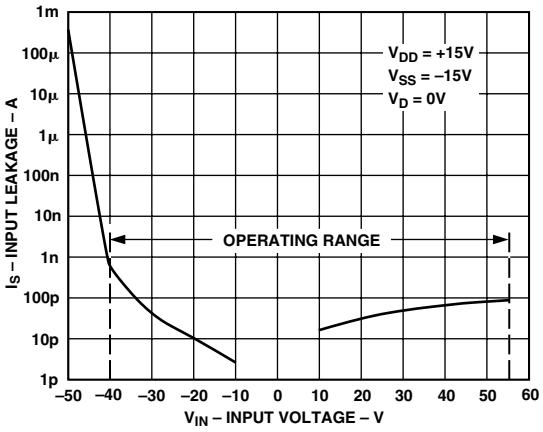
TPC 3. Output Leakage Current as a Function of V_S (Power Supplies ON) During Overvoltage Conditions



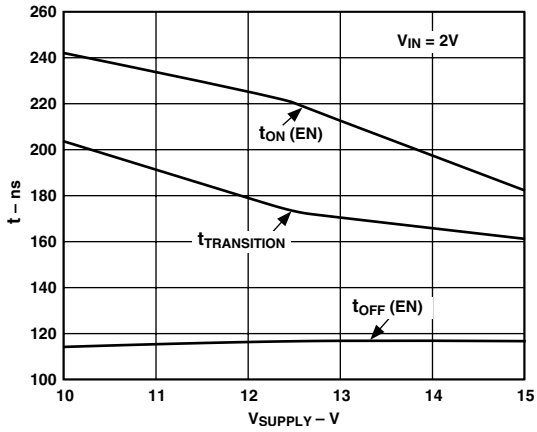
TPC 4. On Resistance as a Function of V_D (V_S) for Different Temperatures



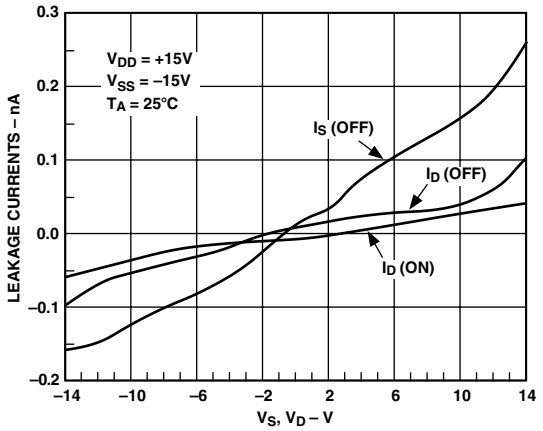
TPC 7. Leakage Currents as a Function of Temperature



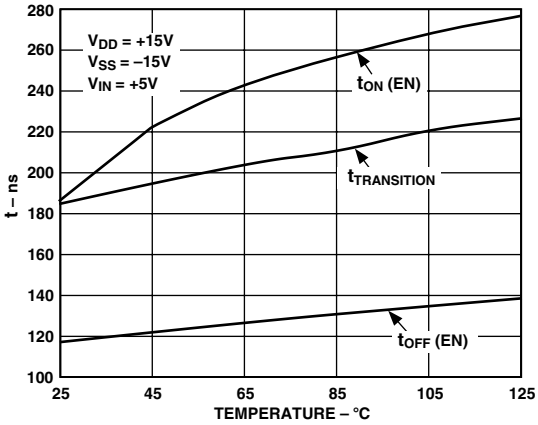
TPC 5. Input Leakage Current as a Function of V_S (Power Supplies ON) During Overvoltage Conditions



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 V to +55 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 V to V_{DD} – 1.5 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 Ω 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 V and V_{TP} is typically 3 V, the analog input range to the multiplexer is limited to –12 V to +13.5 V when a ±15 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.

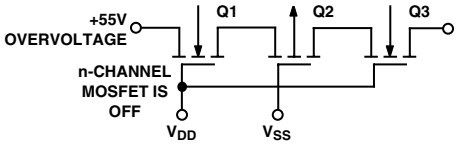


Figure 3. +55 V Overvoltage Input to the ON Channel

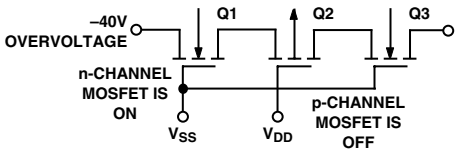


Figure 4. –40 V Overvoltage on an OFF Channel with Multiplexer Power ON

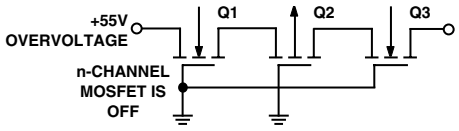


Figure 5. +55 V Overvoltage with Power OFF

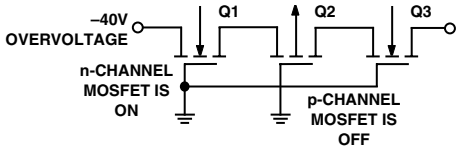
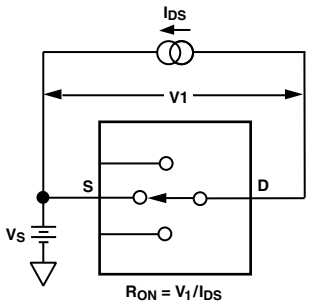
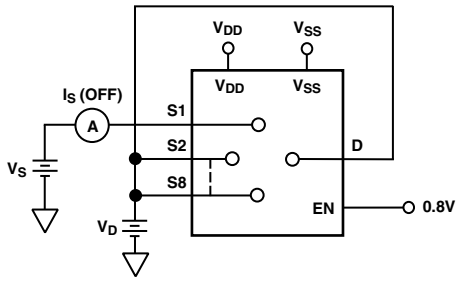


Figure 6. –40 V Overvoltage with Power OFF

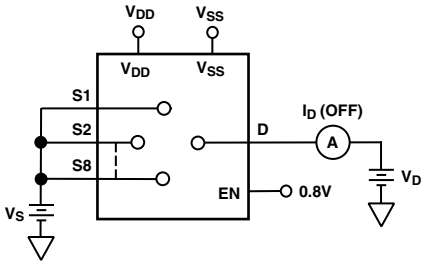
Test Circuits



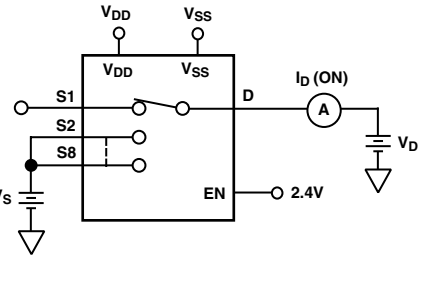
Test Circuit 1. On Resistance



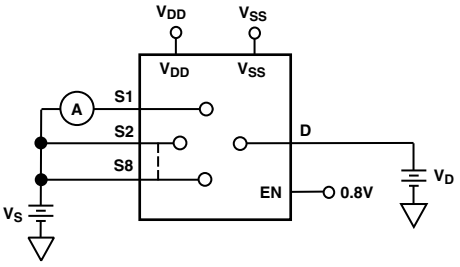
Test Circuit 2. I_S (OFF)



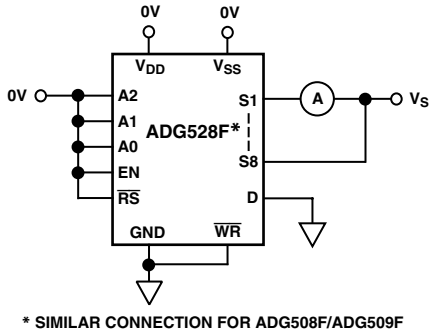
Test Circuit 3. I_D (OFF)



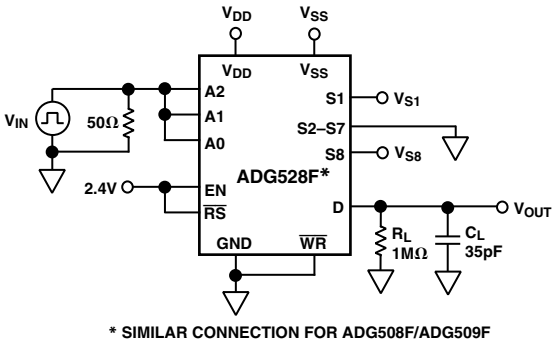
Test Circuit 4. I_D (ON)

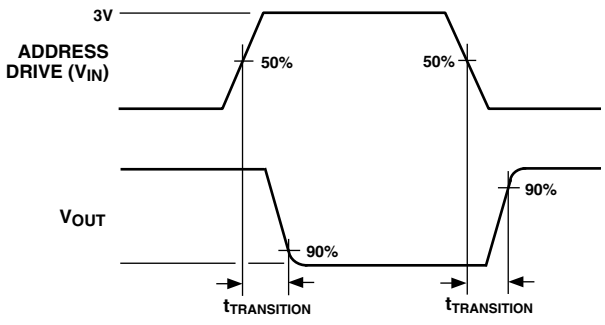


Test Circuit 5. Input Leakage Current (with Overvoltage)

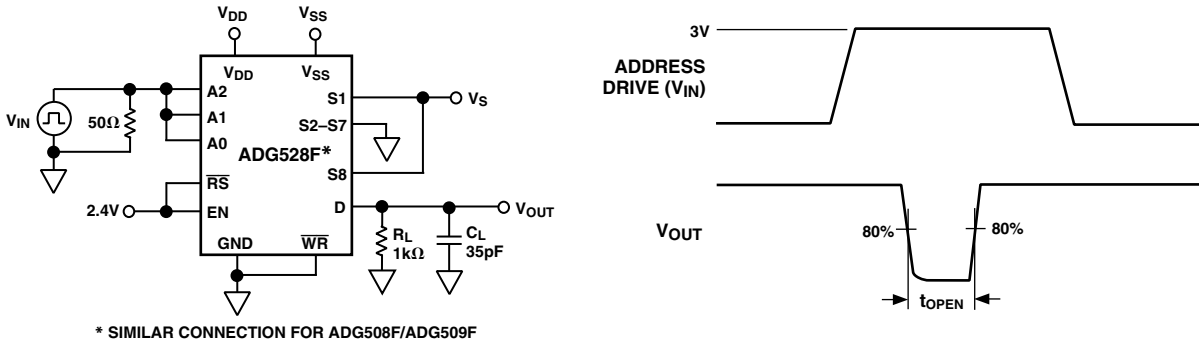


Test Circuit 6. Input Leakage Current (with Power Supplies OFF)

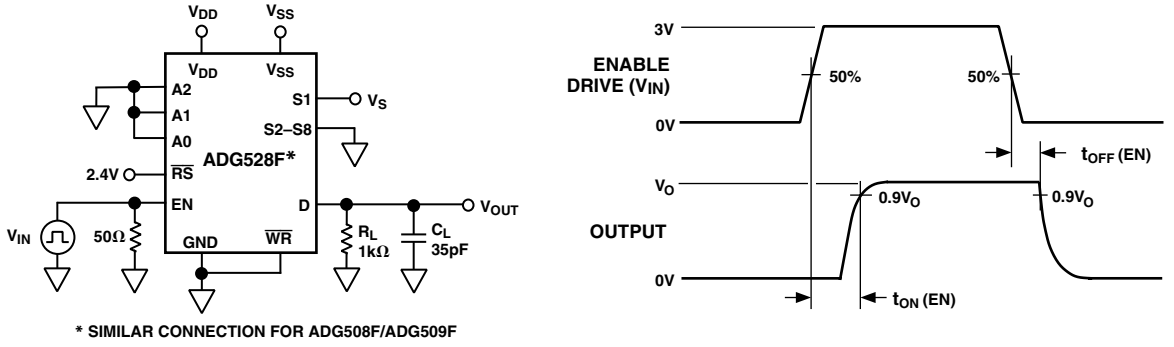




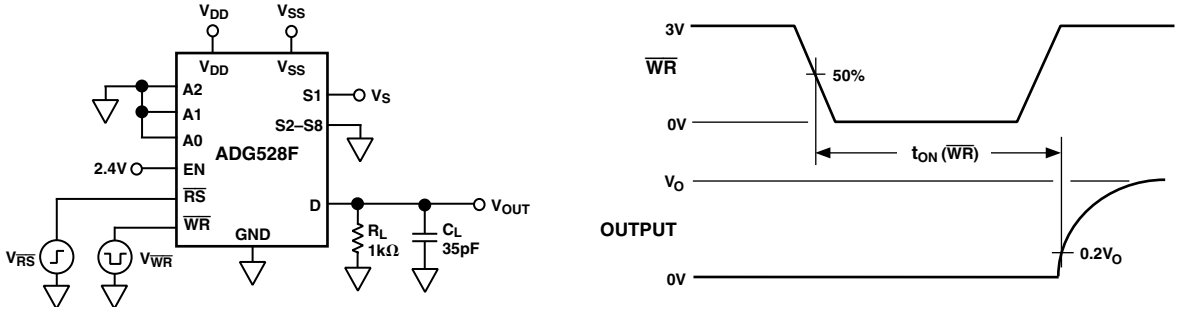
Test Circuit 7. Switching Time of Multiplexer, $t_{TRANSITION}$



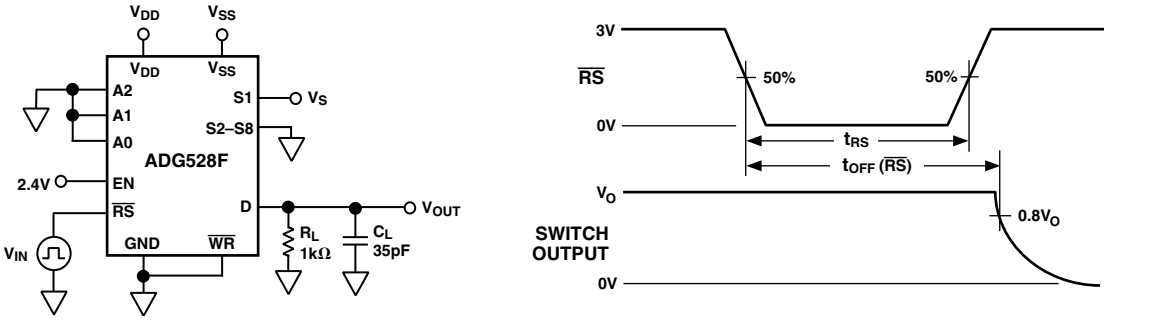
Test Circuit 8. Break-Before-Make Delay, t_{OPEN}



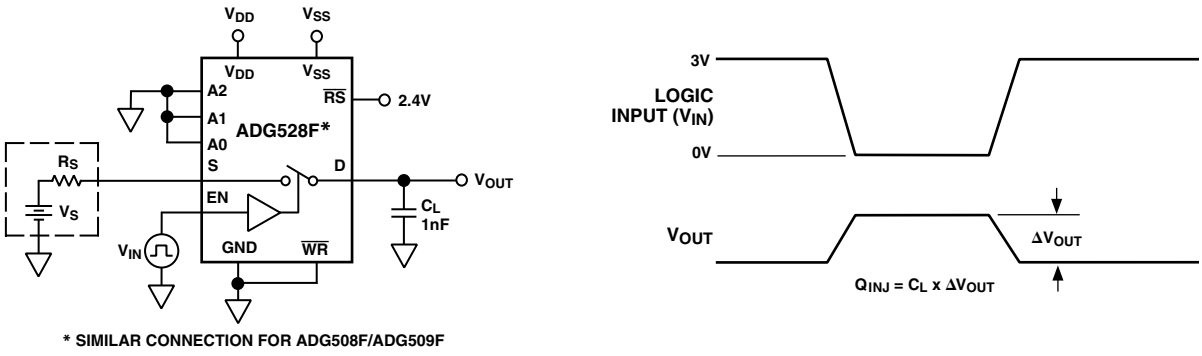
Test Circuit 9. Enable Delay, t_{ON} (EN), t_{OFF} (EN)



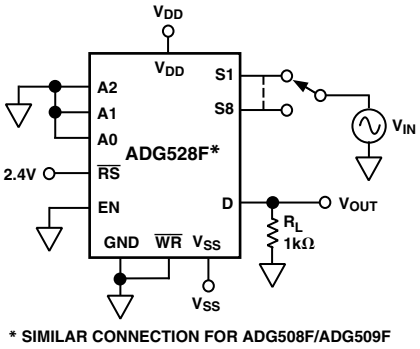
Test Circuit 10. Write Turn-On Time, t_{ON} ($\overline{WR}$)



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



Test Circuit 12. Charge Injection

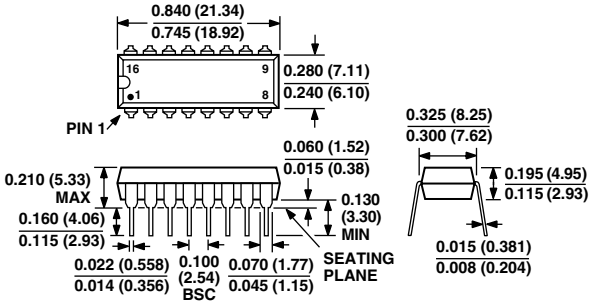


Test Circuit 13. OFF Isolation

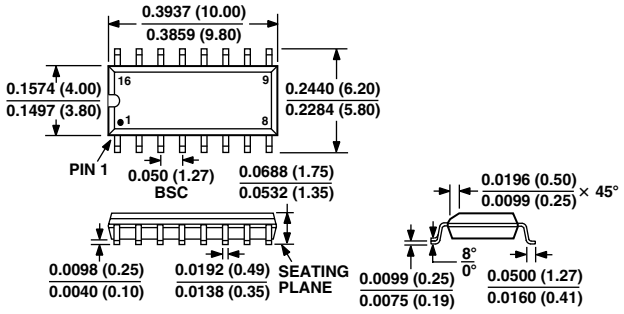
OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).

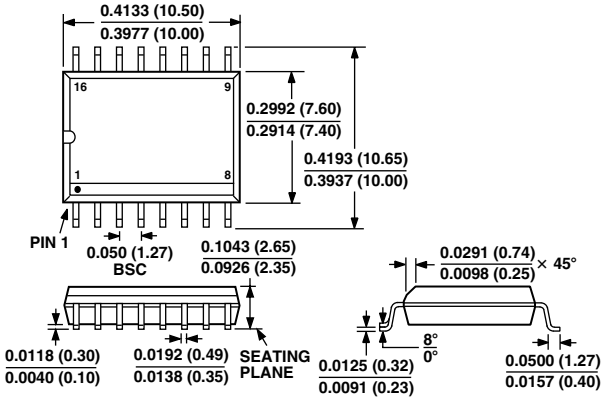
16-Lead Plastic (N-16)



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



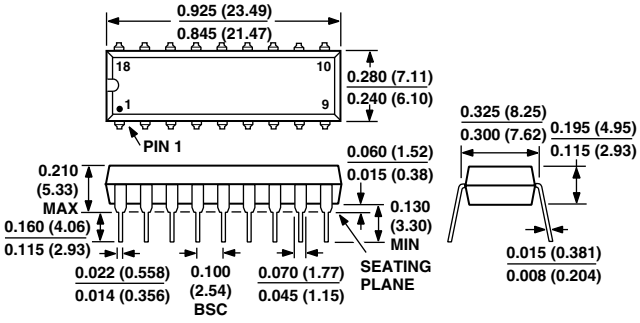
16-Lead SOIC (R-16W)
(Wide Body)



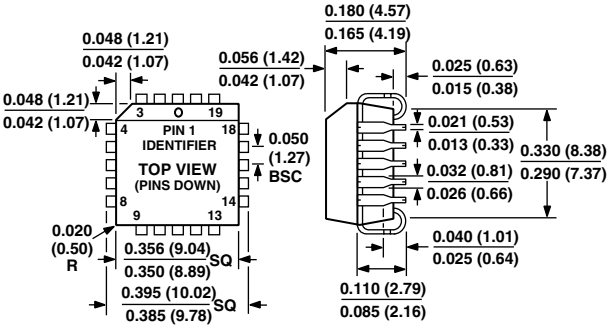
OUTLINE DIMENSIONS

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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