



# CMOS Low Voltage 4 $\Omega$ Dual SPST Switches

## ADG721/ADG722/ADG723

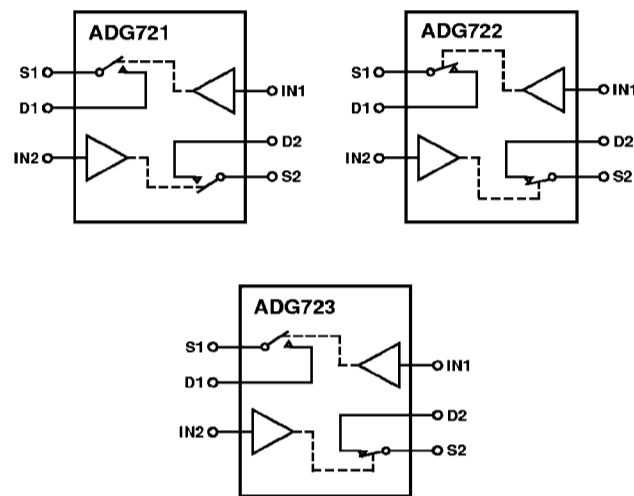
### FEATURES

+1.8 V to +5.5 V Single Supply  
4  $\Omega$  (Max) On Resistance  
Low On-Resistance Flatness  
-3 dB Bandwidth >200 MHz  
Rail-to-Rail Operation  
8-Lead  $\mu$ SOIC Package  
Fast Switching Times  
 $t_{ON}$  20 ns  
 $t_{OFF}$  10 ns  
Low Power Consumption (<0.1  $\mu$ W)  
TTL/CMOS Compatible

### APPLICATIONS

Battery Powered Systems  
Communication Systems  
Sample Hold Systems  
Audio Signal Routing  
Video Switching  
Mechanical Reed Relay Replacement

### FUNCTIONAL BLOCK DIAGRAMS



### GENERAL DESCRIPTION

The ADG721, ADG722 and ADG723 are monolithic CMOS SPST switches. These switches are designed on an advanced submicron process that provides low power dissipation yet gives high switching speed, low On resistance and low leakage currents.

The ADG721, ADG722 and ADG723 are designed to operate from a single +1.8 V to +5.5 V supply, making them ideal for use in battery powered instruments and with the new generation of DACs and ADCs from Analog Devices.

The ADG721, ADG722 and ADG723 contain two independent single-pole/single-throw (SPST) switches. The ADG721 and ADG722 differ only in that both switches are normally open and normally closed respectively. While in the ADG723, Switch 1 is normally open and Switch 2 is normally closed.

Each switch of the ADG721, ADG722 and ADG723 conducts equally well in both directions when on. The ADG723 exhibits break-before-make switching action.

### PRODUCT HIGHLIGHTS

1. +1.8 V to +5.5 V Single Supply Operation. The ADG721, ADG722 and ADG723 offers high performance, including low on resistance and fast switching times and is fully specified and guaranteed with +3 V and +5 V supply rails.
2. Very Low  $R_{ON}$  (4  $\Omega$  max at 5 V, 10  $\Omega$  max at 3 V). At 1.8 V operation,  $R_{ON}$  is typically 40  $\Omega$  over the temperature range.
3. Low On-Resistance Flatness.
4. -3 dB Bandwidth >200 MHz.
5. Low Power Dissipation. CMOS construction ensures low power dissipation.
6. Fast  $t_{ON}/t_{OFF}$ .
7. 8-Lead  $\mu$ SOIC.

### REV. 0

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# ADG721/ADG722/ADG723—SPECIFICATIONS<sup>1</sup>

(V<sub>DD</sub> = +5 V ± 10%, GND = 0 V. All specifications –40°C to +85°C, unless otherwise noted.)

Parameter	B Version –40°C to +85°C		Units	Test Conditions/Comments
	+25°C			
<b>ANALOG SWITCH</b>				
Analog Signal Range		0 V to V <sub>DD</sub>	V	V <sub>S</sub> = 0 V to V <sub>DD</sub> , I <sub>S</sub> = –10 mA, Test Circuit 1
On Resistance (R <sub>ON</sub> )	4	5	Ω max	
On Resistance Match Between Channels (ΔR <sub>ON</sub> )	0.3	1.0	Ω typ Ω max	
On-Resistance Flatness (R <sub>FLAT(ON)</sub> )	0.85	1.5	Ω typ Ω max	
<b>LEAKAGE CURRENTS</b>				
Source OFF Leakage I <sub>S</sub> (OFF)	±0.01		nA typ	V <sub>DD</sub> = +5.5 V V <sub>S</sub> = 4.5 V/1 V, V <sub>D</sub> = 1 V/4.5 V Test Circuit 2
	±0.25	±0.35	nA max	
Drain OFF Leakage I <sub>D</sub> (OFF)	±0.01		nA typ	
	±0.25	±0.35	nA max	
Channel ON Leakage I <sub>D</sub> , I <sub>S</sub> (ON)	±0.01		nA typ	V <sub>S</sub> = V <sub>D</sub> = 1 V, or V <sub>S</sub> = V <sub>D</sub> = 4.5 V Test Circuit 3
	±0.25	±0.35	nA max	
<b>DIGITAL INPUTS</b>				
Input High Voltage, V <sub>INH</sub>		2.4	V min	V <sub>IN</sub> = V <sub>INL</sub> or V <sub>INH</sub>
Input Low Voltage, V <sub>INL</sub>		0.8	V max	
Input Current I <sub>INL</sub> or I <sub>INH</sub>	0.005		μA typ	
		±0.1	μA max	
<b>DYNAMIC CHARACTERISTICS<sup>2</sup></b>				
t <sub>ON</sub>	14	20	ns typ ns max	R <sub>L</sub> = 300 Ω, C <sub>L</sub> = 35 pF V <sub>S</sub> = 3 V, Test Circuit 4
t <sub>OFF</sub>	6	10	ns typ ns max	
Break-Before-Make Time Delay, t <sub>D</sub> (ADG723 Only)	7	1	ns typ ns min	R <sub>L</sub> = 300 Ω, C <sub>L</sub> = 35 pF, V <sub>S1</sub> = V <sub>S2</sub> = 3 V, Test Circuit 5
Charge Injection	2		pC typ	V <sub>S</sub> = 2 V; R <sub>S</sub> = 0 Ω, C <sub>L</sub> = 1 nF, Test Circuit 6
Off Isolation	–60		dB typ	R <sub>L</sub> = 50 Ω, C <sub>L</sub> = 5 pF, f = 10 MHz, Test Circuit 7
	–80		dB typ	
Channel-to-Channel Crosstalk	–77		dB typ	R <sub>L</sub> = 50 Ω, C <sub>L</sub> = 5 pF, f = 10 MHz, Test Circuit 8
	–97		dB typ	
Bandwidth –3 dB	200		MHz typ	R <sub>L</sub> = 50 Ω, C <sub>L</sub> = 5 pF, Test Circuit 9
C <sub>S</sub> (OFF)	7		pF typ	
C <sub>D</sub> (OFF)	7		pF typ	
C <sub>D</sub> , C <sub>S</sub> (ON)	18		pF typ	
<b>POWER REQUIREMENTS</b>				
I <sub>DD</sub>	0.001	1.0	μA typ μA max	V <sub>DD</sub> = +5.5 V Digital Inputs = 0 V or 5 V

## NOTES

<sup>1</sup>Temperature ranges are as follows: B Version, –40°C to +85°C.

<sup>2</sup>Guaranteed by design, not subject to production test.

Specifications subject to change without notice.

## ADG721/ADG722/ADG723

# SPECIFICATIONS<sup>1</sup> (V<sub>DD</sub> = +3 V ± 10%, GND = 0 V. All specifications –40°C to +85°C, unless otherwise noted.)

Parameter	B Version		Units	Test Conditions/Comments
	+25°C	–40°C to +85°C		
<b>ANALOG SWITCH</b>				
Analog Signal Range		0 V to V <sub>DD</sub>	V	
On Resistance (R <sub>ON</sub> )	6.5		Ω typ Ω max	V <sub>S</sub> = 0 V to V <sub>DD</sub> , I <sub>S</sub> = –10 mA Test Circuit 1
On Resistance Match Between Channels (ΔR <sub>ON</sub> )	0.3		Ω typ Ω max	V <sub>S</sub> = 0 V to V <sub>DD</sub> , I <sub>S</sub> = –10 mA
On-Resistance Flatness (R <sub>FLAT(ON)</sub> )		1.0 3.5	Ω typ	V <sub>S</sub> = 0 V to V <sub>DD</sub> , I <sub>S</sub> = –10 mA
<b>LEAKAGE CURRENTS</b>				
Source OFF Leakage I <sub>S</sub> (OFF)	±0.01 ±0.25	±0.35	nA typ nA max	V <sub>DD</sub> = +3.3 V V <sub>S</sub> = 3 V/1 V, V <sub>D</sub> = 1 V/3 V Test Circuit 2
Drain OFF Leakage I <sub>D</sub> (OFF)	±0.01 ±0.25	±0.35	nA typ nA max	V <sub>S</sub> = 3 V/1 V, V <sub>D</sub> = 1 V/3 V Test Circuit 2
Channel ON Leakage I <sub>D</sub> , I <sub>S</sub> (ON)	±0.01 ±0.25	±0.35	nA typ nA max	V <sub>S</sub> = V <sub>D</sub> = 1 V, or 3 V Test Circuit 3
<b>DIGITAL INPUTS</b>				
Input High Voltage, V <sub>INH</sub>		2.0	V min	
Input Low Voltage, V <sub>INL</sub>		0.4	V max	
Input Current I <sub>INL</sub> or I <sub>INH</sub>	0.005	±0.1	μA typ μA max	V <sub>IN</sub> = V <sub>INL</sub> or V <sub>INH</sub>
<b>DYNAMIC CHARACTERISTICS<sup>2</sup></b>				
t <sub>ON</sub>	16	24	ns typ ns max	R <sub>L</sub> = 300 Ω, C <sub>L</sub> = 35 pF V <sub>S</sub> = 2 V, Test Circuit 4
t <sub>OFF</sub>	7	11	ns typ ns max	R <sub>L</sub> = 300 Ω, C <sub>L</sub> = 35 pF V <sub>S</sub> = 2 V, Test Circuit 4
Break-Before-Make Time Delay, t <sub>b</sub> (ADG723 Only)	7	1	ns typ ns min	R <sub>L</sub> = 300 Ω, C <sub>L</sub> = 35 pF, V <sub>S1</sub> = V <sub>S2</sub> = 2 V, Test Circuit 5
Charge Injection	2		pC typ	V <sub>S</sub> = 1.5 V; R <sub>S</sub> = 0 Ω, C <sub>L</sub> = 1 nF, Test Circuit 6
Off Isolation	–60 –80		dB typ dB typ	R <sub>L</sub> = 50 Ω, C <sub>L</sub> = 5 pF, f = 10 MHz R <sub>L</sub> = 50 Ω, C <sub>L</sub> = 5 pF, f = 1 MHz, Test Circuit 7
Channel-to-Channel Crosstalk	–77 –97		dB typ dB typ	R <sub>L</sub> = 50 Ω, C <sub>L</sub> = 5 pF, f = 10 MHz R <sub>L</sub> = 50 Ω, C <sub>L</sub> = 5 pF, f = 1 MHz, Test Circuit 8
Bandwidth –3 dB	200		MHz typ	R <sub>L</sub> = 50 Ω, C <sub>L</sub> = 5 pF, Test Circuit 9
C <sub>S</sub> (OFF)	7		pF typ	
C <sub>D</sub> (OFF)	7		pF typ	
C <sub>D</sub> , C <sub>S</sub> (ON)	18		pF typ	
<b>POWER REQUIREMENTS</b>				
I <sub>DD</sub>	0.001	1.0	μA typ μA max	V <sub>DD</sub> = +3.3 V Digital Inputs = 0 V or 3 V

**NOTES**

<sup>1</sup>Temperature ranges are as follows: B Version, –40°C to +85°C.

<sup>2</sup>Guaranteed by design, not subject to production test.

Specifications subject to change without notice.

## ADG721/ADG722/ADG723

### ABSOLUTE MAXIMUM RATINGS<sup>1</sup>

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

V <sub>DD</sub> to GND	0.3 V to +7 V
Analog, Digital Inputs <sup>2</sup>	-0.3 V to V <sub>DD</sub> + 0.3 V or 30 mA, Whichever Occurs First
Continuous Current, S or D	30 mA
Operating Temperature Range	
Industrial (B Version)	-40°C to +85°C
Storage Temperature Range	-65°C to +150°C
Junction Temperature	+150°C
μSOIC Package, Power Dissipation	450 mW
θ <sub>JA</sub> Thermal Impedance	206°C/W
θ <sub>JC</sub> Thermal Impedance	44°C/W
Lead Temperature, Soldering	
Vapor Phase (60 sec)	+215°C
Infrared (15 sec)	+220°C
ESD	2 kV

#### NOTES

<sup>1</sup>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.

<sup>2</sup>Overvoltages at IN, S or D will be clamped by internal diodes. Current should be limited to the maximum ratings given.

Table I. Truth Table (ADG721/ADG722)

ADG721 In	ADG722 In	Switch Condition
0	1	OFF
1	0	ON

Table II. Truth Table (ADG723)

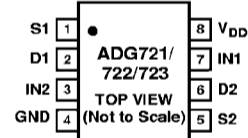
Logic	Switch 1	Switch 2
0	OFF	ON
1	ON	OFF

### TERMINOLOGY

V <sub>DD</sub>	Most Positive Power Supply Potential.
GND	Ground (0 V) Reference.
S	Source Terminal. May be an input or output.
D	Drain Terminal. May be an input or output.
IN	Logic Control Input.
R <sub>ON</sub>	Ohmic resistance between D and S.
ΔR <sub>ON</sub>	On resistance match between any two channels i.e., R <sub>ON</sub> max - R <sub>ON</sub> min.
R <sub>FLAT(ON)</sub>	Flatness is defined as the difference between the maximum and minimum value of on resistance as measured over the specified analog signal range.
I <sub>S</sub> (OFF)	Source leakage current with the switch "OFF."
I <sub>D</sub> (OFF)	Drain leakage current with the switch "OFF."
I <sub>D</sub> , I <sub>S</sub> (ON)	Channel leakage current with the switch "ON."
V <sub>D</sub> (V <sub>S</sub> )	Analog voltage on terminals D, S.
C <sub>S</sub> (OFF)	"OFF" Switch Source Capacitance.
C <sub>D</sub> (OFF)	"OFF" Switch Drain Capacitance.
C <sub>D</sub> , C <sub>S</sub> (ON)	"ON" Switch Capacitance.
t <sub>ON</sub>	Delay between applying the digital control input and the output switching on.
t <sub>OFF</sub>	Delay between applying the digital control input and the output switching off.
t <sub>D</sub>	"OFF" time or "ON" time measured between the 90% points of both switches, When switching from one address state to another. (ADG723 Only)
Crosstalk	A measure of unwanted signal which is coupled through from one channel to another as a result of parasitic capacitance.
Off Isolation	A measure of unwanted signal coupling through an "OFF" switch.
Charge Injection	A measure of the glitch impulse transferred during switching.

### PIN CONFIGURATION

#### 8-Lead μSOIC (RM-8)



### ORDERING GUIDE

Model	Temperature Range	Brand*	Package Description	Package Option
ADG721BRM	-40°C to +85°C	S6B	μSOIC	RM-8
ADG722BRM	-40°C to +85°C	S7B	μSOIC	RM-8
ADG723BRM	40°C to +85°C	S8B	μSOIC	RM-8

\*Brand = Due to package size limitations, these three characters represent the part number.

### 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 ADG721/ADG722/ADG723 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.



## Typical Performance Characteristics—ADG721/ADG722/ADG723

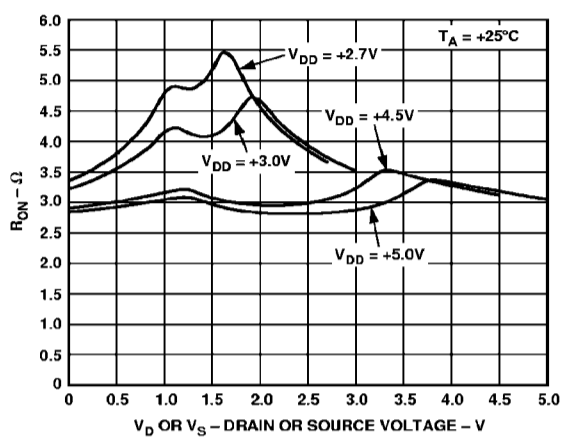


Figure 1. On Resistance as a Function of  $V_D$  ( $V_S$ ) Single Supplies

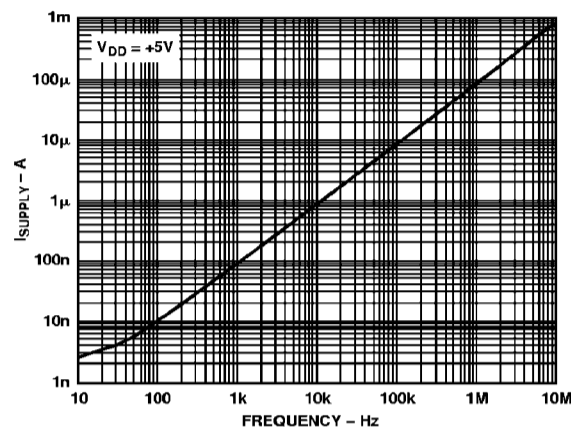


Figure 4. Supply Current vs. Input Switching Frequency

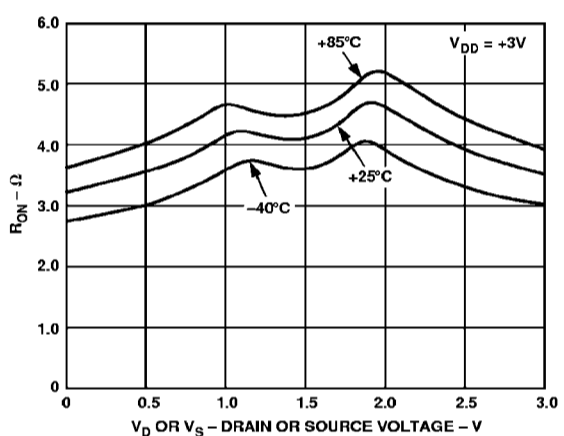


Figure 2. On Resistance as a Function of  $V_D$  ( $V_S$ ) for Different Temperatures  $V_{DD} = +3V$

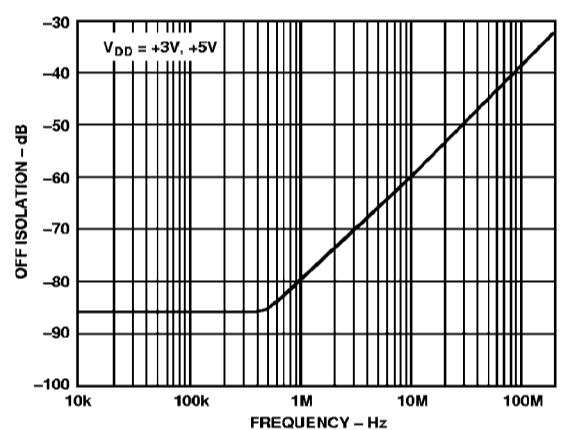


Figure 5. Off Isolation vs. Frequency

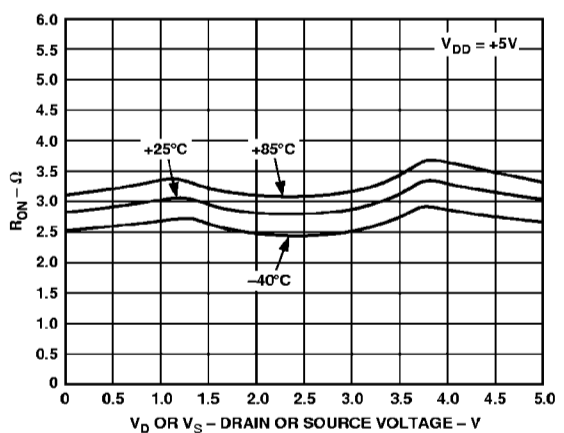


Figure 3. On Resistance as a Function of  $V_D$  ( $V_S$ ) for Different Temperatures  $V_{DD} = +5V$

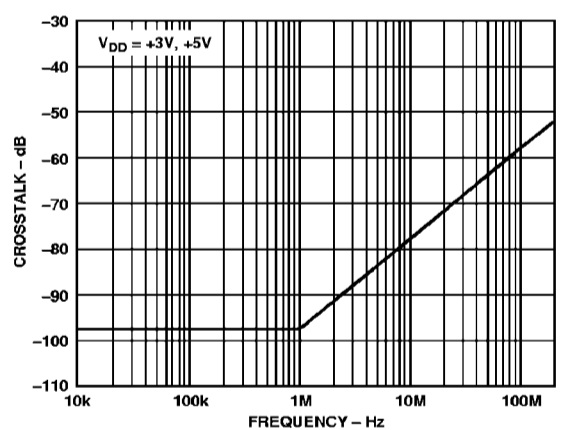


Figure 6. Crosstalk vs. Frequency

## ADG721/ADG722/ADG723

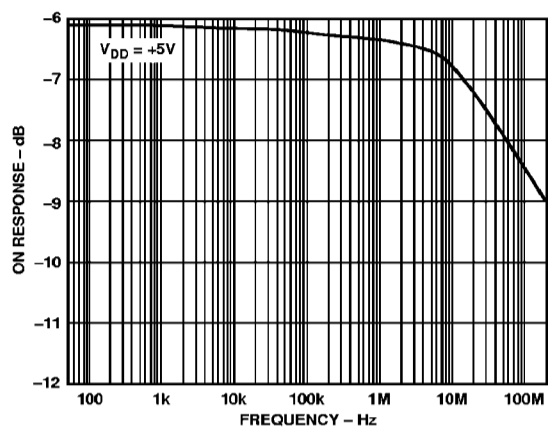
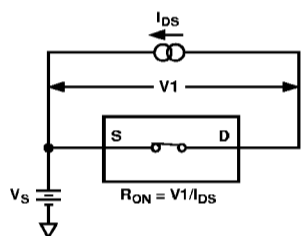
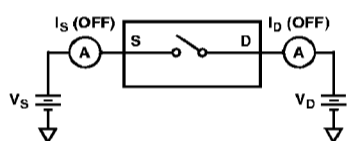


Figure 7. On Response vs. Frequency

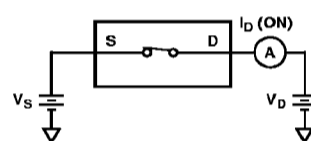
## Test Circuits



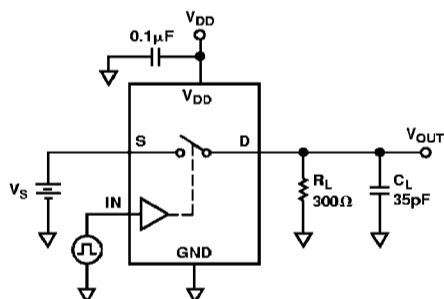
Test Circuit 1. On Resistance



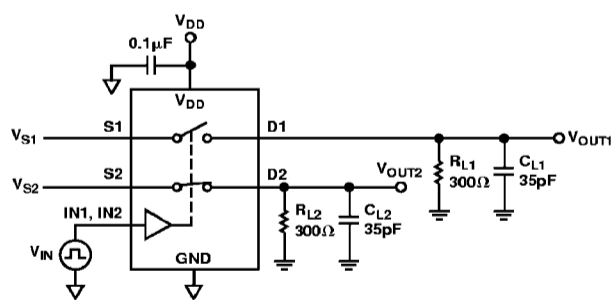
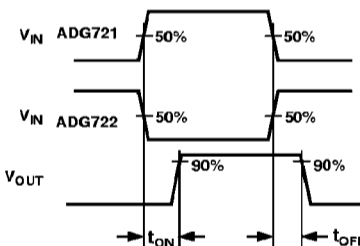
Test Circuit 2. Off Leakage



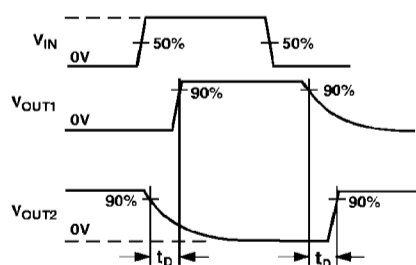
Test Circuit 3. On Leakage



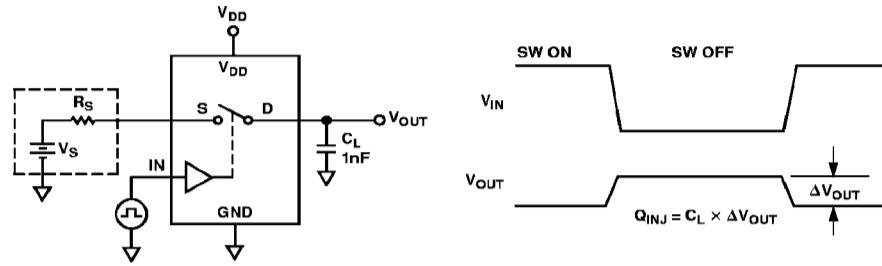
Test Circuit 4. Switching Times



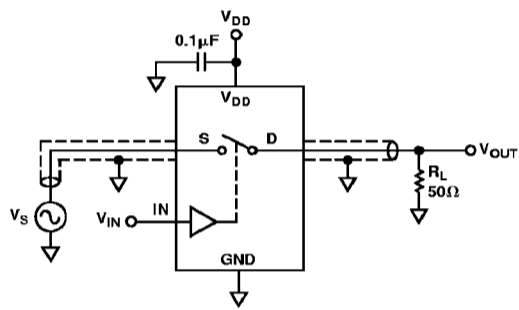
Test Circuit 5. Break-Before-Make Time Delay,  $t_D$  (ADG723 Only)



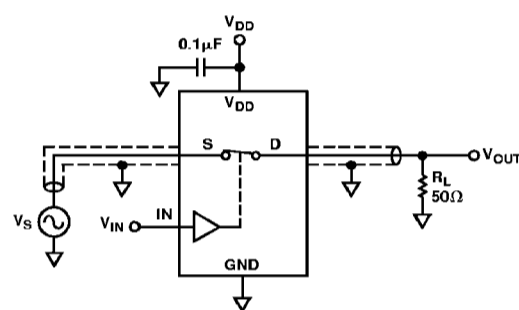
**ADG721/ADG722/ADG723**



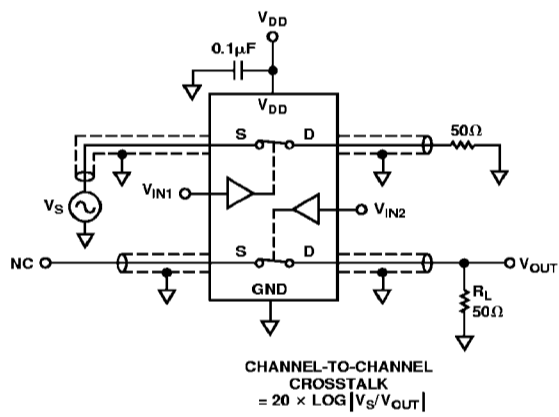
Test Circuit 6. Charge Injection



Test Circuit 7. Off Isolation



Test Circuit 9. Bandwidth



Test Circuit 8. Channel-to-Channel Crosstalk

## ADG721/ADG722/ADG723

### APPLICATIONS INFORMATION

The ADG721/ADG722/ADG723 belongs to Analog Devices' new family of CMOS switches. This series of general purpose switches have improved switching times, lower on resistance, higher bandwidths, low power consumption and low leakage currents.

#### ADG721/ADG722/ADG723 Supply Voltages

Functionality of the ADG721/ADG722/ADG723 extends from +1.8 V to +5.5 V single supply, which makes it ideal for battery powered instruments, where important design parameters are power efficiency and performance.

It is important to note that the supply voltage effects the input signal range, the on resistance and the switching times of the part. By taking a look at the typical performance characteristics and the specifications, the effects of the power supplies can be clearly seen.

For  $V_{DD} = +1.8$  V, on resistance is typically 40  $\Omega$  over the temperature range.

#### On Response vs. Frequency

Figure 8 illustrates the parasitic components that affect the ac performance of CMOS switches (the switch is shown surrounded by a box). Additional external capacitances will further degrade some performance. These capacitances affect feedthrough, crosstalk and system bandwidth.

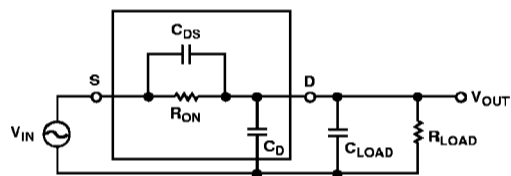


Figure 8. Switch Represented by Equivalent Parasitic Components

The transfer function that describes the equivalent diagram of the switch (Figure 8) is of the form  $A(s)$  shown below.

$$A(s) = R_T \left[ \frac{s(R_{ON} C_{DS}) + 1}{s(R_{ON} C_T R_T) + 1} \right]$$

where:

$$C_T = C_{LOAD} + C_D + C_{DS}$$

$$R_T = R_{LOAD} / (R_{LOAD} + R_{ON})$$

The signal transfer characteristic is dependent on the switch channel capacitance,  $C_{DS}$ . This capacitance creates a frequency zero in the numerator of the transfer function  $A(s)$ . Because the switch on resistance is small, this zero usually occurs at high frequencies. The bandwidth is a function of the switch output capacitance combined with  $C_{DS}$  and the load capacitance. The frequency pole corresponding to these capacitances appears in the denominator of  $A(s)$ .

The dominant effect of the output capacitance,  $C_D$ , causes the pole breakpoint frequency to occur first. Therefore, in order to maximize bandwidth a switch must have a low input and output capacitance and low on resistance. The On Response vs. Frequency plot for the ADG721/ADG722/ADG723 can be seen in Figure 7.

### Off Isolation

Off isolation is a measure of the input signal coupled through an off switch to the switch output. The capacitance,  $C_{DS}$ , couples the input signal to the output load, when the switch is off as shown in Figure 9.

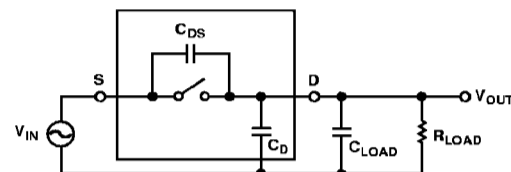


Figure 9. Off Isolation Is Affected by External Load Resistance and Capacitance

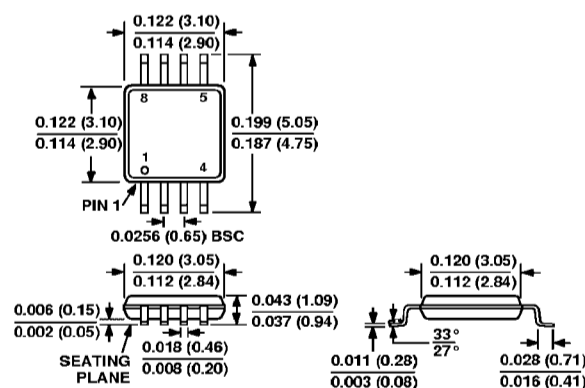
The larger the value of  $C_{DS}$ , larger values of feedthrough will be produced. The typical performance characteristic graph of Figure 5 illustrates the drop in off isolation as a function of frequency. From dc to roughly 1 MHz, the switch shows better than -80 dB isolation. Up to frequencies of 10 MHz, the off isolation remains better than -60 dB. As the frequency increases, more and more of the input signal is coupled through to the output. Off isolation can be maximized by choosing a switch with the smallest  $C_{DS}$  as possible. The values of load resistance and capacitance also affect off isolation, as they contribute to the coefficients of the poles and zeros in the transfer function of the switch when open.

$$A(s) = \left[ \frac{s(R_{LOAD} C_{DS})}{s(R_{LOAD} (C_{LOAD} + C_D + C_{DS}) + 1)} \right]$$

### OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).

#### 8-Lead $\mu$ SOIC (RM-8)



C3294-8-4/98

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