

FEATURES

- 1.5 pF off capacitance
- 0.5 pC charge injection
- 33 V supply range
- 120 Ω on resistance
- Fully specified at ± 15 V/+12 V
- 3 V logic-compatible inputs
- Rail-to-rail operation
- Break-before-make switching action
- 16-lead TSSOP, 20-lead TSSOP, and 4 mm \times 4 mm LFCSP
- Typical power consumption (<0.03 μ W)

APPLICATIONS

- Audio and video routing
- Automatic test equipment
- Data acquisition systems
- Battery-powered systems
- Sample-and-hold systems
- Communication systems

GENERAL DESCRIPTION

The ADG1233 and ADG1234 are monolithic *i*CMOS analog switches comprising three independently selectable single-pole, double throw SPDT switches and four independently selectable SPDT switches, respectively.

All channels exhibit break-before-make switching action preventing momentary shorting when switching channels. An $\overline{\text{EN}}$ input on the ADG1233 and ADG1234 is used to enable or disable the device. When disabled, all channels are switched off.

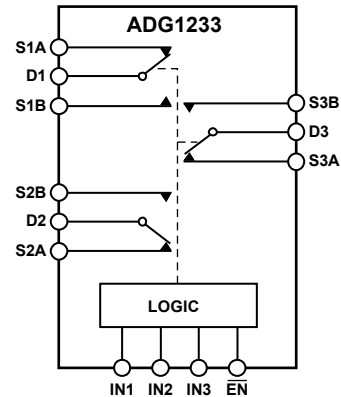
The *i*CMOS (industrial-CMOS) modular manufacturing process combines a high voltage complementary metal-oxide semiconductor (CMOS) and bipolar technologies. It enables the development of a wide range of high performance analog ICs capable of 33 V operation in a footprint that no other generation of high voltage parts has been able to achieve. Unlike analog ICs using conventional CMOS processes, *i*CMOS components can tolerate high supply voltages while providing increased performance, dramatically lowered power consumption, and reduced package size.

The ultralow capacitance and charge injection of these multiplexers make them ideal solutions for data acquisition and sample-and-hold applications, where low glitch and fast settling are required.

Rev. A

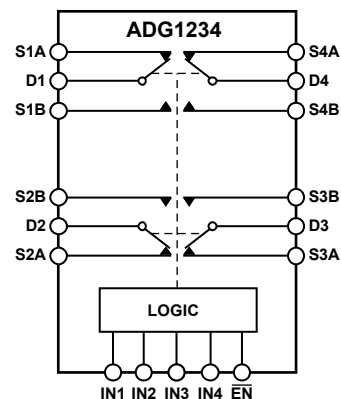
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FUNCTIONAL BLOCK DIAGRAMS



SWITCHES SHOWN FOR A LOGIC 1 INPUT

Figure 1.



SWITCHES SHOWN FOR A LOGIC 1 INPUT

Figure 2.

Fast switching speed coupled with high signal bandwidth make the parts suitable for video signal switching. *i*CMOS construction ensures ultralow power dissipation, making the parts ideally suited for portable and battery-powered instruments.

PRODUCT HIGHLIGHTS

1. 1.5 pF off capacitance (± 15 V supply).
2. 0.5 pC charge injection.
3. 3 V logic-compatible digital input, $V_{\text{IH}} = 2.0$ V, $V_{\text{IL}} = 0.8$ V.
4. 16-lead TSSOP, 20-lead TSSOP, and 4 mm \times 4 mm LFCSP.

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REVISION HISTORY

8/06—Rev. 0 to Rev. A

Updated Format.....	Universal
Changes to Table 1.....	3
Changes to Table 2.....	4
Changes to Figure 11.....	10
Changes to Figure 12.....	11

1/06—Revision 0: Initial Version

SPECIFICATIONS

DUAL SUPPLY

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

Table 1.

Parameter	Y Version ¹			Unit	Test Conditions/Comments
	+25°C	-40°C to +85°C	-40°C to +125°C		
ANALOG SWITCH					
Analog Signal Range			V_{SS} to V_{DD}	V	
On Resistance (R_{ON})	120			Ω typ	$V_S = \pm 10\text{ V}$, $I_S = -1\text{ mA}$; see Figure 24
	190	230	260	Ω max	$V_{DD} = +13.5\text{ V}$, $V_{SS} = -13.5\text{ V}$
On Resistance Match Between Channels (ΔR_{ON})	3.5			Ω typ	$V_S = \pm 10\text{ V}$, $I_S = -1\text{ mA}$
	6	10	12	Ω max	
On Resistance Flatness ($R_{FLAT(ON)}$)	20			Ω typ	$V_S = -5\text{ V}, 0\text{ V}, +5\text{ V}$; $I_S = -1\text{ mA}$
	60	72	79	Ω max	
LEAKAGE CURRENTS					
Source Off Leakage I_S (Off)	± 0.02			nA typ	$V_{DD} = +16.5\text{ V}$, $V_{SS} = -16.5\text{ V}$
	± 0.1	± 0.6	± 1	nA max	$V_D = \pm 10\text{ V}$, $V_S = -10\text{ V}$; see Figure 25
Drain Off Leakage I_D (Off)	± 0.02			nA typ	$V_S = 1\text{ V}/10\text{ V}$, $V_D = 10\text{ V}/1\text{ V}$; see Figure 25
	± 0.1	± 0.6	± 1	nA max	
Channel On Leakage I_D, I_S (On)	± 0.02			nA typ	$V_S = V_D = \pm 10\text{ V}$; see Figure 26
	± 0.2	± 0.6	± 1	nA max	
DIGITAL INPUTS					
Input High Voltage, V_{INH}			2.0	V min	
Input Low Voltage, V_{INL}			0.8	V max	
Input Current					
I_{INL} or I_{INH}	± 0.005			μA typ	$V_{IN} = V_{INL}$ or V_{INH}
			± 0.1	μA max	
Digital Input Capacitance, C_{IN}	3			pF typ	
DYNAMIC CHARACTERISTICS²					
$t_{TRANSITION}$	110			ns typ	$R_L = 300\ \Omega$, $C_L = 35\text{ pF}$
	130	150	170	ns max	$V_S = 10\text{ V}$; see Figure 27
t_{BBM}	25			ns typ	$R_L = 300\ \Omega$, $C_L = 35\text{ pF}$
			10	ns min	$V_{S1} = V_{S2} = +10\text{ V}$; see Figure 28
$t_{ON}(\overline{EN})$	120			ns typ	$R_L = 300\ \Omega$, $C_L = 35\text{ pF}$
	140	170	195	ns max	$V_S = 10\text{ V}$; see Figure 29
$t_{OFF}(\overline{EN})$	40			ns typ	$R_L = 300\ \Omega$, $C_L = 35\text{ pF}$
	45	55	60	ns max	$V_S = 10\text{ V}$; see Figure 29
Charge Injection	0.5			pC typ	$V_S = 0\text{ V}$, $R_S = 0\ \Omega$, $C_L = 1\text{ nF}$; see Figure 30
Off Isolation	-80			dB typ	$R_L = 50\ \Omega$, $C_L = 5\text{ pF}$, $f = 1\text{ MHz}$; see Figure 31
Channel-to-Channel Crosstalk	-85			dB typ	$R_L = 50\ \Omega$, $C_L = 5\text{ pF}$, $f = 1\text{ MHz}$; see Figure 33
Total Harmonic Distortion, THD + N	0.14			% typ	$R_L = 10\text{ k}\Omega$, 5 V rms , $f = 20\text{ Hz}$ to 20 kHz ; see Figure 34
-3 dB Bandwidth	900			MHz typ	$R_L = 50\ \Omega$, $C_L = 5\text{ pF}$; see Figure 32
C_S (Off)	1.5			pF typ	$f = 1\text{ MHz}$; $V_S = 0\text{ V}$
	1.7			pF max	$f = 1\text{ MHz}$; $V_S = 0\text{ V}$
C_D (Off)	1.6			pF typ	$f = 1\text{ MHz}$; $V_S = 0\text{ V}$
	1.8			pF max	$f = 1\text{ MHz}$; $V_S = 0\text{ V}$
C_D, C_S (On)	3.5			pF typ	$f = 1\text{ MHz}$; $V_S = 0\text{ V}$
	4			pF max	$f = 1\text{ MHz}$; $V_S = 0\text{ V}$

ADG1233/ADG1234

Parameter	Y Version ¹			Unit	Test Conditions/Comments
	+25°C	-40°C to +85°C	-40°C to +125°C		
POWER REQUIREMENTS					
I_{DD}	0.002		1.0	$\mu\text{A typ}$ $\mu\text{A max}$	$V_{DD} = +16.5\text{ V}$, $V_{SS} = -16.5\text{ V}$ Digital inputs = 0 V or V_{DD}
I_{DD}	260		420	$\mu\text{A typ}$ $\mu\text{A max}$	Digital inputs = 5 V
I_{SS}	0.002		1.0	$\mu\text{A typ}$ $\mu\text{A max}$	Digital inputs = 0 V or V_{DD}
I_{SS}	0.002		1.0	$\mu\text{A typ}$ $\mu\text{A max}$	Digital inputs = 5 V
V_{DD}/V_{SS}			$\pm 5/\pm 16.5$	V min/max	GND = 0 V

¹ Temperature range for the Y version: -40°C to +125°C.

² Guaranteed by design, not subject to production test.

SINGLE SUPPLY

$V_{DD} = 12\text{ V} \pm 10\%$, $V_{SS} = 0\text{ V}$, $GND = 0\text{ V}$, unless otherwise noted.

Table 2.

Parameter	Y Version ¹			Unit	Test Conditions/Comments
	+25°C	−40°C to +85°C	−40°C to +125°C		
ANALOG SWITCH					
Analog Signal Range			0 to V_{DD}	V	
On Resistance (R_{ON})	300			Ω typ	$V_S = 0\text{ V to }10\text{ V}$, $I_S = -1\text{ mA}$; see Figure 24
On Resistance Match Between Channels (ΔR_{ON})	475 5	567	625	Ω max Ω typ	$V_{DD} = 10.8\text{ V}$, $V_{SS} = 0\text{ V}$ $V_S = 0\text{ V to }10\text{ V}$, $I_S = -1\text{ mA}$
On Resistance Flatness ($R_{FLAT(ON)}$)	16 60	26	27	Ω max Ω typ	$V_S = 3\text{ V}, 6\text{ V}, 9\text{ V}$, $I_S = -1\text{ mA}$
LEAKAGE CURRENTS					
Source Off Leakage I_S (Off)	± 0.02			nA typ	$V_{DD} = 13.2\text{ V}$ $V_S = 1\text{ V}/10\text{ V}$, $V_D = 10\text{ V}/1\text{ V}$; see Figure 25
Drain Off Leakage I_D (Off)	± 0.1 ± 0.02	± 0.6	± 1	nA max nA typ	$V_S = 1\text{ V}/10\text{ V}$, $V_D = 10\text{ V}/1\text{ V}$; see Figure 25
Channel On Leakage I_D, I_S (On)	± 0.1 ± 0.02 ± 0.2	± 0.6	± 1	nA max nA typ nA max	$V_S = V_D = 1\text{ V or }10\text{ V}$, see Figure 26
DIGITAL INPUTS					
Input High Voltage, V_{INH}			2.0	V min	
Input Low Voltage, V_{INL}			0.8	V max	
Input Current, I_{INL} or I_{INH}	± 0.001			μA typ μA max	$V_{IN} = V_{INL}$ or V_{INH}
Digital Input Capacitance, C_{IN}	2			pF typ	
DYNAMIC CHARACTERISTICS²					
$t_{TRANSITION}$	135 170	200	230	ns typ	$R_L = 300\ \Omega$, $C_L = 35\text{ pF}$ $V_S = 8\text{ V}$; see Figure 27
t_{BBM}	45		10	ns typ ns min	$R_L = 300\ \Omega$, $C_L = 35\text{ pF}$ $V_{S1} = V_{S2} = 8\text{ V}$; see Figure 28
$t_{ON}(\overline{EN})$	150			ns typ	$R_L = 300\ \Omega$, $C_L = 35\text{ pF}$ $V_S = 8\text{ V}$; see Figure 29
$t_{OFF}(\overline{EN})$	195 45	230	265	ns typ	$R_L = 300\ \Omega$, $C_L = 35\text{ pF}$ $V_S = 8\text{ V}$; see Figure 29
Charge Injection	60 −0.3	70	75	pC typ	$V_S = 8\text{ V}$; see Figure 29 $V_S = 6\text{ V}$, $R_S = 0\ \Omega$, $C_L = 1\text{ nF}$; see Figure 30
Off Isolation	−80			dB typ	$R_L = 50\ \Omega$, $C_L = 5\text{ pF}$, $f = 1\text{ MHz}$; see Figure 31
Channel-to-Channel Crosstalk	−85			dB typ	$R_L = 50\ \Omega$, $C_L = 5\text{ pF}$, $f = 1\text{ MHz}$; see Figure 33
−3 dB Bandwidth	600			MHz typ	$R_L = 50\ \Omega$, $C_L = 5\text{ pF}$; see Figure 32
C_S (Off)	1.5			pF typ	$f = 1\text{ MHz}$; $V_S = 6\text{ V}$
	1.7			pF max	$f = 1\text{ MHz}$; $V_S = 6\text{ V}$
C_D (Off)	2			pF typ	$f = 1\text{ MHz}$; $V_S = 6\text{ V}$
	2.2			pF max	$f = 1\text{ MHz}$; $V_S = 6\text{ V}$
C_D, C_S (On)	4			pF typ	$f = 1\text{ MHz}$; $V_S = 6\text{ V}$
	4.5			pF max	$f = 1\text{ MHz}$; $V_S = 6\text{ V}$

ADG1233/ADG1234

Parameter	Y Version ¹			Unit	Test Conditions/Comments
	+25°C	-40°C to +85°C	-40°C to +125°C		
POWER REQUIREMENTS					$V_{DD} = 13.2\text{ V}$
I_{DD}	0.002			$\mu\text{A typ}$	Digital inputs = 0 V or V_{DD}
			1.0	$\mu\text{A max}$	
I_{DD}	260			$\mu\text{A typ}$	Digital inputs = 5 V
			440	$\mu\text{A max}$	
V_{DD}			5/16.5	V min/max	$V_{SS} = 0\text{ V}$, GND = 0 V

¹ Temperature range for the Y version: -40°C to +125°C

² Guaranteed by design, not subject to production test.

ABSOLUTE MAXIMUM RATINGS

$T_A = 25^\circ\text{C}$, unless otherwise noted.

Table 3.

Parameter	Rating
V_{DD} to V_{SS}	35 V
V_{DD} to GND	-0.3 V to +25 V
V_{SS} to GND	+0.3 V to -25 V
Analog, Digital Inputs ¹	$V_{SS} - 0.3\text{ V}$ to $V_{DD} + 0.3\text{ V}$ or 30 mA, whichever occurs first
Continuous Current, S or D	24 mA
Peak Current, S or D (Pulsed at 1 ms, 10% Duty Cycle Mximum)	100 mA
Operating Temperature Range	
Automotive Temperature Range (Y Version)	-40°C to +125°C
Storage Temperature Range	-65°C to +150°C
Junction Temperature	150°C
TSSOP, θ_{JA} , Thermal Impedance	112°C/W
LFCSP, θ_{JA} , Thermal Impedance	30.4°C/W
Reflow Soldering Peak Temperature, Pb-Free	260°C

¹Overvoltages at A, \overline{EN} , S, or D are clamped by internal diodes. Current should be limited to the maximum ratings given.

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 indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Only one absolute maximum rating is applied at any one time.

ESD 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 this product 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.



ADG1233/ADG1234

PIN CONFIGURATIONS AND FUNCTION DESCRIPTIONS

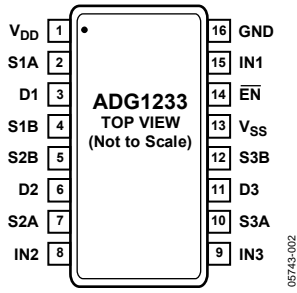


Figure 3. 16-Lead TSSOP Pin Configuration

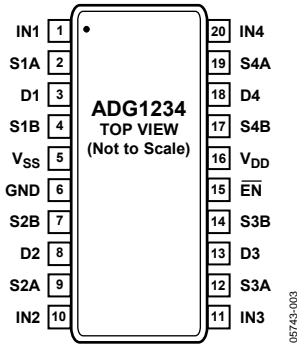


Figure 4. 20-Lead TSSOP Pin Configuration

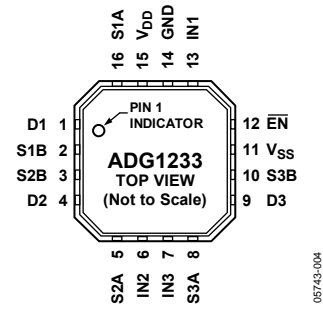


Figure 5. 16-Lead, 4 mm x 4 mm LFCSP Pin Configuration, Exposed Pad Tied to Substrate, V_{SS}

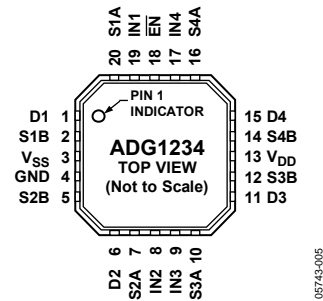


Figure 6. 20-Lead, 4 mm x 4 mm LFCSP Pin Configuration, Exposed Pad Tied to Substrate, V_{SS}

Table 4. 16-Lead TSSOP/20-Lead TSSOP Pin Configurations

Pin No. ADG1233 16-Lead TSSOP	Pin No. ADG1234 20-Lead TSSOP	Mnemonic
1	16	V _{DD}
2	2	S1A
3	3	D1
4	4	S1B
5	7	S2B
6	8	D2
7	9	S2A
8	10	IN2
9	11	IN3
10	12	S3A
11	13	D3
12	14	S3B
13	5	V _{SS}
14	15	EN
15	1	IN1
16	6	GND
N/A	17	S4B
N/A	18	D4
N/A	19	S4A
N/A	20	IN4

Table 5. 16-Lead LFCSP/20-Lead LFCSP Pin Configurations

Pin No. ADG1233 16-Lead LFCSP	Pin No. ADG1234 20-Lead LFCSP	Mnemonic
1	1	D1
2	2	S1B
3	5	S2B
4	6	D2
5	7	S2A
6	8	IN2
7	9	IN3
8	10	S3A
9	11	D3
10	12	S3B
11	3	V _{SS}
12	18	EN
13	19	IN1
14	4	GND
15	13	V _{DD}
16	20	S1A
N/A	14	S4B
N/A	15	D4
N/A	16	S4A
N/A	17	IN4

Table 6. ADG1233/ADG1234 Truth Table

EN	IN _x	Switch xA	Switch xB
1	X	Off	Off
0	0	Off	On
0	1	On	Off

TERMINOLOGY

V_{DD}

Most positive supply potential.

V_{SS}

Most negative power supply potential in dual supplies. In single-supply applications, it can be connected to ground.

GND

Ground (0 V) reference.

R_{ON}

Ohmic resistance between D and S.

ΔR_{ON}

Difference between the R_{ON} of any two channels.

I_S (Off)

Source leakage current when switch is off.

I_D (Off)

Drain leakage current when switch is off.

I_D, I_S (On)

Channel leakage current when switch is on.

V_D, V_S

Analog voltage on Terminal D, Terminal 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.

$t_{ON}(\overline{EN})$

Delay time between the 50% and 90% points of the digital input and switch on condition.

$t_{OFF}(\overline{EN})$

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_{BEM}

Off time measured between the 80% point 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.

I_{DD}

Positive supply current.

I_{SS}

Negative supply current.

Off Isolation

A measure of an 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.

Bandwidth

Frequency at which the output is attenuated by 3 dB.

On Response

Frequency response of the on switch.

THD + N

Ratio of the harmonic amplitude plus noise of the signal to the fundamental.

TYPICAL PERFORMANCE CHARACTERISTICS

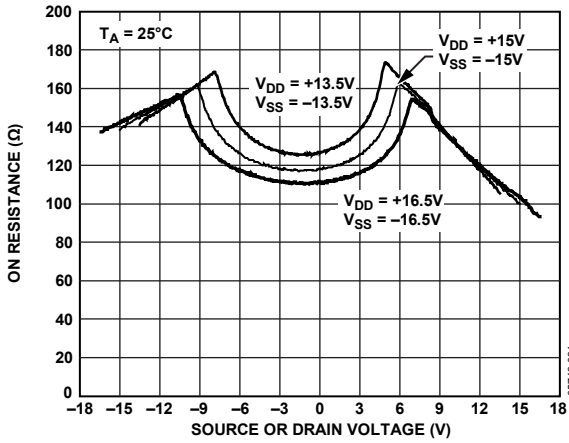


Figure 7. On Resistance as a Function of V_D (V_S) for Dual Supply

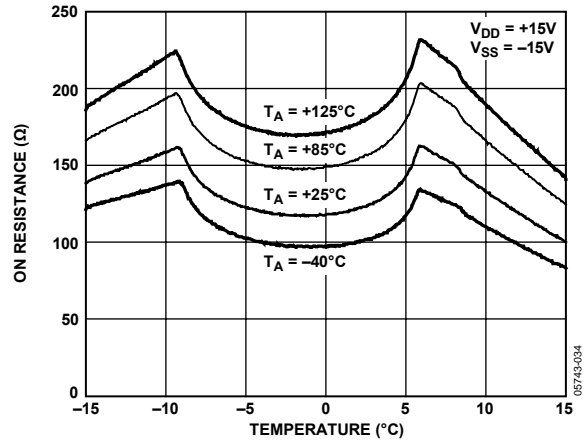


Figure 10. On Resistance as a Function of V_D (V_S) for Different Temperatures, Dual Supply

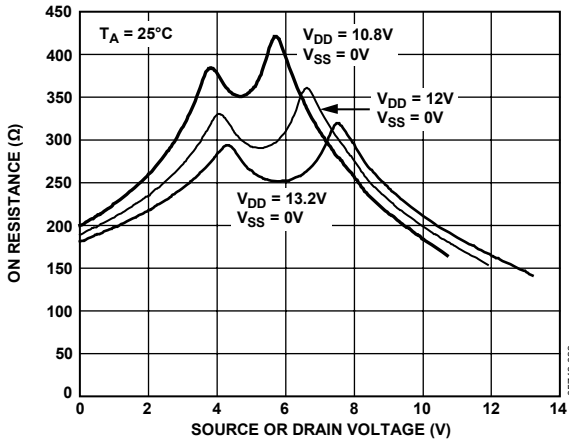


Figure 8. On Resistance as a Function of V_D (V_S) for Dual Supply

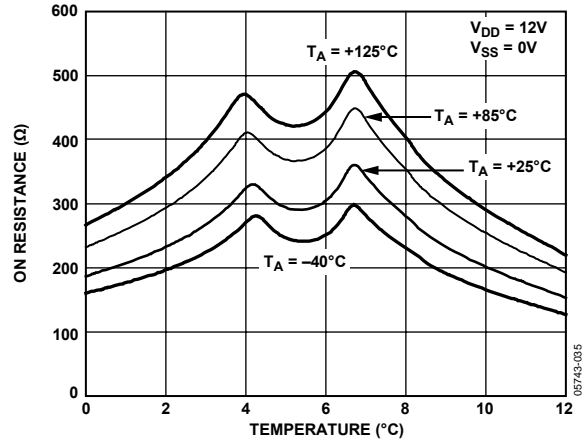


Figure 11. On Resistance as a Function of V_D (V_S) for Different Temperatures, Single Supply

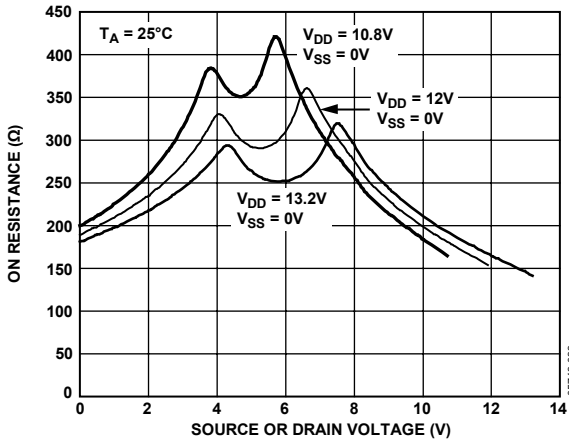


Figure 9. On Resistance as a Function of V_D (V_S) for Single Supply

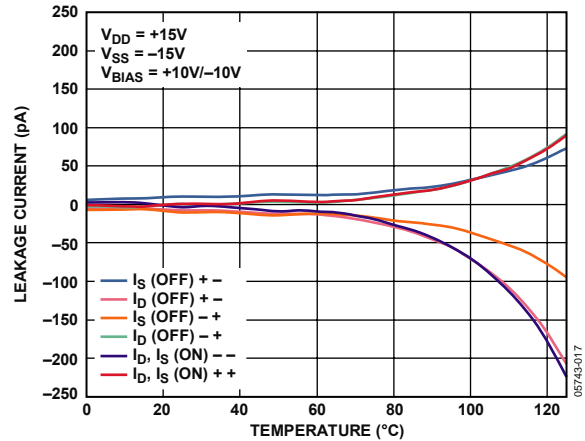


Figure 12. Leakage Currents as a Function of Temperature, Dual Supply

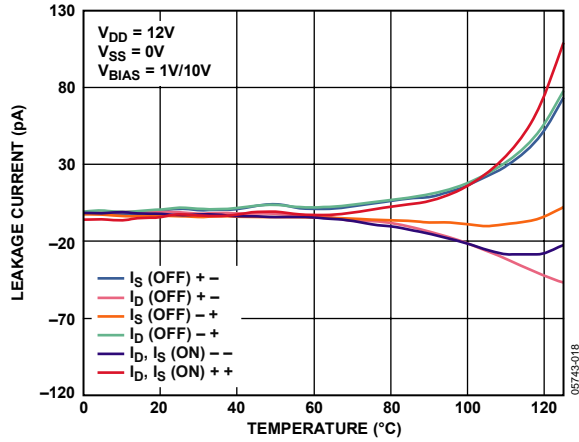


Figure 13. Leakage Currents as a Function of Temperature, Single Supply

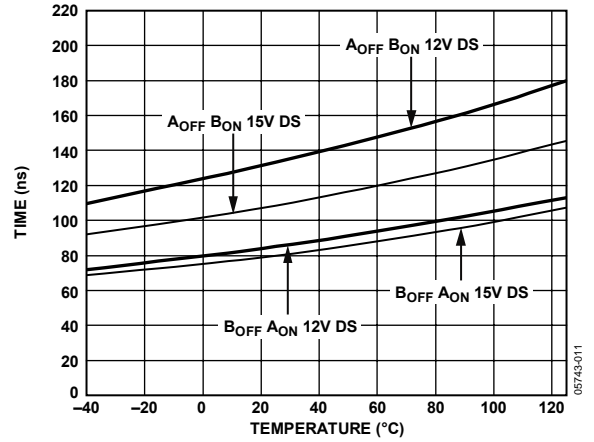


Figure 16. $t_{\text{TRANSITION}}$ vs. Temperature

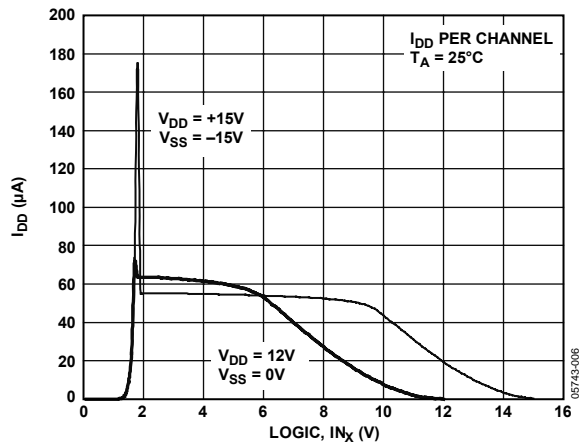


Figure 14. I_{DD} vs. Logic Level

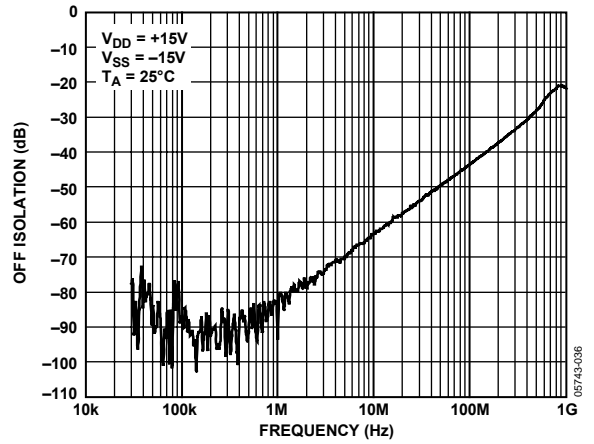


Figure 17. Off Isolation vs. Frequency

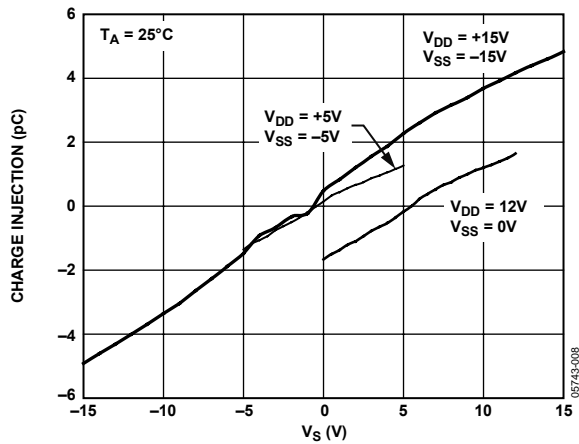


Figure 15. Charge Injection vs. Source Voltage

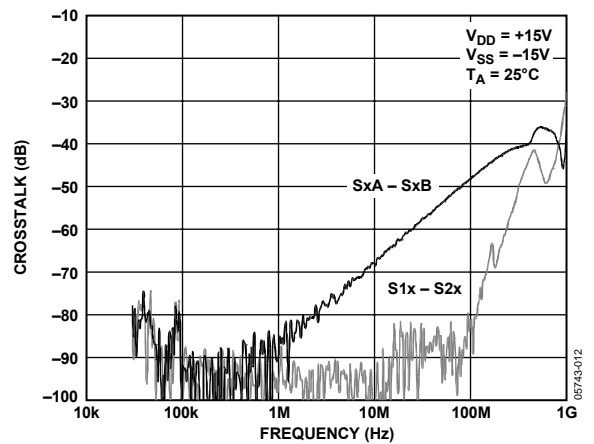


Figure 18. Crosstalk vs. Frequency

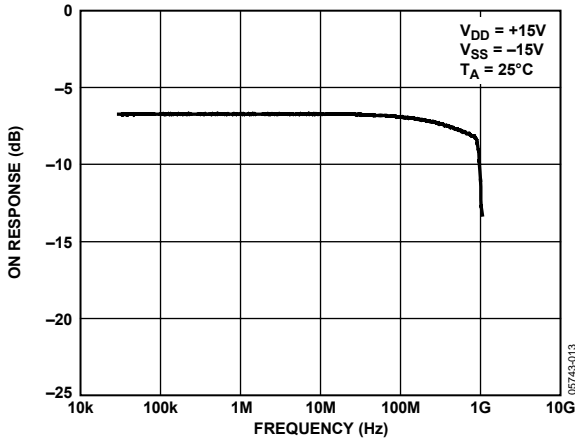


Figure 19. On Response vs. Frequency

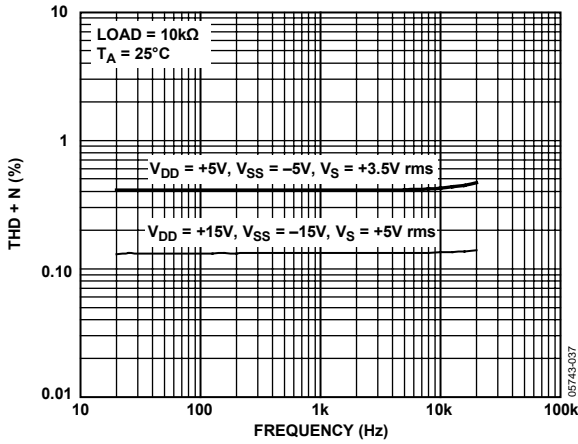


Figure 20. THD + N vs. Frequency

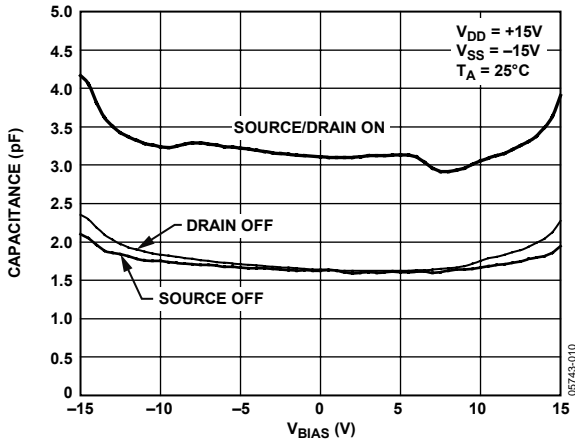


Figure 21. Capacitance vs. Source Voltage for Dual Supply

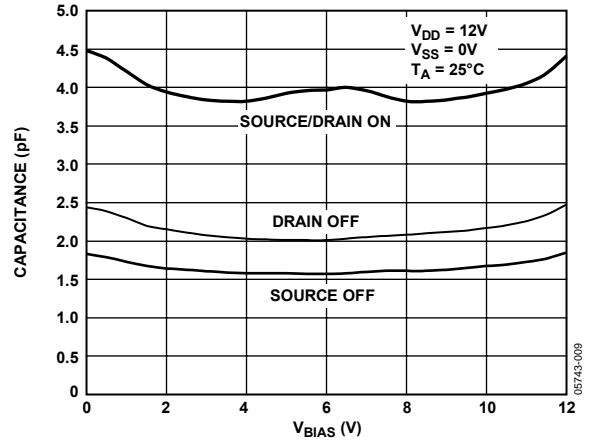


Figure 22. Capacitance vs. Source Voltage for Single Supply

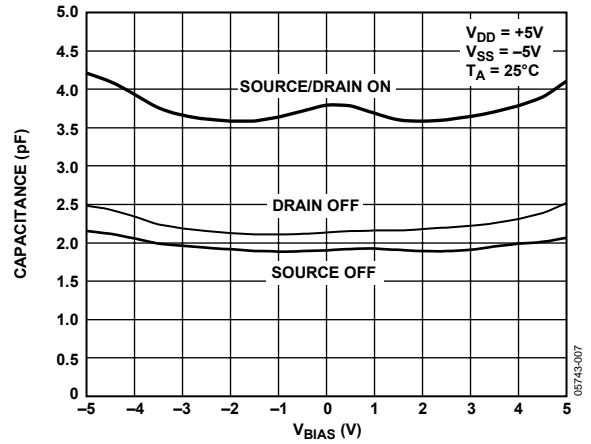


Figure 23. Capacitance vs. Source Voltage for Dual Supply

TEST CIRCUITS

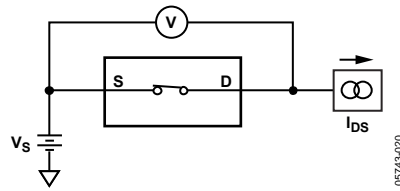


Figure 24. On Resistance

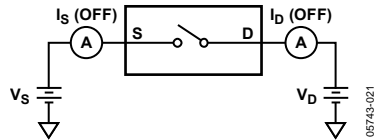


Figure 25. Off Leakage

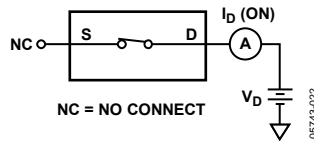


Figure 26. On Leakage

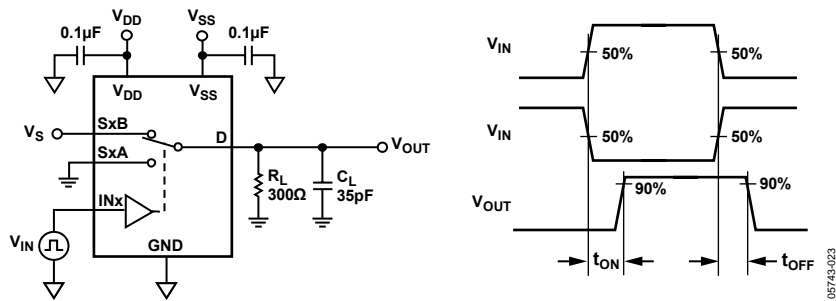


Figure 27. Switching Timing

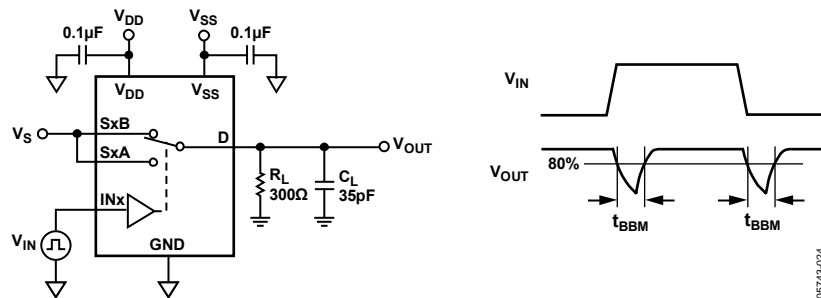


Figure 28. Break-Before-Make Delay

ADG1233/ADG1234

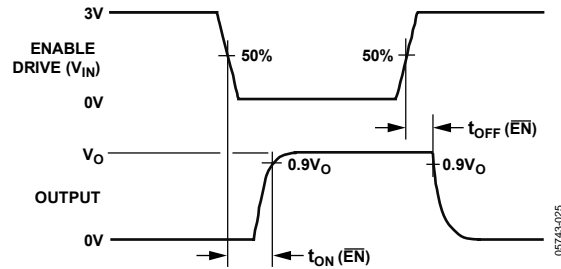
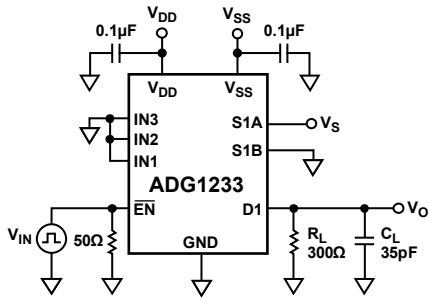


Figure 29. Enable Delay, $t_{ON}(\overline{EN})$, $t_{OFF}(\overline{EN})$

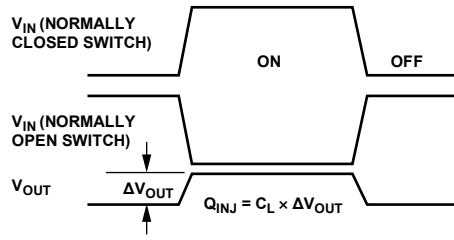
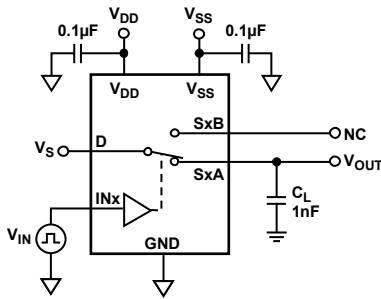
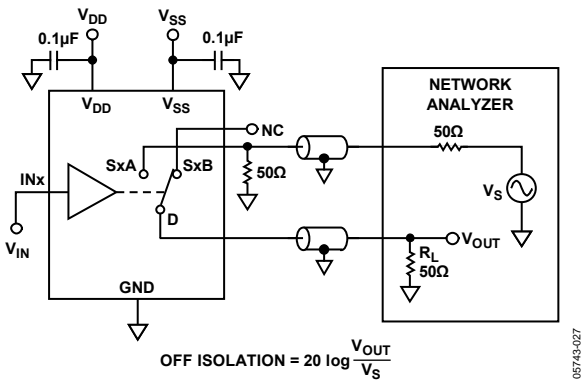
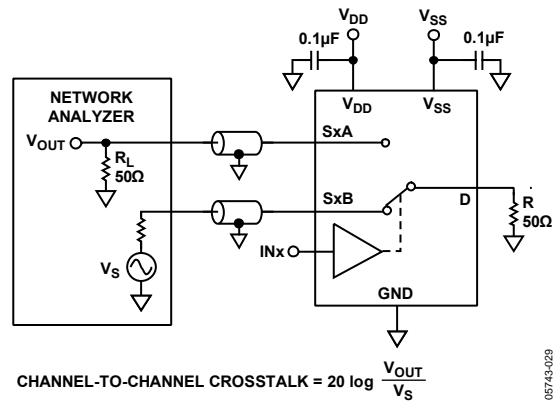


Figure 30. Charge Injection



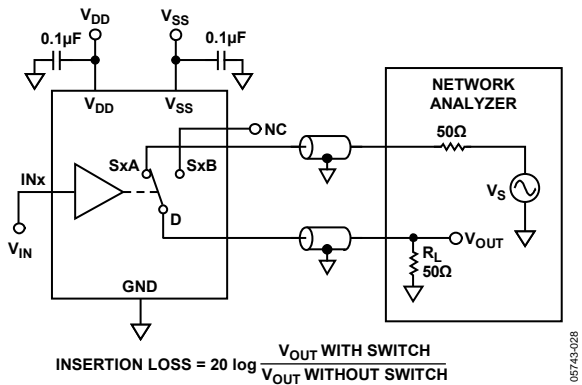
$$\text{OFF ISOLATION} = 20 \log \frac{V_{OUT}}{V_S}$$

Figure 31. Off Isolation



$$\text{CHANNEL-TO-CHANNEL CROSSTALK} = 20 \log \frac{V_{OUT}}{V_S}$$

Figure 33. Channel-to-Channel Crosstalk



$$\text{INSERTION LOSS} = 20 \log \frac{V_{OUT \text{ WITH SWITCH}}}{V_{OUT \text{ WITHOUT SWITCH}}}$$

Figure 32. Bandwidth

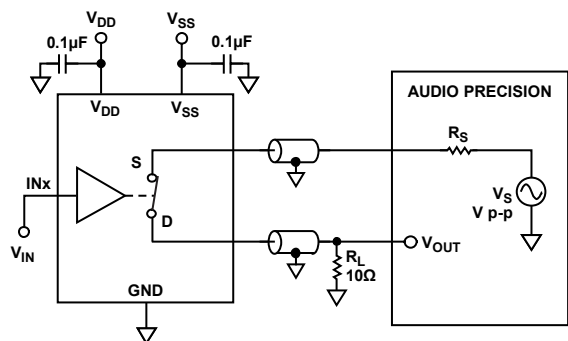
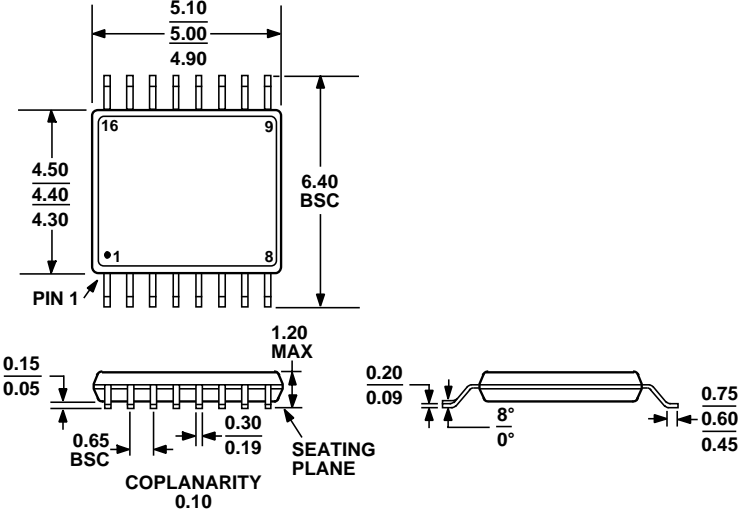


Figure 34. THD + Noise

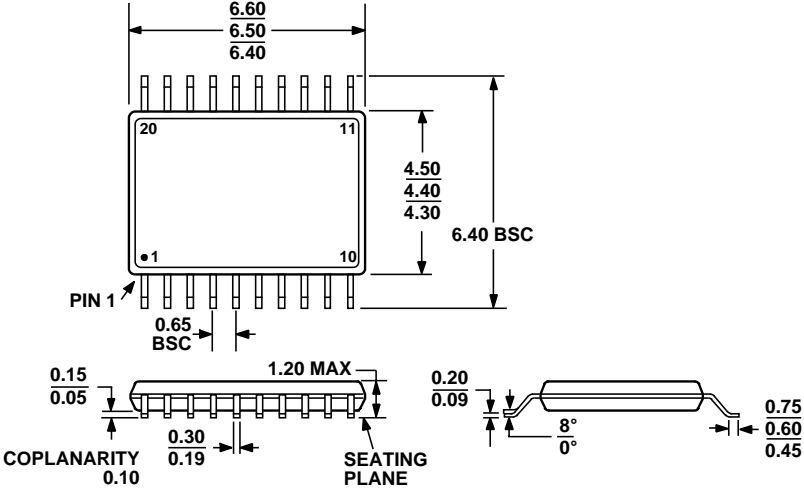
OUTLINE DIMENSIONS



COMPLIANT TO JEDEC STANDARDS MO-153-AB

Figure 35. 16-Lead Thin Shrink Small Outline Package [TSSOP] (RU-16)

Dimensions shown in millimeters

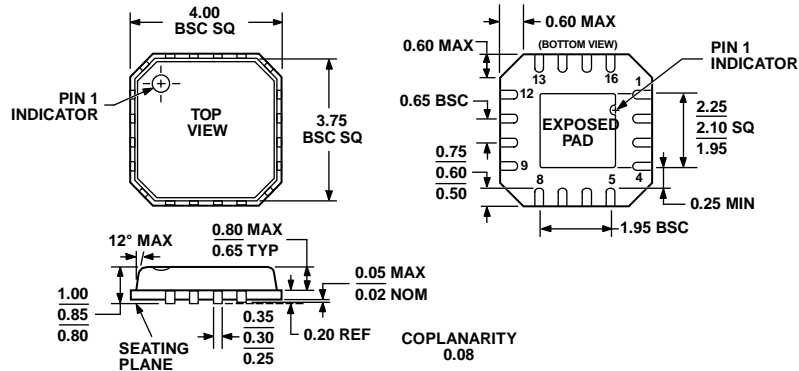


COMPLIANT TO JEDEC STANDARDS MO-153-AC

Figure 36. 20-Lead Thin Shrink Small Outline Package [TSSOP] (RU-20)

Dimensions shown in millimeters

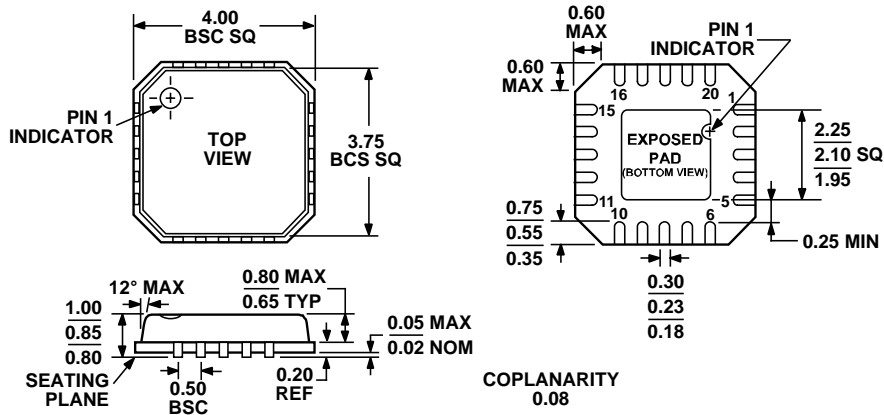
ADG1233/ADG1234



COMPLIANT TO JEDEC STANDARDS MO-220-VGGC

Figure 37. 16-Lead Lead Frame Chip Scale Package [LFCSP_VQ]
4 mm × 4 mm Body, Very Thin Quad
(CP-16-4)

Dimensions shown in millimeters



COMPLIANT TO JEDEC STANDARDS MO-220-VGGD-1

Figure 38. 20-Lead Lead Frame Chip Scale Package [LFCSP_VQ]
4 mm × 4 mm Body, Very Thin Quad
(CP-20-1)

Dimensions shown in millimeters

ORDERING GUIDE

Model	Temperature Range	Package Description	Package Option
ADG1233YRUZ ¹	-40°C to +125°C	16-Lead Thin Shrink Small Outline Package (TSSOP)	RU-16
ADG1233YRUZ-REEL7 ¹	-40°C to +125°C	16-Lead Thin Shrink Small Outline Package (TSSOP)	RU-16
ADG1233YCPZ-REEL ¹	-40°C to +125°C	16-Lead Lead Frame Chip Scale Package (LFCSP_VQ)	CP-16-4
ADG1233YCPZ-REEL7 ¹	-40°C to +125°C	16-Lead Lead Frame Chip Scale Package (LFCSP_VQ)	CP-16-4
ADG1234YRUZ ¹	-40°C to +125°C	20-Lead Thin Shrink Small Outline Package (TSSOP)	RU-20
ADG1234YRUZ-REEL7 ¹	-40°C to +125°C	20-Lead Thin Shrink Small Outline Package (TSSOP)	RU-20
ADG1234YCPZ-REEL ¹	-40°C to +125°C	20-Lead Lead Frame Chip Scale Package (LFCSP_VQ)	CP-20-1
ADG1234YCPZ-REEL7 ¹	-40°C to +125°C	20-Lead Lead Frame Chip Scale Package (LFCSP_VQ)	CP-20-1

¹ Z = Pb-free part.