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Low-Voltage, SPST, CMOS Analog Switches

MAX4501/MAX4502

General Description

The MAX4501/MAX4502 are single-pole/single-throw (SPST), low-voltage, single-supply, CMOS analog switches. The MAX4501 is normally open (NO). The MAX4502 is normally closed (NC).

These CMOS switches can operate continuously with a single supply between +2V and +12V. Each switch can handle rail-to-rail analog signals. The off-leakage current is only 1.0nA at +25°C or 10nA at +85°C.

The digital input has 0.8V and 2.4V logic thresholds, ensuring TTL/CMOS-logic compatibility when using a single +5V supply.

Features

♦ **Available in SOT23-5 Package**
♦ **+2V to +12V Single-Supply Operation**
♦ **Guaranteed On-Resistance: 250Ω at +5V**
♦ **Guaranteed Low Off-Leakage Current:**
    1nA at +25°C
    10nA at +85°C
♦ **Guaranteed Low On-Leakage Current:**
    2nA at +25°C
    20nA at +85°C
♦ **Low Charge Injection: 10pC**
♦ **Fast Switching Speed: t_{ON} = 75ns, t_{OFF} = 50ns**
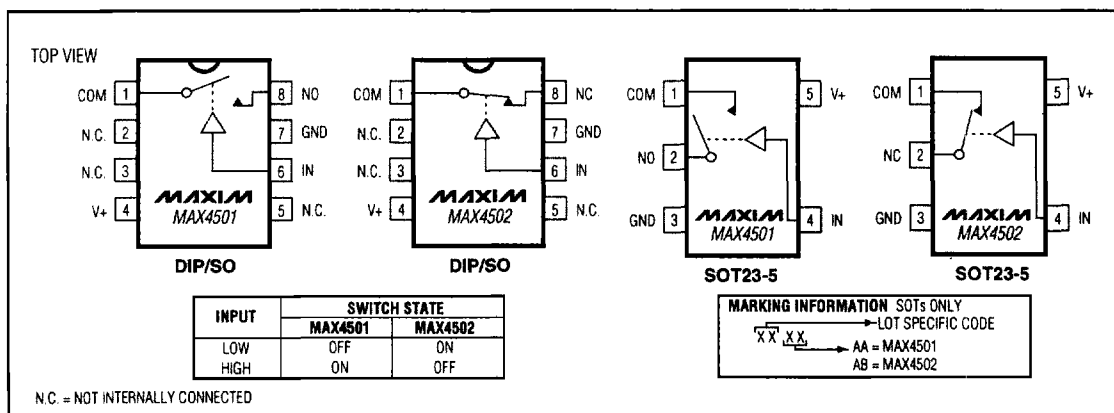♦ **TTL/CMOS-Logic Compatible with +5V Supply**

Applications

Battery-Operated Equipment

Audio and Video Signal Routing

Low-Voltage Data-Acquisition Systems

Communications Circuits

PCMCIA Cards

Cellular Phones

Modems

Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE
MAX4501CPA	0°C to +70°C	8 Plastic DIP
MAX4501CSA	0°C to +70°C	8 SO
MAX4501CUK	0°C to +70°C	5 SOT23-5
MAX4501C/D	0°C to +70°C	Dice*
MAX4501EPA	-40°C to +85°C	8 Plastic DIP
MAX4501ESA	-40°C to +85°C	8 SO
MAX4501EUK	-40°C to +85°C	5 SOT23-5
MAX4501MJA	-55°C to +125°C	8 CERDIP**

Ordering Information continued at end of data sheet.

* Contact factory for dice specifications.
** Contact factory for availability.

Pin Configurations/Functional Diagrams/Truth Table

INPUT	SWITCH STATE	
	MAX4501	**MAX4502**
LOW	OFF	ON
HIGH	ON	OFF

N.C. = NOT INTERNALLY CONNECTED

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Low-Voltage, SPST, CMOS Analog Switches

ABSOLUTE MAXIMUM RATINGS

(Voltages Referenced to GND)

V+ ....-0.3V, +13V
Voltage into Any Terminal (Note 1)..........-0.3V to (V+ + 0.3V)
    or ±10mA (whichever occurs first)
Continuous Current into Any Terminal ....±10mA
Peak Current, NO_ or COM_
    (pulsed at 1ms,10% duty cycle)............ ....±20mA
ESD per Method 3015.7 ....>2000V
Continuous Power Dissipation (T$_A$ = +70°C)
    Plastic DIP (derate 9.09mW/°C above +70°C) 727mW
    SO (derate 5.88mW/°C above +70°C).................... .....471mW

SOT23-5 (derate 7.1mW/°C above +70°C)..................571mW
CERDIP (derate 8.00mW/°C above +70°C).................640mW
Operating Temperature Ranges
    MAX4501C_ _/MAX4502C_ _ ....0°C to +70°C
    MAX4501E_ _/MAX4502E_ _ ....-40°C to +85°C
    MAX4501MJA/MAX4502MJA ....-55°C to +125°C
Storage Temperature Range ....-65°C to +150°C
Lead Temperature (soldering, 10sec)..........................+300°C

Note 1: Voltages exceeding V+ or GND on any signal terminal are clamped by internal diodes. Limit forward-diode current to
      maximum current rating.

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS—+5V Supply

(V+ = +4.5V to +5.5V, V$_{INH}$ = 2.4V, V$_{INL}$ = 0.8V, T$_A$ = T$_{MIN}$ to T$_{MAX}$, unless otherwise noted. Typical values are at T$_A$ = +25°C.)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP (Note 2)	MAX	UNITS
ANALOG SWITCH							
Analog Signal Range	V$_{COM}$, V$_{NO}$, V$_{NC}$			0		V+	V
COM to NO or NC On-Resistance	R$_{ON}$	V$_{COM}$ = 3.5V, I$_{COM}$ = 1mA	T$_A$ = +25°C		90	250	Ω
			T$_A$ = T$_{MIN}$ to T$_{MAX}$			350	
NO or NC Off-Leakage Current (Note 3)	I$_{NO(OFF)}$, I$_{NC(OFF)}$	V+ = 5.5V, V$_{COM}$ = 1V, V$_{NO}$ or V$_{NC}$ = 4.5V	T$_A$ = +25°C	-1	0.01	1	nA
			T$_A$ = T$_{MIN}$ to T$_{MAX}$ — C, E	-10		10	
			M	-100		100	
COM Off-Leakage Current (Note 3)	I$_{COM(OFF)}$	V+ = 5.5V, V$_{COM}$ = 1V, V$_{NO}$ or V$_{NC}$ = 4.5V	T$_A$ = +25°C	-1	0.01	1	nA
			T$_A$ = T$_{MIN}$ to T$_{MAX}$ — C, E	-10		10	
			M	-100		100	
COM On-Leakage Current (Note 3)	I$_{COM(ON)}$	V+ = 5.5V, V$_{COM}$ = 1V, V$_{NO}$ or V$_{NC}$ = 4.5V	T$_A$ = +25°C	-2	0.01	2	nA
			T$_A$ = T$_{MIN}$ to T$_{MAX}$ — C, E	-20		20	
			M	-200		200	
DIGITAL I/O							
Input Logic High	V$_{IH}$			2.4		V+	V
Input Logic Low	V$_{IL}$			0		0.8	V
Input Current Logic High or Low	I$_{IH}$, I$_{IL}$	V$_{IN}$ = V+, 0V		-1	0.03	1	µA
SWITCH DYNAMIC CHARACTERISTICS							
Turn-On Time	t$_{ON}$	V$_{NO}$ = V$_{NC}$ = 1.5V, V$_{IN}$ = 3V, R$_L$ = 1kΩ Figure 1	T$_A$ = +25°C		16	75	ns
			T$_A$ = T$_{MIN}$ to T$_{MAX}$			150	
Turn-Off Time	t$_{OFF}$	V$_{NO}$ = V$_{NC}$ = 1.5V, V$_{IN}$ = 3V, R$_L$ = 1kΩ Figure 1	T$_A$ = +25°C		10	50	ns
			T$_A$ = T$_{MIN}$ to T$_{MAX}$			150	

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ELECTRICAL CHARACTERISTICS—+5V Supply (continued)

(V+ = +4.5V to +5.5V, V_INH = 2.4V, V_INL = 0.8V, T_A = T_MIN to T_MAX, unless otherwise noted. Typical values are at T_A = +25°C.)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP (Note 2)	MAX	UNITS
SWITCH DYNAMIC CHARACTERISTICS (continued)							
Charge Injection (Note 4)	Q	C_L = 1nF, V_{NO} = 0V, R_S = 0Ω, T_A = +25°C, Figure 2			1	10	pC
Off Isolation	V_{ISO}	R_L = 50Ω, C_L = 15pF, V_{NO} = 1V_RMS, f = 100kHz, T_A = +25°C, Figure 3			< -100		dB
NO or NC Off Capacitance	$C_{NO(OFF)}$, $C_{NC(OFF)}$	f = 1MHz, Figure 4			3		pF
COM Off Capacitance	$C_{COM(OFF)}$	f = 1MHz, Figure 4			3		pF
COM On Capacitance	$C_{COM(ON)}$	f = 1MHz, Figure 4			8		pF
POWER SUPPLY							
V+ Supply Current	I+	V_{IN} = 0V or V+	T_A = +25°C	-1		1	μA
			T_A = T_{MIN} to T_{MAX}	-10		10	

ELECTRICAL CHARACTERISTICS—+12V Supply

(V+ = +11.4V to +12.6V, V_INH = 5.0V, V_INL = 0.8V, T_A = T_MIN to T_MAX, unless otherwise noted. Typical values are at T_A = +25°C.)

PARAMETER	SYMBOL	CONDITIONS			MIN	TYP (Note 2)	MAX	UNITS
ANALOG SWITCH								
Analog Signal Range	V_{COM}, V_{NO}, V_{NC}				0		V+	V
COM to NO or NC On-Resistance	R_{ON}	V_{COM} = 10V, I_{COM} = 1mA	T_A = +25°C			40	160	Ω
			T_A = T_{MIN} to T_{MAX}				200	
NO or NC Off-Leakage Current (Note 3)	$I_{NO(OFF)}$, $I_{NC(OFF)}$	V_{COM} = 10V, V_{NO} or V_{NC} = 1V	T_A = +25°C		-5		5	nA
			T_A = T_{MIN} to T_{MAX}	C, E	-50		50	
				M	-500		500	
COM Off-Leakage Current (Note 3)	$I_{COM(OFF)}$	V_{COM} = 10V, V_{NO} or V_{NC} = 1V	T_A = +25°C		-5		5	nA
			T_A = T_{MIN} to T_{MAX}	C, E	-50		50	
				M	-500		500	
COM On-Leakage Current (Note 3)	$I_{COM(ON)}$	V_{COM} = 10V	T_A = +25°C		-10		10	nA
			T_A = T_{MIN} to T_{MAX}	C, E	-100		100	
				M	-1000		1000	
DIGITAL I/O								
Input Logic High	V_{INH}				5.0		V+	V
Input Logic Low	V_{INL}				0		0.8	V
Input Current Logic High or Low	I_{INH}, I_{INL}	V_{IN} = V+, 0V			-1	0.03	1	μA
POWER SUPPLY								
V+ Supply Current	I+	IN = 0V or V+	T_A = +25°C		-1		1	μA
			T_A = T_{MIN} to T_{MAX}		-10		10	

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ELECTRICAL CHARACTERISTICS—+3V Supply

(V+ = +3.0V to +3.6V, T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A = +25°C.)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP (Note 2)	MAX	UNITS
ANALOG SWITCH							
Analog Signal Range	V_{COM}, V_{NO}, V_{NC}			0		V+	V
COM to NO or NC On-Resistance	R_{ON}	V_{COM} = 1.5V, I_{NO} = 0.1mA	T_A = +25°C		175	600	Ω
			T_A = T_{MIN} to T_{MAX}			800	
DIGITAL I/O							
Input Logic High	V_{INH}			2.4		V+	V
Input Logic Low	V_{INL}			0		0.8	V
Input Current Logic High or Low	I_{INH}, I_{INL}	V_{IN} = V+, 0V		-1.00	0.03	1.00	µA
SWITCH DYNAMIC CHARACTERISTICS							
Turn-On-Time (Note 4)	t_{ON}	V_{NO} = V_{NC} = 1.5V, V_{IN} = 3V, R_L = 1kΩ Figure 1	T_A = +25°C		45	300	ns
			T_A = T_{MIN} to T_{MAX}			500	
Turn-Off-Time (Note 4)	t_{OFF}	V_{NO} = V_{NC} = 1.5V, V_{IN} = 3V, R_L = 1kΩ Figure 1	T_A = +25°C		10	125	ns
			T_A = T_{MIN} to T_{MAX}			175	
Charge Injection (Note 4)	Q	C_L = 1nF, T_A = +25°C, Figure 2			0.5	10	pC
POWER SUPPLY							
V+ Supply Current	I+	IN = 0V or V+	T_A = +25°C	-1		1	µA
			T_A = T_{MIN} to T_{MAX}	-10		10	

Note 2: The algebraic convention is used in this data sheet; the most negative value is shown in the minimum column.

Note 3: Leakage parameters are 100% tested at maximum-rated hot operating temperature, and are guaranteed by correlation at +25°C.

Note 4: Guaranteed, not production tested.

Note 5: SOT packaged parts are 100% tested at +25°C. Limits at maximum and minimum rated temperature are guaranteed by design and correlation limits at +25°C.
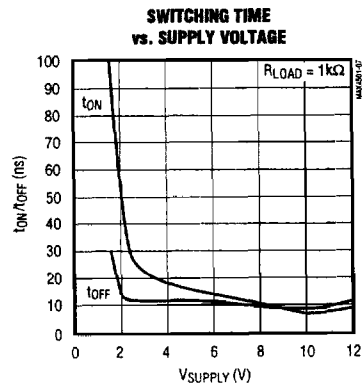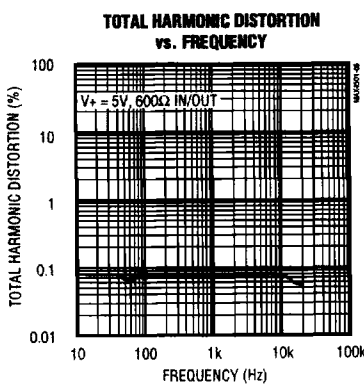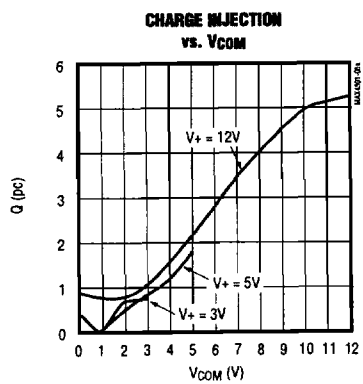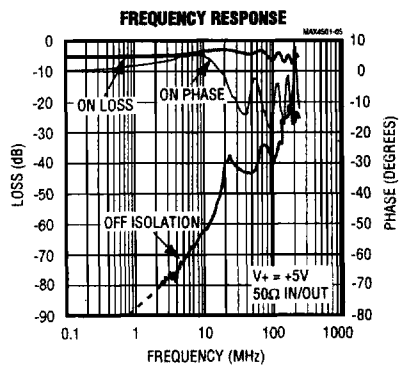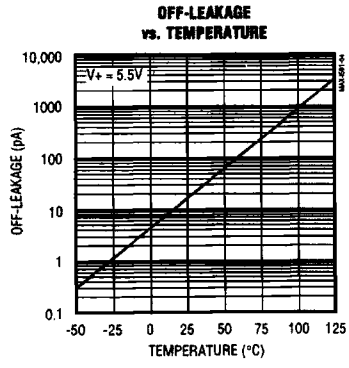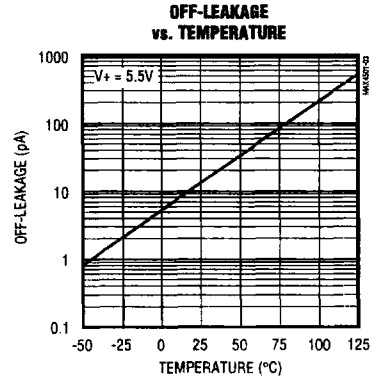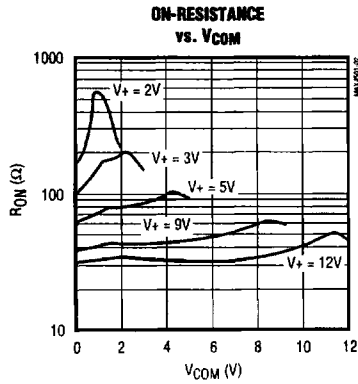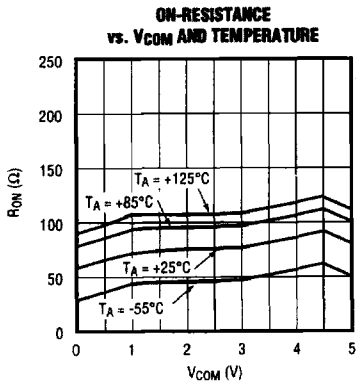
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Low-Voltage, SPST, CMOS Analog Switches

Typical Operating Characteristics

(V+ = 5V, GND = 0V, T$_A$ = +25°C, unless otherwise noted.)

ON-RESISTANCE
vs. V$_{COM}$ AND TEMPERATURE

ON-RESISTANCE
vs. V$_{COM}$

OFF-LEAKAGE
vs. TEMPERATURE

OFF-LEAKAGE
vs. TEMPERATURE

FREQUENCY RESPONSE

CHARGE INJECTION
vs. V$_{COM}$

TOTAL HARMONIC DISTORTION
vs. FREQUENCY

SWITCHING TIME
vs. SUPPLY VOLTAGE

Low-Voltage, SPST, CMOS Analog Switches

Pin Description

PIN				NAME	FUNCTION
MAX4501		MAX4502			
DIP/SO	SOT23-5	DIP/SO	SOT23-5		
1	1	1	1	COM	Analog Switch Common Terminal
2, 3, 5	—	2, 3, 5	—	N.C.	No Connect (not internally connected)
4	5	4	5	V+	Positive Supply-Voltage Input (analog and digital)
6	4	6	4	IN	Digital Control Input
7	3	7	3	GND	Ground
8	2	—	—	NO	Analog Switch (normally open)
—	—	8	2	NC	Analog Switch (normally closed)

Note: NO, NC, and COM pins are identical and interchangeable. Any may be considered as an input or an output; signals pass equally well in both directions.

Applications Information

Power-Supply Considerations

The MAX4501/MAX4502 are constructed like most CMOS analog switches, except they have only two supply pins: V+ and GND. V+ and GND drive the internal CMOS switches and set the analog voltage limits of the switch. Reverse ESD-protection diodes are internally connected between each analog-signal pin and both V+ and GND. One of these diodes conducts if any analog signal exceeds V+ or GND. During normal operation, these and other reverse-biased ESD diodes leak, forming the only current drawn from V+ or GND.

Virtually all the analog leakage current comes from the ESD diodes. Although the ESD diodes on a given signal pin are identical and therefore fairly well balanced, they are reverse biased differently. Each is biased by either V+ or GND and the analog signal. This means their leakages will vary as the signal varies. The *difference* in the two diode leakages to the V+ and GND pins constitutes the analog-signal-path leakage current. All analog leakage current flows between each pin and one of the supply terminals, not to the other switch terminal. This is why both sides of a given switch can show leakage currents of the same or opposite polarity.

There is no connection between the analog-signal paths and V+ or GND.

V+ and GND also power the internal logic and logic-level translators, and set both the input and output logic limits. The logic-level translators convert the logic levels to switched V+ and GND signals to drive the analog

signal gates. This drive signal is the only connection between the logic supplies (and signals) and the analog supplies. COM, NO, and NC pins have ESD-protection diodes to V+ and GND.

The logic-level thresholds are CMOS/TTL-compatible when V+ is +5V. As V+ is raised, the threshold increases slightly. When V+ reaches +12V, the logic-level threshold is about 3V—above the TTL guaranteed high-level minimum of 2.8V, but still compatible with CMOS outputs.

Do not connect the MAX4501/MAX4502's V+ to +3V and then connect the logic-level pins to TTL logic-level signals. TTL levels can exceed +3V and violate the absolute maximum ratings, damaging the part and/or external circuits.

High-Frequency Performance

In 50Ω systems, signal response is reasonably flat up to 250MHz (see *Typical Operating Characteristics*). Above 20MHz, the on response has several minor peaks which are highly layout dependent. The problem is not in turning the switch on; it's in turning it off. The off-state switch acts like a capacitor and passes higher frequencies with less attenuation. At 10MHz, off isolation is about -60dB in 50Ω systems, decreasing approximately 20dB per decade as frequency increases. Higher circuit impedances also cause off isolation to decrease. Adjacent channel attenuation is about 3dB above that of a bare IC socket, and is due entirely to capacitive coupling.

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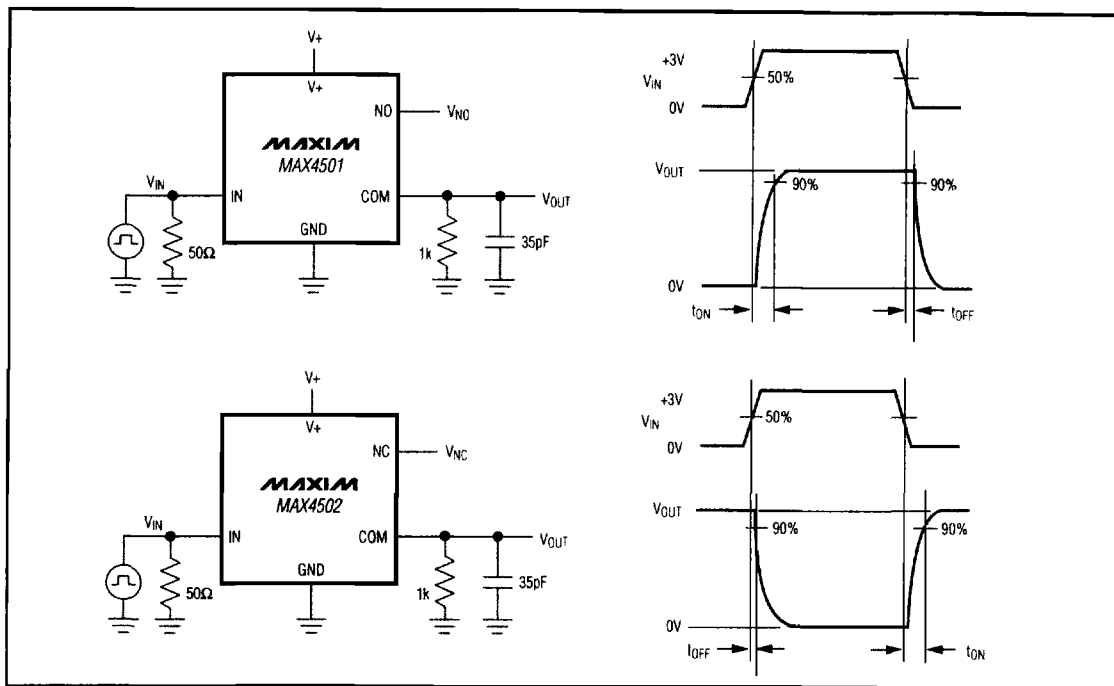# Low-Voltage, SPST, CMOS Analog Switches
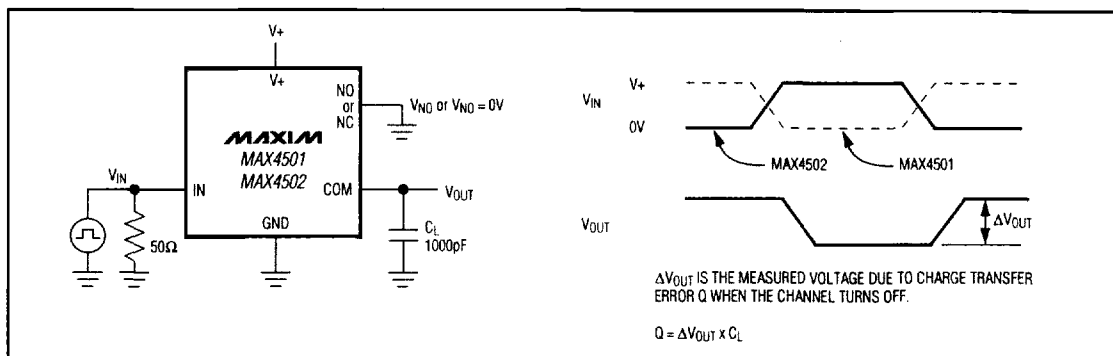
Test Circuits/Timing Diagrams

Figure 1. Switching Times

Figure 2. Charge Injection

Low-Voltage, SPST, CMOS Analog Switches

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

$$\text{ON LOSS} = 20\log \frac{V_{OUT}}{V_{IN}}$$

MEASUREMENTS ARE STANDARDIZED AGAINST SHORT AT SOCKET TERMINALS. OFF ISOLATION IS MEASURED BETWEEN COM AND NO OR NC TERMINAL. ON LOSS IS MEASURED BETWEEN COM AND NO OR NC TERMINAL. SIGNAL DIRECTION THROUGH SWITCH IS REVERSED; WORST VALUES ARE RECORDED.

Figure 3. Off Isolation and On Loss
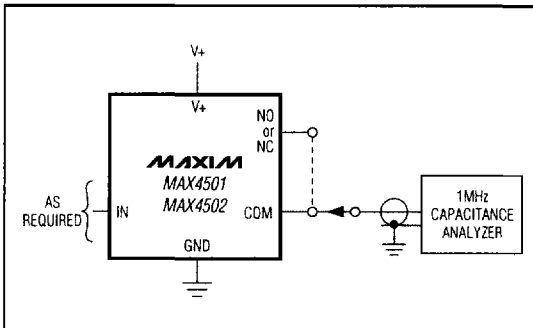
Figure 4. NO, NC, and COM Capacitance

Ordering Information (continued)

PART	TEMP. RANGE	PIN-PACKAGE
MAX4502CPA	0°C to +70°C	8 Plastic DIP
MAX4502CSA	0°C to +70°C	8 SO
MAX4502CUK	0°C to +70°C	5 SOT23-5
MAX4502C/D	0°C to +70°C	Dice*
MAX4502EPA	-40°C to +85°C	8 Plastic DIP
MAX4502ESA	-40°C to +85°C	8 SO
MAX4502EUK	-40°C to +85°C	5 SOT23-5
MAX4502MJA	-55°C to +125°C	8 CERDIP**

* Contact factory for dice specifications.
** Contact factory for availability.

Chip Topography
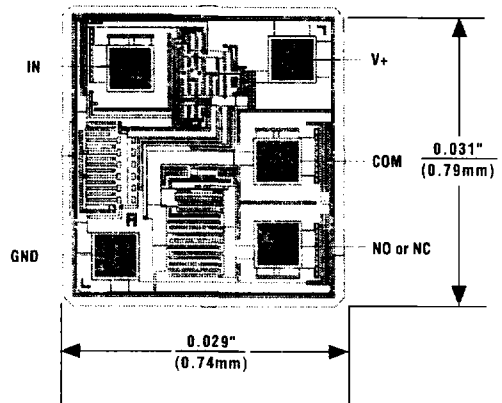
TRANSISTOR COUNT: 17
SUBSTRATE CONNECTED TO V+

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Low-Voltage, SPST, CMOS Analog Switches

NOTE: DIMENSIONS ARE IN MM.
AND FOLLOW EIA481-1 STANDARD.

A_0	3.200	±0.102		E	1.753	±0.102	P_0	3.988	±0.102
B_0	3.099	±0.102		F	3.505	±0.051	$P_0$10	40.005	±0.203
D	1.499	+0.102 +0.000		K_0	1.397	±0.102	P_2	2.007	±0.051
				P	3.988	±0.102	t	0.254	±0.127
D_1	0.991	+0.254 +0.000					W	8.001	+0.305 -0.102

5 SOT23-5

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MAX4501/MAX4502

1