19-1062; Rev 1; 11/99

MAXIM

Low-Voltage, SPST, CMOS Analog Switches

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 1nA 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 and SC70-5 Packages**
- ♦ **+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

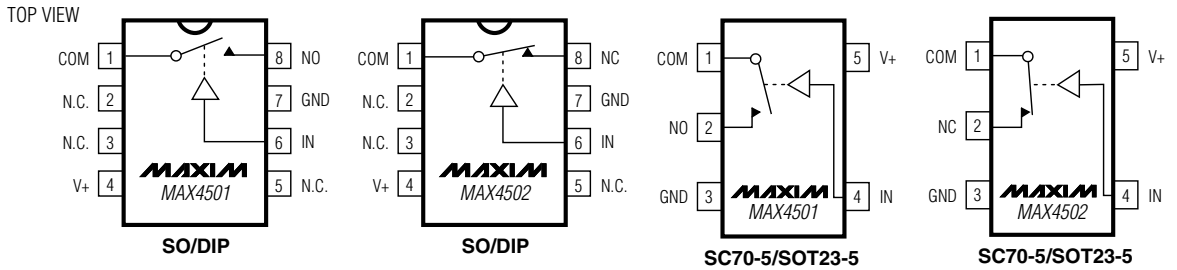
PART	TEMP. RANGE	PIN-PACKAGE	TOP MARK
MAX4501CUK-T	0°C to +70°C	5 SOT23-5	AAAA
MAX4501CSA	0°C to +70°C	8 SO	—
MAX4501CPA	0°C to +70°C	8 Plastic DIP	—
MAX4501C/D	0°C to +70°C	Dice*	—
MAX4501EXK-T	-40°C to +85°C	5 SC70-5	AAE
MAX4501EUK-T	-40°C to +85°C	5 SOT23-5	AAAA
MAX4501ESA	-40°C to +85°C	8 SO	—
MAX4501EPA	-40°C to +85°C	8 Plastic DIP	—
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

Rail-to-Rail is a registered trademark of Nippon Motorola, Ltd.

Low-Voltage, SPST, CMOS Analog Switches

ABSOLUTE MAXIMUM RATINGS

(Voltages Referenced to GND)
V+ .....-0.3V to +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)
5-Pin SC70-5 (derate 2.5mW/°C above +70°C).....200mW
5-Pin SOT23-5 (derate 7.1mW/°C above +70°C) 571mW
8-Pin SO (derate 5.88mW/°C above +70°C).....471mW
8-Pin Plastic DIP (derate 9.09mW/°C above +70°C) ...727mW
8-Pin 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, 10s) .....+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.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS			MIN	TYP	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 (Notes 3, 4)	$I_{NO(OFF)}$, $I_{NC(OFF)}$	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 (Notes 3, 4)	$I_{COM(OFF)}$	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 (Notes 3, 4)	$I_{COM(ON)}$	V+ = 5.5V, V_{COM} = 1V, 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_{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+, 0			-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, C_L = 35pF, 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, C_L = 35pF, Figure 1	T_A = +25°C			10	50	ns
			T_A = T_{MIN} to T_{MAX}				150	

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.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
SWITCH DYNAMIC CHARACTERISTICS (continued)							
Charge Injection (Note 5)	Q	C_L = 1nF, V_{NO} = 0, 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} = 0 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.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS			MIN	TYP	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 (Notes 3, 4)	$I_{NO(OFF)}$, $I_{NC(OFF)}$	V_{COM} = 10V, V_{NO} or V_{NC} = 1V, V+ = +12.6V	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 (Notes 3, 4)	$I_{COM(OFF)}$	V_{COM} = 10V, V_{NO} or V_{NC} = 1V, V+ = +12.6V	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 (Notes 3, 4)	$I_{COM(ON)}$	V_{COM} = 10V, V+ = +12.6V	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} = 0 or V+			-1	0.03	1	µA
POWER SUPPLY								
V+ Supply Current	I+	IN = 0 or V+	T_A = +25°C		-1		1	µA
			T_A = T_{MIN} to T_{MAX}		-10		10	

ELECTRICAL CHARACTERISTICS—+3V Supply

(V+ = +3.0V to +3.6V, 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.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	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_{COM} = 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} = 0 or V+		-1.00	0.03	1.00	µA
SWITCH DYNAMIC CHARACTERISTICS							
Turn-On Time (Note 5)	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 5)	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 5)	Q	C_L = 1nF, T_A = +25°C, Figure 2			0.5	10	pC
POWER SUPPLY							
V+ Supply Current	I+	IN = 0 or V+	T_A = +25°C	-1		1	µA
			T_A = T_{MIN} to T_{MAX}	-10		10	

Note 2: 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.

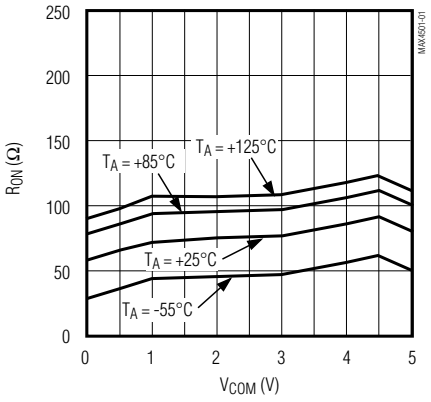
Note 4: SOT and SC70 packaged parts are 100% tested at +25°C. Limits at maximum and minimum rated temperature are guaranteed by design and correlation limits at +25°C.

Note 5: Guaranteed, not production tested.

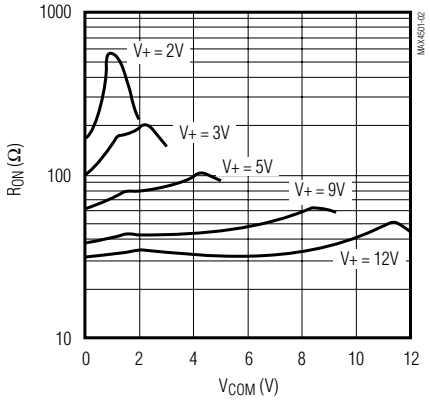
Typical Operating Characteristics

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

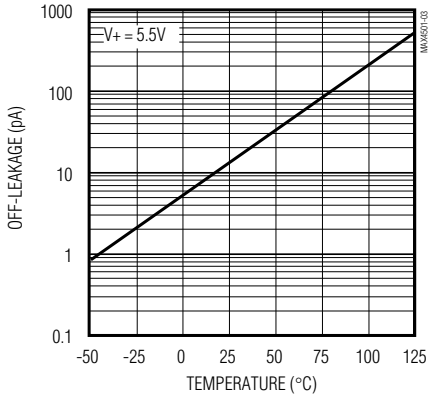
ON-RESISTANCE vs. V_{COM} AND TEMPERATURE



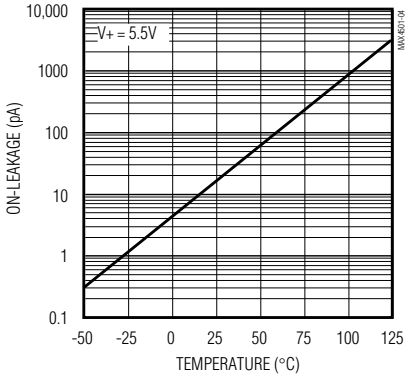
ON-RESISTANCE vs. V_{COM}



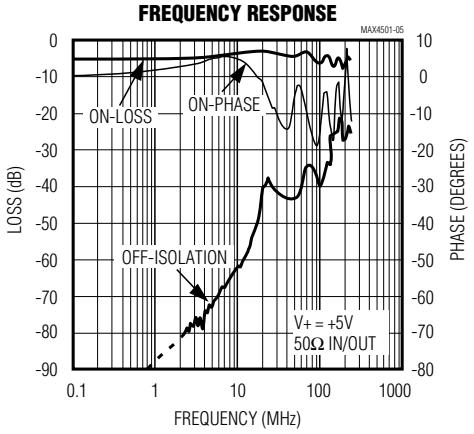
OFF-LEAKAGE vs. TEMPERATURE



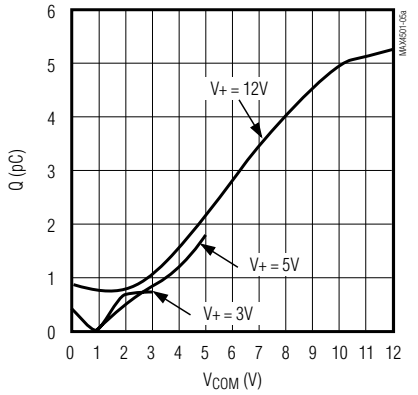
ON-LEAKAGE vs. TEMPERATURE



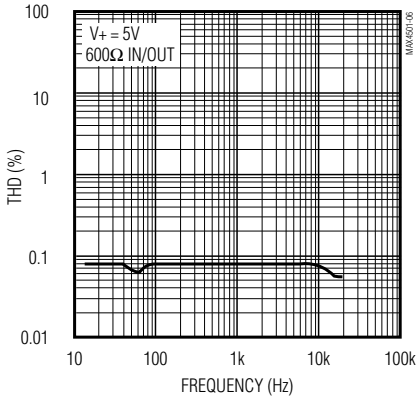
FREQUENCY RESPONSE



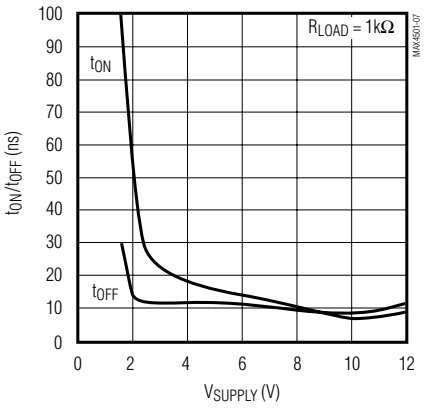
CHARGE INJECTION vs. V_{COM}



TOTAL HARMONIC DISTORTION vs. FREQUENCY



SWITCHING TIME vs. SUPPLY VOLTAGE



Low-Voltage, SPST, CMOS Analog Switches

Pin Description

PIN				NAME	FUNCTION
MAX4501		MAX4502			
SO/DIP	SC70-5/SOT23-5	SO/DIP	SC70-5/SOT23-5		
1	1	1	1	COM	Analog Switch Common Terminal
2, 3, 5	—	2, 3, 5	—	N.C.	No Connection. 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 the input 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+ rises, 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+ pin 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 that 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.

Test Circuits/Timing Diagrams

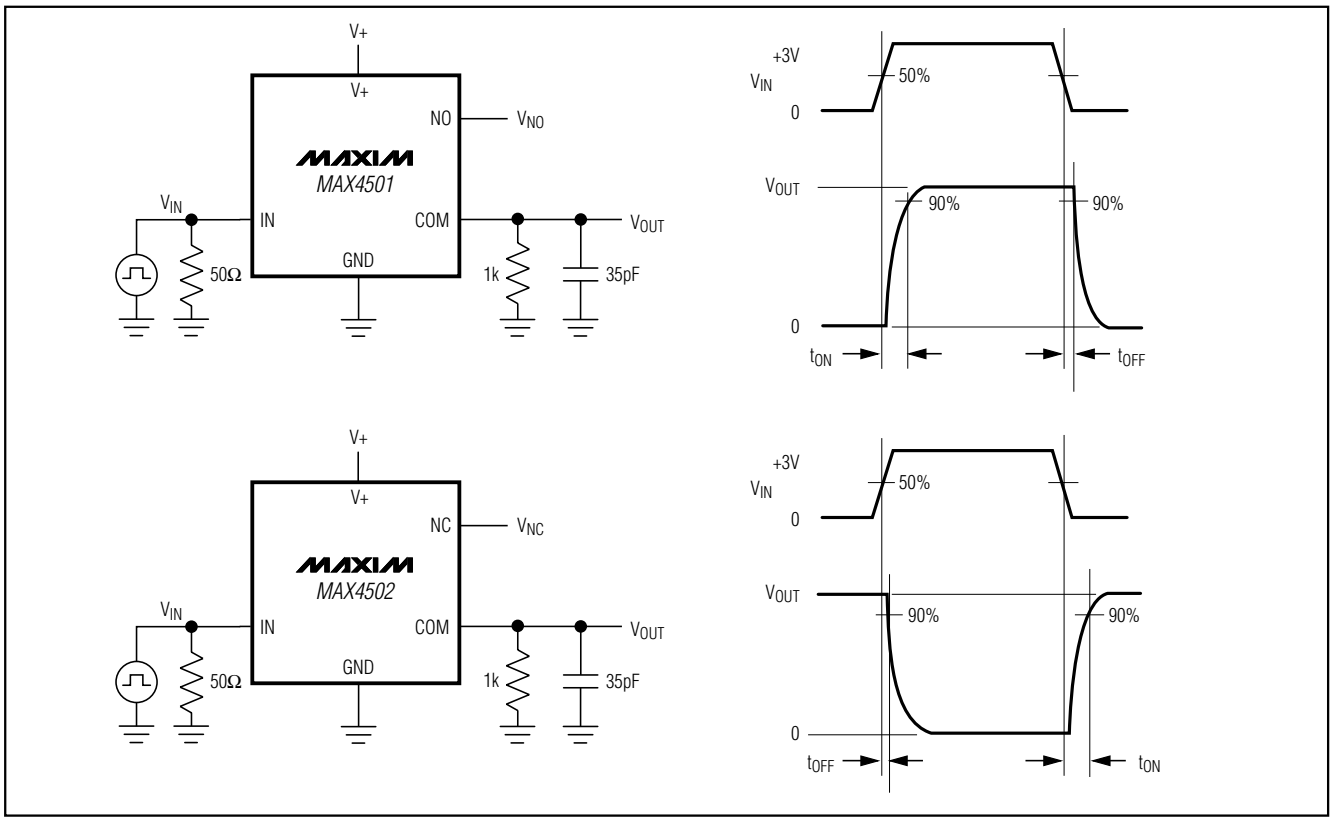


Figure 1. Switching Times

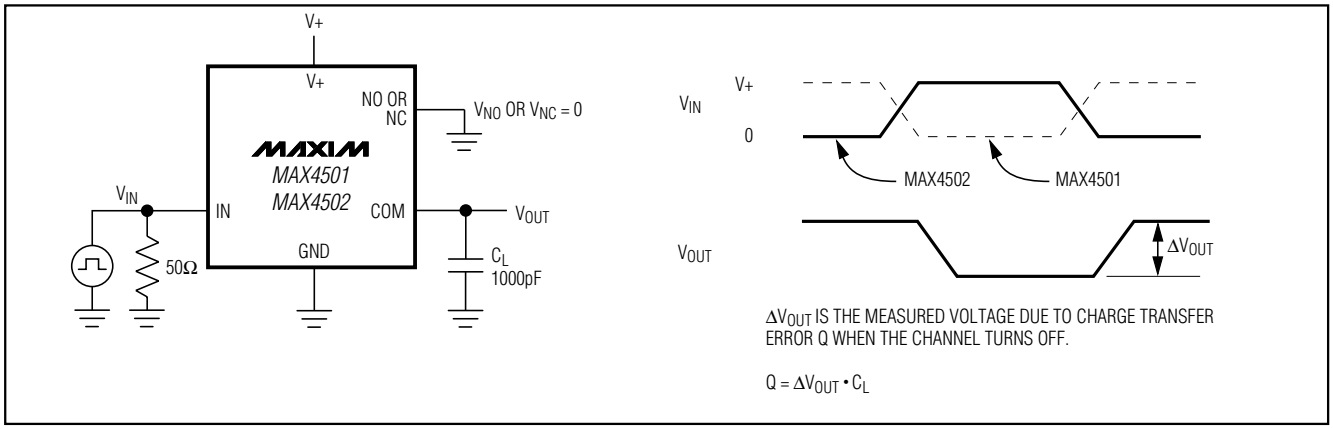


Figure 2. Charge Injection

Low-Voltage, SPST, CMOS Analog Switches

Test Circuits/Timing Diagrams (continued)

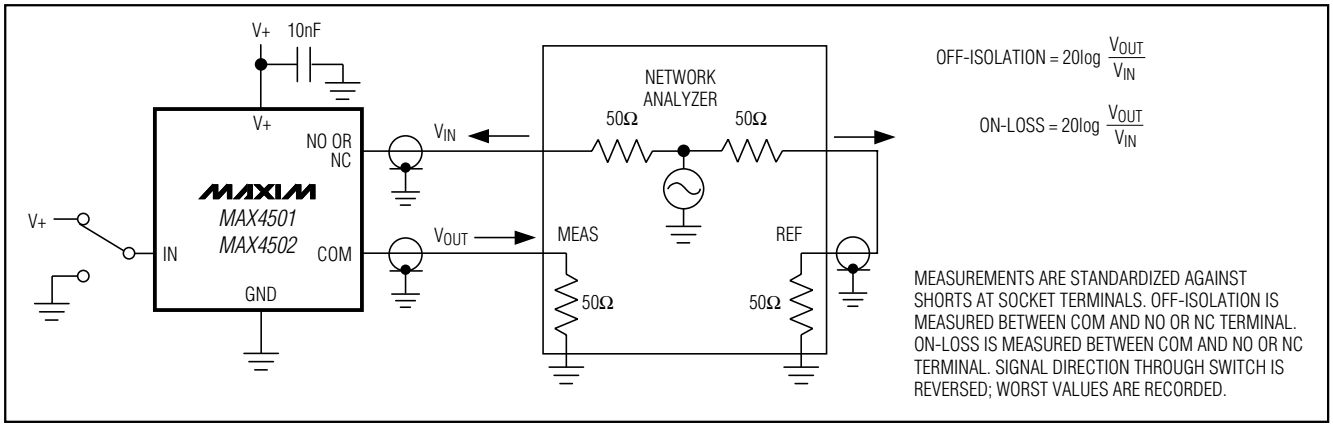


Figure 3. Off-Isolation and On-Loss

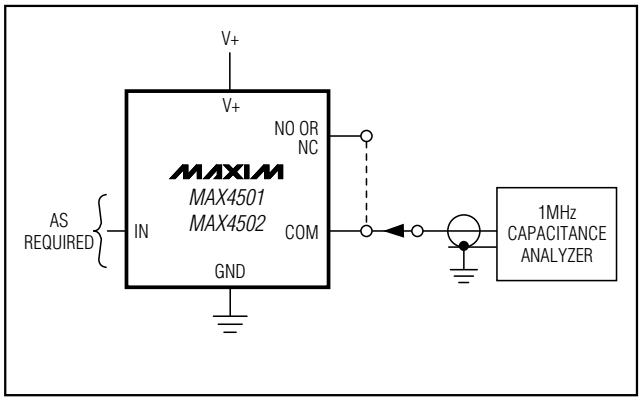
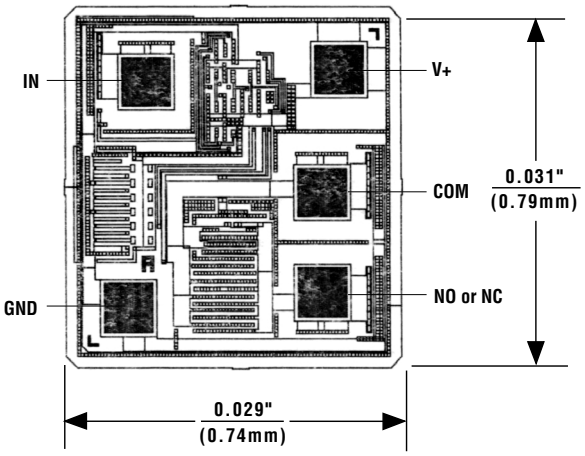


Figure 4. NO, NC, and COM Capacitance

Chip Topography



TRANSISTOR COUNT: 17

SUBSTRATE CONNECTED TO V+

Ordering Information (continued)

PART	TEMP. RANGE	PIN-PACKAGE	TOP MARK
MAX4502CUK-T	0°C to +70°C	5 SOT23-5	AAAB
MAX4502CSA	0°C to +70°C	8 SO	—
MAX4502CPA	0°C to +70°C	8 Plastic DIP	—
MAX4502C/D	0°C to +70°C	Dice*	—
MAX4502EXK-T	-40°C to +85°C	5 SC70-5	AAF
MAX4502EUK-T	-40°C to +85°C	5 SOT23-5	AAAB
MAX4502ESA	-40°C to +85°C	8 SO	—
MAX4502EPA	-40°C to +85°C	8 Plastic DIP	—
MAX4502MJA	-55°C to +125°C	8 CERDIP**	—

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