National Semiconductor

August 1989

MM54HC4016/MM74HC4016 Quad Analog Switch

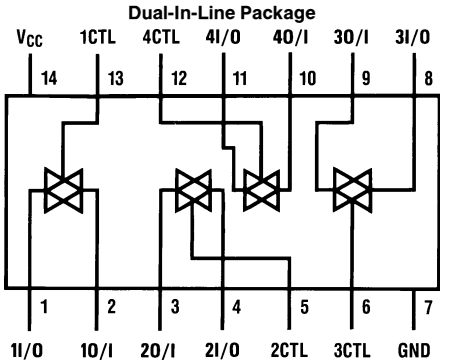
General Description

These devices are digitally controlled analog switches implemented in advanced silicon-gate CMOS technology. These switches have low ''on'' resistance and low ''off'' leakages. They are bidirectional switches, thus any analog input may be used as an output and vice-versa. The '4016 devices allow control of up to 12V (peak) analog signals with digital control signals of the same range. Each switch has its own control input which disables each switch when low. All analog inputs and outputs and digital inputs are protected from electrostatic damage by diodes to V_{CC} and ground.

Features

- Typical switch enable time: 15 ns
- Wide analog input voltage range: 0–12V
- Low ''on'' resistance: 50Ω typ.
- Low quiescent current: 80 μA maximum (74HC)
- Matched switch characteristics
- Individual switch controls

Connection Diagram



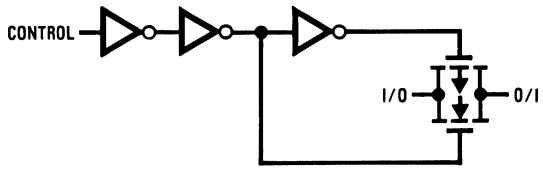
Top View

Order Number MM54HC4016 or MM74HC4016

Truth Table

Input	Switch
CTL	I/O-O/I
L	''OFF''
H	''ON''

Schematic Diagram



Absolute Maximum Ratings (Notes 1 & 2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Supply Voltage (V_{CC})	−0.5 to +15V
DC Control Input Voltage (V_{IN})	−1.5 to V_{CC} +1.5V
DC Switch I/O Voltage (V_{IO})	−0.5 to V_{CC} +0.5V
Clamp Diode Current (I_{IK}, I_{OK})	±20 mA
DC Output Current, per pin (I_{OUT})	±25 mA
DC V_{CC} or GND Current, per pin (I_{CC})	±50 mA
Storage Temperature Range (T_{STG})	−65°C to +150°C
Power Dissipation (P_D)	
(Note 3)	600 mW
S.O. Package only	500 mW
Lead Temp. (T_L) (Soldering 10 seconds)	260°C

Operating Conditions

	Min	Max	Units
Supply Voltage (V_{CC})	2	12	V
DC Input or Output Voltage (V_{IN}, V_{OUT})	0	V_{CC}	V
Operating Temp. Range (T_A)			
MM74HC	−40	+85	°C
MM54HC	−55	+125	°C
Input Rise or Fall Times (t_r, t_f) V_{CC} = 2.0V		1000	ns
V_{CC} = 4.5V		500	ns
V_{CC} = 6.0V		400	ns

DC Electrical Characteristics (Note 4)

Symbol	Parameter	Conditions	V_{CC}	T_A = 25°C	74HC T_A = −40 to 85°C	54HC T_A = −55 to 125°C	Units
				Typ	Guaranteed Limits		
V_{IH}	Minimum High Level Input Voltage		2.0V		1.5	1.5	1.5	V
			4.5V		3.15	3.15	3.15	V
			9.0V		6.3	6.3	6.3	V
			12.0V		8.4	8.4	8.4	V
V_{IL}	Maximum Low Level Input Voltage**		2.0V		0.5	0.5	0.5	V
			4.5V		1.35	1.35	1.35	V
			9.0V		2.7	2.7	2.7	V
			12.0V		3.6	3.6	3.6	V
R_{ON}	Maximum 'ON' Resistance (See Note 5)	V_{CTL} = V_{IH}, I_S = 2.0 mA V_{IS} = V_{CC} to GND (Figure 1)	4.5V	100	170	200	220	Ω
			9.0V	50	85	105	120	Ω
			12.0V	30	70	85	100	Ω
		V_{CTL} = V_{IH}, I_S = 2.0 mA V_{IS} = V_{CC} or GND (Figure 1)	2.0V	100	180	215	240	Ω
			4.5V	40	80	100	120	Ω
			9.0V	35	60	75	80	Ω
			12.0V	20	40	60	70	Ω
R_{ON}	Maximum 'ON' Resistance Matching	V_{CTL} = V_{IH} V_{IS} = V_{CC} to GND	4.5V	10	15	20	20	Ω
			9.0V	5	10	15	15	Ω
			12.V	5	10	15	15	Ω
I_{IN}	Maximum Control Input Current	V_{IN} = V_{CC} or GND	6.0V		±0.1	±1.0	±1.0	μA
I_{IZ}	Maximum Switch 'OFF' Leakage Current	V_{OS} = V_{CC} or GND V_{IS} = GND or V_{CC} V_{CTL} = V_{IL} (Figure 2)	6.0V		±60	±600	±600	nA
			9.0V		±80	±800	±800	nA
			12.0V		±100	±1000	±1000	nA
I_{IZ}	Maximum Switch 'ON' Leakage Current	V_{IS} = V_{CC} to GND V_{CTL} = V_{IH}, V_{OH} = OPEN (Figure 3)	6.0V		±40	±150	±150	nA
			9.0V		±50	±200	±200	nA
			12.0V		±60	±300	±300	nA
I_{CC}	Maximum Quiescent Supply Current	V_{IN} = V_{CC} or GND I_{OUT} = 0 μA	6.0V		2.0	20	40	μA
			9.0V		4.0	40	80	μA
			12.0V		8.0	80	160	μA

Note 1: Absolute Maximum Ratings are those values beyond which damage to the device may occur.

Note 2: Unless otherwise specified all voltages are referenced to ground.

Note 3: Power Dissipation temperature derating — plastic "N" package: −12 mW/°C from 65°C to 85°C; ceramic "J" package: −12 mW/°C from 100°C to 125°C.

Note 4: For a power supply of 5V ±10% the worst case on resistances (R_{ON}) occurs for HC at 4.5V. Thus the 4.5V values should be used when designing with this supply. Worst case V_{IH} and V_{IL} occur at V_{CC} = 5.5V and 4.5V respectively. (The V_{IH} value at 5.5V is 3.85V.) The worst case leakage current occur for CMOS at the higher voltage and so these values should be used.

Note 5: At supply voltages (V_{CC}–GND) approaching 2V the analog switch on resistance becomes extremely non-linear. Therefore it is recommended that these devices be used to transmit digital only when using these supply voltages.

**V_{IL} limits are currently tested at 20% of V_{CC}. The above V_{IL} specification (30% of V_{CC}) will be implemented no later than Q1, CY'89.

AC Electrical Characteristics V_{CC} = 2.0V–12.0V, C_L = 50 pF (unless otherwise specified), (Notes 6 and 7)

Symbol	Parameter	Conditions	V_{CC}	$T_A = 25°C$		74HC $T_A = -40$ to 85°C	54HC $T_A = -55$ to 125°C	Units
				Typ		Guaranteed Limits		
t_{PHL}, t_{PLH}	Maximum Propagation Delay Switch In to Out		2.0V	25	50	62	75	ns
			4.5V	5	10	13	15	ns
			9.0V	4	8	12	14	ns
			12.0V	3	7	11	13	ns
t_{PZL}, t_{PZH}	Maximum Switch Turn "ON" Delay	$R_L = 1\ k\Omega$	2.0V	32	100	125	150	ns
			4.5V	8	20	25	30	ns
			9.0V	6	12	15	18	ns
			12.0V	5	10	13	15	ns
t_{PHZ}, t_{PLZ}	Maximum Switch Turn "OFF" Delay	$R_L = 1\ k\Omega$	2.0V	45	168	210	252	ns
			4.5V	15	36	45	54	ns
			9.0V	10	32	40	48	ns
			12.0V	8	30	38	45	ns
	Minimum Frequency Response (Figure 7) 20 log (V_{OS}/V_{IS}) = −3 dB	$R_L = 600\Omega$, $V_{IS} = 2V_{PP}$ at ($V_{CC}/2$) (Notes 6 & 7)	4.5V	40				MHz
			9.0V	100				MHz
	Control to Switch Feedthrough Noise (Figure 8)	$R_L = 600\Omega$, F = 1 MHz C_L = 50 pF (Notes 7 & 8)	4.5V	100				mV
			9.0V	250				mV
	Crosstalk Between any Two Switches (Figure 9)	$R_L = 600\Omega$, F = 1 MHz	4.5V	−52				dB
			9.0V	−50				dB
	Switch OFF Signal Feedthrough Isolation (Figure 10)	$R_L = 600\Omega$, F = 1 MHz $V_{CTL} = V_{IL}$ (Notes 7 & 8)	4.5V	−42				dB
			9.0V	−44				dB
THD	Sinewave Harmonic Distortion (Figure 11)	$R_L = 10\ k\Omega$, C_L = 50 pF, F = 1 kHz $V_{IS} = 4V_{PP}$	4.5V	0.013				%
		$V_{IS} = 8V_{PP}$	9.0V	0.008				%
C_{IN}	Maximum Control Input Capacitance			5	10	10	10	pF
C_{IN}	Maximum Switch Input Capacitance			15				pF
C_{IN}	Maximum Feedthrough Capacitance	V_{CTL} = GND		5				pF
C_{PD}	Power Dissipation Capacitance	(per switch)		15				pF

Note 6: Adjust 0 dBm for F = 1 kHz (Null R_L/R_{ON} Attenuation)

Note 7: V_{IS} is centered at $V_{CC}/2$

Note 8: Adjust input for 0 dBm

AC Test Circuits and Switching Time Waveforms

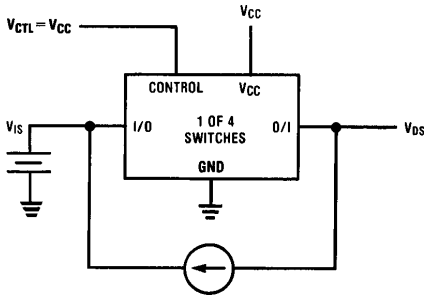


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FIGURE 1. "ON" Resistance

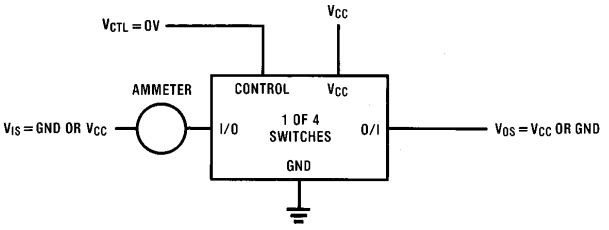

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FIGURE 2. "OFF" Channel Leakage Current

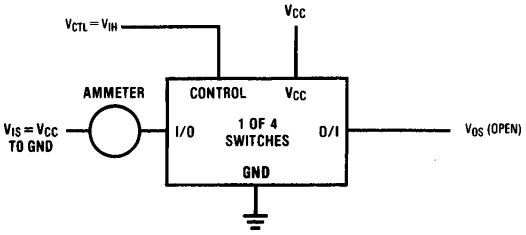

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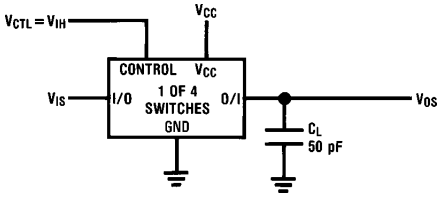
FIGURE 3. "ON" Channel Leakage Current



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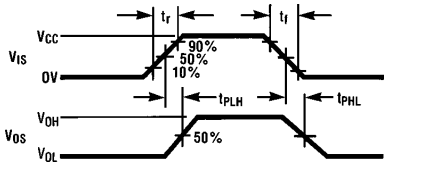

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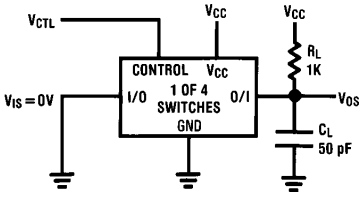
FIGURE 4. t_{PHL}, t_{PLH} Propagation Delay Time Signal Input to Signal Output



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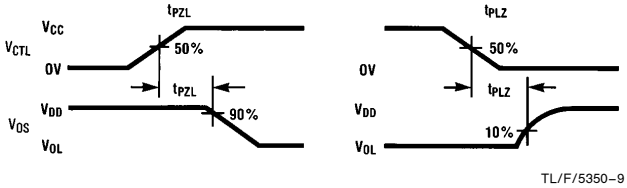

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FIGURE 5. t_{PZL}, t_{PLZ} Propagation Delay Time Control to Signal Output

AC Test Circuits and Switching Time Waveforms (Continued)

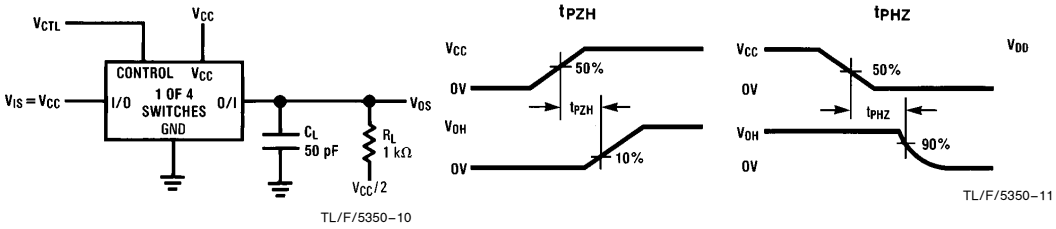


FIGURE 6. t_{PZH}, t_{PHZ} Propagation Delay Time Control to Signal Output

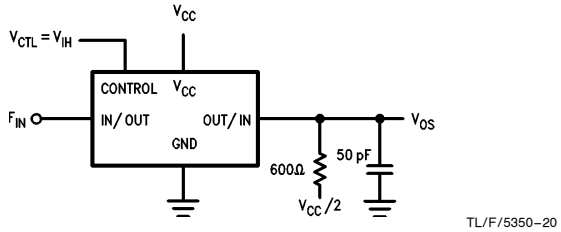


FIGURE 7. Frequency Response

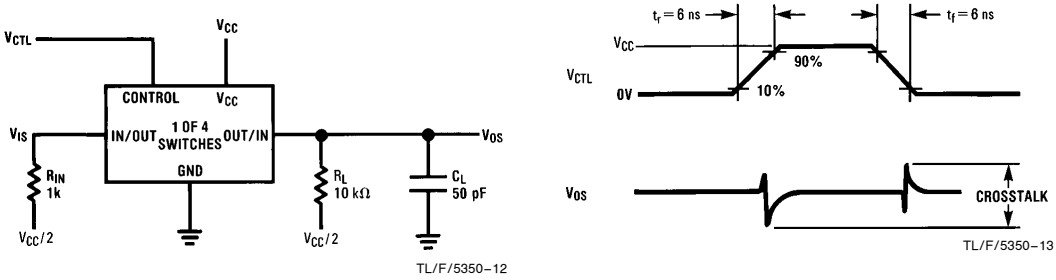
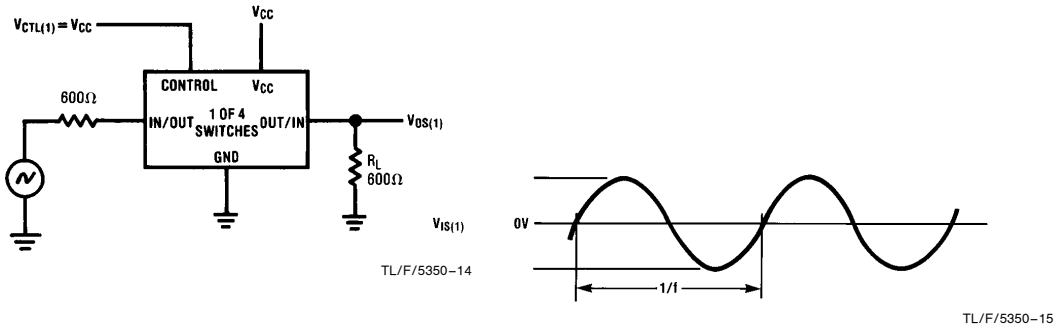


FIGURE 8. Crosstalk: Control Input to Signal Output

AC Test Circuits and Switching Time Waveforms (Continued)



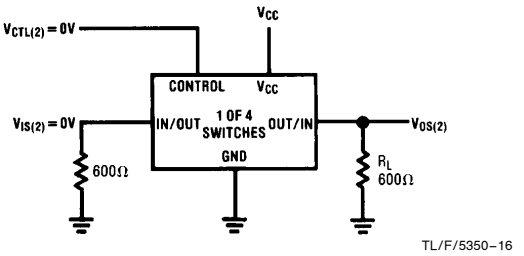


FIGURE 9. Crosstalk Between Any Two Switches

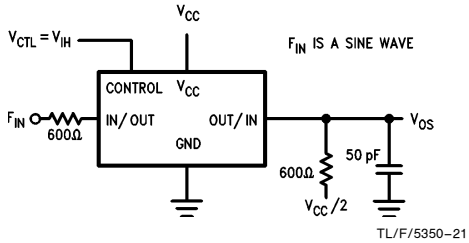


FIGURE 10. Switch OFF Signal Feedthrough Isolation

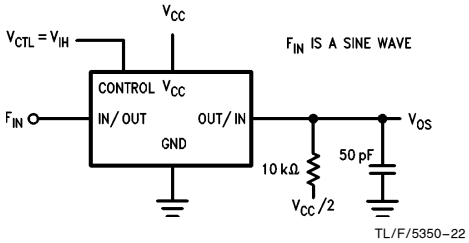
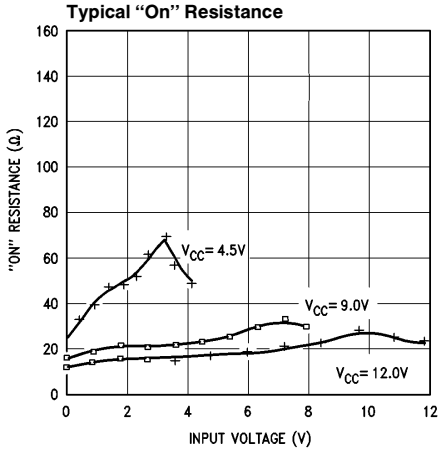


FIGURE 11. Sinewave Distortion

Typical Performance Characteristics

Typical "On" Resistance



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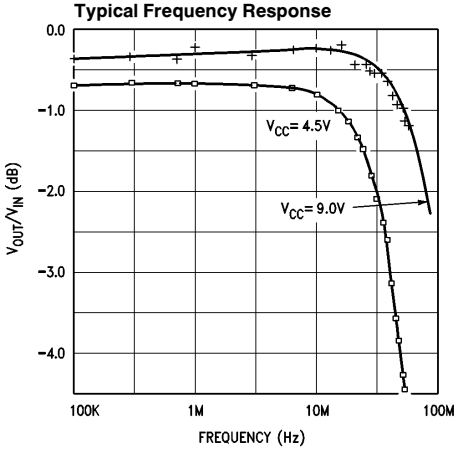
Typical Frequency Response



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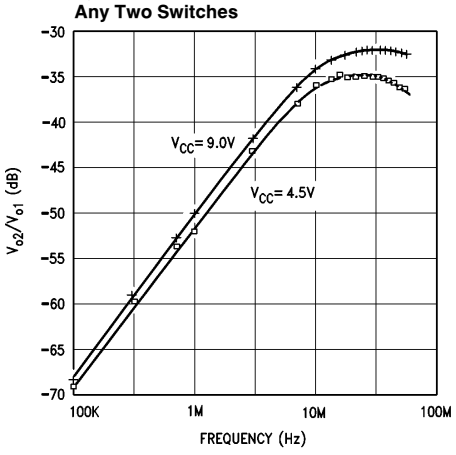
Typical Crosstalk Between Any Two Switches



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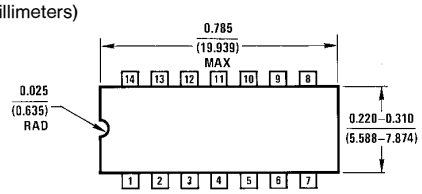
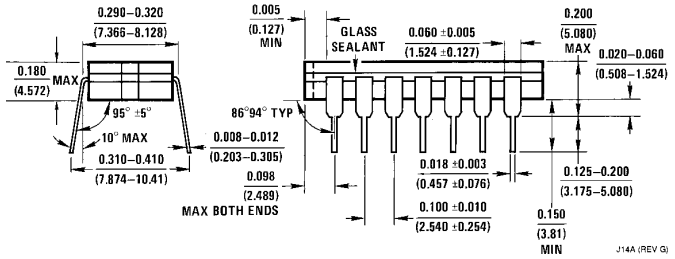
Special Considerations

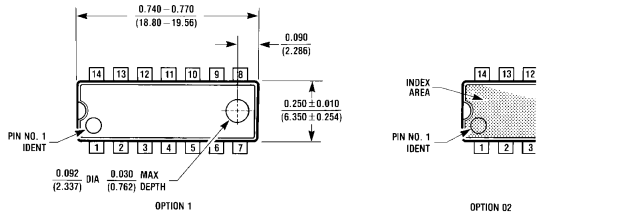
In certain applications the external load-resistor current may include both V_{CC} and signal line components. To avoid drawing V_{CC} current when switch current flows into the analog switch input pins, the voltage drop across the switch must not exceed 0.6V (calculated from the ON resistance).

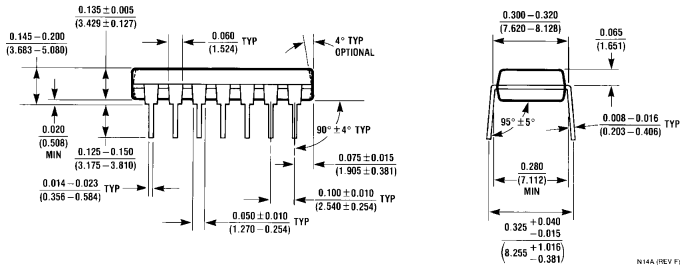
Physical Dimensions inches (millimeters)



Ceramic Dual in Line Pkg (J)
Order Number MM54HC4016J or MM74HC4016J
NS Package Number J14A







Molded Dual in Line Package (N)
Order Number MM74HC4016N
NS Package Number N14A

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