

CD4067B, CD4097B Types

CMOS Analog Multiplexers/Demultiplexers

High-Voltage Types (20-Volt Rating)

CD4067B – Single 16-Channel Multiplexer/Demultiplexer

CD4097B – Differential 8-Channel Multiplexer/Demultiplexer

■ CD4067B and CD4097B CMOS analog multiplexers/demultiplexers* are digitally controlled analog switches having low ON impedance, low OFF leakage current, and internal address decoding. In addition, the ON resistance is relatively constant over the full input-signal range.

The CD4067B is a 16-channel multiplexer with four binary control inputs, A, B, C, D, and an inhibit input, arranged so that any combination of the inputs selects one switch.

The CD4097B is a differential 8-channel multiplexer having three binary control inputs A, B, C, and an inhibit input. The inputs permit selection of one of eight pairs of switches.

A logic "1" present at the inhibit input turns all channels off.

The CD4067B and CD4097B types are supplied in 24-lead hermetic dual-in-line ceramic packages (F3A suffix), 24-lead dual-in-line plastic packages (E suffix), 24-lead small-outline packages (M, M96, and NSR suffixes), and 24-lead thin shrink small-outline packages (P and PWR suffixes).

*When these devices are used as demultiplexers, the channel in/out terminals are the outputs and the common out/in terminals are the inputs.

Recommended Operating Conditions at $T_A = 25^\circ\text{C}$ (Unless Otherwise Specified)

For maximum reliability, nominal operating conditions should be selected so that operation is always within the following ranges. Values shown apply to all types except as noted.

Characteristic	Min.	Max.	Units
Supply-Voltage Range (T_A =Full Package-Temp. Range)	3	18	V
Multiplexer Switch Input Current Capability	–	25	mA
Output Load Resistance	100	–	Ω

NOTE:

In certain applications, the external load-resistor current may include both V_{DD} and signal-line components. To avoid drawing V_{DD} current when switch current flows into the transmission gate inputs, the voltage drop across the bidirectional switch must not exceed 0.8 volt (calculated from R_{ON} values shown in ELECTRICAL CHARACTERISTICS CHART). No V_{DD} current will flow through R_L if the switch current flows into terminal 1 on the CD4067; terminals 1 and 17 on the CD4097.

Features:

- Low ON resistance: 125Ω (typ.) over 15 V_{pp} signal-input range for $V_{DD}-V_{SS}=15 \text{ V}$
- High OFF resistance: channel leakage of $\pm 10 \text{ pA}$ (typ.) @ $V_{DD}-V_{SS}=10 \text{ V}$
- Matched switch characteristics: $R_{ON}=5 \Omega$ (typ.) for $V_{DD}-V_{SS}=15 \text{ V}$
- Very low quiescent power dissipation under all digital-control input and supply conditions: $0.2 \mu\text{W}$ (typ.) @ $V_{DD}-V_{SS}=10 \text{ V}$
- Binary address decoding on chip
- 5-V, 10-V, and 15-V parametric ratings
- 100% tested for quiescent current at 20 V
- Standardized symmetrical output characteristics
- Maximum input current of $1 \mu\text{A}$ at 18 V over full package temperature range; 100 nA at 18 V and 25°C
- Meets all requirements of JEDEC Tentative Standard No. 13B, "Standard Specifications for Description of 'B' Series CMOS Devices"

Applications:

- Analog and digital multiplexing and demultiplexing
- A/D and D/A conversion
- Signal gating

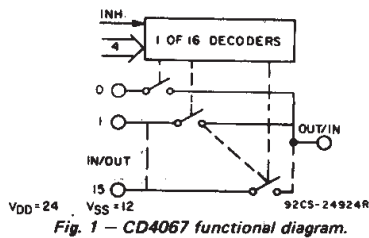
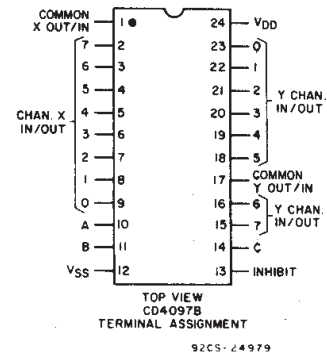
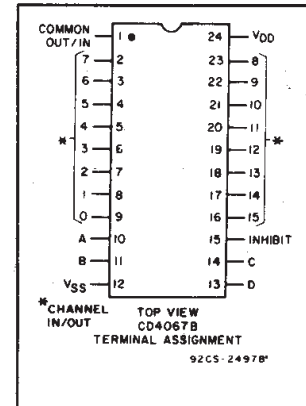


Fig. 1 – CD4067 functional diagram.

CD4067 TRUTH TABLE

A	B	C	D	Inh	Selected Channel
X	X	X	X	1	None
0	0	0	0	0	0
1	0	0	0	0	1
0	1	0	0	0	2
1	1	0	0	0	3
0	0	1	0	0	4
1	0	1	0	0	5
0	1	1	0	0	6
1	1	1	0	0	7
0	0	0	1	0	8
1	0	0	1	0	9
0	1	0	1	0	10
1	1	0	1	0	11
0	0	1	1	0	12
1	0	1	1	0	13
0	1	1	1	0	14
1	1	1	1	0	15

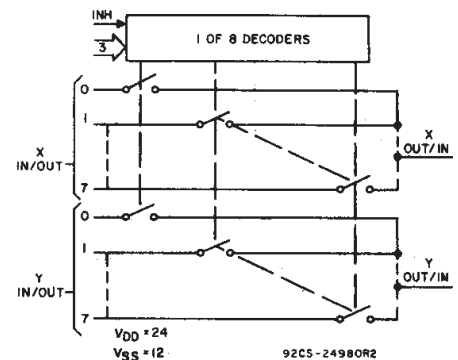


Fig. 2 – CD4097 functional diagram.

CD4097 TRUTH TABLE

A	B	C	Inh	Selected Channel
X	X	X	1	None
0	0	0	0	0X, 0Y
1	0	0	0	1X, 1Y
0	1	0	0	2X, 2Y
1	1	0	0	3X, 3Y
0	0	1	0	4X, 4Y
1	0	1	0	5X, 5Y
0	1	1	0	6X, 6Y
1	1	1	0	7X, 7Y

CD4067B, CD4097B Types

ELECTRICAL CHARACTERISTICS

CHARACTERISTIC	CONDITIONS			LIMITS AT INDICATED TEMPERATURES (°C)						Units	
	V_{is} (V)	V_{SS} (V)	V_{DD} (V)	-55	-40	+85	+125	+25			
								Min.	Typ.		Max.
SIGNAL INPUTS (V_{is}) AND OUTPUTS (V_{OS})											
Quiescent Device Current, I_{DD} Max.			5	5	5	150	150	—	0.04	5	μA
			10	10	10	300	300	—	0.04	10	
			15	20	20	600	600	—	0.04	20	
			20	100	100	3000	3000	—	0.08	100	
ON-state Resistance $V_{SS} \leq V_{is} \leq V_{DD}$ r_{on} Max.		0	5	800	850	1200	1300	—	470	1050	Ω
		0	10	310	330	520	550	—	180	400	
		0	15	200	210	300	320	—	125	240	
Change in on-state Resistance (Between Any Two Channels) Δr_{on}		0	5	—	—	—	—	—	15	—	Ω
		0	10	—	—	—	—	—	10	—	
		0	15	—	—	—	—	—	5	—	
OFF Channel Leakage Current: Any Channel OFF (Common OUT/IN) Max. or All Channels OFF		0	18	$\pm 100^*$		$\pm 1000^*$			± 0.1	$\pm 100^*$	nA
Capacitance: Input, C_{is}				—	—	—	—	—	5	—	pF
Output, C_{os}				—	—	—	—	—	55	—	
CD4067 CD4097		-5	5	—	—	—	—	—	35	—	
Feed-through, C_{ios}				—	—	—	—	—	0.2	—	pF
				—	—	—	—	—	—	—	
				—	—	—	—	—	—	—	
Propagation Delay Time (Signal Input to Output)	V_{DD} 	$R_L = 200 K\Omega$ $C_L = 50 pF$ $t_r, t_f = 20 ns$	5	—	—	—	—	—	30	60	ns
			10	—	—	—	—	—	15	30	
			15	—	—	—	—	—	10	20	
CONTROL (ADDRESS or INHIBIT) V_C											
Input Low Voltage, V_{IL} Max.	$=V_{DD}$ thru $1 K\Omega$	$R_L = 1 K\Omega$ to V_{SS} $I_{IS} < 2 \mu A$ on all OFF Channels	5	1.5						1.5	V
			10	3					3		
			15	4					4		
Input High Voltage, V_{IH} Min.	$=V_{DD}$ thru $1 K\Omega$	$R_L = 1 K\Omega$ to V_{SS} $I_{IS} < 2 \mu A$ on all OFF Channels	5	3.5				3.5			V
			10	7				7			
			15	11				11			

* Determined by minimum feasible leakage measurement for automatic testing.

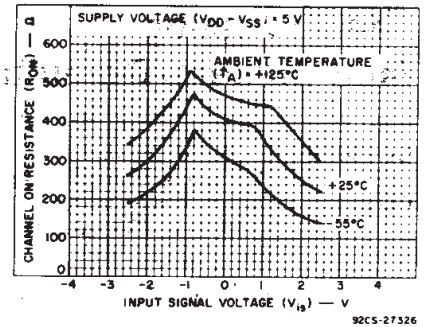


Fig. 3—Typical ON resistance vs. input signal voltage (all types).

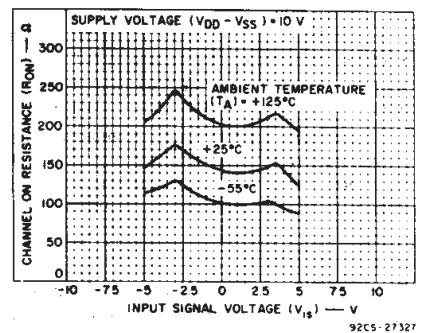


Fig. 4—Typical ON resistance vs. input signal voltage (all types).

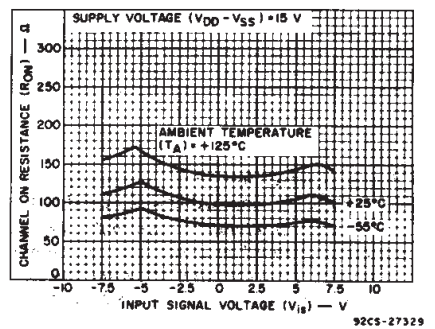


Fig. 5—Typical ON resistance vs. input signal voltage (all types).

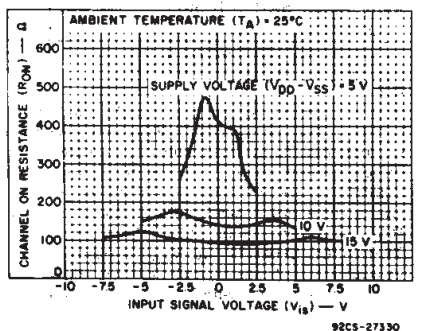


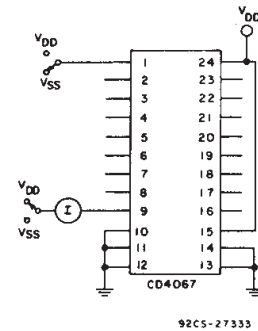
Fig. 6—Typical ON resistance vs. input signal voltage (all types).

CD4067B, CD4097B Types

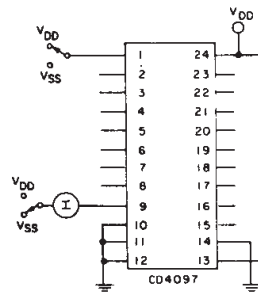
ELECTRICAL CHARACTERISTICS (Cont'd)

CHARACTERISTIC	CONDITIONS			LIMITS AT INDICATED TEMPERATURES (°C)							Units
	V _{is} (V)	V _{SS} (V)	V _{DD} (V)	-55	-40	+85	+125	+25			
								Min.	Typ.	Max.	
Input Current, I _{IN} Max.	V _{IN} = 0, 18 V			±0.1	±0.1	±1	±1	—	±10 ⁻⁵	±0.1	μA
Propagation Delay Time: Address or Inhibit-to-Signal OUT (Channel turning ON)	R _L = 10 KΩ, C _L = 50 pF, t _r , t _f = 20 ns			—	—	—	—	—	325	650	ns
	0	5	—	—	—	—	—	—	135	270	
	0	10	—	—	—	—	—	—	95	190	
Address or Inhibit-to-Signal OUT (Channel turning OFF)	R _L = 300 Ω, C _L = 50 pF, t _r , t _f = 20 ns			—	—	—	—	—	220	440	ns
	0	5	—	—	—	—	—	—	90	180	
	0	15	—	—	—	—	—	—	65	130	
Input Capacitance, C _{IN}	Any Address or Inhibit Input			—	—	—	—	—	5	7.5	pF

TEST CIRCUITS



92CS-27333



92CS-27332

Fig. 7—OFF channel leakage current—any channel OFF.

MAXIMUM RATINGS, Absolute-Maximum Values:

DC SUPPLY-VOLTAGE RANGE, (V_{DD})

Voltages referenced to V_{SS} Terminal) -0.5V to +20V

INPUT VOLTAGE RANGE, ALL INPUTS -0.5V to V_{DD} +0.5V

DC INPUT CURRENT, ANY ONE INPUT ±10mA

POWER DISSIPATION PER PACKAGE (P_D):

For T_A = -55°C to +100°C 500mW

For T_A = +100°C to +125°C Derate Linearly at 12mW/°C to 200mW

DEVICE DISSIPATION PER OUTPUT TRANSISTOR

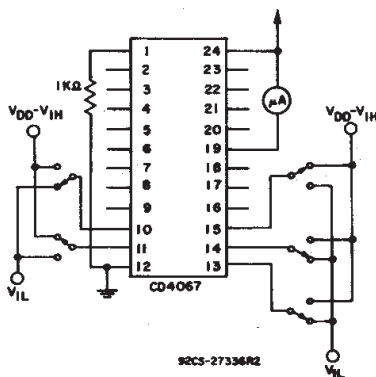
FOR T_A = FULL PACKAGE-TEMPERATURE RANGE (All Package Types) 100mW

OPERATING-TEMPERATURE RANGE (T_A) -55°C to +125°C

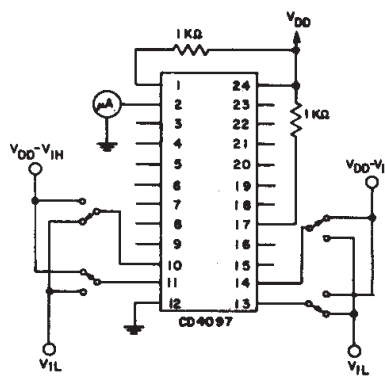
STORAGE TEMPERATURE RANGE (T_{stg}) -65°C to +150°C

LEAD TEMPERATURE (DURING SOLDERING):

At distance 1/16 ± 1/32 inch (1.59 ± 0.79mm) from case for 10s max +265°C

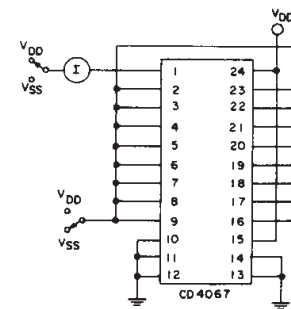


92CS-27336R2

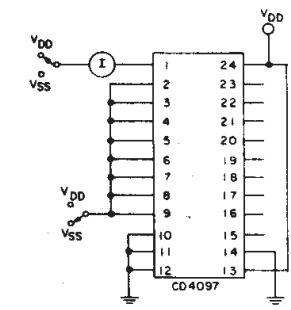


92CS-27337R2

Fig. 8—Input voltage—measure < 2 μA on all OFF channels (e.g., channel 12).



92CS-27334



92CS-27335

Fig. 9—OFF channel leakage current—all channels OFF.

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ELECTRICAL CHARACTERISTICS (Cont'd)

CHARACTERISTIC	TEST CONDITIONS			TYPICAL VALUES	UNITS			
	V _{is} (V)	V _{DD} (V)	R _L (KΩ)					
Cutoff (-3 dB) Frequency Channel ON (Sine Wave Input)	5 [●]	10	1	CD4067	14	MHz		
	20 log $\frac{V_{os}}{V_{is}} = -3$ dB			CD4097	20			
Total Harmonic Distortion, THD	f _{is} = 1 kHz sine wave			V _{os} at Common OUT/IN		%		
				V _{os} at Any Channel			60	
				2 [●]	5		10	0.3
				3 [●]	10			0.2
5 [●]	15	0.12						
-40 dB Feedthrough Frequency (All Channels OFF)	5 [●]	10	1	CD4067	20	MHz		
	20 log $\frac{V_{os}}{V_{is}} = -40$ dB			CD4097	12			
Signal Crosstalk (Frequency at -40 dB)	5 [●]	10	1	Between Any 2 Channels [▲]		1	MHz	
	20 log $\frac{V_{os}}{V_{is}} = -40$ dB			Between Sections CD4097 Only	Measured on Common	10		
					Measured on Any Channel	18		
Address-or-Inhibit-to-Signal Crosstalk	V _{SS} =0, t _r , t _f =20 ns, V _C =V _{DD} -V _{SS} (Square Wave)					75	mV (Peak)	

● Peak-to-peak voltage symmetrical about $\frac{V_{DD}-V_{SS}}{2}$.

▲ Worst case.

* Both ends of channel.

TEST CIRCUITS (Cont'd)

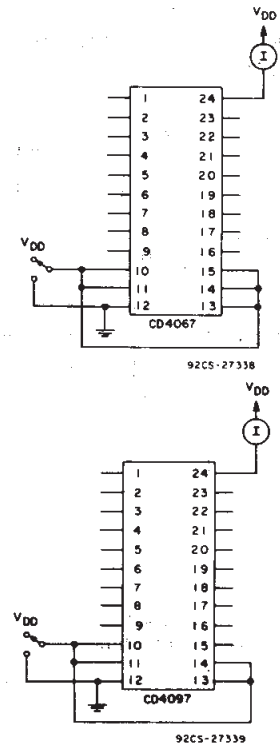


Fig. 10—Quiescent device current.

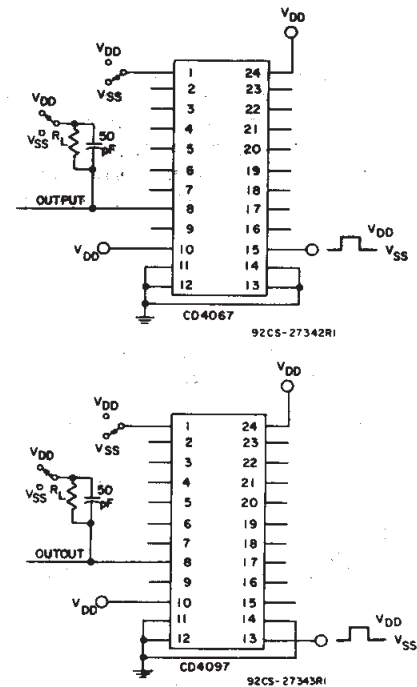


Fig. 12—Turn-on and turn-off propagation delay—
inhibit input to signal output (e.g. measured on channel 1).

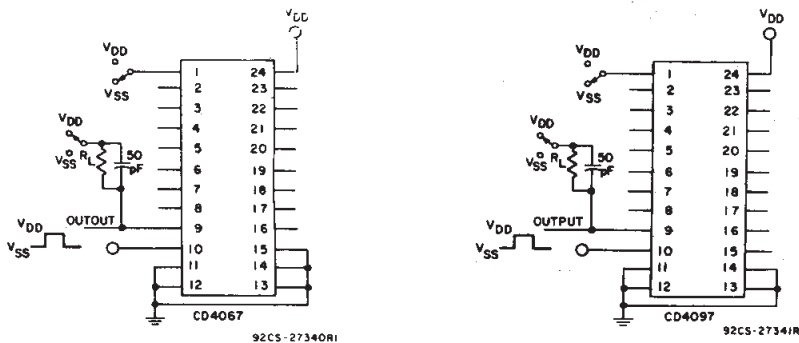


Fig. 11—Turn-on and turn-off propagation delay—address select input to signal output (e.g. measured on channel 0).

CD4067B, CD4097B Types

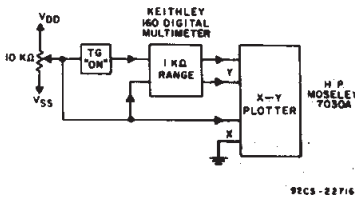


Fig. 13- Channel ON resistance measurement circuit.

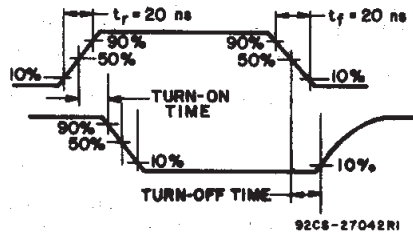


Fig. 14- Propagation delay waveform channel being turned ON ($R_L = 10\text{ K}\Omega$, $C_L = 50\text{ pF}$).

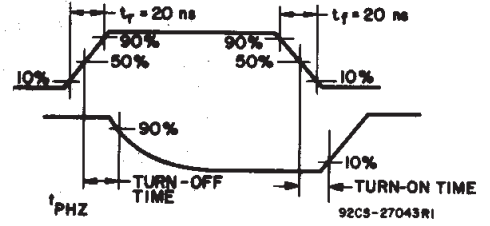


Fig. 15- Propagation delay waveform, channel being turned OFF ($R_L = 300\Omega$, $C_L = 50\text{ pF}$).

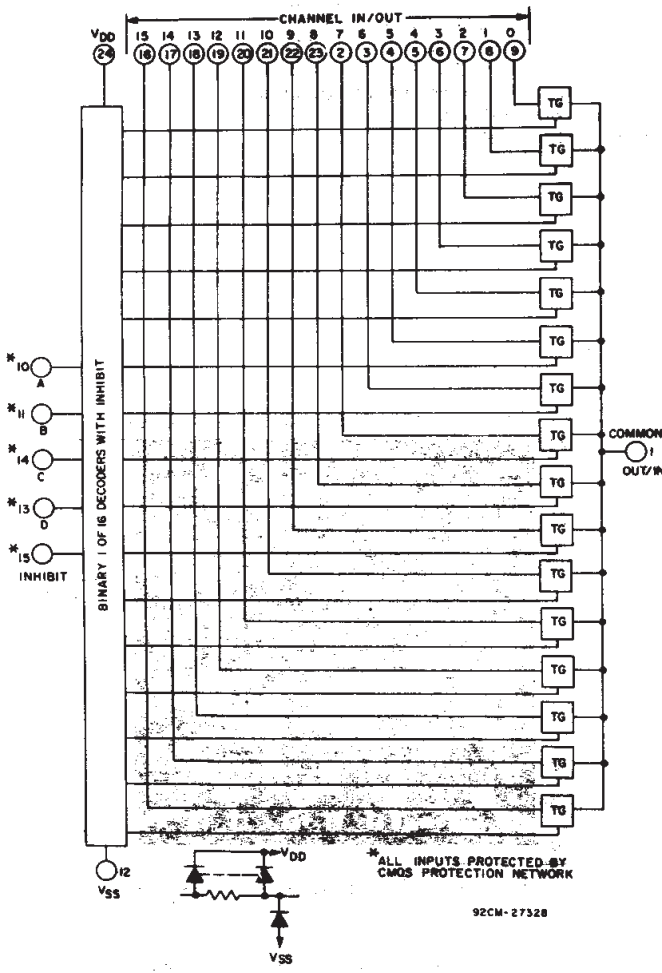


Fig. 16- CD4067 logic diagram.

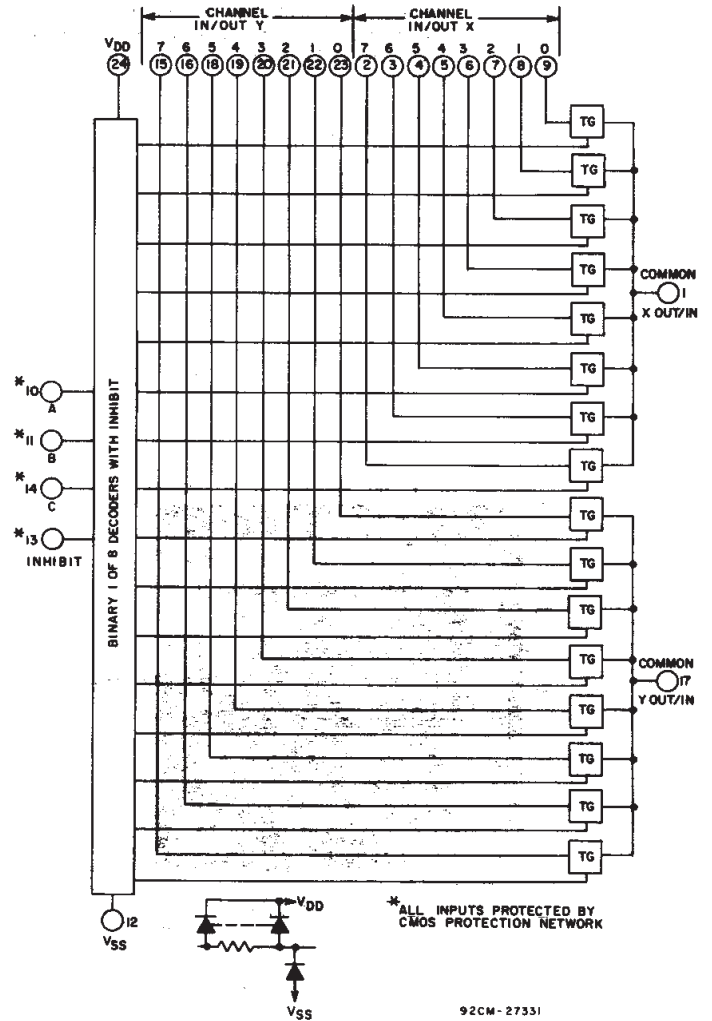


Fig. 17- CD4097 logic diagram.

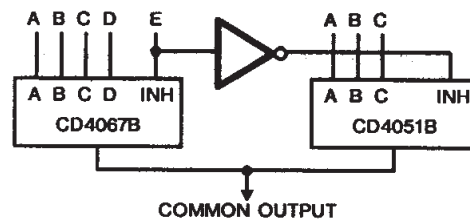


Fig. 18-24-to-1 MUX Addressing

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SPECIAL CONSIDERATIONS

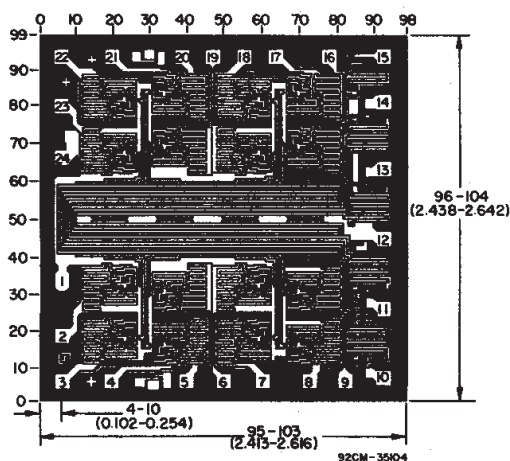
In applications where separate power sources are used to drive V_{DD} and the signal inputs, the V_{DD} current capability should exceed V_{DD}/R_L (R_L =effective external load). This provision avoids permanent current flow or clamp action on the V_{DD} supply when power is applied or removed from the CD4067B or CD4097B.

When switching from one address to another, some of the ON periods of the channels of the multiplexers will overlap momentarily, which may be objectionable in certain applications. Also when a channel is turned on or off by an address input, there is a momentary conductive path from the channel to V_{SS} , which will dump some charge from any capacitor connected to the input or output of the channel. The inhibit input turning on a channel will similarly dump some charge to V_{SS} .

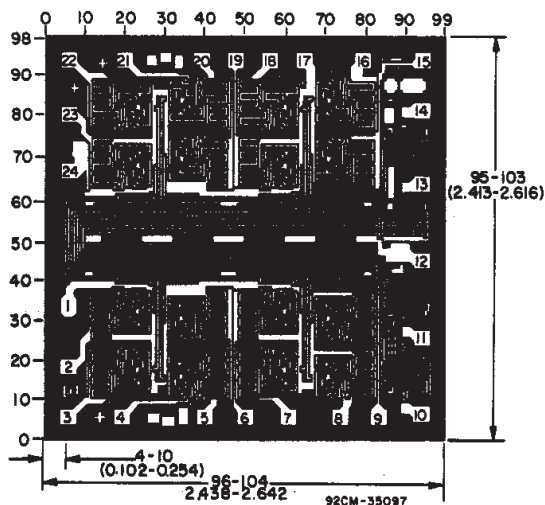
The amount of charge dumped is mostly a function of the signal level above V_{SS} . Typically, at $V_{DD}-V_{SS}=10$ V, a 100-pF

capacitor connected to the input or output of the channel will lose 3-4% of its voltage at the moment the channel turns on or off. This loss of voltage is essentially independent of the address or inhibit signal transition time, if the transition time is less than 1-2 μ s. When the inhibit signal turns a channel off, there is no charge dumping to V_{SS} . Rather, there is a slight rise in the channel voltage level (65 mV typ.) due to capacitive coupling from inhibit input to channel input or output. Address inputs also couple some voltage steps onto the channel signal levels.

In certain applications, the external load-resistor current may include both V_{DD} and signal-line components. To avoid drawing V_{DD} current when switch current flows into the transmission gate inputs, the voltage drop across the bidirectional switch must not exceed 0.8 volt (calculated from R_{ON} values shown in ELECTRICAL CHARACTERISTICS CHART). No V_{DD} current will flow through R_L if the switch current flows into terminal 1 on the CD4067B, terminals 1 and 17 on the CD4097B.



Dimensions and pad layout for CD4067BH.



Dimensions and pad layout for CD4097BH.

Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated. Grid graduations are in mils (10^{-3} inch).

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
CD4067BF	ACTIVE	CDIP	J	24	1	Non-RoHS & Non-Green	Call TI	N / A for Pkg Type	-55 to 125	CD4067BF	Samples
CD4067BF3A	ACTIVE	CDIP	J	24	1	Non-RoHS & Non-Green	Call TI	N / A for Pkg Type	-55 to 125	CD4067BF3A	Samples
CD4067BM	LIFEBUY	SOIC	DW	24	25	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-55 to 125	CD4067BM	
CD4067BM96	ACTIVE	SOIC	DW	24	2000	RoHS & Green	NIPDAU SN	Level-1-260C-UNLIM	-55 to 125	CD4067BM	Samples
CD4067BM96G4	LIFEBUY	SOIC	DW	24	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-55 to 125	CD4067BM	
CD4067BPW	LIFEBUY	TSSOP	PW	24	60	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-55 to 125	CM067B	
CD4067BPWG4	LIFEBUY	TSSOP	PW	24	60	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-55 to 125	CM067B	
CD4067BPWR	ACTIVE	TSSOP	PW	24	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-55 to 125	CM067B	Samples
CD4097BF	ACTIVE	CDIP	J	24	1	Non-RoHS & Non-Green	Call TI	N / A for Pkg Type	-55 to 125	CD4097BF	Samples
CD4097BM	LIFEBUY	SOIC	DW	24	25	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-55 to 125	CD4097BM	
CD4097BME4	LIFEBUY	SOIC	DW	24	25	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-55 to 125	CD4097BM	
CD4097BMG4	LIFEBUY	SOIC	DW	24	25	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-55 to 125	CD4097BM	
CD4097BPW	LIFEBUY	TSSOP	PW	24	60	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-55 to 125	CM097B	
CD4097BPWR	LIFEBUY	TSSOP	PW	24	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-55 to 125	CM097B	
CD4097BPWRE4	LIFEBUY	TSSOP	PW	24	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-55 to 125	CM097B	

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSELETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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OTHER QUALIFIED VERSIONS OF CD4067B, CD4067B-MIL, CD4097B, CD4097B-MIL :

● Catalog : [CD4067B](#), [CD4097B](#)

● Military : [CD4067B-MIL](#), [CD4097B-MIL](#)

NOTE: Qualified Version Definitions:

● Catalog - TI's standard catalog product

● Military - QML certified for Military and Defense Applications

TAPE AND REEL INFORMATION

QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
CD4067BM96	SOIC	DW	24	2000	330.0	24.4	10.75	15.7	2.7	12.0	24.0	Q1
CD4067BM96G4	SOIC	DW	24	2000	330.0	24.4	10.75	15.7	2.7	12.0	24.0	Q1
CD4067BPWR	TSSOP	PW	24	2000	330.0	16.4	6.95	8.3	1.6	8.0	16.0	Q1
CD4097BPWR	TSSOP	PW	24	2000	330.0	16.4	6.95	8.3	1.6	8.0	16.0	Q1

TAPE AND REEL BOX DIMENSIONS


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
CD4067BM96	SOIC	DW	24	2000	350.0	350.0	43.0
CD4067BM96G4	SOIC	DW	24	2000	350.0	350.0	43.0
CD4067BPWR	TSSOP	PW	24	2000	356.0	356.0	35.0
CD4097BPWR	TSSOP	PW	24	2000	356.0	356.0	35.0

TUBE


*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (μm)	B (mm)
CD4067BM	DW	SOIC	24	25	506.98	12.7	4826	6.6
CD4067BPW	PW	TSSOP	24	60	530	10.2	3600	3.5
CD4067BPWG4	PW	TSSOP	24	60	530	10.2	3600	3.5
CD4097BM	DW	SOIC	24	25	506.98	12.7	4826	6.6
CD4097BME4	DW	SOIC	24	25	506.98	12.7	4826	6.6
CD4097BMG4	DW	SOIC	24	25	506.98	12.7	4826	6.6
CD4097BPW	PW	TSSOP	24	60	530	10.2	3600	3.5

DW (R-PDSO-G24)

PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in inches (millimeters). Dimensioning and tolerancing per ASME Y14.5M-1994.
 - B. This drawing is subject to change without notice.
 - C. Body dimensions do not include mold flash or protrusion not to exceed 0.006 (0,15).
 - D. Falls within JEDEC MS-013 variation AD.

J (R-GDIP-T**)

CERAMIC DUAL-IN-LINE PACKAGE

24 PINS SHOWN



- NOTES: A. All linear dimensions are in inches (millimeters).
 B. This drawing is subject to change without notice.
 C. Window (lens) added to this group of packages (24-, 28-, 32-, 40-pin).
 D. This package can be hermetically sealed with a ceramic lid using glass frit.
 E. Index point is provided on cap for terminal identification.

PW0024A



PACKAGE OUTLINE

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



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NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-153.

EXAMPLE BOARD LAYOUT

PW0024A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 10X



SOLDER MASK DETAILS

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NOTES: (continued)

- 6. Publication IPC-7351 may have alternate designs.
- 7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

PW0024A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



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NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

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