

CD4026B, CD4033B Types

CMOS Decade Counters/Dividers

High-Voltage Types (20-Volt Rating)

With Decoded 7-Segment Display Outputs and:

Display Enable - CD4026B

Ripple Blanking - CD4033B

■ CD4026B and CD4033B each consist of a 5-stage Johnson decade counter and an output decoder which converts the Johnson code to a 7-segment decoded output for driving one stage in a numerical display.

These devices are particularly advantageous in display applications where low power dissipation and/or low package count are important.

Inputs common to both types are CLOCK, RESET, & CLOCK INHIBIT; common outputs are CARRY OUT and the seven decoded outputs (a, b, c, d, e, f, g). Additional inputs and outputs for the CD4026B include DISPLAY ENABLE input and DISPLAY ENABLE and UNGATED "C-SEGMENT" outputs. Signals peculiar to the CD4033B are RIPPLE-BLANKING INPUT AND LAMP TEST INPUT and a RIPPLE-BLANKING OUTPUT.

A high RESET signal clears the decade counter to its zero count. The counter is advanced one count at the positive clock signal transition if the CLOCK INHIBIT signal is low. Counter advancement via the clock line is inhibited when the CLOCK INHIBIT signal is high. The CLOCK INHIBIT signal can be used as a negative-edge clock if the clock line is held high. Antilock gating is provided on the JOHNSON counter, thus assuring proper counting sequence. The CARRY-OUT (C_{out}) signal completes one cycle every ten CLOCK INPUT cycles and is used to clock the succeeding decade directly in a multi-decade counting chain. The seven decoded outputs (a, b, c, d, e, f, g) illuminate the proper segments in a seven

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 $\pm 10mA$

POWER DISSIPATION PER PACKAGE (P_D):

For $T_A = -55^\circ C$ to $+100^\circ C$ 500mW

For $T_A = +100^\circ C$ to $+125^\circ C$ Derate Linearly at 12mW/ $^\circ C$ to 200mW

DEVICE DISSIPATION PER OUTPUT TRANSISTOR

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

OPERATING-TEMPERATURE RANGE (T_A) $-55^\circ C$ to $+125^\circ C$

STORAGE TEMPERATURE RANGE (T_{stg}) $-65^\circ C$ to $+150^\circ C$

LEAD TEMPERATURE (DURING SOLDERING):

At distance 1/16 \pm 1/32 inch (1.59 \pm 0.79mm) from case for 10s max $+265^\circ C$

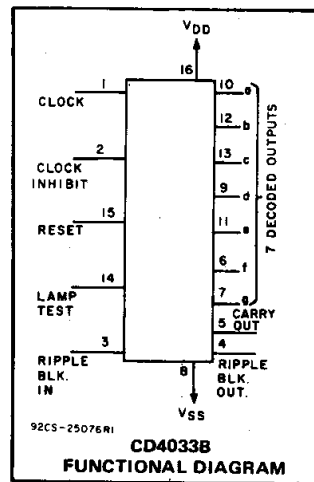
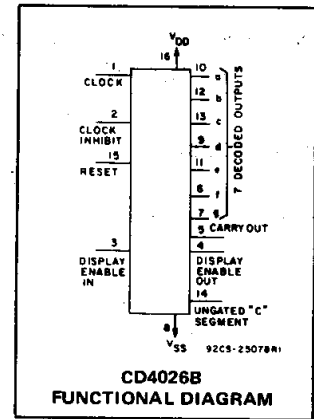
Features:

- Counter and 7-segment decoding in one package
- Easily interfaced with 7-segment display types
- Fully static counter operation: DC to 6 MHz (typ.) at $V_{DD}=10V$
- Ideal for low-power displays
- Display enable output (CD4026B)
- "Ripple blanking" and lamp test (CD4033B)
- 100% tested for quiescent current at 20 V
- Standardized, symmetrical output characteristics
- 5-V, 10-V, and 15-V parametric ratings
- Schmitt-triggered clock inputs
- Meets all requirements of JEDEC Tentative Standard No. 13B, "Standard Specifications for Description of 'B' Series CMOS Devices"

Applications

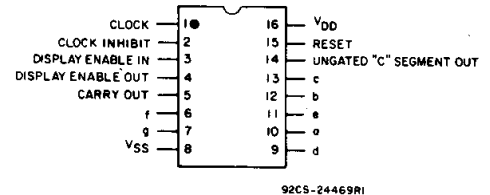
- Decade counting 7-segment decimal display
- Frequency division 7-segment decimal displays
- Clocks, watches, timers (e.g. $\div 60$, $\div 60$, $\div 12$ counter/display)
- Counter/display driver for meter applications

segment display device used for representing the decimal numbers 0 to 9. The 7-segment outputs go high on selection in the CD4033B; in the CD4026B these outputs go high only when the DISPLAY ENABLE IN is high.



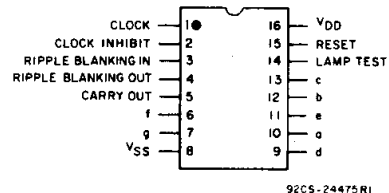
TERMINAL DIAGRAMS

Top View



CD4026B

Top View



CD4033B

CD4026B, CD4033B Types

RECOMMENDED OPERATING CONDITIONS

For maximum reliability, nominal operating conditions should be selected so that operation is always within the following ranges:

CHARACTERISTIC	VDD (V)	LIMITS		UNITS
		MIN.	MAX.	
Supply-Voltage Range (For T _A = Full Package Temperature Range)		3	18	V
Clock Input Frequency, f _{CL}	5	—	2.5	MHz
	10	—	5.5	
	15	—	8	
Clock Pulse Width, t _{WCL}	5	220	—	ns
	10	100	—	
	15	80	—	
Clock Rise and Fall Time, t _{rCL} , t _{fCL}	5	—	Unlimited	ns
	10	—		
	15	—		
Clock Inhibit Set Up Time, t _{SU}	5	200	—	ns
	10	50	—	
	15	30	—	
Reset Pulse Width, t _W	5	200	—	ns
	10	100	—	
	15	50	—	
Reset Removal Time	5	30	—	ns
	10	15	—	
	15	10	—	

CD4026B

When the DISPLAY ENABLE IN is low the seven decoded outputs are forced low regardless of the state of the counter. Activation of the display only when required results in significant power savings. This system also facilitates implementation of display-character multiplexing.

The CARRY OUT and UNGATED "C-SEGMENT" signals are not gated by the DISPLAY ENABLE and therefore are available continuously. This feature is a requirement in implementation of certain divider functions such as divide-by-60 and divide-by-12.

CD4033B

The CD4033B has provisions for automatic blanking of the non-significant zeros in a multi-digit decimal number which results in an easily readable display consistent with normal writing practice. For example, the number 0050.0700 in an eight digit display would be displayed as 50.07. Zero suppression on the integer side is obtained by connecting the RBI terminal of the CD4033B associated with the most significant digit in the display to a low-level voltage and connecting the RBO terminal of that stage to the RBI terminal of the CD4033B in the next-lower significant position in the display. This procedure is continued for each succeeding CD4033B on the integer side of the display.

On the fraction side of the display the RBI of the CD4033B associated with the least significant bit is connected to a low-level voltage and the RBO of that CD4033B is connected to the RBI terminal of the CD4033B in the next more-significant-bit position. Again, this procedure is continued for all CD4033B's on the fraction side of the display.

In a purely fractional number the zero immediately preceding the decimal point can be displayed by connecting the RBI of that stage to a high level voltage (instead of to the RBO of the next more-significant-stage). For example: optional zero → 0.7346. Likewise, the zero in a number such as 763.0 can be displayed by connecting the RBI of the CD4033B associated with it to a high-level voltage.

Ripple blanking of non-significant zeros provides an appreciable savings in display power.

The CD4033B has a LAMP TEST input which, when connected to a high-level voltage, overrides normal decoder operation and enables a check to be made on possible display malfunctions by putting the seven outputs in the high state.

The CD4026B- and CD4033B-series types are supplied in 16-lead dual-in-line plastic packages (E suffix), 16-lead small-outline packages (NSR suffix), and 16-lead thin shrink small-outline packages (PW and PWR suffixes).

STATIC ELECTRICAL CHARACTERISTICS

CHARACTERISTIC	CONDITIONS			LIMITS AT INDICATED TEMPERATURES (°C)							UNITS
	V _O (V)	V _{IN} (V)	V _{DD} (V)	-55	-40	+85	+125	+25			
								Min.	Typ.	Max.	
Quiescent Device Current, I _{DD} Max.	—	0,5	5	5	5	150	150	—	0.04	5	μA
	—	0,10	10	10	10	300	300	—	0.04	10	
	—	0,15	15	20	20	600	600	—	0.04	20	
	—	0,20	20	100	100	3000	3000	—	0.08	100	
Output Low (Sink) Current I _{OL} Min.	0.4	0,5	5	0.64	0.61	0.42	0.36	0.51	1	—	mA
	0.5	0,10	10	1.6	1.5	1.1	0.9	1.3	2.6	—	
	1.5	0,15	15	4.2	4	2.8	2.4	3.4	6.8	—	
Output High (Source) Current, I _{OH} Min.	4.6	0,5	5	-0.64	-0.61	-0.42	-0.36	-0.51	-1	—	mA
	2.5	0,5	5	-2	-1.8	-1.3	-1.15	-1.6	-3.2	—	
	9.5	0,10	10	-1.6	-1.5	-1.1	-0.9	-1.3	-2.6	—	
	13.5	0,15	15	-4.2	-4	-2.8	-2.4	-3.4	-6.8	—	
Output Voltage: Low-Level, V _{OL} Max.	—	0,5	5	0.05				—	0	0.05	V
	—	0,10	10	0.05				—	0	0.05	
	—	0,15	15	0.05				—	0	0.05	
Output Voltage: High-Level, V _{OH} Min.	—	0,5	5	4.95				4.95	5	—	V
	—	0,10	10	9.95				9.95	10	—	
	—	0,15	15	14.95				14.95	15	—	
Input Low Voltage, V _{IL} Max.	0.5, 4.5	—	5	1.5				—	—	1.5	V
	1, 9	—	10	3				—	—	3	
	1.5, 13.5	—	15	4				—	—	4	
Input High Voltage, V _{IH} Min.	0.5, 4.5	—	5	3.5				3.5	—	—	V
	1, 9	—	10	7				7	—	—	
	1.5, 13.5	—	15	11				11	—	—	
Input Current I _{IN} Max.	—	0,18	18	±0.1	±0.1	±1	±1	—	±10 ⁻⁵	±0.1	μA

CD4026B, CD4033B Types

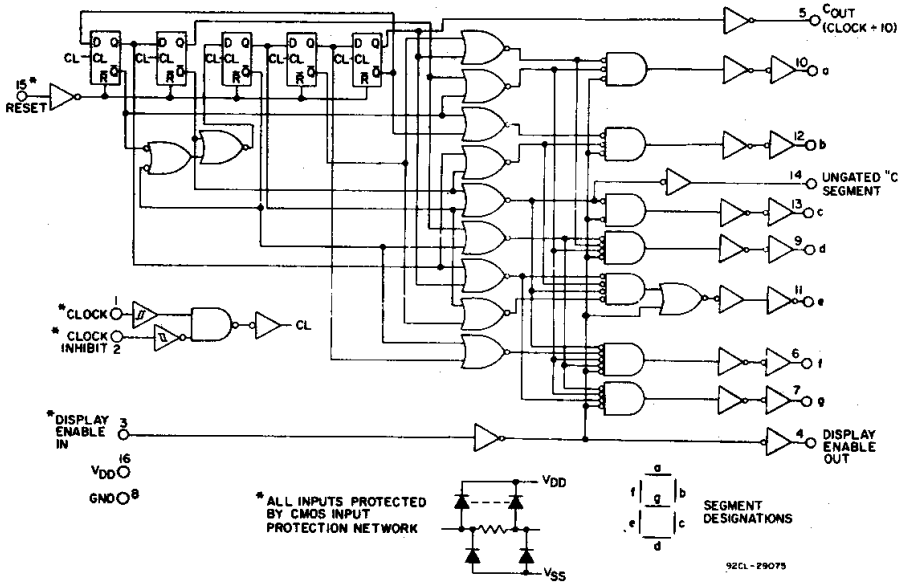


Fig. 1 - CD4026B logic diagram.

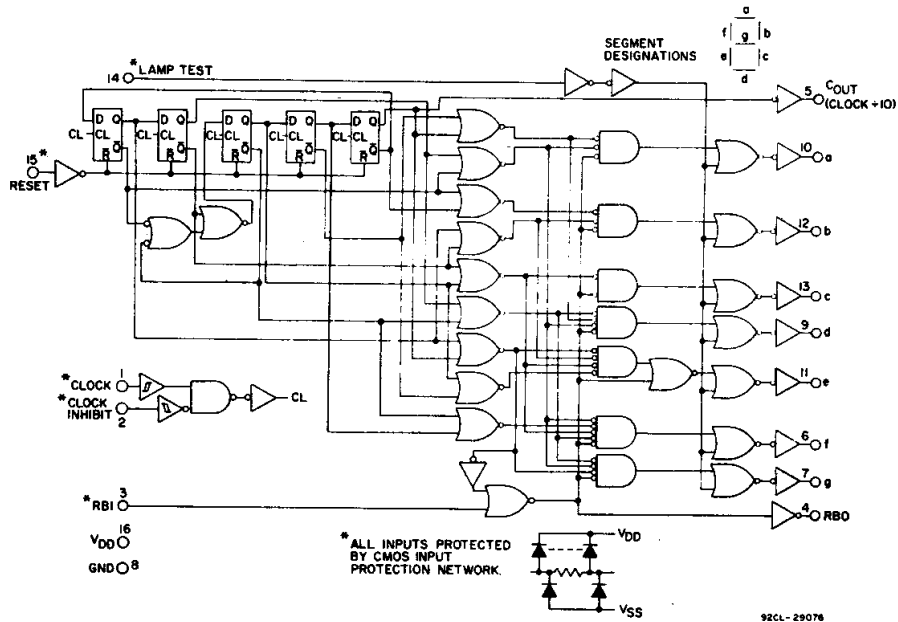


Fig. 2 - CD4033B logic diagram.

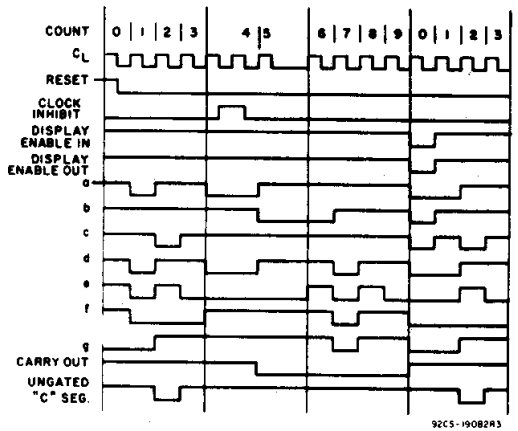


Fig. 3 - CD4026B timing diagram.

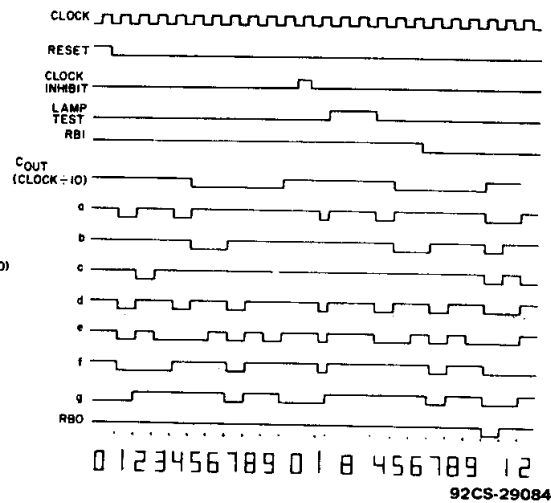


Fig. 4 - CD4033B timing diagram.

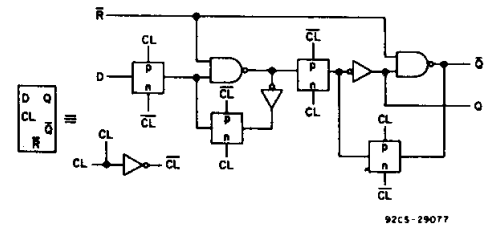


Fig. 5 - Detail of typical flip-flop stage for both types.

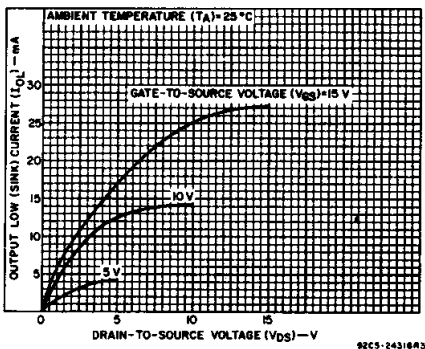


Fig. 6 - Typical n-channel output low (sink) current characteristics.

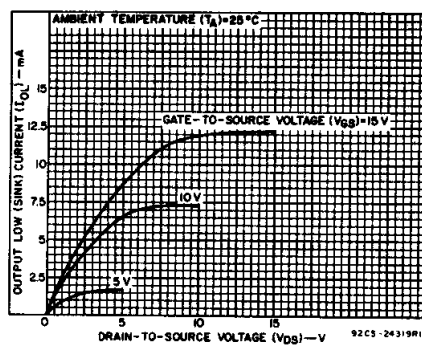


Fig. 7 - Minimum n-channel output low (sink) current characteristics.

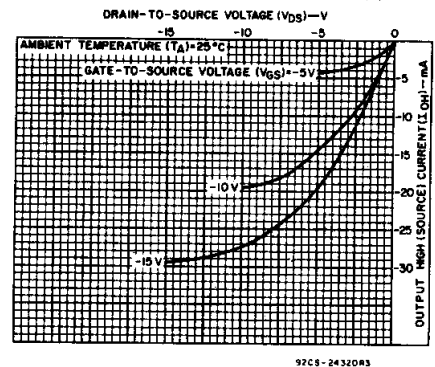


Fig. 8 - Typical p-channel output high (source) current characteristics.

CD4026B, CD4033B Types

DYNAMIC ELECTRICAL CHARACTERISTICS at $T_A = 25^\circ\text{C}$, Input $t_r, t_f = 20\text{ ns}$,
 $C_L = 50\text{ pF}$, $R_L = 200\text{ k}\Omega$

CHARACTERISTIC	TEST CONDITIONS	LIMITS			UNITS	
		VDD (V)	Min.	Typ.		Max.
CLOCKED OPERATION						
Propagation Delay Time; Carry-Out Line t_{PLH}, t_{PHL}		5	—	250	500	ns
		10	—	100	200	
		15	—	75	150	
Decode Outlines		5	—	350	700	ns
		10	—	125	250	
		15	—	90	180	
Transition Time; Carry-Out Line t_{THL}, t_{TLH}		5	—	100	200	ns
		10	—	50	100	
		15	—	25	50	
Maximum Clock Input Frequency, f_{CL}^{Δ}		5	2.5	5	—	MHz
		10	5.5	11	—	
		15	8	16	—	
Min. Clock Pulse Width, t_W		5	—	110	220	ns
		10	—	50	100	
		15	—	40	80	
Clock and Clock Inhibit Rise or Fall Time; t_{rCL}, t_{fCL}		5	Unlimited		ns	
		10	Unlimited			
		15	Unlimited			
Average Input Capacitance, C_{IN}	Any Input	—	5	7	pF	
RESET OPERATION						
Propagation Delay Time; To Carry-Out Line, t_{PLH}		5	—	275	550	ns
		10	—	120	240	
		15	—	80	160	
To Decode Out Lines, t_{PHL}, t_{PLH}		5	—	300	600	ns
		10	—	125	250	
		15	—	90	180	
Min. Reset Pulse Width, t_W		5	—	100	120	ns
		10	—	50	100	
		15	—	25	50	
Min. Reset Removal Time		5	—	0	30	ns
		10	—	0	15	
		15	—	0	10	

Δ Measured with respect to carry-out line.

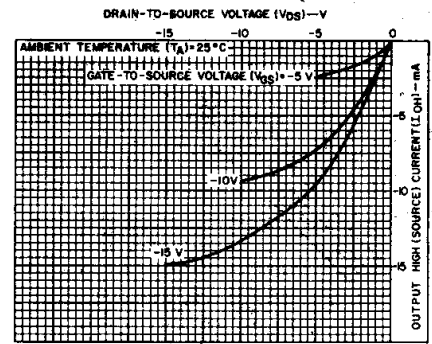


Fig. 9 — Minimum p-channel output high (source) current characteristics.

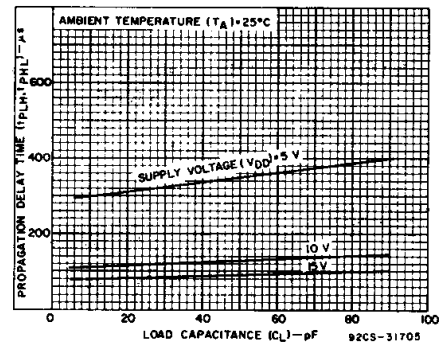


Fig. 10 — Typical propagation delay time as a function of load capacitance for decoded outputs.

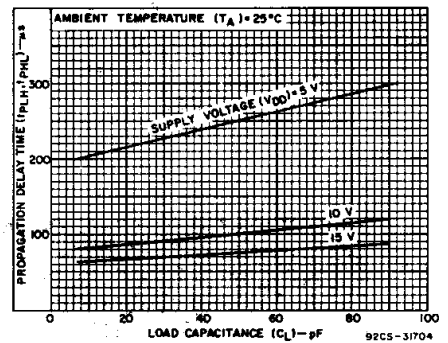


Fig. 11 — Typical propagation delay time as a function of load capacitance for carry-out outputs.

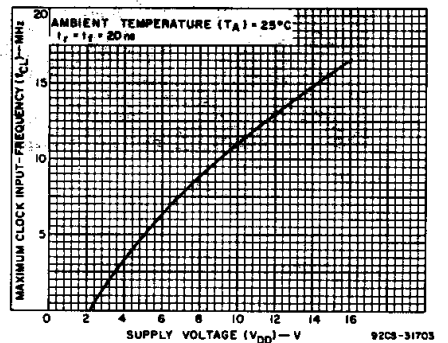


Fig. 12 — Typical maximum clock input frequency as a function of supply voltage.

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COMMERCIAL CMOS
HIGH VOLTAGE ICs

CD4026B, CD4033B Types



Fig. 13 - Typical power dissipation as a function of clock input frequency.

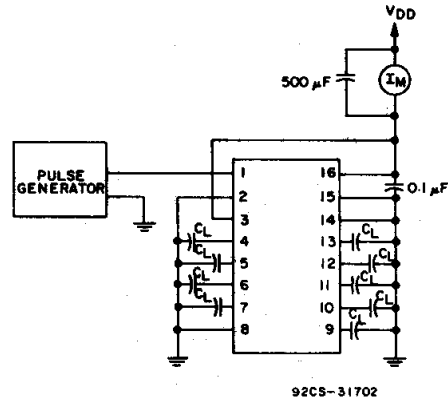


Fig. 14 - Dynamic power dissipation test circuit for CD4033B.

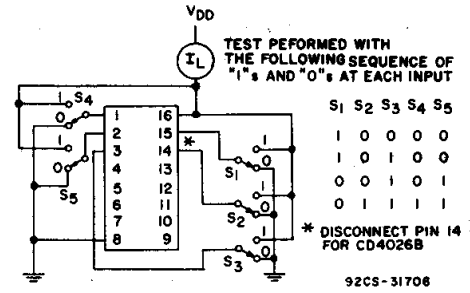
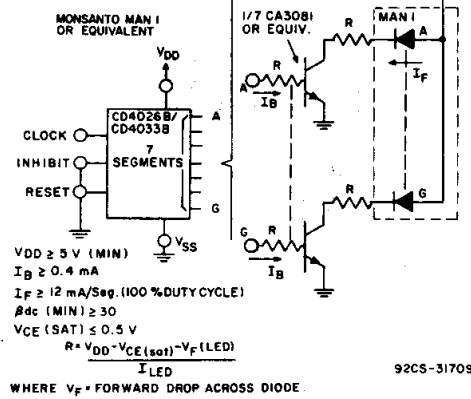
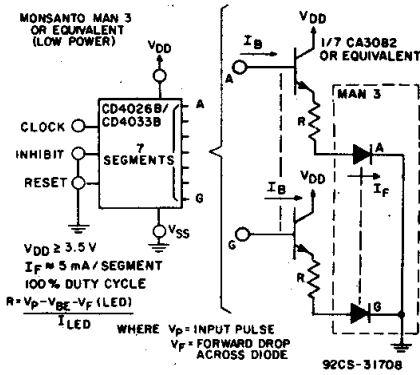


Fig. 15 - Quiescent device current.

INTERFACING THE CD4026B AND CD4033B WITH COMMERCIALY AVAILABLE LIGHT EMITTING DIODE DISPLAYS



WHERE V_F = FORWARD DROP ACROSS DIODE.

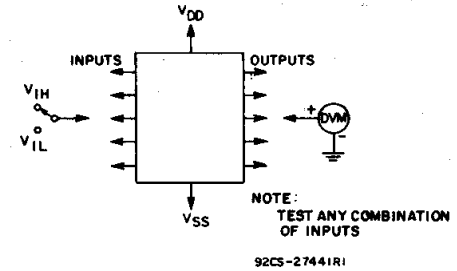


Fig. 16 - Input voltage.

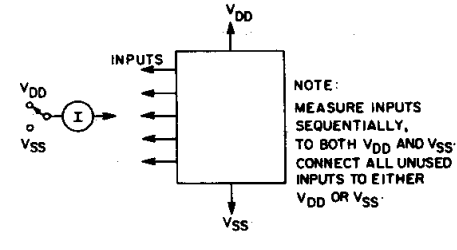
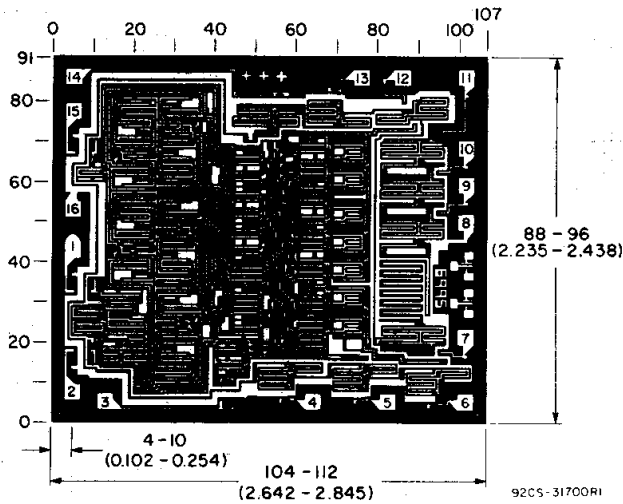
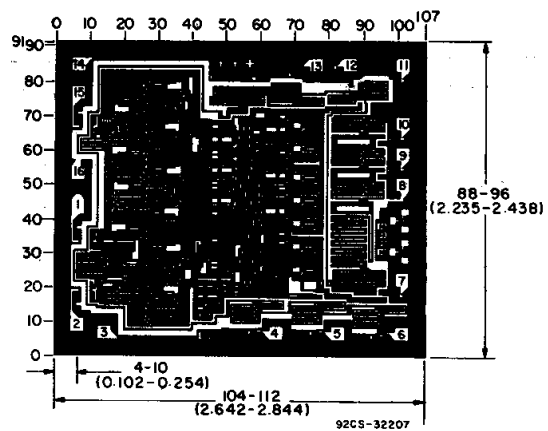


Fig. 17 - Input current.



Chip dimensions and pad layout for CD4026B

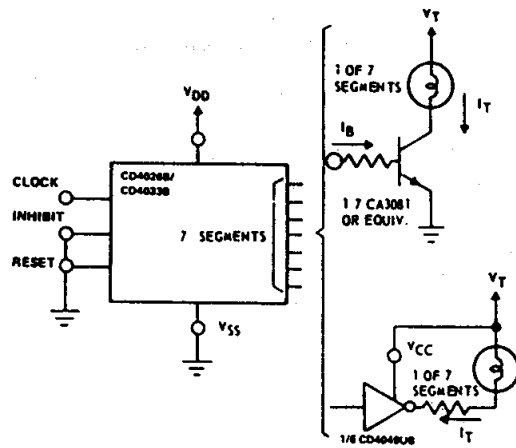
Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated. Grid graduations are in mils (10⁻³ inch).



Chip dimensions and pad layout for CD4033B

CD4026B, CD4033B Types

INTERFACING THE CD4026B AND CD4033B WITH COMMERCIALY AVAILABLE 7-SEGMENT DISPLAY DEVICES*



INCANDESCENT READOUTS
 RCA Numitron DR2000 Series
TUBE REQUIREMENTS
 $V_T = 3.5-5V$
 $I_T = 24 \text{ mA Segment}$

ASSUMED TRANSISTOR CHARACTERISTICS @ $V_{CC} = 10 \text{ V (min.)}$
 $\beta_{dc} (\text{min.}) \geq 25$
 $V_{CE(\text{sat.})} \leq 0.5 \text{ V}$
 $V_{DD} = 8 \text{ V (min.)}$
 $I_B = 1 \text{ mA (min.)}$
 $I_T = 24 \text{ mA (min.)}$

COMMON-EMITTER CHARACTERISTICS @ $V_{CC} = 10 \text{ V (min.)}$
 $V_{CE} \leq 0.6 \text{ V}$
 $I_T = 8 \text{ mA (min.)}$

LOW-POWER INCANDESCENT READOUTS

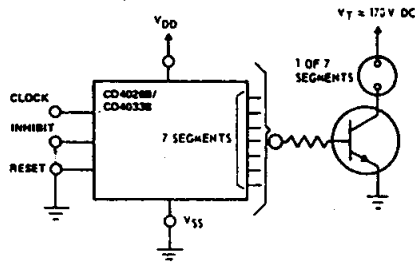
PINLITES INC-Series O and R

TUBE REQUIREMENTS	V_T (V)	mA/Segment
O-03-15	1.5	8
O-04-30	3	8
O-06-30	3	8
R-R3-20	2	4.3
R-R4-30	3	4.3

ASSUMED TRANSISTOR CHARACTERISTICS
 $\beta_{dc} (\text{min.}) \geq 30$
 $V_{CE(\text{sat.})} \leq 0.5 \text{ V}$
 $V_{CC} \geq 3.5 \text{ V (min.)}$
 $I_B \geq 0.25 \text{ mA (min.)}$
 $I_T \leq 7.5 \text{ mA (min.)}$

92CM-31707

* The interfacing buffers shown, while a necessity with the CD4026A and CD4033A, are not required when using the "B" devices; the "B" outputs (≈ 10 times the "A" outputs) can drive most display devices directly especially at voltages above 10 V.



NEON READOUT (NIXIE TUBE*)

- Alco Electronics - MG19
- Burroughs - B5971, B7971, B8971

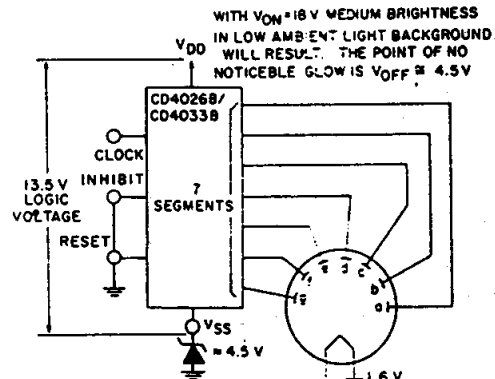
TUBE REQUIREMENTS	V_T (Vdc)	mA Segment
Alco MG19	180	0.5
Burroughs B5971	170	3
Burroughs B7971, B8971	170	6

* (Trademark) Burroughs Corp.

TRANSISTOR CHARACTERISTICS

Leakage with transistor cutoff - 0.05 mA
 $V_{(BR)CER} > V_T$
 $\beta_{dc} (\text{min.}) \geq 30$

92CS-31710



LOW VOLTAGE VACUUM FLUORESCENT READOUTS

- Tung-Sol DIGIVAC S/G ; Type DT1704A or DT1705C
 - Nippon Electric (NEC); Type DG12E or LD91S
- TUBE REQUIREMENTS:** 100 to 300 μA /segment at tube voltages of 12 V to 25 V depending on required brightness Filament requirement 45 mA at 1.6 V, ac or dc.

* (Trademark) Wagner Electric Co.

92CS-31711

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HIGH VOLTAGE ICs

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
CD4026BE	ACTIVE	PDIP	N	16	25	RoHS & Green	NIPDAU	N / A for Pkg Type	-55 to 125	CD4026BE	Samples
CD4026BEE4	ACTIVE	PDIP	N	16	25	RoHS & Green	NIPDAU	N / A for Pkg Type	-55 to 125	CD4026BE	Samples
CD4026BNSR	ACTIVE	SOP	NS	16	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-55 to 125	CD4026B	Samples
CD4026BPW	OBSOLETE	TSSOP	PW	16		TBD	Call TI	Call TI	-55 to 125	CM026B	
CD4026BPWR	ACTIVE	TSSOP	PW	16	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-55 to 125	CM026B	Samples
CD4033BE	ACTIVE	PDIP	N	16	25	RoHS & Green	NIPDAU	N / A for Pkg Type	-55 to 125	CD4033BE	Samples
CD4033BPW	OBSOLETE	TSSOP	PW	16		TBD	Call TI	Call TI	-55 to 125	CM033B	

(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.

OBSOLETE: 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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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
CD4026BNSR	SOP	NS	16	2000	330.0	16.4	8.2	10.5	2.5	12.0	16.0	Q1
CD4026BPWR	TSSOP	PW	16	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1

TAPE AND REEL BOX DIMENSIONS


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
CD4026BNSR	SOP	NS	16	2000	356.0	356.0	35.0
CD4026BPWR	TSSOP	PW	16	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)
CD4026BE	N	PDIP	16	25	506	13.97	11230	4.32
CD4026BE	N	PDIP	16	25	506	13.97	11230	4.32
CD4026BEE4	N	PDIP	16	25	506	13.97	11230	4.32
CD4026BEE4	N	PDIP	16	25	506	13.97	11230	4.32
CD4033BE	N	PDIP	16	25	506	13.97	11230	4.32
CD4033BE	N	PDIP	16	25	506	13.97	11230	4.32

N (R-PDIP-T**)

PLASTIC DUAL-IN-LINE PACKAGE

16 PINS SHOWN



- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - (C) Falls within JEDEC MS-001, except 18 and 20 pin minimum body length (Dim A).
 - (D) The 20 pin end lead shoulder width is a vendor option, either half or full width.



PACKAGE OUTLINE

NS0016A

SOP - 2.00 mm max height

SOP



4220735/A 12/2021

NOTES:

1. All linear dimensions are in millimeters. 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.

EXAMPLE STENCIL DESIGN

NS0016A

SOP - 2.00 mm max height

SOP



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:7X

4220735/A 12/2021

NOTES: (continued)

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



4220204/A 02/2017

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

PW0016A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 10X



SOLDER MASK DETAILS

4220204/A 02/2017

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

PW0016A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE: 10X

4220204/A 02/2017

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.

MECHANICAL DATA

NS (R-PDSO-G**)

PLASTIC SMALL-OUTLINE PACKAGE

14-PINS SHOWN



- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Body dimensions do not include mold flash or protrusion, not to exceed 0,15.

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