

# SN54LS297, SN74LS297 DIGITAL PHASE-LOCKED-LOOP FILTERS

SDLS155 – JANUARY 1981 – REVISED MARCH 1988

- Digital Design Avoids Analog Compensation Errors
- Easily Cascadable for Higher Order Loops
- Useful Frequency from DC to:  
50 MHz Typical (K Clock)  
35 MHz Typical (I/D Clock)

## description

The SN54LS297 and SN74LS297 devices are designed to provide a simple, cost-effective solution to high-accuracy, digital, phase-locked-loop applications. These devices contain all the necessary circuits, with the exception of the divide-by-N counter, to build first order phase-locked loops as described in Figure 1.

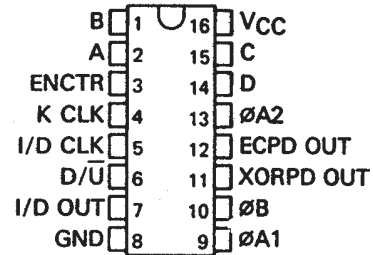
Both exclusive-OR (XORPD) and edge-controlled (ECPD) phase detectors are provided for maximum flexibility.

Proper partitioning of the loop function, with many of the building blocks external to the package, makes it easy for the designer to incorporate ripple cancellation or to cascade to higher order phase-locked loops.

The length of the up/down K counter is digitally programmable according to the K counter function table. With A, B, C, and D all low, the K counter is disabled. With A high and B, C, and D low, the K counter is only three stages long, which widens the bandwidth or capture range and shortens the lock time of the loop. When A, B, C, and D are all programmed high, the K counter becomes seventeen stages long, which narrows the bandwidth or capture range and lengthens the lock time. Real-time control of loop bandwidth by manipulating the A through D inputs can maximize the overall performance of the digital phase-locked loop.

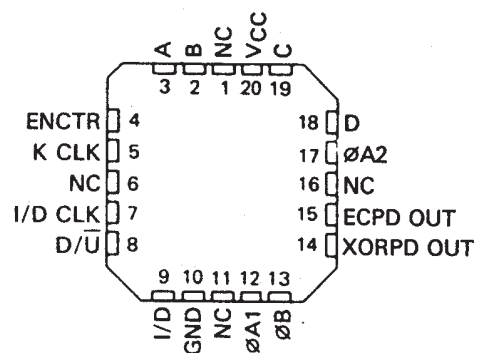
SN54LS297 . . . J OR W PACKAGE  
SN74LS297 . . . N PACKAGE

(TOP VIEW)



SN54LS297 . . . FK PACKAGE

(TOP VIEW)



NC—No internal connection

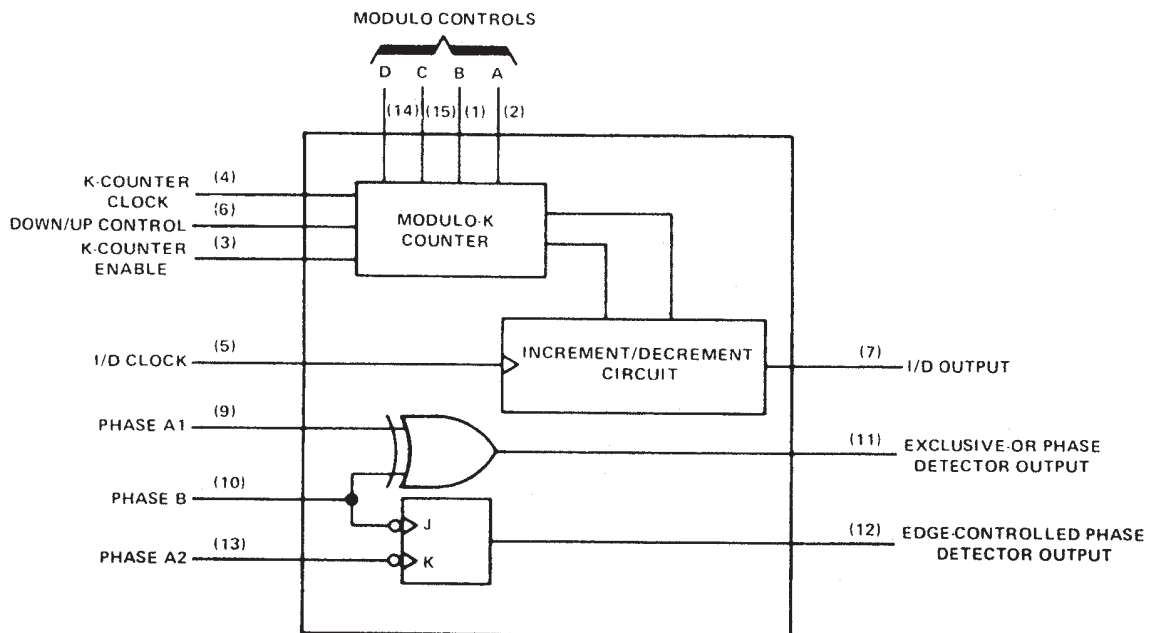


FIGURE 1—SIMPLIFIED BLOCK DIAGRAM

Pin numbers shown are for J, N and W packages.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

 **TEXAS  
INSTRUMENTS**

POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

Copyright © 1988, Texas Instruments Incorporated

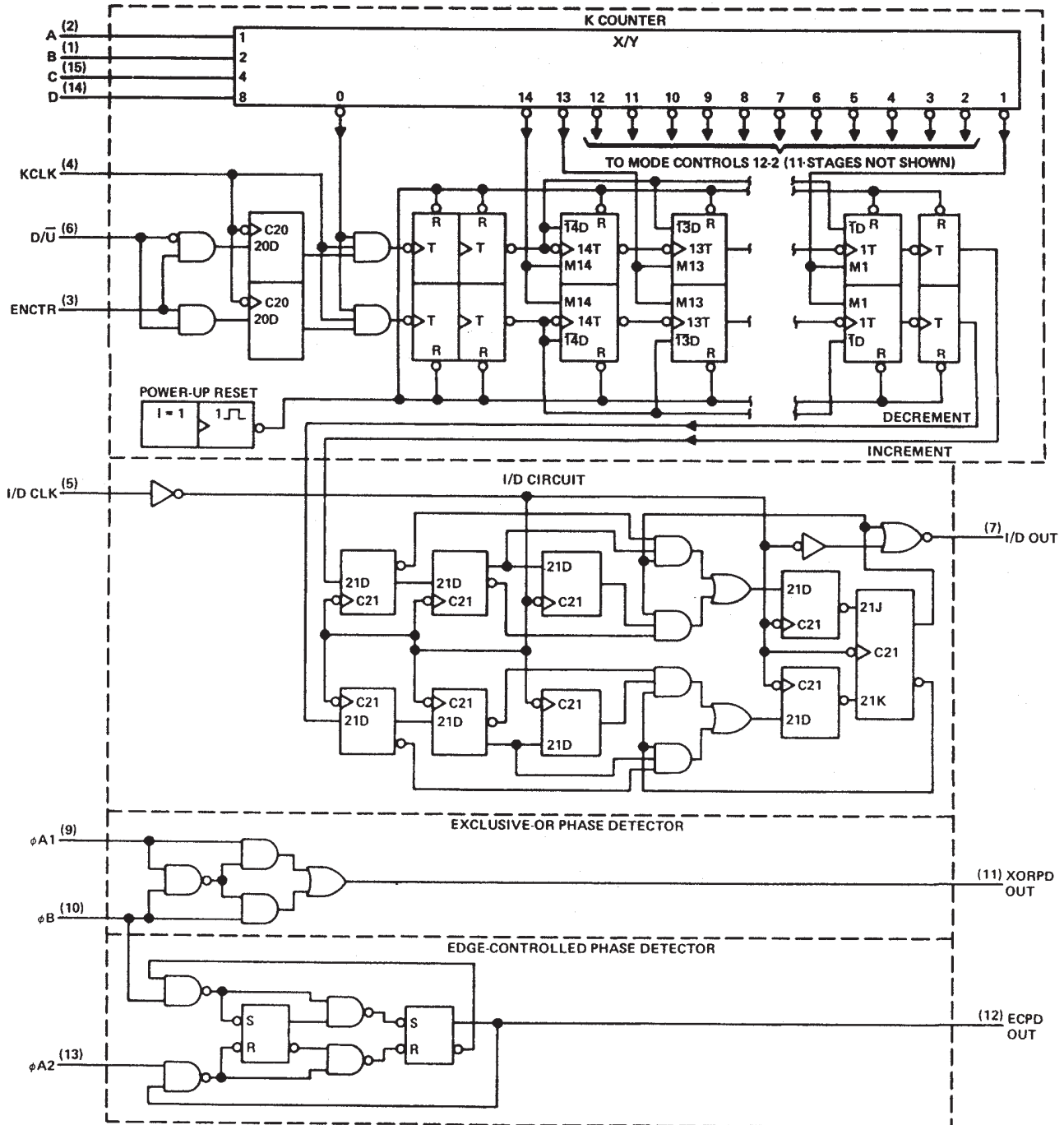
# SN54LS297, SN74LS297 DIGITAL PHASE-LOCKED-LOOP FILTERS

SDLS155 – JANUARY 1981 – REVISED MARCH 1988

## description (continued)

The 'LS297 can perform the classic first-order phase-locked loop function without using analog components. The accuracy of the digital phase-locked loop (DPLL) is not affected by  $V_{CC}$  and temperature variations, but depends solely on accuracies of the K clock, I/D clock, and loop propagation delays. The I/D clock frequency and the divide-by-N modulus will determine the center frequency of the DPLL. The center frequency is defined by the relationship  $f_c = I/D \text{ Clock}/2N$  (Hz).

## logic diagram (positive logic)



Pin numbers shown are for J, N, and W packages.



POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

# SN54LS297, SN74LS297 DIGITAL PHASE-LOCKED-LOOP FILTERS

SDLS155 – JANUARY 1981 – REVISED MARCH 1988

**K COUNTER FUNCTION TABLE  
(DIGITAL CONTROL)**

D	C	B	A	MODULO (K)
L	L	L	L	Inhibited
L	L	L	H	23
L	L	H	L	24
L	L	H	H	25
L	H	L	L	26
L	H	L	H	27
L	H	H	L	28
L	H	H	H	29
H	L	L	L	210
H	L	L	H	211
H	L	H	L	212
H	L	H	H	213
H	H	L	L	214
H	H	L	H	215
H	H	H	L	216
H	H	H	H	217

**FUNCTION TABLE  
EXCLUSIVE-OR PHASE DETECTOR**

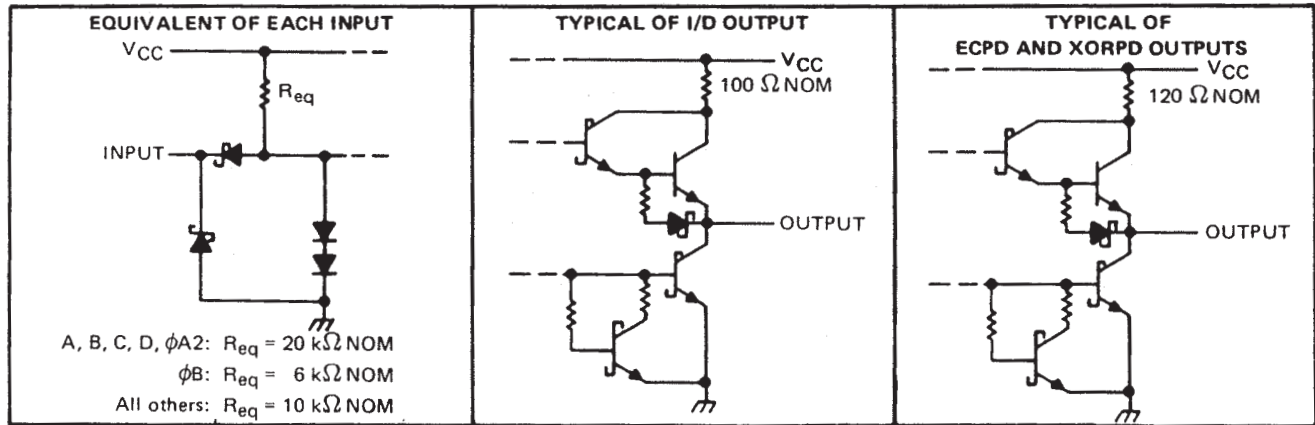
$\phi A1$	$\phi B$	XORPD OUT
L	L	L
L	H	H
H	L	H
H	H	L

**FUNCTION TABLE  
EDGE-CONTROLLED PHASE DETECTOR**

$\phi A2$	$\phi B$	ECPD OUT
H or L	↓	H
↓	H or L	L
H or L	↑	No change
↑	H or L	No change

H = steady-state high level  
L = steady-state low level  
↓ = transition from high to low  
↑ = transition from low to high

## schematics of inputs and outputs



## operation

The phase detector generates an error signal waveform that, at zero phase error, is a 50% duty cycle square wave. At the limits of linear operation, the phase detector output will be either high or low all of the time, depending on the direction of the phase error ( $\phi_{in} - \phi_{out}$ ). Within these limits, the phase detector output varies linearly with the input phase error according to the gain  $k_D$ , which is expressed in terms of phase detector output per cycle of phase error. The phase detector output can be defined to vary between  $\pm 1$  according to the relation:

$$\text{PD Output} = \frac{\% \text{ high} - \% \text{ low}}{100} \quad (1)$$

The output of the phase detector will be  $k_D \phi_e$ , where the phase error  $\phi_e = \phi_{in} - \phi_{out}$ .

# SN54LS297, SN74LS297 DIGITAL PHASE-LOCKED-LOOP FILTERS

SDLS155 – JANUARY 1981 – REVISED MARCH 1988

Exclusive-OR phase detectors (XORPD) and edge-controlled phase detectors (ECPD) are commonly used digital types. The ECPD is more complex than the XORPD logic function, but can be described generally as a circuit that changes states on one of the transitions of its inputs.  $k_d$  for an XORPD is 4 because its output remains high (PD output = 1) for a phase error of 1/4 cycle. Similarly,  $k_d$  for the ECPD is 2 since its output remains high for a phase error of 1/2 cycle. The type of phase detector will determine the zero-phase-error point, i.e., the phase separation of the phase detector inputs for  $\phi_e$  defined to be zero. For the basic DPLL system of Figure 2,  $\phi_e = 0$  when the phase detector output is a square wave. The XORPD inputs are 1/4 cycle out of phase for zero phase error. For the ECPD,  $\phi_e = 0$  when the inputs are 1/2 cycle out of phase.

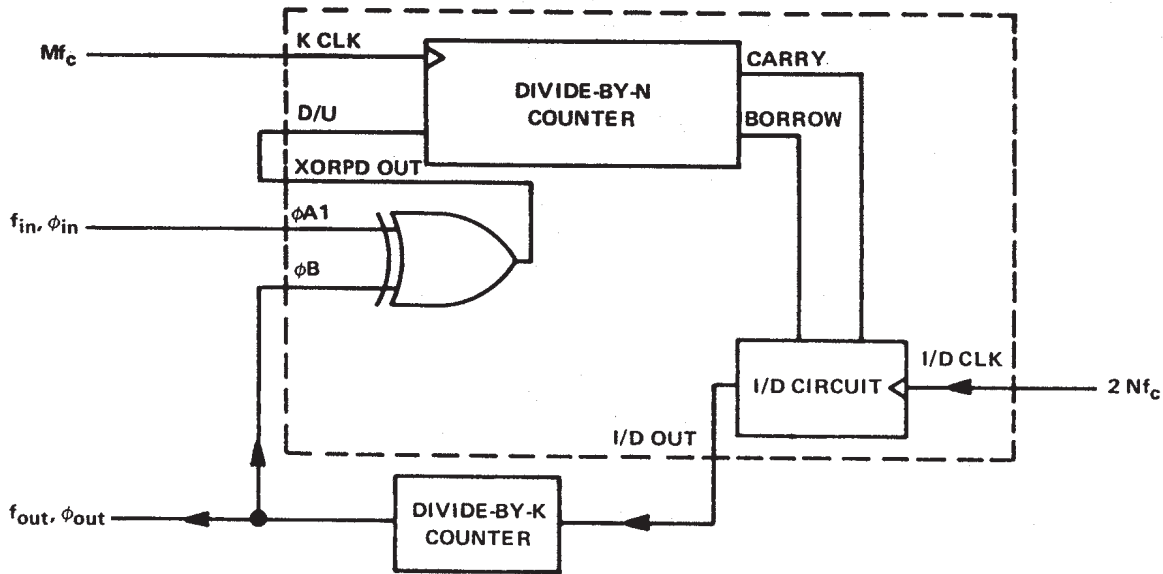


FIGURE 2—DPLL USING EXCLUSIVE-OR PHASE DETECTION

The phase detector output controls the up/down input to the K counter. The counter is clocked by input frequency  $Mf_c$ , which is a multiple  $M$  of the loop center frequency  $f_c$ . When the K counter recycles up, it generates a carry pulse. Recycling while counting down generates a borrow pulse. If the carry and borrow outputs are conceptually combined into one output that is positive for a carry and negative for a borrow, and if the K counter is considered as a frequency divider with the ratio  $Mf_c/K$ , the output of the K counter will equal the input frequency multiplied by the division ratio. Thus the output from the K counter is  $(k_d \phi_e Mf_c)/K$ .

The carry and borrow pulses go to the increment/decrement (I/D) circuit, which, in the absence of any carry or borrow pulse, has an output that is 1/2 of the input clock I/D CLK. The input clock is just a multiple,  $2N$ , of the loop center frequency. In response to a carry or borrow pulse, the I/D circuit will either add or delete a pulse at I/D OUT. Thus the output of the I/D circuit will be  $Nf_c + (k_d \phi_e Mf_c)/2K$ .

The output of the N counter (or the output of the phase-locked loop) is thus:

$$f_o = f_c + (k_d \phi_e Mf_c)/2KN$$

If this result is compared to the equation for a first-order analog phase-locked loop, the digital equivalent of the gain of the VCO is just  $Mf_c/2KN$  or  $f_c/K$  for  $M = 2N$ .

Thus the simple first-order phase-locked loop with an adjustable K counter is the equivalent of an analog phase-locked loop with a programmable VCO gain.

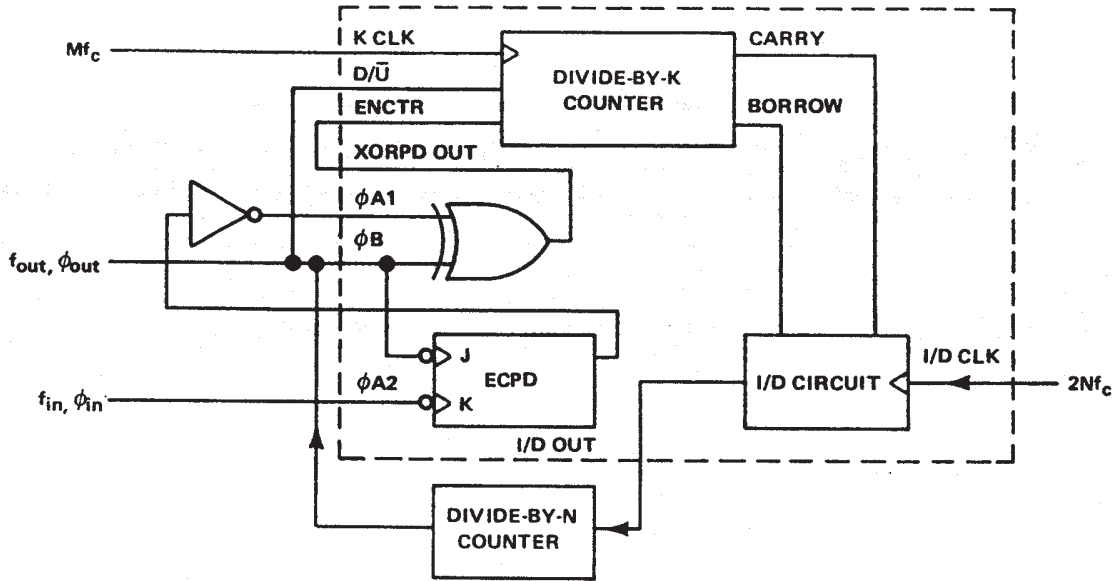


FIGURE 3—DPLL USING BOTH PHASE DETECTORS IN A RIPPLE-CANCELLATION SCHEME

absolute maximum rating over operating free-air temperature range (unless otherwise noted)

Supply voltage, $V_{CC}$ (see Note 1) .....	7 V
Input voltage .....	7 V
Operating free-air temperature range: SN54LS297 .....	-55°C to 125°C
SN74LS297 .....	0°C to 70°C
Storage temperature range .....	-65°C to 150°C

NOTE 1: Voltage values are with respect to network ground terminal.

recommended operating conditions

		SN54LS297			SN74LS297			UNIT
		MIN	NOM	MAX	MIN	NOM	MAX	
$V_{CC}$	Supply voltage	4.5	5	5.5	4.75	5	5.25	V
$I_{OH}$	High-level output current	I/D OUT		-1.2	-1.2		mA	
		EXOR, ECPD		-400	-400		$\mu$ A	
$I_{OL}$	Low-level output current	I/D OUT		12	24		mA	
		XOR, ECPD		4	8		mA	
$f_{clock}$	Clock frequency	K Clock		0	32	0	32	MHz
		I/D Clock		0	16	0	16	MHz
$t_w$	Width of clock input pulse	K Clock		16	16		ns	
		I/D Clock		33	33		ns	
$t_{su, to K}$	Setup time to K Clock $\dagger$	U/ $\bar{D}$ , ENCTR		30	30		ns	
$t_h$	Hold time from K Clock $\dagger$	U/ $\bar{D}$ , ENCTR		0	0		ns	
$T_A$	Operating free-air temperature	-55	125	0	70	°C		

# SN54LS297, SN74LS297 DIGITAL PHASE-LOCKED-LOOP FILTERS

SDLS155 – JANUARY 1981 – REVISED MARCH 1988

electrical characteristics over recommended operating free-air temperature range (unless otherwise noted)

PARAMETER		TEST CONDITIONS†	SN54LS297			SN74LS297			UNIT
			MIN	TYP‡	MAX	MIN	TYP‡	MAX	
V <sub>IH</sub>	High-level input voltage		2			2			V
V <sub>IL</sub>	Low-level input voltage			0.7			0.8		V
V <sub>IK</sub>	Input clamp voltage	V <sub>CC</sub> = MIN, I <sub>I</sub> = -18 mA			-1.5			-1.5	V
V <sub>OH</sub>	High-level output voltage	I/D OUT	V <sub>CC</sub> = MIN, V <sub>IH</sub> = 2 V, V <sub>IL</sub> = V <sub>IL max</sub>	I <sub>OH</sub> = MAX	2.4		2.4		V
		Others		I <sub>OH</sub> = MAX	2.5		2.7		
V <sub>OL</sub>	Low-level output voltage	I/D OUT	V <sub>CC</sub> = MIN, V <sub>IH</sub> = 2 V, V <sub>IL</sub> = V <sub>IL max</sub>	I <sub>OL</sub> = 12 mA	0.25	0.4	0.25	0.4	V
				I <sub>OL</sub> = 24 mA			0.35	0.5	
		Others		I <sub>OL</sub> = 4 mA	0.25	0.4	0.25	0.4	
				I <sub>OL</sub> = 8 mA			0.35	0.5	
I <sub>I</sub>	Input current at maximum input voltage	V <sub>CC</sub> = MAX, V <sub>I</sub> = 7 V			0.1		0.1	mA	
I <sub>IH</sub>	High-level input current	U/D, EN, φA1	V <sub>CC</sub> = MAX, V <sub>I</sub> = 2.7 V			40		40	μA
		φB				60		60	
		All others				20		20	
I <sub>IL</sub>	Low-level input current	U/D, EN, φA1	V <sub>CC</sub> = MAX, V <sub>I</sub> = 0.4 V			-0.8		-0.8	mA
		φB				-1.2		-1.2	
		All others				-0.4		-0.4	
I <sub>OS</sub>	Short-circuit output current §	I/D OUT	V <sub>CC</sub> = MAX		-30	-130	-30	-130	mA
		Others			-20	-100	-20	-100	
I <sub>CC</sub>	Supply current	V <sub>CC</sub> = MAX, All inputs grounded, All outputs open		75	120		75	120	mA

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

‡ All typical values are of V<sub>CC</sub> = 5 V, T<sub>A</sub> = 25°C.

§ Not more than one output should be shorted at a time and the duration of the short-circuit should not exceed one second.

switching characteristics, V<sub>CC</sub> = 5 V, T<sub>A</sub> = 25°C

PARAMETER¶	FROM (INPUT)		TO (OUTPUT)	TEST CONDITIONS	MIN	TYP	MAX	UNIT
f <sub>max</sub>	KCLK		I/D OUT	R <sub>L</sub> = 667 Ω, C <sub>L</sub> = 45 pF, See Note 2	32	50		MHz
	I/D CLK		I/D OUT		16	35		
t <sub>PLH</sub>	I/D CLK ↑		I/D OUT			15	25	ns
t <sub>PHL</sub>	I/D CLK ↑		I/D OUT			22	35	ns
t <sub>PLH</sub>	φA1 or φB	Other input low	XOR OUT	R <sub>L</sub> = 2 k Ω, C <sub>L</sub> = 45 pF, See Note 2		10	15	ns
	φA1 or φB	Other input high	XOR OUT			17	25	
t <sub>PHL</sub>	φA1 or φB	Other input low	XOR OUT			15	25	ns
	φA1 or φB	Other input high	XOR OUT			17	25	
t <sub>PLH</sub>	φB ↓		ECPD OUT			20	30	ns
t <sub>PHL</sub>	φA2 ↓		ECPD OUT			20	30	ns

¶ t<sub>PLH</sub> = propagation delay time, low-to-high-level output

t<sub>PHL</sub> = propagation delay time, high-to-low-level output

NOTE 2: Load circuits and voltage waveforms are shown in Section 1.



**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
SN74LS297N	ACTIVE	PDIP	N	16	25	RoHS & Non-Green	NIPDAU	N / A for Pkg Type	0 to 70	SN74LS297N	<b>Samples</b>

(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.

**Important Information and Disclaimer:**The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

**TUBE**


\*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (μm)	B (mm)
SN74LS297N	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.
  - Falls within JEDEC MS-001, except 18 and 20 pin minimum body length (Dim A).
  - The 20 pin end lead shoulder width is a vendor option, either half or full width.

## IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on [ti.com](http://ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2022, Texas Instruments Incorporated