

# SN5490A, SN5492A, SN5493A, SN54LS90, SN54LS92, SN54LS93 SN7490A, SN7492A, SN7493A, SN74LS90, SN74LS92, SN74LS93 DECADE, DIVIDE-BY-TWELVE AND BINARY COUNTERS

SDLS940A – MARCH 1974 – REVISED MARCH 1988

'90A, 'LS90 . . . Decade Counters

'92A, 'LS92 . . . Divide By-Twelve Counters

'93A, 'LS93 . . . 4-Bit Binary Counters

TYPES	TYPICAL POWER DISSIPATION
'90A	145 mW
'92A, '93A	130 mW
'LS90, 'LS92, 'LS93	45 mW

## description

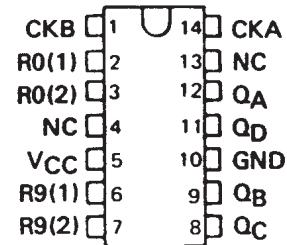
Each of these monolithic counters contains four master-slave flip-flops and additional gating to provide a divide-by-two counter and a three-stage binary counter for which the count cycle length is divide-by-five for the '90A and 'LS90, divide-by-six for the '92A and 'LS92, and the divide-by-eight for the '93A and 'LS93.

All of these counters have a gated zero reset and the '90A and 'LS90 also have gated set-to-nine inputs for use in BCD nine's complement applications.

To use their maximum count length (decade, divide-by-twelve, or four-bit binary) of these counters, the CKB input is connected to the  $Q_A$  output. The input count pulses are applied to CKA input and the outputs are as described in the appropriate function table. A symmetrical divide-by-ten count can be obtained from the '90A or 'LS90 counters by connecting the  $Q_D$  output to the CKA input and applying the input count to the CKB input which gives a divide-by-ten square wave at output  $Q_A$ .

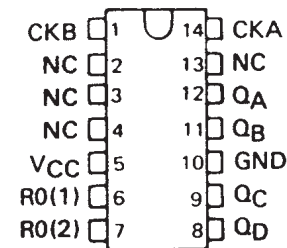
SN5490A, SN54LS90 . . . J OR W PACKAGE  
SN7490A . . . N PACKAGE  
SN74LS90 . . . D OR N PACKAGE

(TOP VIEW)



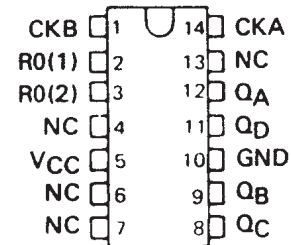
SN5492A, SN54LS92 . . . J OR W PACKAGE  
SN7492A . . . N PACKAGE  
SN74LS92 . . . D OR N PACKAGE

(TOP VIEW)



SN5493A, SN54LS93 . . . J OR W PACKAGE  
SN7493 . . . N PACKAGE  
SN74LS93 . . . D OR N PACKAGE

(TOP VIEW)



SN5490A, SN5492A, SN5493A, SN54LS90, SN54LS92, SN54LS93  
 SN7490A, SN7492A, SN7493A, SN74LS90, SN74LS92, SN74LS93  
 DECADE, DIVIDE-BY-TWELVE AND BINARY COUNTERS

SDLS940A – MARCH 1974 – REVISED MARCH 1988

logic symbols†



†These symbols are in accordance with ANSI/IEEE Std. 91-1984 and IEC Publication 617-12.



SN5490A, SN5492A, SN5493A, SN54LS90, SN54LS92, SN54LS93  
 SN7490A, SN7492A, SN7493A, SN74LS90, SN74LS92, SN74LS93  
 DECADE, DIVIDE-BY-TWELVE AND BINARY COUNTERS

SDLS940A - MARCH 1974 - REVISED MARCH 1988

'90A, 'LS90  
 BCD COUNT SEQUENCE  
 (See Note A)

COUNT	OUTPUT			
	Q <sub>D</sub>	Q <sub>C</sub>	Q <sub>B</sub>	Q <sub>A</sub>
0	L	L	L	L
1	L	L	L	H
2	L	L	H	L
3	L	L	H	H
4	L	H	L	L
5	L	H	L	H
6	L	H	H	L
7	L	H	H	H
8	H	L	L	L
9	H	L	L	H

'90A, 'LS90  
 BI-QUINARY (5-2)  
 (See Note B)

COUNT	OUTPUT			
	Q <sub>A</sub>	Q <sub>D</sub>	Q <sub>C</sub>	Q <sub>B</sub>
0	L	L	L	L
1	L	L	L	H
2	L	L	H	L
3	L	L	H	H
4	L	H	L	L
5	H	L	L	L
6	H	L	L	H
7	H	L	H	L
8	H	L	H	H
9	H	H	L	L

'92A, 'LS92  
 COUNT SEQUENCE  
 (See Note C)

COUNT	OUTPUT			
	Q <sub>D</sub>	Q <sub>C</sub>	Q <sub>B</sub>	Q <sub>A</sub>
0	L	L	L	L
1	L	L	L	H
2	L	L	H	L
3	L	L	H	H
4	L	H	L	L
5	L	H	L	H
6	H	L	L	L
7	H	L	L	H
8	H	L	H	L
9	H	L	H	H
10	H	H	L	L
11	H	H	L	H

'90A, 'LS90  
 RESET/COUNT FUNCTION TABLE

RESET INPUTS				OUTPUT			
R <sub>0</sub> (1)	R <sub>0</sub> (2)	R <sub>9</sub> (1)	R <sub>9</sub> (2)	Q <sub>D</sub>	Q <sub>C</sub>	Q <sub>B</sub>	Q <sub>A</sub>
H	H	L	X	L	L	L	L
H	H	X	L	L	L	L	L
X	X	H	H	H	L	L	H
X	L	X	L	COUNT			
L	X	L	X	COUNT			
L	X	X	L	COUNT			
X	L	L	X	COUNT			

'93A, 'LS93  
 COUNT SEQUENCE  
 (See Note C)

COUNT	OUTPUT			
	Q <sub>D</sub>	Q <sub>C</sub>	Q <sub>B</sub>	Q <sub>A</sub>
0	L	L	L	L
1	L	L	L	H
2	L	L	H	L
3	L	L	H	H
4	L	H	L	L
5	L	H	L	H
6	L	H	H	L
7	L	H	H	H
8	H	L	L	L
9	H	L	L	H
10	H	L	H	L
11	H	L	H	H
12	H	H	L	L
13	H	H	L	H
14	H	H	H	L
15	H	H	H	H

'92A, 'LS92, '93A, 'LS93  
 RESET/COUNT FUNCTION TABLE

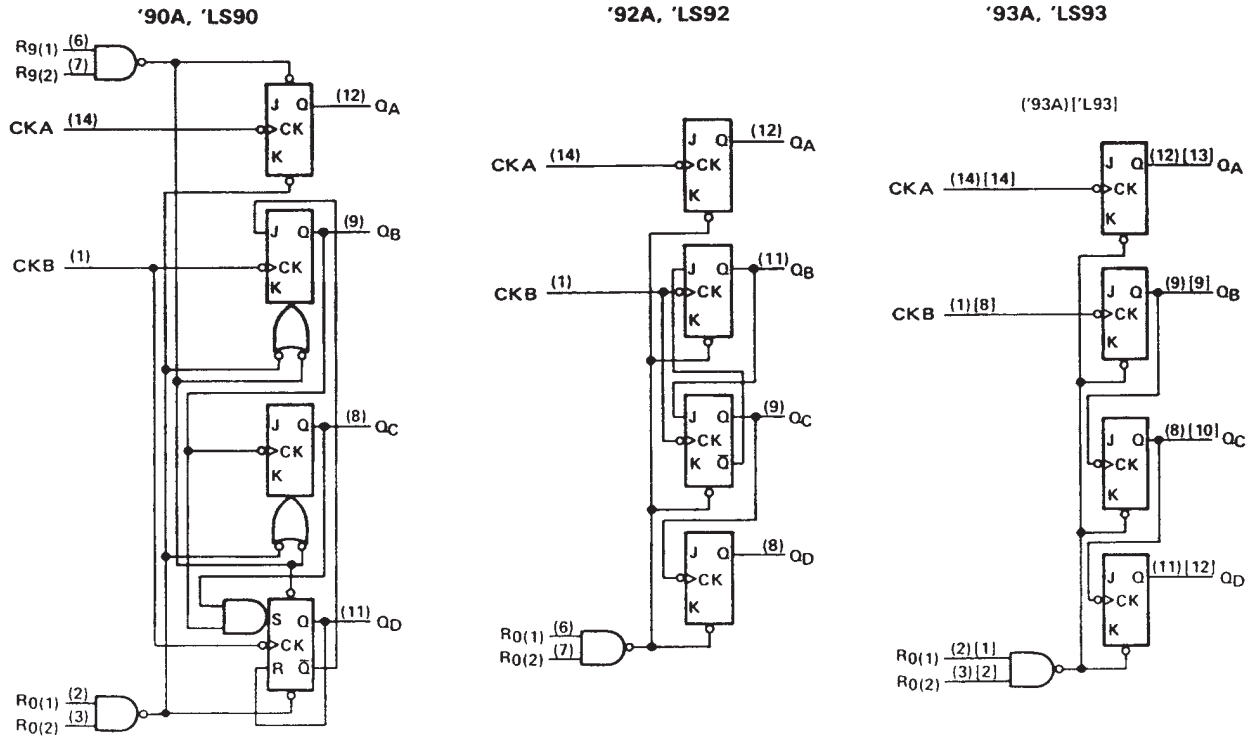
RESET INPUTS		OUTPUT			
R <sub>0</sub> (1)	R <sub>0</sub> (2)	Q <sub>D</sub>	Q <sub>C</sub>	Q <sub>B</sub>	Q <sub>A</sub>
H	H	L	L	L	L
L	X	COUNT			
X	L	COUNT			

- NOTES: A. Output Q<sub>A</sub> is connected to input CKB for BCD count.  
 B. Output Q<sub>D</sub> is connected to input CKA for bi-quinary count.  
 C. Output Q<sub>A</sub> is connected to input CKB.  
 D. H = high level, L = low level, X = irrelevant

# SN5490A, SN5492A, SN5493A, SN54LS90, SN54LS92, SN54LS93 SN7490A, SN7492A, SN7493A, SN74LS90, SN74LS92, SN74LS93 DECADE, DIVIDE-BY-TWELVE AND BINARY COUNTERS

SDLS940A – MARCH 1974 – REVISED MARCH 1988

## logic diagrams (positive logic)



The J and K inputs shown without connection are for reference only and are functionally at a high level. Pin numbers shown in ( ) are for the 'LS93 and '93A and pin numbers shown in [ ] are for the 54L93.

## schematics of inputs and outputs

'90A, '92A, '93A

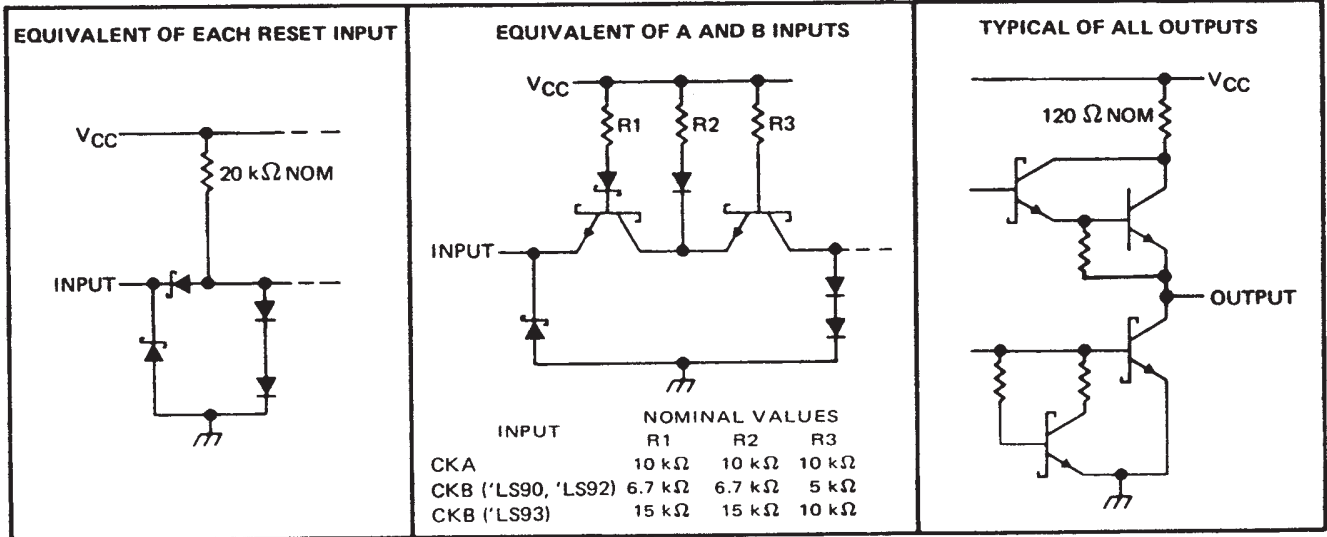


SN5490A, SN5492A, SN5493A, SN54LS90, SN54LS92, SN54LS93  
 SN7490A, SN7492A, SN7493A, SN74LS90, SN74LS92, SN74LS93  
 DECADE, DIVIDE-BY-TWELVE AND BINARY COUNTERS

SDLS940A - MARCH 1974 - REVISED MARCH 1988

schematics of inputs and outputs (continued)

'LS90, 'LS92, 'LS93



# SN5490A, SN5492A, SN5493A, SN54LS90, SN54LS92, SN54LS93 SN7490A, SN7492A, SN7493A, SN74LS90, SN74LS92, SN74LS93 DECADE, DIVIDE-BY-TWELVE AND BINARY COUNTERS

SDLS940A – MARCH 1974 – REVISED MARCH 1988

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

Supply voltage, $V_{CC}$ (see Note 1)	7 V
Input voltage	5.5 V
Interemitter voltage (see Note 2)	5.5 V
Operating free-air temperature range: SN5490A, SN5492A, SN5493A	-55°C to 125°C
SN7490A, SN7492A, SN7493A	0°C to 70°C
Storage temperature range	-65°C to 150°C

NOTES: 1. Voltage values, except interemitter voltage, are with respect to network ground terminal.  
2. This is the voltage between two emitters of a multiple-emitter transistor. For these circuits, this rating applies between the two  $R_0$  inputs, and for the '90A circuit, it also applies between the two  $R_0$  inputs.

## recommended operating conditions

	SN5490A, SN5492A SN5493A			SN7490A, SN7492A SN7493A			UNIT
	MIN	NOM	MAX	MIN	NOM	MAX	
Supply voltage, $V_{CC}$	4.5	5	5.5	4.75	5	5.25	V
High-level output current, $I_{OH}$			-800			-800	$\mu$ A
Low-level output current, $I_{OL}$			16			16	mA
Count frequency, $f_{count}$ (see Figure 1)	A input	0	32	0		32	MHz
	B input	0	16	0		16	
Pulse width, $t_w$	A input	15		15			ns
	B input	30		30			
	Reset inputs	15		15			
Reset inactive-state setup time, $t_{su}$		25			25		ns
Operating free-air temperature, $T_A$		-55	125		0	70	°C

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

PARAMETER <sup>¶</sup>	TEST CONDITIONS <sup>†</sup>	'90A			'92A			'93A			UNIT
		MIN	TYP <sup>‡</sup>	MAX	MIN	TYP <sup>‡</sup>	MAX	MIN	TYP <sup>‡</sup>	MAX	
$V_{IH}$ High-level input voltage		2			2			2			V
$V_{IL}$ Low-level input voltage				0.8			0.8			0.8	V
$V_{IK}$ Input clamp voltage	$V_{CC} = \text{MIN}, I_I = -12 \text{ mA}$			-1.5			-1.5			-1.5	V
$V_{OH}$ High-level output voltage	$V_{CC} = \text{MIN}, V_{IH} = 2 \text{ V}, V_{IL} = 0.8 \text{ V}, I_{OH} = -800 \mu\text{A}$	2.4	3.4		2.4	3.4		2.4	3.4		V
$V_{OL}$ Low-level output voltage	$V_{CC} = \text{MIN}, V_{IH} = 2 \text{ V}, V_{IL} = 0.8 \text{ V}, I_{OL} = 16 \text{ mA}^{\parallel}$		0.2	0.4		0.2	0.4		0.2	0.4	V
$I_I$ Input current at maximum input voltage	$V_{CC} = \text{MAX}, V_I = 5.5 \text{ V}$			1			1			1	mA
$I_{IH}$ High-level input current	Any reset CKA CKB $V_{CC} = \text{MAX}, V_I = 2.4 \text{ V}$			40			40			40	$\mu$ A
				80			80			80	
				120			120			80	
$I_{IL}$ Low-level input current	Any reset CKA CKB $V_{CC} = \text{MAX}, V_I = 0.4 \text{ V}$			-1.6			-1.6			-1.6	mA
				-3.2			-3.2			-3.2	
				-4.8			-4.8			-3.2	
$I_{OS}$ Short-circuit output current <sup>§</sup>	$V_{CC} = \text{MAX}$	SN54'	-20	-57	-20	-57	-20	-57			mA
		SN74'	-18	-57	-18	-57	-18	-57			
$I_{CC}$ Supply current	$V_{CC} = \text{MAX}, \text{ See Note 3}$		29	42		26	39		26	39	mA

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

<sup>‡</sup> All typical values are at  $V_{CC} = 5 \text{ V}, T_A = 25^\circ\text{C}$ .

<sup>§</sup> Not more than one output should be shorted at a time.

<sup>¶</sup> '90A outputs are tested at  $I_{OL} = 16 \text{ mA}$  plus the limit value for  $I_{IL}$  for the CKB input. This permits driving the CKB input while maintaining full fan-out capability.

NOTE 3:  $I_{CC}$  is measured with all outputs open, both  $R_0$  inputs grounded following momentary connection to 4.5 V, and all other inputs grounded.



SN5490A, SN5492A, SN5493A, SN54LS90, SN54LS92, SN54LS93  
 SN7490A, SN7492A, SN7493A, SN74LS90, SN74LS92, SN74LS93  
 DECADE, DIVIDE-BY-TWELVE AND BINARY COUNTERS

SDLS940A - MARCH 1974 - REVISED MARCH 1988

switching characteristics,  $V_{CC} = 5\text{ V}$ ,  $T_A = 25^\circ\text{C}$

PARAMETER†	FROM (INPUT)	TO (OUTPUT)	TEST CONDITIONS	'90A			'92A			'93A			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$f_{\max}$	CKA	$Q_A$	$C_L = 15\text{ pF}$ , $R_L = 400\ \Omega$ , See Figure 1	32	42		32	42		32	42		MHz
	CKB	$Q_B$		16			16			16			
$t_{PLH}$	CKA	$Q_A$		10	16		10	16		10	16		ns
$t_{PHL}$				12	18		12	18		12	18		
$t_{PLH}$	CKA	$Q_D$		32	48		32	48		46	70		ns
$t_{PHL}$				34	50		34	50		46	70		
$t_{PLH}$	CKB	$Q_B$		10	16		10	16		10	16		ns
$t_{PHL}$				14	21		14	21		14	21		
$t_{PLH}$	CKB	$Q_C$		21	32		10	16		21	32		ns
$t_{PHL}$				23	35		14	21		23	35		
$t_{PLH}$	CKB	$Q_D$		21	32		21	32		34	51		ns
$t_{PHL}$				23	35		23	35		34	51		
$t_{PHL}$	Set-to-0	Any		26	40		26	40		26	40		ns
$t_{PLH}$	Set-to-9	$Q_A, Q_D$		20	30								ns
$t_{PHL}$		$Q_B, Q_C$		26	40								

†  $f_{\max}$  = maximum count frequency  
 $t_{PLH}$  = propagation delay time, low-to-high-level output  
 $t_{PHL}$  = propagation delay time, high-to-low-level output



**SN5490A, SN5492A, SN5493A, SN54LS90, SN54LS92, SN54LS93  
SN7490A, SN7492A, SN7493A, SN74LS90, SN74LS92, SN74LS93  
DECADE, DIVIDE-BY-TWELVE AND BINARY COUNTERS**

SDLS940A – MARCH 1974 – REVISED MARCH 1988

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

Supply voltage, $V_{CC}$ (see Note 1)	7 V
Input voltage: R inputs	7 V
A and B inputs	5.5 V
Operating free-air temperature range: SN54LS' Circuits	-55°C to 125°C
SN74LS' Circuits	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**

		SN54LS90 SN54LS92 SN54LS93			SN74LS90 SN74LS92 SN74LS93			UNIT
		MIN	NOM	MAX	MIN	NOM	MAX	
Supply voltage, $V_{CC}$		4.5	5	5.5	4.75	5	5.25	V
High-level output current, $I_{OH}$				-400			-400	$\mu$ A
Low-level output current, $I_{OL}$				4			8	mA
Count frequency, $f_{count}$ (see Figure 1)	A input	0		32	0		32	MHz
	B input	0		16	0		16	
Pulse width, $t_w$	A input	15			15			ns
	B input	30			30			
	Reset inputs	30			30			
Reset inactive-state setup time, $t_{su}$		25			25			ns
Operating free-air temperature, $T_A$		-55		125	0		70	°C

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

PARAMETER	TEST CONDITIONS†	SN54LS90 SN54LS92			SN74LS90 SN74LS92			UNIT
		MIN	TYP‡	MAX	MIN	TYP‡	MAX	
$V_{IH}$ High-level input voltage		2			2			V
$V_{IL}$ Low-level input voltage				0.7			0.8	V
$V_{IK}$ Input clamp voltage	$V_{CC} = \text{MIN}, I_I = -18 \text{ mA}$			-1.5			-1.5	V
$V_{OH}$ High-level output voltage	$V_{CC} = \text{MIN}, V_{IH} = 2 \text{ V}, V_{IL} = V_{IL \text{ max}}, I_{OH} = -400 \mu\text{A}$	2.5	3.4		2.7	3.4		V
$V_{OL}$ Low-level output voltage	$V_{CC} = \text{MIN}, V_{IH} = 2 \text{ V}, V_{IL} = V_{IL \text{ max}}, I_{OL} = 4 \text{ mA} \parallel$ $I_{OL} = 8 \text{ mA} \parallel$	0.25	0.4		0.25	0.4		V
					0.35	0.5		
$I_I$ Input current at maximum input voltage	Any reset			0.1			0.1	mA
	CKA			0.2			0.2	
	CKB			0.4			0.4	
$I_{IH}$ High-level input current	Any reset			20			20	$\mu$ A
	CKA			40			40	
	CKB			80			80	
$I_{IL}$ Low-level input current	Any reset			-0.4			-0.4	mA
	CKA			-2.4			-2.4	
	CKB			-3.2			-3.2	
$I_{OS}$ Short-circuit output current§	$V_{CC} = \text{MAX}$	-20		-100	-20		-100	mA
$I_{CC}$ Supply current	$V_{CC} = \text{MAX},$ See Note 3	'LS90	9	15	9	15		mA
		'LS92	9	15	9	15		

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

‡ All typical values are at  $V_{CC} = 5 \text{ V}, T_A = 25^\circ\text{C}$ .

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

¶  $I_{QA}$  outputs are tested at specified  $I_{OL}$  plus the limit value of  $I_{IL}$  for the CKB input. This permits driving the CKB input while maintaining full fan-out capability.

NOTE 3:  $I_{CC}$  is measured with all outputs open, both  $R_0$  inputs grounded following momentary connection to 4.5 V, and all other inputs grounded.





SN5490A, SN5492A, SN5493A, SN54LS90, SN54LS92, SN54LS93  
 SN7490A, SN7492A, SN7493A, SN74LS90, SN74LS92, SN74LS93  
 DECADE, DIVIDE-BY-TWELVE AND BINARY COUNTERS

SDLS940A - MARCH 1974 - REVISED MARCH 1988

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

PARAMETER	TEST CONDITIONS†	SN54LS93			SN74LS93			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	V <sub>CC</sub> = MIN, V <sub>IH</sub> = 2 V, V <sub>IL</sub> = V <sub>IL</sub> max, I <sub>OH</sub> = -400 μA	2.5	3.4		2.7	3.4		V	
V <sub>OL</sub> Low-level output voltage	V <sub>CC</sub> = MIN, V <sub>IH</sub> = 2 V, V <sub>IL</sub> = V <sub>IL</sub> max	I <sub>OL</sub> = 4 mA¶			0.25	0.4	0.25	0.4	V
		I <sub>OL</sub> = 8 mA¶					0.35	0.5	
I <sub>I</sub> Input current at maximum input voltage	Any reset	V <sub>CC</sub> = MAX, V <sub>I</sub> = 7 V			0.1			mA	
	CKA or CKB	V <sub>CC</sub> = MAX, V <sub>I</sub> = 5.5 V			0.2				
I <sub>IH</sub> High-level input current	Any reset	V <sub>CC</sub> = MAX, V <sub>I</sub> = 2.7 V			20			μA	
	CKA or CKB				40				
I <sub>IL</sub> Low-level input current	Any reset	V <sub>CC</sub> = MAX, V <sub>I</sub> = 0.4 V			-0.4			mA	
	CKA				-2.4				
	CKB				-1.6				
I <sub>OS</sub> Short-circuit output current §	V <sub>CC</sub> = MAX	-20		-100	-20		-100	mA	
I <sub>CC</sub> Supply current	V <sub>CC</sub> = MAX, See Note 3		9	15		9	15	mA	

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

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

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

¶ Q<sub>A</sub> outputs are tested at specified I<sub>OL</sub> plus the limit value for I<sub>IL</sub> for the CKB input. This permits driving the CKB input while maintaining full fan-out capability.

NOTE 3: I<sub>CC</sub> is measured with all outputs open, both R<sub>0</sub> inputs grounded following momentary connection to 4.5 V, and all other inputs grounded.

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

PARAMETER#	FROM (INPUT)	TO (OUTPUT)	TEST CONDITIONS	'LS90			'LS92			'LS93			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
f <sub>max</sub>	CKA	Q <sub>A</sub>	C <sub>L</sub> = 15 pF, R <sub>L</sub> = 2 kΩ See Figure 1	32	42		32	42		32	42		MHz
	CKB	Q <sub>B</sub>		16			16			16			
t <sub>PLH</sub>	CKA	Q <sub>A</sub>		10	16		10	16		10	16		ns
t <sub>PHL</sub>				12	18		12	18		12	18		
t <sub>PLH</sub>	CKA	Q <sub>D</sub>		32	48		32	48		46	70		ns
t <sub>PHL</sub>				34	50		34	50		46	70		
t <sub>PLH</sub>	CKB	Q <sub>B</sub>		10	16		10	16		10	16		ns
t <sub>PHL</sub>				14	21		14	21		14	21		
t <sub>PLH</sub>	CKB	Q <sub>C</sub>		21	32		10	16		21	32		ns
t <sub>PHL</sub>				23	35		14	21		23	35		
t <sub>PLH</sub>	CKB	Q <sub>D</sub>		21	32		21	32		34	51		ns
t <sub>PHL</sub>				23	35		23	35		34	51		
t <sub>PHL</sub>	Set-to-0	Any		26	40		26	40		26	40		ns
t <sub>PLH</sub>	Set-to-9	Q <sub>A</sub> , Q <sub>D</sub>		20	30								ns
t <sub>PHL</sub>		Q <sub>B</sub> , Q <sub>C</sub>		26	40								

#f<sub>max</sub> = maximum count frequency

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

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



SN5490A, SN5492A, SN5493A, SN54LS90, SN54LS92, SN54LS93  
 SN7490A, SN7492A, SN7493A, SN74LS90, SN74LS92, SN74LS93  
 DECADE, DIVIDE-BY-TWELVE AND BINARY COUNTERS

SDLS940A - MARCH 1974 - REVISED MARCH 1988

PARAMETER MEASUREMENT INFORMATION



NOTES: A. Input pulses are supplied by a generator having the following characteristics:

- for '90A, '92A, '93A,  $t_r \leq 5$  ns,  $t_f \leq 5$  ns, PRR = 1 MHz, duty cycle = 50%,  $Z_{out} \approx 50$  ohms;
- for 'LS90, 'LS92, 'LS93,  $t_r \leq 15$  ns,  $t_f \leq 5$  ns, PRR = 1 MHz, duty cycle = 50%,  $Z_{out} \approx 50$  ohms.
- B.  $C_L$  includes probe and jig capacitance.
- C. All diodes are 1N3064 or equivalent.
- D. Each reset input is tested separately with the other reset at 4.5 V.
- E. Reference waveforms are shown with dashed lines.
- F. For '90A, '92A, and '93A;  $V_{ref} = 1.5$  V. For 'LS90, 'LS92, and 'LS93;  $V_{ref} = 1.3$  V.

FIGURE 1A



PARAMETER MEASUREMENT INFORMATION



- NOTES: A. Input pulses are supplied by a generator having the following characteristics:  
for '90A, '92A, '93A,  $t_r \leq 5$  ns,  $t_f \leq 5$  ns, PRR = 1 MHz, duty cycle = 50%,  $Z_{out} \approx 50$  ohms;  
for 'LS90, 'LS92, 'LS93,  $t_r \leq 15$  ns,  $t_f \leq 5$  ns, PRR = 1 MHz, duty cycle = 50%,  $Z_{out} \approx 50$  ohms.
- B.  $C_L$  includes probe and jig capacitance.
- C. All diodes are 1N3064 or equivalent.
- D. Each reset input is tested separately with the other reset at 4.5 V.
- E. Reference waveforms are shown with dashed lines.
- F. For '90A, '92A, and '93A;  $V_{ref} = 1.5$  V. For 'LS90, 'LS92, and 'LS93;  $V_{ref} = 1.3$  V.

FIGURE 1B

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