

## DM74LS90/DM74LS93 Decade and Binary Counters

### General 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 'LS90 and divide-by-eight for the 'LS93.

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

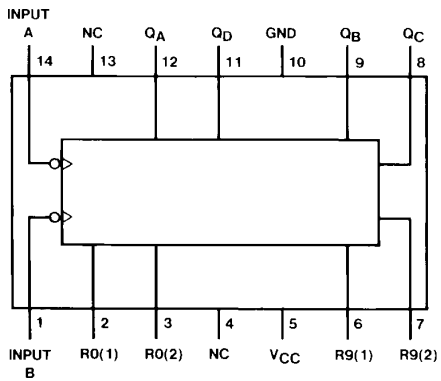
To use their maximum count length (decade or four bit binary), the B input is connected to the  $Q_A$  output. The input

count pulses are applied to input A and the outputs are as described in the appropriate truth table. A symmetrical divide-by-ten count can be obtained from the 'LS90 counters by connecting the  $Q_D$  output to the A input and applying the input count to the B input which gives a divide-by-ten square wave at output  $Q_A$ .

### Features

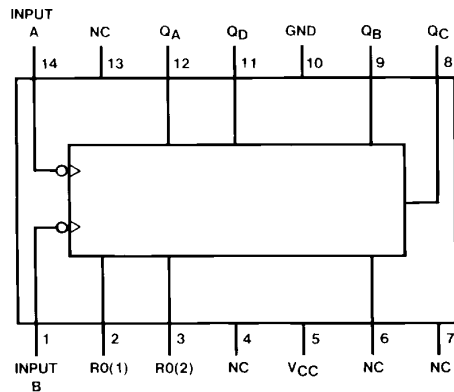
- Typical power dissipation 45 mW
- Count frequency 42 MHz

### Connection Diagrams (Dual-In-Line Packages)



TL/F/6381-1

Order Number DM74LS90M or DM74LS90N  
See NS Package Number M14A or N14A



TL/F/6381-2

Order Number DM74LS93M or DM74LS93N  
See NS Package Number M14A or N14A

## Absolute Maximum Ratings (Note)

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

|                                      |                 |
|--------------------------------------|-----------------|
| Supply Voltage                       | 7V              |
| Input Voltage (Reset)                | 7V              |
| Input Voltage (A or B)               | 5.5V            |
| Operating Free Air Temperature Range |                 |
| DM74LS                               | 0°C to +70°C    |
| Storage Temperature Range            | -65°C to +150°C |

Note: The "Absolute Maximum Ratings" are those values beyond which the safety of the device cannot be guaranteed. The device should not be operated at these limits. The parametric values defined in the "Electrical Characteristics" table are not guaranteed at the absolute maximum ratings. The "Recommended Operating Conditions" table will define the conditions for actual device operation.

## Recommended Operating Conditions

| Symbol           | Parameter                      | DM74LS90            |     |      | Units |
|------------------|--------------------------------|---------------------|-----|------|-------|
|                  |                                | Min                 | Nom | Max  |       |
| V <sub>CC</sub>  | Supply Voltage                 | 4.75                | 5   | 5.25 | V     |
| V <sub>IH</sub>  | High Level Input Voltage       | 2                   |     |      | V     |
| V <sub>IL</sub>  | Low Level Input Voltage        |                     |     | 0.8  | V     |
| I <sub>OH</sub>  | High Level Output Current      |                     |     | -0.4 | mA    |
| I <sub>OL</sub>  | Low Level Output Current       |                     |     | 8    | mA    |
| f <sub>CLK</sub> | Clock Frequency (Note 1)       | A to Q <sub>A</sub> | 0   | 32   | MHz   |
|                  |                                | B to Q <sub>B</sub> | 0   | 16   |       |
| f <sub>CLK</sub> | Clock Frequency (Note 2)       | A to Q <sub>A</sub> | 0   | 20   | MHz   |
|                  |                                | B to Q <sub>B</sub> | 0   | 10   |       |
| t <sub>W</sub>   | Pulse Width (Note 1)           | A                   | 15  |      | ns    |
|                  |                                | B                   | 30  |      |       |
|                  |                                | Reset               | 15  |      |       |
| t <sub>W</sub>   | Pulse Width (Note 2)           | A                   | 25  |      | ns    |
|                  |                                | B                   | 50  |      |       |
|                  |                                | Reset               | 25  |      |       |
| t <sub>REL</sub> | Reset Release Time (Note 1)    | 25                  |     |      | ns    |
| t <sub>REL</sub> | Reset Release Time (Note 2)    | 35                  |     |      | ns    |
| T <sub>A</sub>   | Free Air Operating Temperature | 0                   |     | 70   | °C    |

Note 1: C<sub>L</sub> = 15 pF, R<sub>L</sub> = 2 kΩ, T<sub>A</sub> = 25°C and V<sub>CC</sub> = 5V.

Note 2: C<sub>L</sub> = 50 pF, R<sub>L</sub> = 2 kΩ, T<sub>A</sub> = 25°C and V<sub>CC</sub> = 5V.

## 'LS90 Electrical Characteristics

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

| Symbol          | Parameter                         | Conditions   | Min   | Typ (Note 1) | Max  | Units |
|-----------------|-----------------------------------|--|-------|--------------|------|-------|
| V <sub>I</sub>  | Input Clamp Voltage               | V <sub>CC</sub> = Min, I <sub>I</sub> = -18 mA   |       |              | -1.5 | V     |
| V <sub>OH</sub> | High Level Output Voltage         | V <sub>CC</sub> = Min, I <sub>OH</sub> = Max<br>V <sub>IL</sub> = Max, V <sub>IH</sub> = Min             | 2.7   | 3.4          |      | V     |
| V <sub>OL</sub> | Low Level Output Voltage          | V <sub>CC</sub> = Min, I <sub>OL</sub> = Max<br>V <sub>IL</sub> = Max, V <sub>IH</sub> = Min<br>(Note 4) |       | 0.35         | 0.5  | V     |
|                 |                                   | I <sub>OL</sub> = 4 mA, V <sub>CC</sub> = Min  |       | 0.25         | 0.4  |       |
| I <sub>I</sub>  | Input Current @ Max Input Voltage | V <sub>CC</sub> = Max, V <sub>I</sub> = 7V   | Reset |              | 0.1  | mA    |
|                 |                                   | V <sub>CC</sub> = Max<br>V <sub>I</sub> = 5.5V   | A     |              | 0.2  |       |
|                 |                                   |  | B     |              | 0.4  |       |

## 'LS90 Electrical Characteristics

over recommended operating free air temperature range (unless otherwise noted) (Continued)

| Symbol          | Parameter                    | Conditions                                   | Min   | Typ<br>(Note 1) | Max  | Units |
|-----------------|------------------------------|--|-------|-----------------|------|-------|
| I <sub>IH</sub> | High Level Input Current     | V <sub>CC</sub> = Max, V <sub>I</sub> = 2.7V | Reset |                 | 20   | μA    |
|                 |                              |  | A     |                 | 40   |       |
|                 |                              |  | B     |                 | 80   |       |
| I <sub>IL</sub> | Low Level Input Current      | V <sub>CC</sub> = Max, V <sub>I</sub> = 0.4V | Reset |                 | -0.4 | mA    |
|                 |                              |  | A     |                 | -2.4 |       |
|                 |                              |  | B     |                 | -3.2 |       |
| I <sub>OS</sub> | Short Circuit Output Current | V <sub>CC</sub> = Max (Note 2)               | -20   |                 | -100 | mA    |
| I <sub>CC</sub> | Supply Current               | V <sub>CC</sub> = Max (Note 3)               |       | 9               | 15   | mA    |

**Note 1:** All typicals are at V<sub>CC</sub> = 5V, T<sub>A</sub> = 25°C.

**Note 2:** Not more than one output should be shorted at a time, and the duration should not exceed one second.

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

**Note 4:** Q<sub>A</sub> outputs are tested at I<sub>OL</sub> = Max plus the limit value of I<sub>IL</sub> for the B input. This permits driving the B input while maintaining full fan-out capability.

## 'LS90 Switching Characteristics

at V<sub>CC</sub> = 5V and T<sub>A</sub> = 25°C (See Section 1 for Test Waveforms and Output Load)

| Symbol           | Parameter                                       | From (Input)<br>To (Output)              | R <sub>L</sub> = 2 kΩ  |     |                        |     | Units |
|------------------|---|--|------------------------|-----|------------------------|-----|-------|
|                  |   |  | C <sub>L</sub> = 15 pF |     | C <sub>L</sub> = 50 pF |     |       |
|                  |   |  | Min                    | Max | Min                    | Max |       |
| f <sub>MAX</sub> | Maximum Clock Frequency                         | A to Q <sub>A</sub>                      | 32                     |     | 20                     |     | MHz   |
|                  |   | B to Q <sub>B</sub>                      | 16                     |     | 10                     |     |       |
| t <sub>PLH</sub> | Propagation Delay Time Low to High Level Output | A to Q <sub>A</sub>                      |                        | 16  |                        | 20  | ns    |
| t <sub>PHL</sub> | Propagation Delay Time High to Low Level Output | A to Q <sub>A</sub>                      |                        | 18  |                        | 24  | ns    |
| t <sub>PLH</sub> | Propagation Delay Time Low to High Level Output | A to Q <sub>D</sub>                      |                        | 48  |                        | 52  | ns    |
| t <sub>PHL</sub> | Propagation Delay Time High to Low Level Output | A to Q <sub>D</sub>                      |                        | 50  |                        | 60  | ns    |
| t <sub>PLH</sub> | Propagation Delay Time Low to High Level Output | B to Q <sub>B</sub>                      |                        | 16  |                        | 23  | ns    |
| t <sub>PHL</sub> | Propagation Delay Time High to Low Level Output | B to Q <sub>B</sub>                      |                        | 21  |                        | 30  | ns    |
| t <sub>PLH</sub> | Propagation Delay Time Low to High Level Output | B to Q <sub>C</sub>                      |                        | 32  |                        | 37  | ns    |
| t <sub>PHL</sub> | Propagation Delay Time High to Low Level Output | B to Q <sub>C</sub>                      |                        | 35  |                        | 44  | ns    |
| t <sub>PLH</sub> | Propagation Delay Time Low to High Level Output | B to Q <sub>D</sub>                      |                        | 32  |                        | 36  | ns    |
| t <sub>PHL</sub> | Propagation Delay Time High to Low Level Output | B to Q <sub>D</sub>                      |                        | 35  |                        | 44  | ns    |
| t <sub>PLH</sub> | Propagation Delay Time Low to High Level Output | SET-9 to Q <sub>A</sub> , Q <sub>D</sub> |                        | 30  |                        | 35  | ns    |
| t <sub>PHL</sub> | Propagation Delay Time High to Low Level Output | SET-9 to Q <sub>B</sub> , Q <sub>C</sub> |                        | 40  |                        | 48  | ns    |
| t <sub>PHL</sub> | Propagation Delay Time High to Low Level Output | SET-0 to Any Q                           |                        | 40  |                        | 52  | ns    |

## Recommended Operating Conditions

| Symbol           | Parameter                      |                     | DM74LS93 |     |      | Units |
|------------------|--------------------------------|---------------------|----------|-----|------|-------|
|                  |                                |                     | Min      | Nom | Max  |       |
| V <sub>CC</sub>  | Supply Voltage                 |                     | 4.75     | 5   | 5.25 | V     |
| V <sub>IH</sub>  | High Level Input Voltage       |                     | 2        |     |      | V     |
| V <sub>IL</sub>  | Low Level Input Voltage        |                     |          |     | 0.8  | V     |
| I <sub>OH</sub>  | High Level Output Current      |                     |          |     | -0.4 | mA    |
| I <sub>OL</sub>  | Low Level Output Current       |                     |          |     | 8    | mA    |
| f <sub>CLK</sub> | Clock Frequency (Note 1)       | A to Q <sub>A</sub> | 0        |     | 32   | MHz   |
|                  |                                | B to Q <sub>B</sub> | 0        |     | 16   |       |
| f <sub>CLK</sub> | Clock Frequency (Note 2)       | A to Q <sub>A</sub> | 0        |     | 20   |       |
|                  |                                | B to Q <sub>B</sub> | 0        |     | 10   |       |
| t <sub>w</sub>   | Pulse Width (Note 1)           | A                   | 15       |     |      | ns    |
|                  |                                | B                   | 30       |     |      |       |
|                  |                                | Reset               | 15       |     |      |       |
| t <sub>w</sub>   | Pulse Width (Note 2)           | A                   | 25       |     |      | ns    |
|                  |                                | B                   | 50       |     |      |       |
|                  |                                | Reset               | 25       |     |      |       |
| t <sub>REL</sub> | Reset Release Time (Note 1)    |                     | 25       |     |      | ns    |
| t <sub>REL</sub> | Reset Release Time (Note 2)    |                     | 35       |     |      | ns    |
| T <sub>A</sub>   | Free Air Operating Temperature |                     | 0        |     | 70   | °C    |

Note 1: C<sub>L</sub> = 15 pF, R<sub>L</sub> = 2 kΩ, T<sub>A</sub> = 25°C and V<sub>CC</sub> = 5V.

Note 2: C<sub>L</sub> = 50 pF, R<sub>L</sub> = 2 kΩ, T<sub>A</sub> = 25°C and V<sub>CC</sub> = 5V.

## 'LS93 Electrical Characteristics

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

| Symbol          | Parameter                        | Conditions   | Min   | Typ (Note 1) | Max  | Units |
|-----------------|----------------------------------|--|-------|--------------|------|-------|
| V <sub>I</sub>  | Input Clamp Voltage              | V <sub>CC</sub> = Min, I <sub>I</sub> = -18 mA   |       |              | -1.5 | V     |
| V <sub>OH</sub> | High Level Output Voltage        | V <sub>CC</sub> = Min, I <sub>OH</sub> = Max<br>V <sub>IL</sub> = Max, V <sub>IH</sub> = Min             | 2.7   | 3.4          |      | V     |
| V <sub>OL</sub> | Low Level Output Voltage         | V <sub>CC</sub> = Min, I <sub>OL</sub> = Max<br>V <sub>IL</sub> = Max, V <sub>IH</sub> = Min<br>(Note 4) |       | 0.35         | 0.5  | V     |
|                 |                                  | I <sub>OL</sub> = 4 mA, V <sub>CC</sub> = Min  |       | 0.25         | 0.4  |       |
| I <sub>I</sub>  | Input Current @Max Input Voltage | V <sub>CC</sub> = Max, V <sub>I</sub> = 7V   | Reset |              | 0.1  | mA    |
|                 |                                  | V <sub>CC</sub> = Max<br>V <sub>I</sub> = 5.5V   | A     |              | 0.2  |       |
|                 |                                  |  | B     |              | 0.4  |       |
| I <sub>IH</sub> | High Level Input Current         | V <sub>CC</sub> = Max<br>V <sub>I</sub> = 2.7V   | Reset |              | 20   | μA    |
|                 |                                  |  | A     |              | 40   |       |
|                 |                                  |  | B     |              | 80   |       |

## 'LS93 Electrical Characteristics

over recommended operating free air temperature range (unless otherwise noted) (Continued)

| Symbol   | Parameter                    | Conditions                        | Min   | Typ (Note 1) | Max  | Units |    |
|----------|------------------------------|-----------------------------------|-------|--------------|------|-------|----|
| $I_{IL}$ | Low Level Input Current      | $V_{CC} = \text{Max}, V_I = 0.4V$ | Reset |              |      | -0.4  | mA |
|          |                              |                                   | A     |              |      | -2.4  |    |
|          |                              |                                   | B     |              |      | -1.6  |    |
| $I_{OS}$ | Short Circuit Output Current | $V_{CC} = \text{Max}$ (Note 2)    | -20   |              | -100 | mA    |    |
| $I_{CC}$ | Supply Current               | $V_{CC} = \text{Max}$ (Note 3)    |       | 9            | 15   | mA    |    |

**Note 1:** All typicals are at  $V_{CC} = 5V, T_A = 25^\circ C$ .

**Note 2:** Not more than one output should be shorted at a time, and the duration should not exceed one second.

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

**Note 4:**  $Q_A$  outputs are tested at  $I_{OL} = \text{max}$  plus the limit value of  $I_{IL}$  for the B input. This permits driving the B input while maintaining full fan-out capability.

## 'LS93 Switching Characteristics

at  $V_{CC} = 5V$  and  $T_A = 25^\circ C$  (See Section 1 for Test Waveforms and Output Load)

| Symbol    | Parameter                                       | From (Input)<br>To (Output) | $R_L = 2 k\Omega$ |     |               |     | Units |
|-----------|---|-----------------------------|-------------------|-----|---------------|-----|-------|
|           |   |                             | $C_L = 15 pF$     |     | $C_L = 50 pF$ |     |       |
|           |   |                             | Min               | Max | Min           | Max |       |
| $f_{MAX}$ | Maximum Clock Frequency                         | A to $Q_A$                  | 32                |     | 20            |     | MHz   |
|           |   | B to $Q_B$                  | 16                |     | 10            |     |       |
| $t_{PLH}$ | Propagation Delay Time Low to High Level Output | A to $Q_A$                  |                   | 16  |               | 20  | ns    |
| $t_{PHL}$ | Propagation Delay Time High to Low Level Output | A to $Q_A$                  |                   | 18  |               | 24  | ns    |
| $t_{PLH}$ | Propagation Delay Time Low to High Level Output | A to $Q_D$                  |                   | 70  |               | 85  | ns    |
| $t_{PHL}$ | Propagation Delay Time High to Low Level Output | A to $Q_D$                  |                   | 70  |               | 90  | ns    |
| $t_{PLH}$ | Propagation Delay Time Low to High Level Output | B to $Q_B$                  |                   | 16  |               | 23  | ns    |
| $t_{PHL}$ | Propagation Delay Time High to Low Level Output | B to $Q_B$                  |                   | 21  |               | 30  | ns    |
| $t_{PLH}$ | Propagation Delay Time Low to High Level Output | B to $Q_C$                  |                   | 32  |               | 37  | ns    |
| $t_{PHL}$ | Propagation Delay Time High to Low Level Output | B to $Q_C$                  |                   | 35  |               | 44  | ns    |
| $t_{PLH}$ | Propagation Delay Time Low to High Level Output | B to $Q_D$                  |                   | 51  |               | 60  | ns    |
| $t_{PHL}$ | Propagation Delay Time High to Low Level Output | B to $Q_D$                  |                   | 51  |               | 70  | ns    |
| $t_{PHL}$ | Propagation Delay Time High to Low Level Output | SET-0 to Any Q              |                   | 40  |               | 52  | ns    |

## Function Tables

**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              |

**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              |

**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              |

**LS90**  
Reset/Count Truth Table

| Reset Inputs |       |       |       | Output         |                |                |                |
|--------------|-------|-------|-------|----------------|----------------|----------------|----------------|
| R0(1)        | R0(2) | R9(1) | R9(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          |                |                |                |

**LS93**  
Reset/Count Truth Table

| Reset Inputs |       | Output         |                |                |                |
|--------------|-------|----------------|----------------|----------------|----------------|
| R0(1)        | R0(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          |                |                |                |

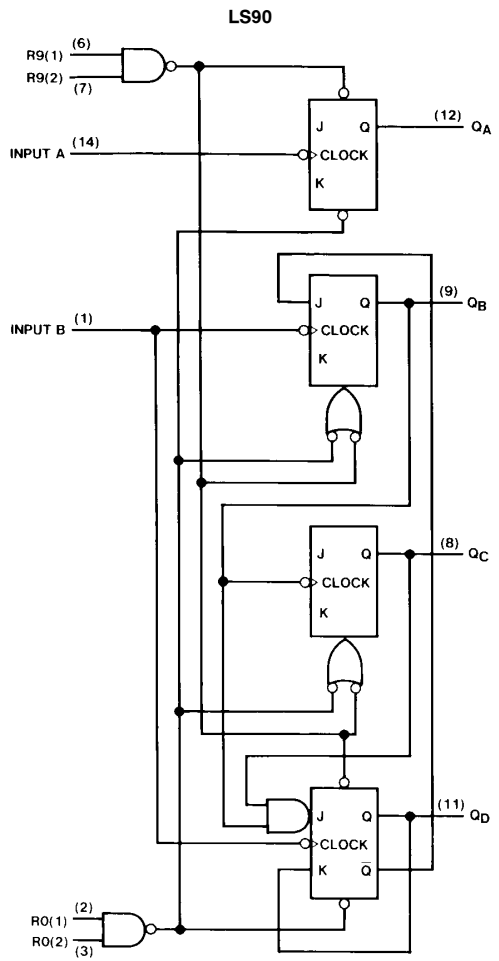
**Note A:** Output Q<sub>A</sub> is connected to input B for BCD count.

**Note B:** Output Q<sub>D</sub> is connected to input A for bi-quinary count.

**Note C:** Output Q<sub>A</sub> is connected to input B.

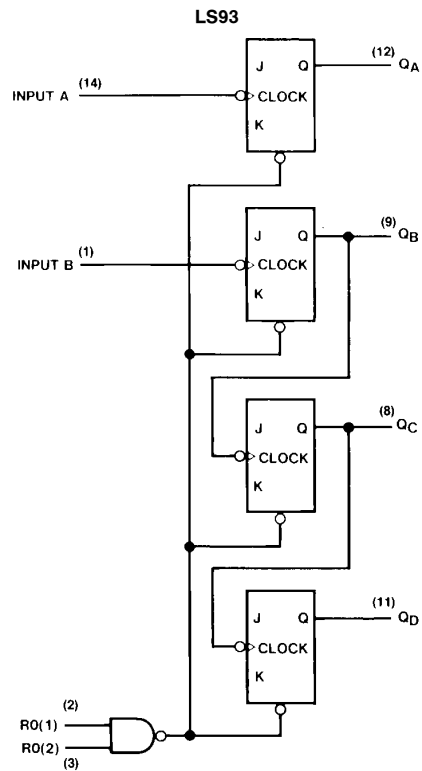
**Note D:** H = High Level, L = Low Level, X = Don't Care.

# Logic Diagrams



TL/F/6381-3

The J and K inputs shown without connection are for reference only and are functionally at a high level.

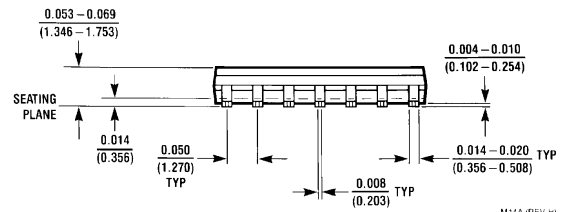
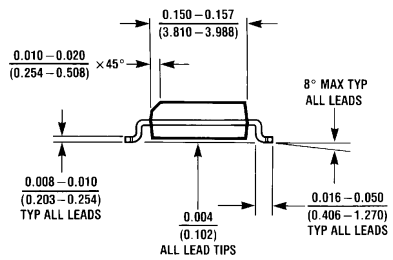
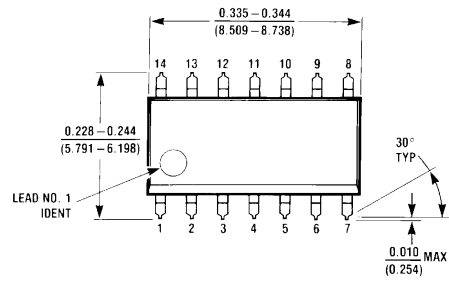


TL/F/6381-4





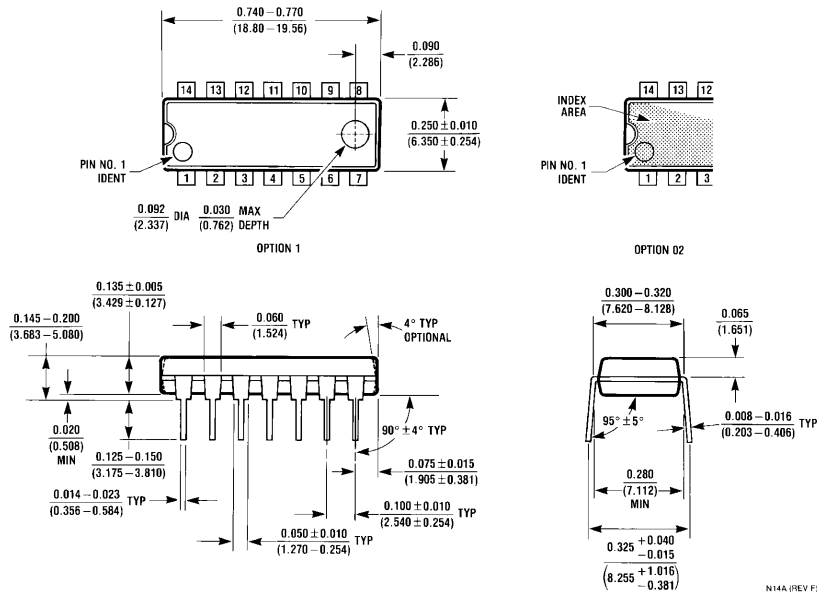
**Physical Dimensions** inches (millimeters)



**14-Lead Small Outline Molded Package (M)**  
**Order Number DM74LS90M or DM74LS93M**  
**NS Package Number M14A**

M14A (REV HI)

**Physical Dimensions** inches (millimeters) (Continued)



**14-Lead Molded Dual-In-Line Package (N)**  
**Order Number DM74LS90N or DM74LS93N**  
**NS Package Number N14A**

N14A (REV F)

**LIFE SUPPORT POLICY**

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform, when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.



**National Semiconductor Corporation**  
 1111 West Bardin Road  
 Arlington, TX 76017  
 Tel: 1(800) 272-9959  
 Fax: 1(800) 737-7018

**National Semiconductor Europe**  
 Fax: (+49) 0-180-530 85 86  
 Email: cnjwge@tevm2.nsc.com  
 Deutsch Tel: (+49) 0-180-530 85 85  
 English Tel: (+49) 0-180-532 78 32  
 Français Tel: (+49) 0-180-532 93 58  
 Italiano Tel: (+49) 0-180-534 16 80

**National Semiconductor Hong Kong Ltd.**  
 19th Floor, Straight Block,  
 Ocean Centre, 5 Canton Rd.  
 Tsimshatsui, Kowloon  
 Hong Kong  
 Tel: (852) 2737-1600  
 Fax: (852) 2736-9960

**National Semiconductor Japan Ltd.**  
 Tel: 81-043-299-2309  
 Fax: 81-043-299-2408

National does not assume any responsibility for use of any circuitry described, no circuit patent licenses are implied and National reserves the right at any time without notice to change said circuitry and specifications.