

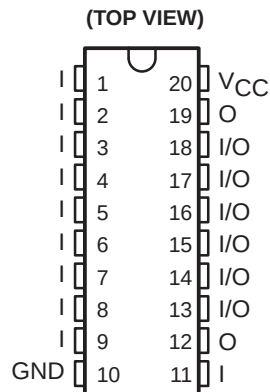
# TIBPAL16L8-10C, TIBPAL16R4-10C, TIBPAL16R6-10C, TIBPAL16R8-10C TIBPAL16L8-12M, TIBPAL16R4-12M, TIBPAL16R6-12M, TIBPAL16R8-12M HIGH-PERFORMANCE **IMPACT-X**™ **PAL**® CIRCUITS

SRPS017 – D3023, MAY 1987 – REVISED MARCH 1992

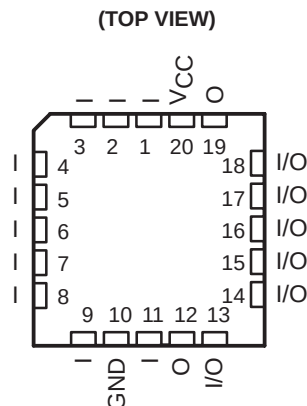
- **High-Performance Operation:**  
 $f_{\max}$  (w/o feedback)  
 TIBPAL16R'-10C Series . . . 62.5 MHz Min  
 TIBPAL16R'-12M Series . . . 56 MHz Min  
 $f_{\max}$  (with feedback)  
 TIBPAL16R'-10C Series . . . 55.5 MHz Min  
 TIBPAL16R'-12M Series . . . 48 MHz Min  
**Propagation Delay**  
 TIBPAL16L'-10C Series . . . 10 ns Max  
 TIBPAL16L'-12M Series . . . 12 ns Max
- **Functionally Equivalent, but Faster than, Existing 20-Pin PLDs**
- **Preload Capability on Output Registers Simplifies Testing**
- **Power-Up Clear on Registered Devices (All Register Outputs are Set Low, but Voltage Levels at the Output Pins Go High)**
- **Package Options Include Both Plastic and Ceramic Chip Carriers in Addition to Plastic and Ceramic DIPs**
- **Security Fuse Prevents Duplication**
- **Dependable Texas Instruments Quality and Reliability**

| DEVICE  | I INPUTS | 3-STATE O OUTPUTS | REGISTERED Q OUTPUTS | I/O PORTS |
|---------|----------|-------------------|----------------------|-----------|
| PAL16L8 | 10       | 2                 | 0                    | 6         |
| PAL16R4 | 8        | 0                 | 4 (3-state buffers)  | 4         |
| PAL16R6 | 8        | 0                 | 6 (3-state buffers)  | 2         |
| PAL16R8 | 8        | 0                 | 8 (3-state buffers)  | 0         |

TIBPAL16L8'  
C SUFFIX . . . J OR N PACKAGE  
M SUFFIX . . . J PACKAGE



TIBPAL16L8'  
C SUFFIX . . . FN PACKAGE  
M SUFFIX . . . FK PACKAGE



Pin assignments in operating mode

## description

These programmable array logic devices feature high speed and functional equivalency when compared with currently available devices. These **IMPACT-X**™ circuits combine the latest Advanced Low-Power Schottky technology with proven titanium-tungsten fuses to provide reliable, high-performance substitutes for conventional TTL logic. Their easy programmability allows for quick design of custom functions and typically results in a more compact circuit board. In addition, chip carriers are available for further reduction in board space.

All of the register outputs are set to a low level during power up. Extra circuitry has been provided to allow loading of each register asynchronously to either a high or low state. This feature simplifies testing because the registers can be set to an initial state prior to executing the test sequence.

The TIBPAL16' C series is characterized from 0°C to 75°C. The TIBPAL16' M series is characterized for operation over the full military temperature range of -55°C to 125°C.

These devices are covered by U.S. Patent 4,410,987.  
**IMPACT-X** is a trademark of Texas Instruments Incorporated.  
**PAL** is a registered trademark of Advanced Micro Devices Inc.

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.



POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

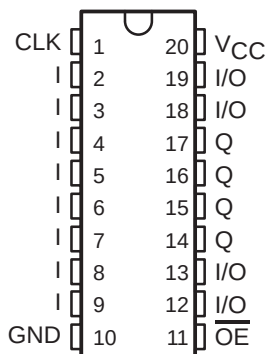
Copyright © 1992, Texas Instruments Incorporated

# TIBPAL16R4-10C, TIBPAL16R6-10C, TIBPAL16R8-10C TIBPAL16R4-12M, TIBPAL16R6-12M, TIBPAL16R8-12M HIGH-PERFORMANCE *IMPACT-X*™ PAL® CIRCUITS

SRPS017 – D3023, MAY 1987 – REVISED MARCH 1992

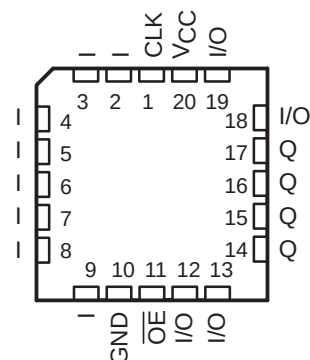
**TIBPAL16R4'**  
C SUFFIX ... J OR N PACKAGE  
M SUFFIX ... J PACKAGE

(TOP VIEW)



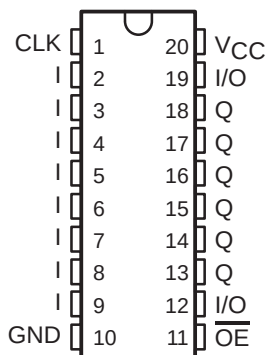
**TIBPAL16R4'**  
C SUFFIX ... FN PACKAGE  
M SUFFIX ... FK PACKAGE

(TOP VIEW)



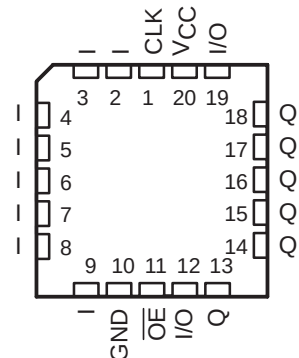
**TIBPAL16R6'**  
C SUFFIX ... J OR N PACKAGE  
M SUFFIX ... J PACKAGE

(TOP VIEW)



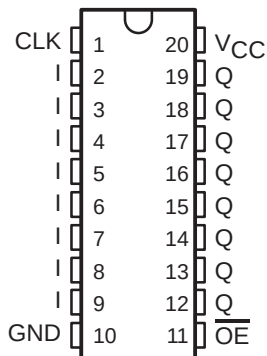
**TIBPAL16R6'**  
C SUFFIX ... FN PACKAGE  
M SUFFIX ... FK PACKAGE

(TOP VIEW)



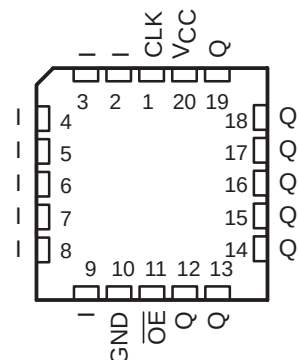
**TIBPAL16R8'**  
C SUFFIX ... J OR N PACKAGE  
M SUFFIX ... J PACKAGE

(TOP VIEW)



**TIBPAL16R8'**  
C SUFFIX ... FN PACKAGE  
M SUFFIX ... FK PACKAGE

(TOP VIEW)

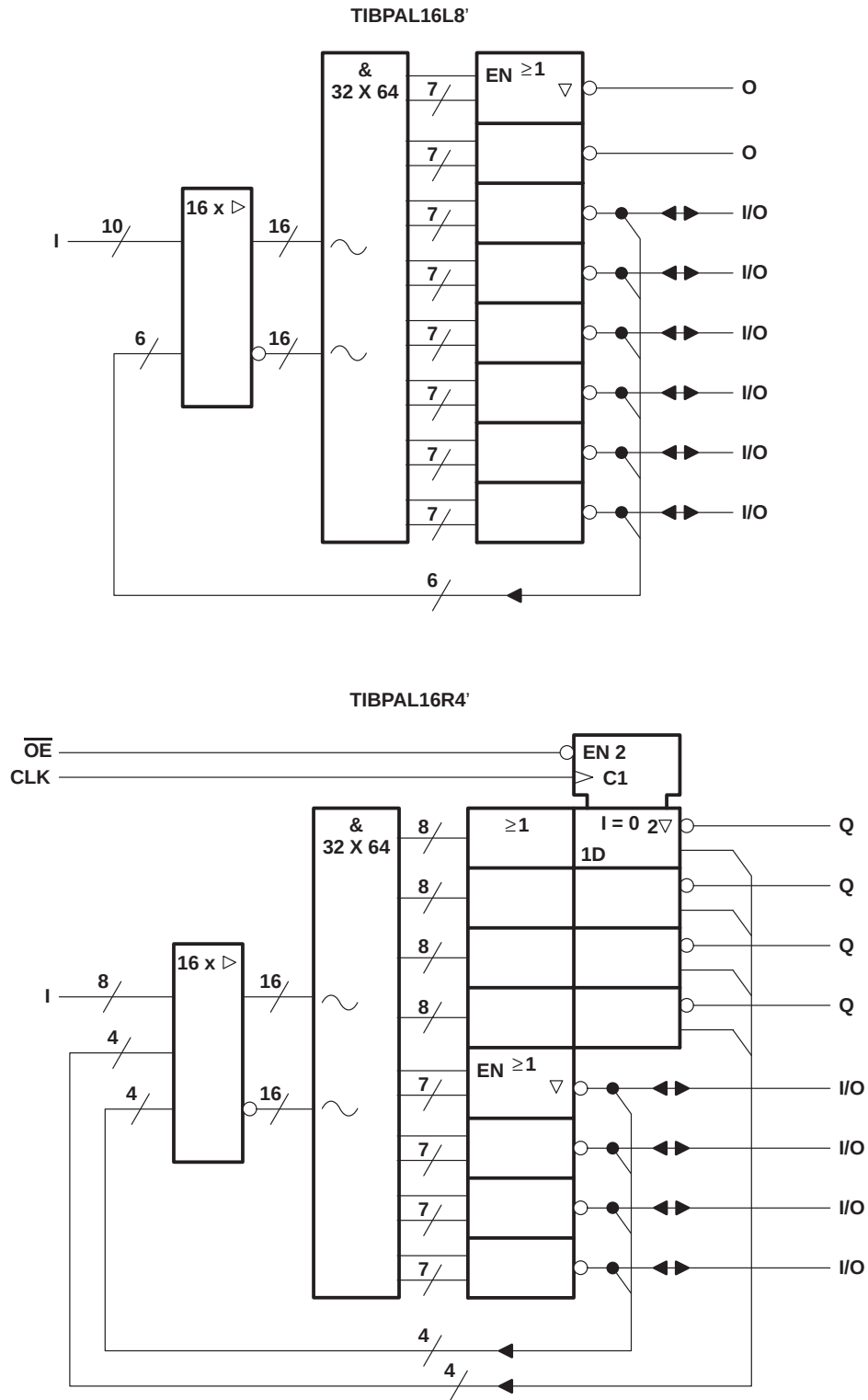


Pin assignments in operating mode

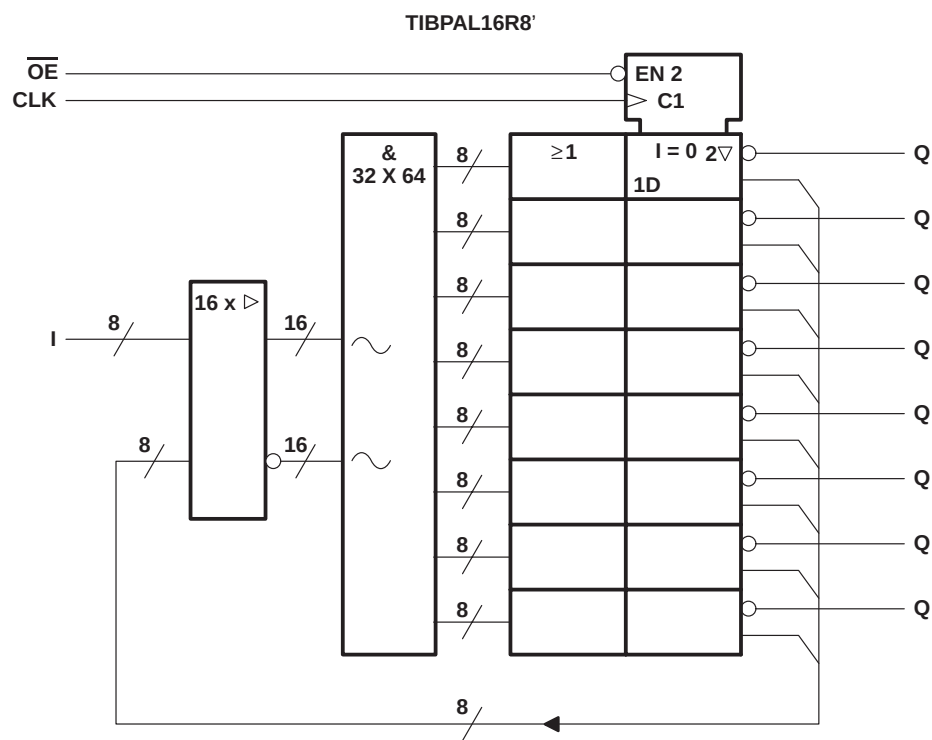
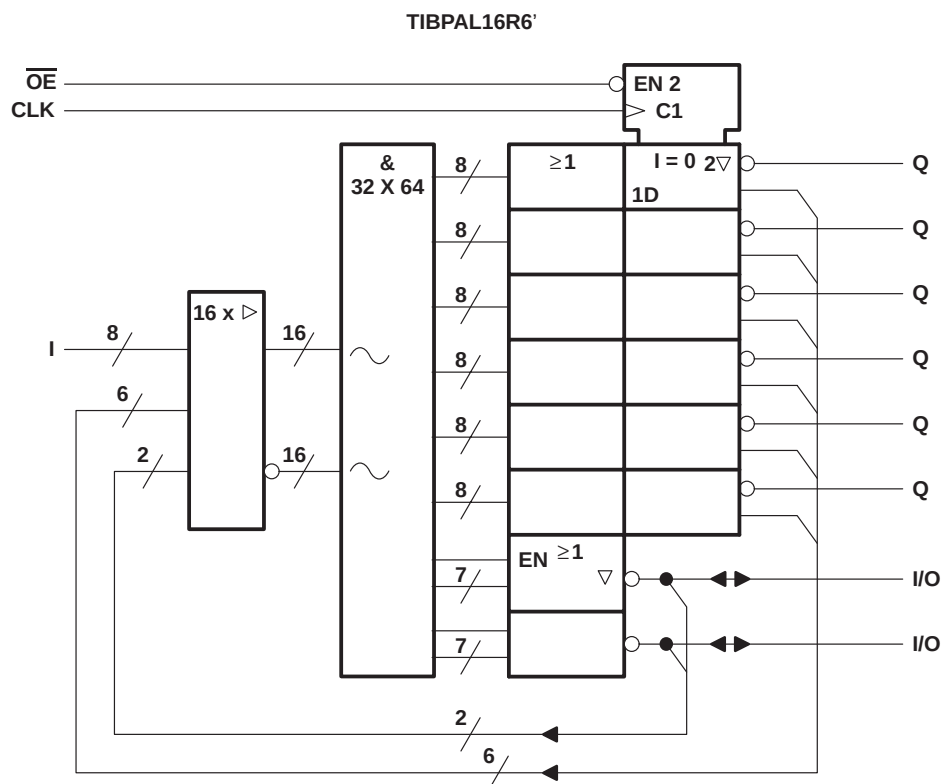
**TEXAS**  
**INSTRUMENTS**

POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

functional block diagrams (positive logic)

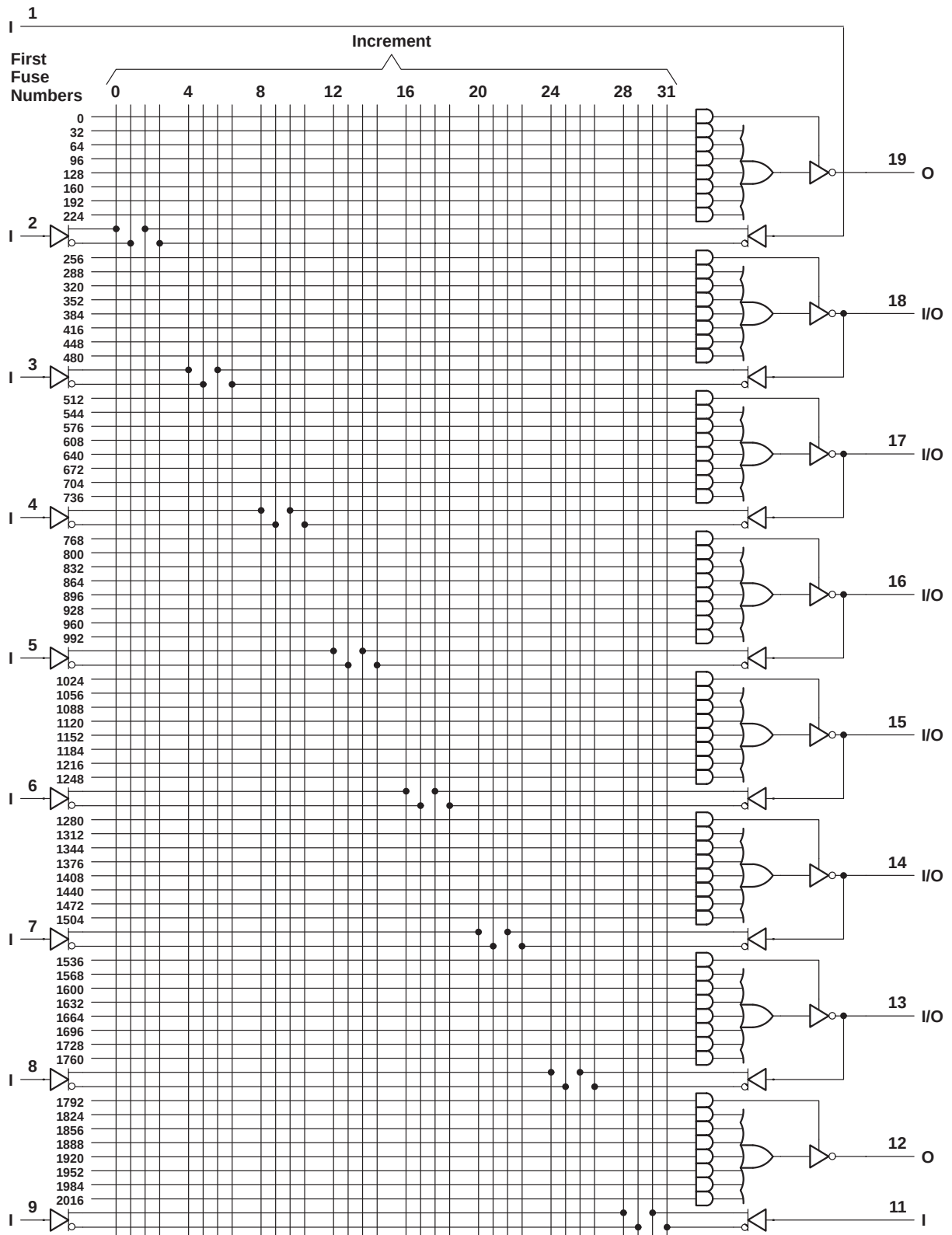


functional block diagrams (positive logic)



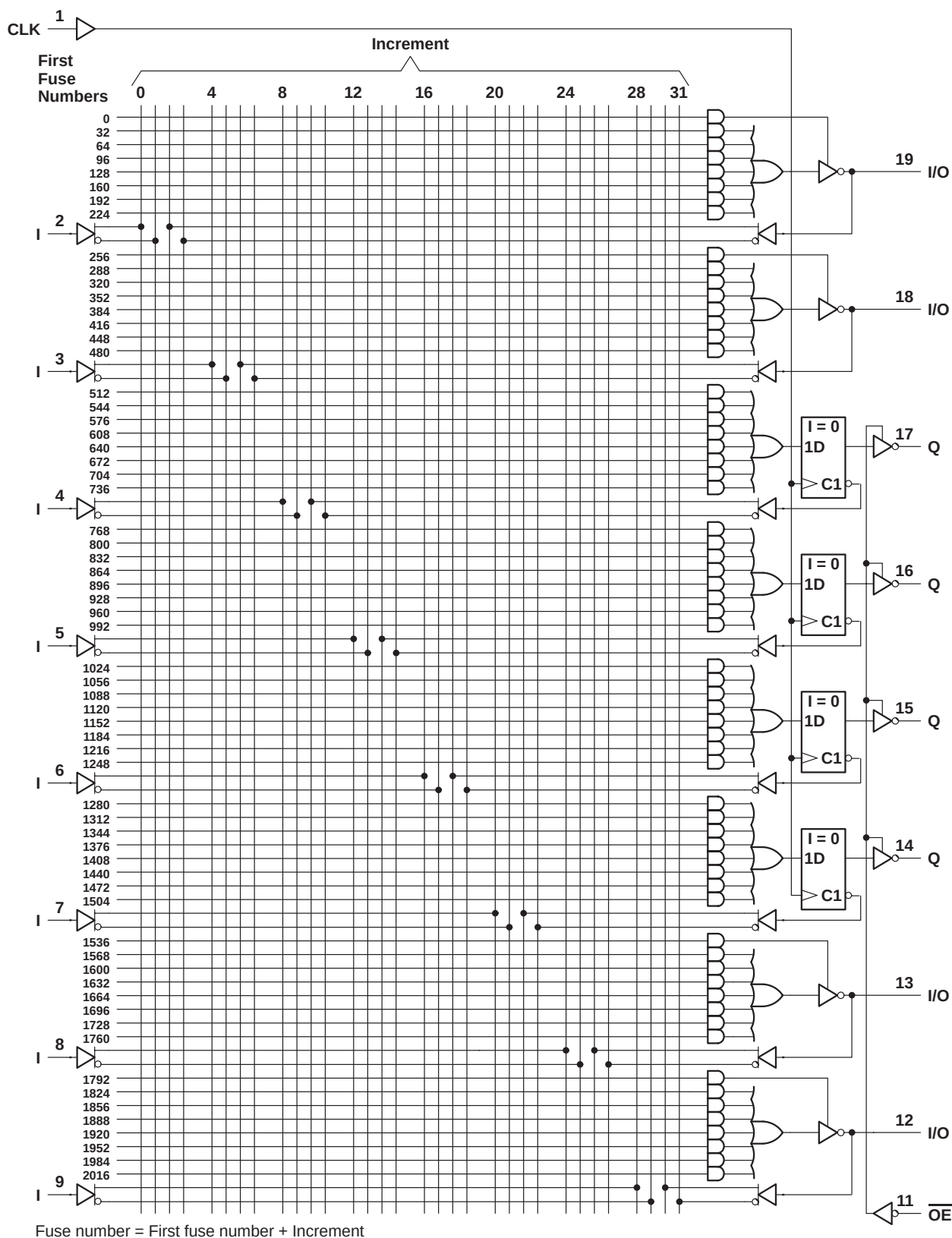
~ denotes fused inputs

logic diagram (positive logic)

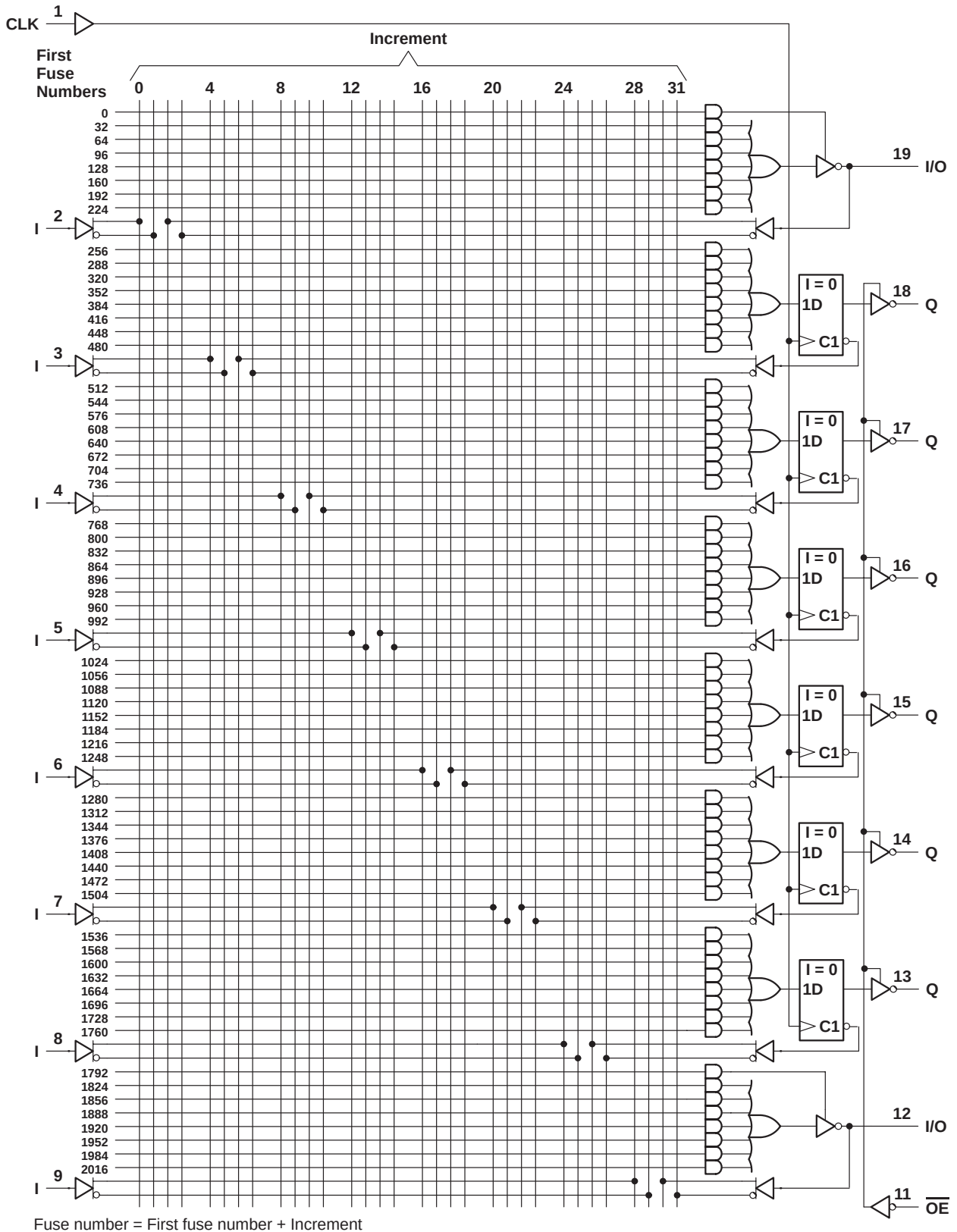


Fuse number = First fuse number + Increment

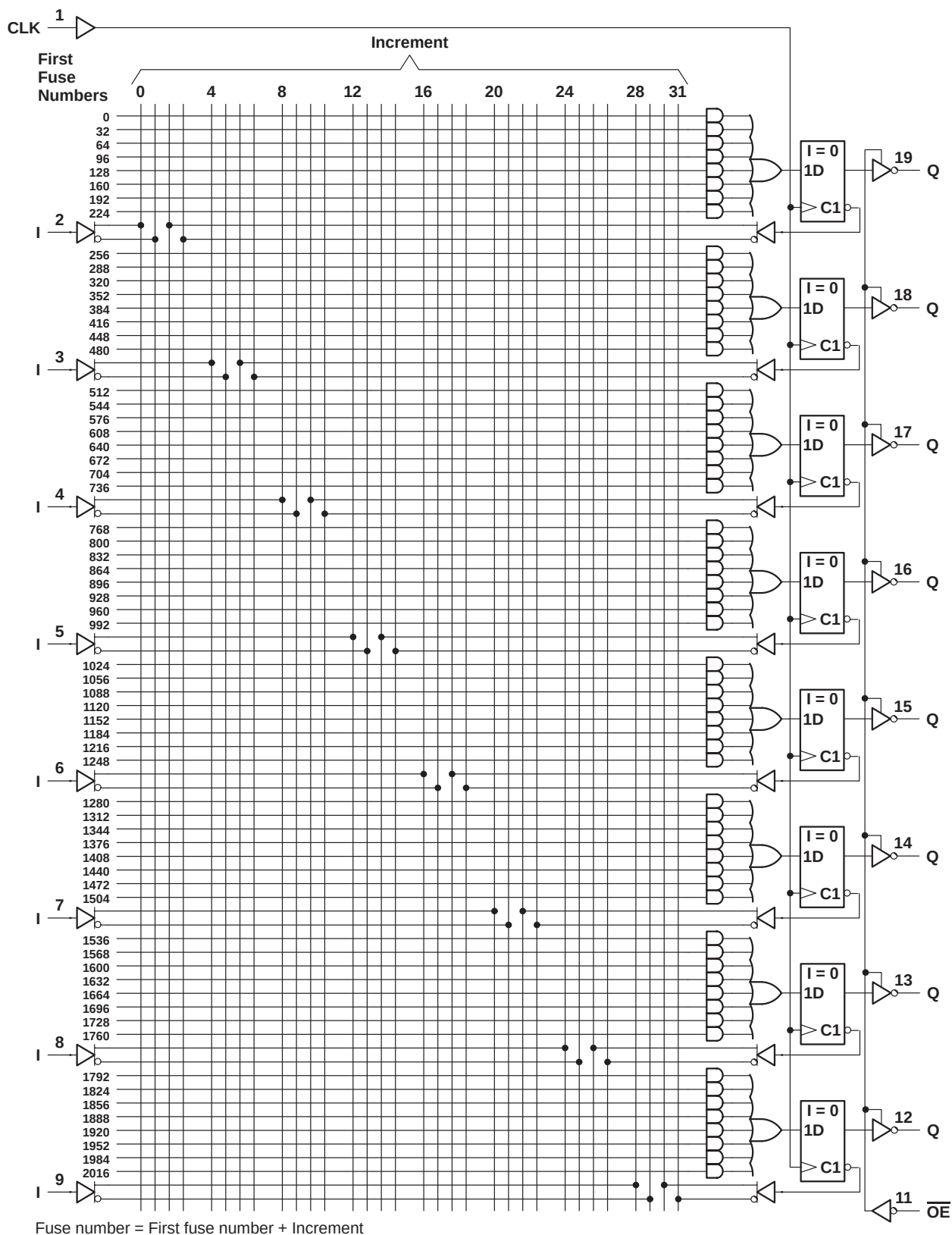
**logic diagram (positive logic)**



logic diagram (positive logic)



**logic diagram (positive logic)**





# TIBPAL16L8-10C, TIBPAL16R4-10C, TIBPAL16R6-10C, TIBPAL16R8-10C HIGH-PERFORMANCE *IMPACT-X*™ *PAL*® CIRCUITS

SRPS017 – D3023, MAY 1987 – REVISED MARCH 1992

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

|                                                 |                |
|-------------------------------------------------|----------------|
| Supply voltage, $V_{CC}$ (see Note 1)           | 7 V            |
| Input voltage (see Note 1)                      | 5.5 V          |
| Voltage applied to disabled output (see Note 1) | 5.5 V          |
| Operating free-air temperature range            | 0°C to 75°C    |
| Storage temperature range                       | –65°C to 150°C |

NOTE 1: These ratings apply except for programming pins during a programming cycle.

## recommended operating conditions

|             |                                             | MIN  | NOM | MAX  | UNIT |
|-------------|---------------------------------------------|------|-----|------|------|
| $V_{CC}$    | Supply voltage                              | 4.75 | 5   | 5.25 | V    |
| $V_{IH}$    | High-level input voltage (see Note 2)       | 2    |     | 5.5  | V    |
| $V_{IL}$    | Low-level input voltage (see Note 2)        |      |     | 0.8  | V    |
| $I_{OH}$    | High-level output current                   |      |     | –3.2 | mA   |
| $I_{OL}$    | Low-level output current                    |      |     | 24   | mA   |
| $f_{clock}$ | Clock frequency                             | 0    |     | 62.5 | MHz  |
| $t_w$       | Pulse duration, clock (see Note 2)          | High | 8   |      | ns   |
|             |                                             | Low  | 8   |      |      |
| $t_{su}$    | Setup time, input or feedback before clock↑ | 10   |     |      | ns   |
| $t_h$       | Hold time, input or feedback after clock↑   | 0    |     |      | ns   |
| $T_A$       | Operating free-air temperature              | 0    | 25  | 75   | °C   |

NOTE 2: These are absolute voltage levels with respect to the ground pin of the device and include all overshoots due to system and/or tester noise. Testing these parameters should not be attempted without suitable equipment.

## electrical characteristics over recommended operating free-air temperature range

| PARAMETER            | TEST CONDITIONS    |                          | MIN | TYP†  | MAX   | UNIT |
|----------------------|--------------------|--------------------------|-----|-------|-------|------|
| $V_{IK}$             | $V_{CC} = 4.75$ V, | $I_I = -18$ mA           |     | –0.8  | –1.5  | V    |
| $V_{OH}$             | $V_{CC} = 4.75$ V, | $I_{OH} = -3.2$ mA       | 2.4 | 3.2   |       | V    |
| $V_{OL}$             | $V_{CC} = 4.75$ V, | $I_{OL} = 24$ mA         |     | 0.3   | 0.5   | V    |
| $I_{OZH}^{\ddagger}$ | $V_{CC} = 5.25$ V, | $V_O = 2.4$ V            |     |       | 100   | μA   |
| $I_{OZL}^{\ddagger}$ | $V_{CC} = 5.25$ V, | $V_O = 0.4$ V            |     |       | –100  | μA   |
| $I_I$                | $V_{CC} = 5.25$ V, | $V_I = 5.5$ V            |     |       | 0.2   | mA   |
| $I_{IH}^{\ddagger}$  | $V_{CC} = 5.25$ V, | $V_I = 2.4$ V            |     |       | 25    | μA   |
| $I_{IL}^{\ddagger}$  | $V_{CC} = 5.25$ V, | $V_I = 0.4$ V            |     | –0.08 | –0.25 | mA   |
| $I_{OS}^{\S}$        | $V_{CC} = 5.25$ V, | $V_O = 0$                | –30 | –70   | –130  | mA   |
| $I_{CC}$             | $V_{CC} = 5.25$ V, | $V_I = 0$ , Outputs open |     | 140   | 180   | mA   |
| $C_i$                | $f = 1$ MHz,       | $V_I = 2$ V              |     | 5     |       | pF   |
| $C_o$                | $f = 1$ MHz,       | $V_O = 2$ V              |     | 6     |       | pF   |
| $C_{i/o}$            | $f = 1$ MHz,       | $V_{I/O} = 2$ V          |     | 7.5   |       | pF   |
| $C_{clk}$            | $f = 1$ MHz,       | $V_{CLK} = 2$ V          |     | 6     |       | pF   |

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

‡ I/O leakage is the worst case of  $I_{OZL}$  and  $I_{IL}$  or  $I_{OZH}$  and  $I_{IH}$  respectively.

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

# TIBPAL16L8-10C, TIBPAL16R4-10C, TIBPAL16R6-10C, TIBPAL16R8-10C HIGH-PERFORMANCE *IMPACT-X*™ PAL® CIRCUITS

SRPS017 – D3023, MAY 1987 – REVISED MARCH 1992

switching characteristics over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

| PARAMETER        | FROM<br>(INPUT)  | TO<br>(OUTPUT) | TEST CONDITION                             | MIN  | TYP† | MAX | UNIT |
|------------------|------------------|----------------|--------------------------------------------|------|------|-----|------|
| f <sub>max</sub> | With feedback    |                | R1 = 200 Ω,<br>R2 = 390 Ω,<br>See Figure 3 | 55.5 | 80   |     | MHz  |
|                  | Without feedback |                |                                            | 62.5 | 85   |     |      |
| t <sub>pd</sub>  | I, I/O           | O, I/O         |                                            | 3    | 7    | 10  | ns   |
| t <sub>pd</sub>  | CLK↑             | Q              |                                            | 2    | 5    | 8   | ns   |
| t <sub>en</sub>  | OE↓              | Q              |                                            | 1    | 4    | 10  | ns   |
| t <sub>dis</sub> | OE↑              | Q              |                                            | 1    | 4    | 10  | ns   |
| t <sub>en</sub>  | I, I/O           | O, I/O         |                                            | 3    | 8    | 10  | ns   |
| t <sub>dis</sub> | I, I/O           | O, I/O         |                                            | 3    | 8    | 10  | ns   |

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

$$‡ f_{\text{max}}(\text{with feedback}) = \frac{1}{t_{\text{su}} + t_{\text{pd}} (\text{CLK to Q})}, \quad f_{\text{max}}(\text{without feedback}) = \frac{1}{t_{\text{w high}} + t_{\text{w low}}}$$



POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

# TIBPAL16L8-12M, TIBPAL16R4-12M, TIBPAL16R6-12M, TIBPAL16R8-12M HIGH-PERFORMANCE *IMPACT-X*™ *PAL*® CIRCUITS

SRPS017 – D3023, MAY 1987 – REVISED MARCH 1992

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

|                                                 |                |
|-------------------------------------------------|----------------|
| Supply voltage, $V_{CC}$ (see Note 1)           | 7 V            |
| Input voltage (see Note 1)                      | 5.5 V          |
| Voltage applied to disabled output (see Note 1) | 5.5 V          |
| Operating free-air temperature range            | –55°C to 125°C |
| Storage temperature range                       | –65°C to 150°C |

NOTE 1: These ratings apply except for programming pins during a programming cycle.

## recommended operating conditions

|                                                                          | MIN  | NOM | MAX | UNIT |
|--------------------------------------------------------------------------|------|-----|-----|------|
| $V_{CC}$ Supply voltage                                                  | 4.5  | 5   | 5.5 | V    |
| $V_{IH}$ High-level input voltage                                        | 2    |     | 5.5 | V    |
| $V_{IL}$ Low-level input voltage                                         |      |     | 0.8 | V    |
| $I_{OH}$ High-level output current                                       |      |     | –2  | mA   |
| $I_{OL}$ Low-level output current                                        |      |     | 12  | mA   |
| $f_{clock}^{\dagger}$ Clock frequency                                    | 0    |     | 56  | MHz  |
| $t_w$ Pulse duration, clock (see Note 2)                                 | High |     | 9   | ns   |
|                                                                          | Low  |     | 9   |      |
| $t_{su}^{\dagger}$ Setup time, input or feedback before clock $\uparrow$ | 11   |     |     | ns   |
| $t_h^{\dagger}$ Hold time, input or feedback after clock $\uparrow$      | 0    |     |     | ns   |
| $T_A$ Operating free-air temperature                                     | –55  | 25  | 125 | °C   |

NOTE 2: These are absolute voltage levels with respect to the ground pin of the device and include all overshoots due to system and/or tester noise. Testing these parameters should not be attempted without suitable equipment.

## electrical characteristics over recommended operating free-air temperature range

| PARAMETER            | TEST CONDITIONS   |                            | MIN | TYP $^{\dagger}$ | MAX   | UNIT |
|----------------------|-------------------|----------------------------|-----|------------------|-------|------|
| $V_{IK}$             | $V_{CC} = 4.5$ V, | $I_I = -18$ mA             |     | –0.8             | –1.5  | V    |
| $V_{OH}$             | $V_{CC} = 4.5$ V, | $I_{OH} = -2$ mA           | 2.4 | 3.2              |       | V    |
| $V_{OL}$             | $V_{CC} = 4.5$ V, | $I_{OL} = 12$ mA           |     | 0.3              | 0.5   | V    |
| $I_{OZH}^{\ddagger}$ | $V_{CC} = 5.5$ V, | $V_O = 2.4$ V              |     |                  | 100   | μA   |
| $I_{OZL}^{\ddagger}$ | $V_{CC} = 5.5$ V, | $V_O = 0.4$ V              |     |                  | –100  | μA   |
| $I_I$                | $V_{CC} = 5.5$ V, | $V_I = 5.5$ V              |     |                  | 0.2   | mA   |
| $I_{IH}^{\ddagger}$  | $V_{CC} = 5.5$ V, | $V_I = 2.4$ V              |     |                  | 25    | μA   |
| $I_{IL}^{\ddagger}$  | $V_{CC} = 5.5$ V, | $V_I = 0.4$ V              |     | –0.08            | –0.25 | mA   |
| $I_{OS}^{\S}$        | $V_{CC} = 5.5$ V, | $V_O = 0.5$ V              | –30 | –70              | –250  | mA   |
| $I_{CC}$             | $V_{CC} = 5.5$ V, | $V_I = GND$ , Outputs open |     | 140              | 220   | mA   |
| $C_i$                | $f = 1$ MHz,      | $V_I = 2$ V                |     | 5                |       | pF   |
| $C_o$                | $f = 1$ MHz,      | $V_O = 2$ V                |     | 6                |       | pF   |
| $C_{i/o}$            | $f = 1$ MHz,      | $V_{I/O} = 2$ V            |     | 7.5              |       | pF   |
| $C_{clk}$            | $f = 1$ MHz,      | $V_{CLK} = 2$ V            |     | 6                |       | pF   |

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

$^{\ddagger}$  I/O leakage is the worst case of  $I_{OZL}$  and  $I_{IL}$  or  $I_{OZH}$  and  $I_{IH}$  respectively.

$^{\S}$  Not more than one output should be shorted at a time, and the duration of the short circuit should not exceed one second.  $V_O$  is set at 0.5 V to avoid test problems caused by test equipment ground degradation.



# TIBPAL16L8-12M, TIBPAL16R4-12M, TIBPAL16R6-12M, TIBPAL16R8-12M HIGH-PERFORMANCE *IMPACT-X*™ *PAL*® CIRCUITS

SRPS017 – D3023, MAY 1987 – REVISED MARCH 1992

switching characteristics over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

| PARAMETER        | FROM<br>(INPUT)  | TO<br>(OUTPUT) | TEST CONDITION                             | MIN | TYP† | MAX | UNIT |
|------------------|------------------|----------------|--------------------------------------------|-----|------|-----|------|
| f <sub>max</sub> | With feedback    |                | R1 = 390 Ω,<br>R2 = 750 Ω,<br>See Figure 3 | 48  | 80   |     | MHz  |
|                  | Without feedback |                |                                            | 56  | 85   |     |      |
| t <sub>pd</sub>  | I, I/O           | O, I/O         |                                            | 3   | 7    | 12  | ns   |
| t <sub>pd</sub>  | CLK↑             | Q              |                                            | 2   | 5    | 10  | ns   |
| t <sub>en</sub>  | OE↓              | Q              |                                            | 1   | 4    | 10  | ns   |
| t <sub>dis</sub> | OE↑              | Q              |                                            | 1   | 4    | 10  | ns   |
| t <sub>en</sub>  | I, I/O           | O, I/O         |                                            | 3   | 8    | 14  | ns   |
| t <sub>dis</sub> | I, I/O           | O, I/O         |                                            | 2   | 8    | 12  | ns   |

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

$$\ddagger f_{\max}(\text{with feedback}) = \frac{1}{t_{su} + t_{pd}(\text{CLK to Q})}, f_{\max}(\text{without feedback}) = \frac{1}{t_{w \text{ high}} + t_{w \text{ low}}}$$



POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

## programming information

Texas Instruments programmable logic devices can be programmed using widely available software and inexpensive device programmers.

Complete programming specifications, algorithms, and the latest information on hardware, software, and firmware are available upon request. Information on programmers capable of programming Texas Instruments programmable logic is also available, upon request, from the nearest TI field sales office, local authorized TI distributor, or by calling Texas Instruments at (214) 997-5666.

## preload procedure for registered outputs (see Figure 1 and Note 3)

The output registers can be preloaded to any desired state during device testing. This permits any state to be tested without having to step through the entire state-machine sequence. Each register is preloaded individually by following the steps given below.

- Step 1. With  $V_{CC}$  at 5 volts and Pin 1 at  $V_{IL}$ , raise Pin 11 to  $V_{IHH}$ .
- Step 2. Apply either  $V_{IL}$  or  $V_{IH}$  to the output corresponding to the register to be preloaded.
- Step 3. Pulse Pin 1, clocking in preload data.
- Step 4. Remove output voltage, then lower Pin 11 to  $V_{IL}$ . Preload can be verified by observing the voltage level at the output pin.

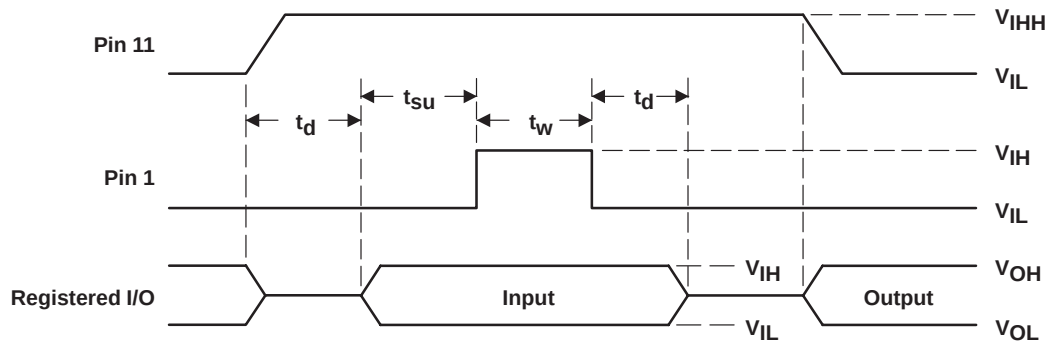
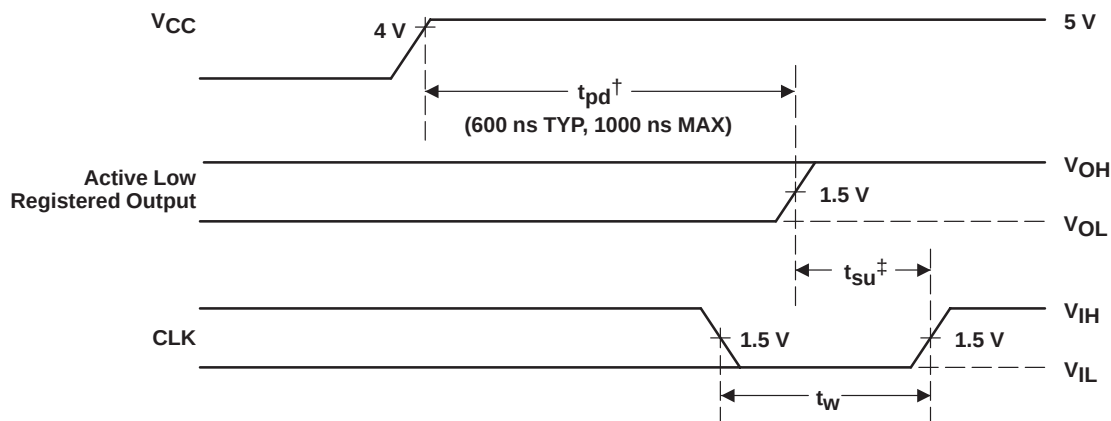


Figure 1. Preload Waveforms

NOTE 3:  $t_d = t_{su} = t_h = 100$  ns to  $1000$  ns  $V_{IHH} = 10.25$  V to  $10.75$  v

## power-up reset (see Figure 2)

Following power up, all registers are reset to zero. This feature provides extra flexibility to the system designer and is especially valuable in simplifying state-machine initialization. To ensure a valid power-up reset, it is important that the rise of  $V_{CC}$  be monotonic. Following power-up reset, a low-to-high clock transition must not occur until all applicable input and feedback setup times are met.

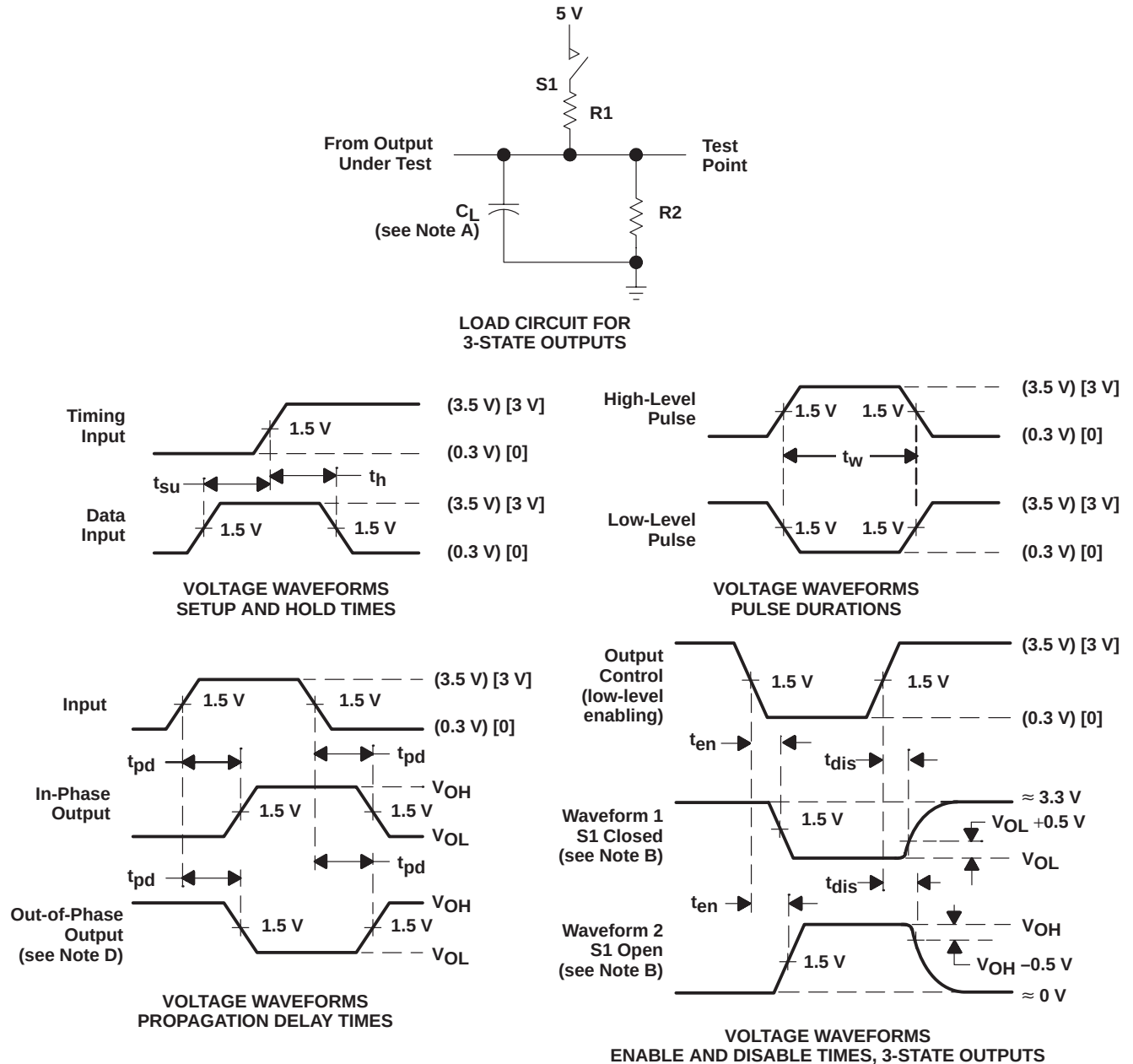


† This is the power-up reset time and applies to registered outputs only. The values shown are from characterization data.

‡ This is the setup time for input or feedback.

Figure 2. Power-Up Reset Waveforms

## PARAMETER MEASUREMENT INFORMATION



- NOTES: A. C<sub>L</sub> includes probe and jig capacitance and is 50 pF for t<sub>pd</sub> and t<sub>en</sub>, 5 pF for t<sub>dis</sub>.  
B. Waveform 1 is for an output with internal conditions such that the output is low except when disabled by the output control. Waveform 2 is for an output with internal conditions such that the output is high except when disabled by the output control.  
C. All input pulses have the following characteristics: For C suffix, use the voltage levels indicated in parentheses ( ), PRR ≤ 1 MHz, t<sub>r</sub> = t<sub>f</sub> = 2 ns, duty cycle = 50%; For M suffix, use the voltage levels indicated in brackets [ ], PRR ≤ 10 MHz, t<sub>r</sub> and t<sub>f</sub> ≤ 2 ns, duty cycle = 50%.  
D. When measuring propagation delay times of 3-state outputs, switch S1 is closed.  
E. Equivalent loads may be used for testing.

Figure 3. Load Circuit and Voltage Waveforms

## metastable characteristics of TIBPAL16R4-10C, TIBPAL16R6-10C, and TIBPAL16R8-10C

At some point a system designer is faced with the problem of synchronizing two digital signals operating at two different frequencies. This problem is typically overcome by synchronizing one of the signals to the local clock through use of a flip-flop. However, this solution presents an awkward dilemma since the setup and hold time specifications associated with the flip-flop are sure to be violated. The metastable characteristics of the flip-flop can influence overall system reliability.

Whenever the setup and hold times of a flip-flop are violated, its output response becomes uncertain and is said to be in the metastable state if the output hangs up in the region between  $V_{IL}$  and  $V_{IH}$ . This metastable condition lasts until the flip-flop falls into one of its two stable states, which takes longer than the specified maximum propagation delay time (CLK to Q max).

From a system engineering standpoint, a designer cannot use the specified data sheet maximum for propagation delay time when using the flip-flop as a data synchronizer – how long to wait after the specified data sheet maximum must be known before using the data in order to guarantee reliable system operation.

The circuit shown in Figure 4 can be used to evaluate MTBF (Mean Time Between Failure) and  $\Delta t$  for a selected flip-flop. Whenever the Q output of the DUT is between 0.8 V and 2 V, the comparators are in opposite states. When the Q output of the DUT is higher than 2 V or lower than 0.8 V, the comparators are at the same logic level. The outputs of the two comparators are sampled a selected time ( $\Delta t$ ) after SCLK. The exclusive OR gate detects the occurrence of a failure and increments the failure counter.

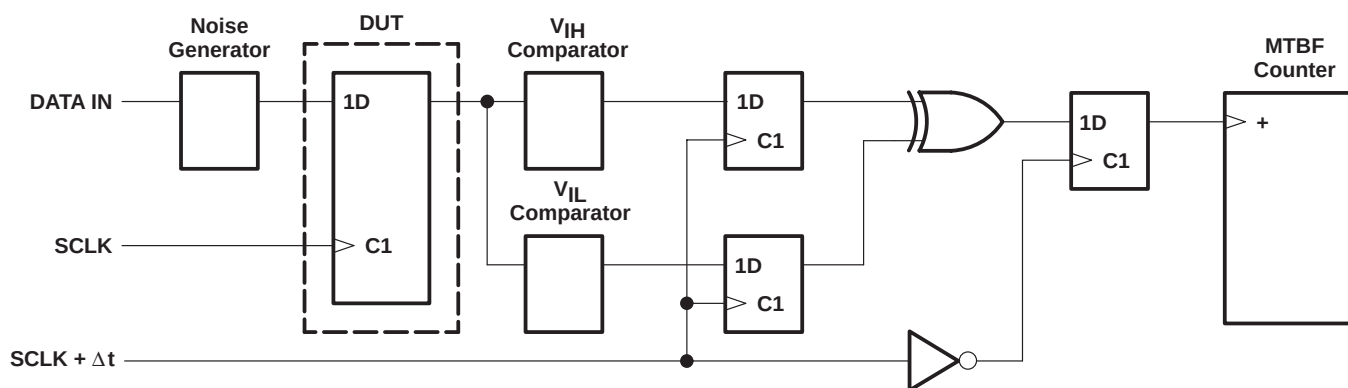


Figure 4. Metastable Evaluation Test Circuit

In order to maximize the possibility of forcing the DUT into a metastable state, the input data signal is applied so that it always violates the setup and hold time. This condition is illustrated in the timing diagram in Figure 5. Any other relationship of SCLK to data will provide less chance for the device to enter into the metastable state.

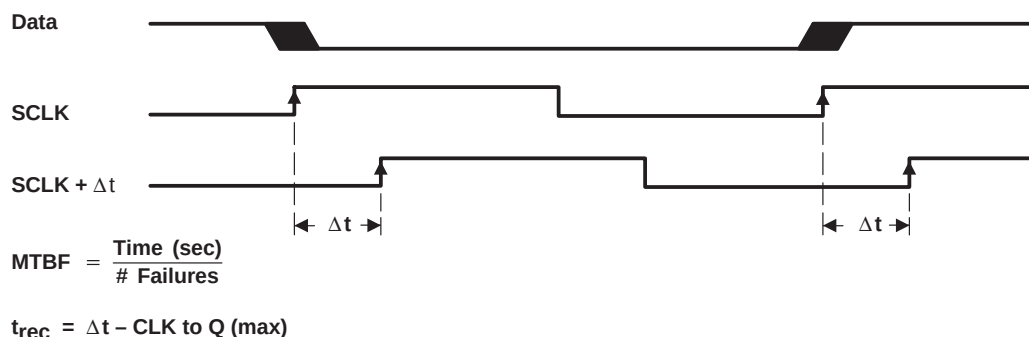


Figure 5. Timing Diagram



By using the described test circuit, MTBF can be determined for several different values of  $\Delta t$  (see Figure 4). Plotting this information on semilog scale demonstrates the metastable characteristics of the selected flip-flop. Figure 6 shows the results for the TIBPAL16'-10C operating at 1 MHz.

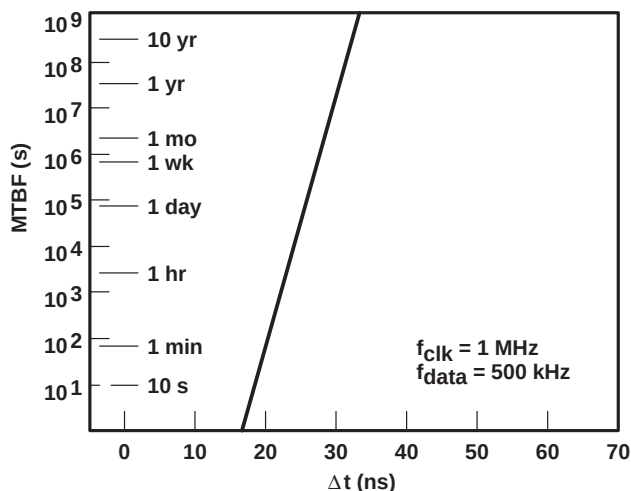


Figure 6. Metastable Characteristics

From the data taken in the above experiment, an equation can be derived for the metastable characteristics at other clock frequencies.

The metastable equation:  $\frac{1}{\text{MTBF}} = f_{\text{SCLK}} \times f_{\text{data}} \times C1 \times e^{(-C2 \times \Delta t)}$

The constants C1 and C2 describe the metastable characteristics of the device. From the experimental data, these constants can be solved for:  $C1 = 9.15 \times 10^{-7}$  and  $C2 = 0.959$

Therefore

$$\frac{1}{\text{MTBF}} = f_{\text{SCLK}} \times f_{\text{data}} \times 9.15 \times 10^{-7} \times e^{(-0.959 \times \Delta t)}$$

## definition of variables

DUT (Device Under Test): The DUT is a 10-ns registered PLD programmed with the equation  $Q = D$ .

MTBF (Mean Time Between Failures): The average time (s) between metastable occurrences that cause a violation of the device specifications.

$f_{\text{SCLK}}$  (system clock frequency): Actual clock frequency for the DUT.

$f_{\text{data}}$  (data frequency): Actual data frequency for a specified input to the DUT.

C1: Calculated constant that defines the magnitude of the curve.

C2: Calculated constant that defines the slope of the curve.

$t_{\text{rec}}$  (metastability recovery time): Minimum time required to guarantee recovery from metastability, at a given MTBF failure rate.  $t_{\text{rec}} = \Delta t - t_{\text{pd}}$  (CLK to Q, max)

$\Delta t$ : The time difference (ns) from when the synchronizing flip-flop is clocked to when its output is sampled.

The test described above has shown the metastable characteristics of the TIBPAL16R4/R6/R8-10C series. For additional information on metastable characteristics of Texas Instruments logic circuits, please refer to TI Applications publication SDAA004, "Metastable Characteristics, Design Considerations for ALS, AS, and LS Circuits."

TIBPAL16L8-10C, TIBPAL16R4-10C, TIBPAL16R6-10C, TIBPAL16R8-10C  
TIBPAL16L8-12M, TIBPAL16R4-12M, TIBPAL16R6-12M, TIBPAL16R8-12M  
HIGH-PERFORMANCE *IMPACT-X*™ PAL® CIRCUITS

SRPS017 – D3023, MAY 1987 – REVISED MARCH 1992

TYPICAL CHARACTERISTICS

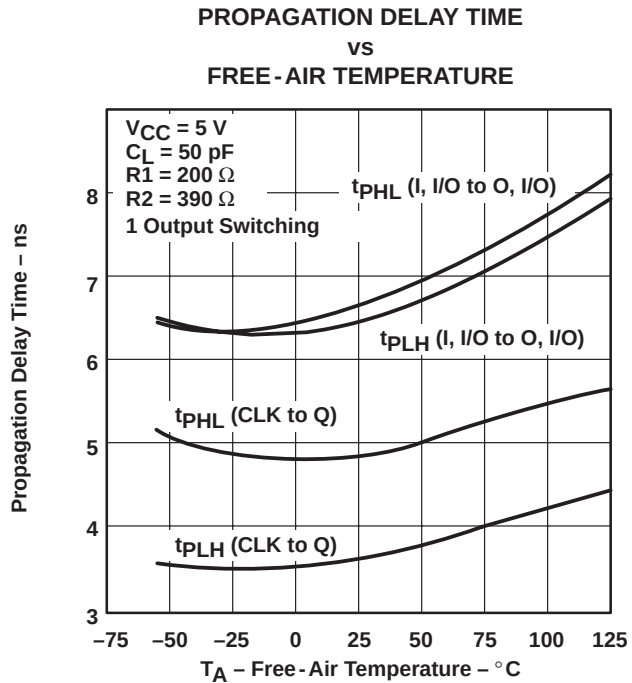


Figure 7

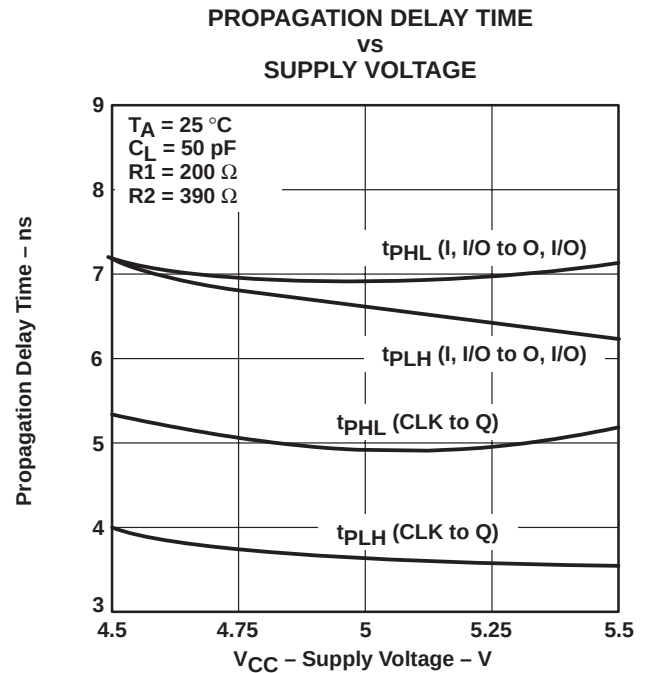


Figure 8

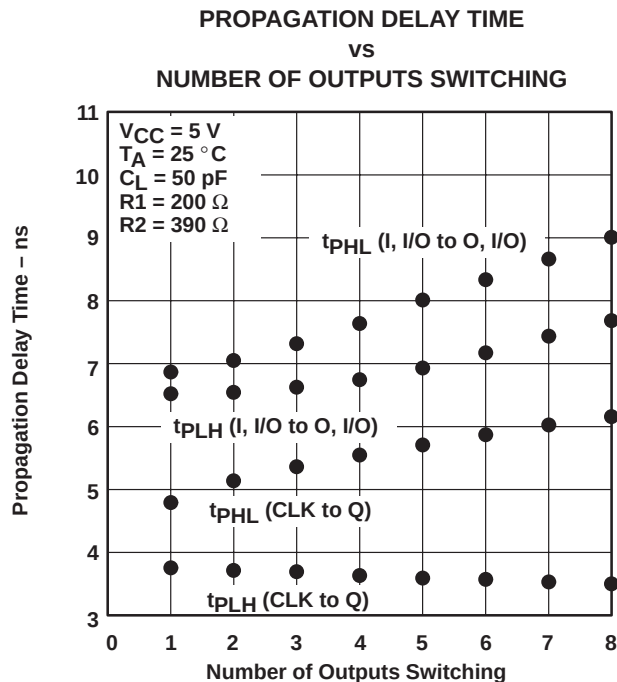


Figure 9

## TYPICAL CHARACTERISTICS

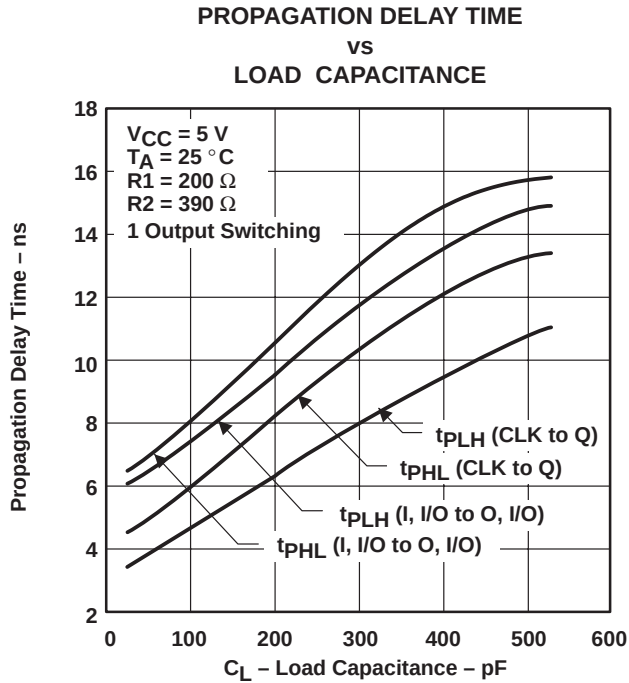


Figure 10

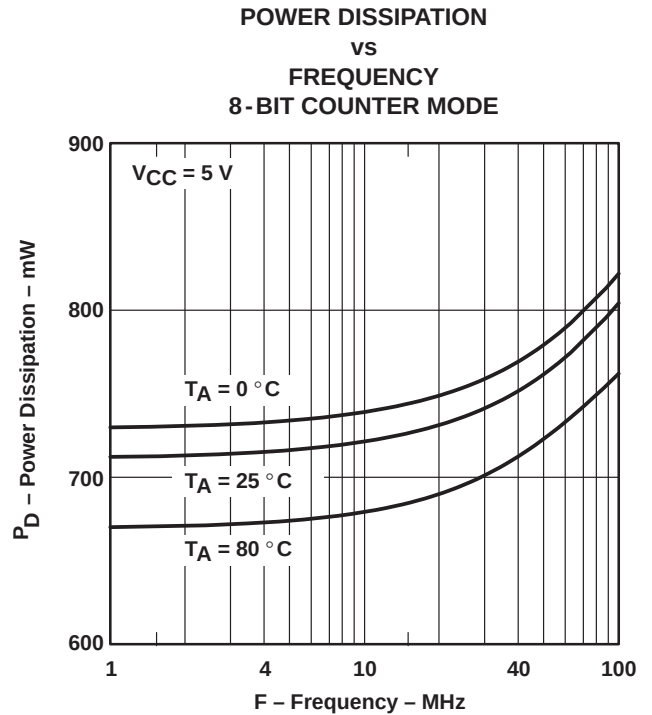


Figure 11

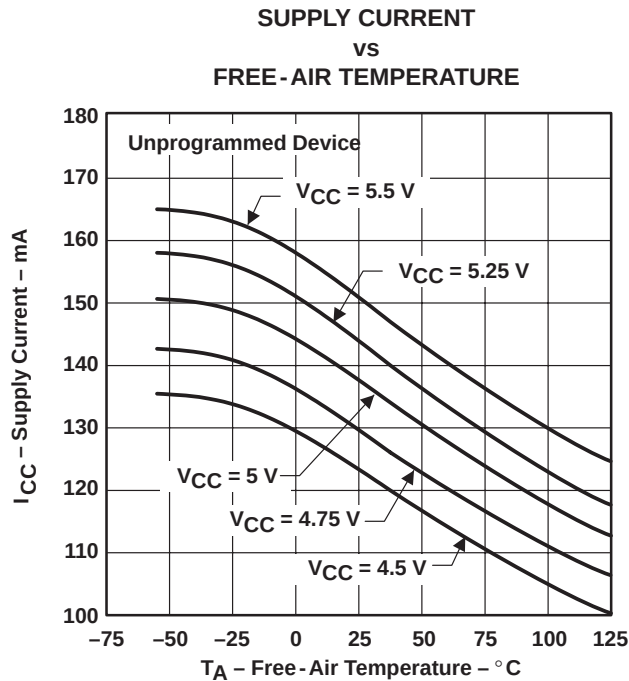


Figure 12

# TI North American Sales Offices

**ALABAMA:** Huntsville: (205) 837-7530  
**ARIZONA:** Phoenix: (602) 995-1007  
**CALIFORNIA:** Irvine: (714) 660-1200  
**San Diego:** (619) 278-9600  
**Santa Clara:** (408) 980-9000  
**Woodland Hills:** (818) 704-8100  
**COLORADO:** Aurora: (303) 368-8000  
**CONNECTICUT:** Wallingford: (203) 269-0074  
**FLORIDA:** Altamonte Springs: (407) 260-2116  
**Fort Lauderdale:** (305) 973-8502  
**Tampa:** (813) 885-7588  
**GEORGIA:** Norcross: (404) 662-7967  
**ILLINOIS:** Arlington Heights: (708) 640-3000  
**INDIANA:** Carmel: (317) 573-6400  
**Fort Wayne:** (219) 489-4697  
**KANSAS:** Overland Park: (913) 451-4511  
**MARYLAND:** Columbia: (410) 964-2003  
**MASSACHUSETTS:** Waltham: (617) 895-9100  
**MICHIGAN:** Farmington Hills: (313) 553-1581  
**MINNESOTA:** Eden Prairie: (612) 828-9300  
**MISSOURI:** St. Louis: (314) 821-8400  
**NEW JERSEY:** Iselin: (908) 750-1050  
**NEW MEXICO:** Albuquerque: (505) 345-2555  
**NEW YORK:** East Syracuse: (315) 463-9291  
**Fishkill:** (914) 897-2900  
**Melville:** (516) 454-6600  
**Pittsford:** (716) 385-6770  
**NORTH CAROLINA:** Charlotte: (704) 527-0930  
**Raleigh:** (919) 876-2725  
**OHIO:** Beachwood: (216) 765-7258  
**Beavercreek:** (513) 427-6200  
**OREGON:** Beaverton: (503) 643-6758  
**PENNSYLVANIA:** Blue Bell: (215) 825-9500  
**PUERTO RICO:** Hato Rey: (809) 753-8700  
**TEXAS:** Austin: (512) 250-6769  
**Dallas:** (214) 917-1264  
**Houston:** (713) 778-6592  
**Midland:** (915) 561-7137  
**UTAH:** Salt Lake City: (801) 466-8972  
**WISCONSIN:** Waukesha: (414) 798-1001  
**CANADA:** Nepean: (613) 726-1970  
**Richmond Hill:** (416) 884-9181  
**St. Laurent:** (514) 335-8392

# TI Regional Technology Centers

**CALIFORNIA:** Irvine: (714) 660-8140  
**Santa Clara:** (408) 748-2222  
**GEORGIA:** Norcross: (404) 662-7945  
**ILLINOIS:** Arlington Heights: (708) 640-2909  
**INDIANA:** Indianapolis: (317) 573-6400  
**MASSACHUSETTS:** Waltham: (617) 895-9196  
**MEXICO:** Mexico City: 491-70834  
**MINNESOTA:** Minneapolis: (612) 828-9300  
**TEXAS:** Dallas: (214) 917-3881  
**CANADA:** Nepean: (613) 726-1970

## Customer Response Center

**TOLL FREE:** (800) 336-5236  
**OUTSIDE USA:** (214) 995-6611  
(8:00 a.m. – 5:00 p.m. CST)

# TI Authorized North American Distributors

Alliance Electronics, Inc. (military product only)  
Almac/Arrow  
Anthem Electronics  
Arrow/Schweber  
Future Electronics (Canada)  
GRS Electronics Co., Inc.  
Hall-Mark Electronics  
Marshall Industries  
Newark Electronics  
Rochester Electronics, Inc.  
(obsolete product only (508) 462-9332)  
Wyle Laboratories  
Zeus Components

# TI Distributors

**ALABAMA:** Arrow/Schweber (205) 837-6955; Hall-Mark (205) 837-8700; Marshall (205) 881-9235.  
**ARIZONA:** Anthem (602) 966-6600; Arrow/Schweber (602) 437-0750; Hall-Mark (602) 431-0030; Marshall (602) 496-0290; Wyle (602) 437-2088.  
**CALIFORNIA: Los Angeles/Orange County:** Anthem (818) 775-1333, (714) 768-4444; Arrow/Schweber (818) 380-9686, (714) 838-5422; Hall-Mark (818) 773-4500, (714) 727-6000; Marshall (818) 878-7000, (714) 458-5301; Wyle (818) 880-9000, (714) 863-9953; Zeus (714) 921-9000, (818) 889-3838;  
**Sacramento:** Anthem (916) 624-9744; Hall-Mark (916) 624-9781; Marshall (916) 635-9700; Wyle (916) 638-5282;  
**San Diego:** Anthem (619) 453-9005; Arrow/Schweber (619) 565-4800; Hall-Mark (619) 268-1201; Marshall (619) 578-9600; Wyle (619) 565-9171; Zeus (619) 277-9681.  
**San Francisco Bay Area:** Anthem (408) 453-1200; Arrow/Schweber (408) 441-9700, (510) 490-9477; Hall-Mark (408) 432-4000; Marshall (408) 942-4600; Wyle (408) 727-2500; Zeus (408) 629-4789.  
**COLORADO:** Anthem (303) 790-4500; Arrow/Schweber (303) 799-0258; Hall-Mark (303) 790-1662; Marshall (303) 451-8383; Wyle (303) 457-9953.  
**CONNECTICUT:** Anthem (203) 575-1575; Arrow/Schweber (203) 265-7741; Hall-Mark (203) 271-2844; Marshall (203) 265-3822.  
**FLORIDA: Fort Lauderdale:** Arrow/Schweber (305) 429-8200; Hall-Mark (305) 971-9280; Marshall (305) 977-4880.  
**Orlando:** Arrow/Schweber (407) 333-9300; Hall-Mark (407) 830-5855; Marshall (407) 767-8585; Zeus (407) 788-9100.  
**Tampa:** Hall-Mark (813) 541-7440; Marshall (813) 573-1399.  
**GEORGIA:** Arrow/Schweber (404) 497-1300; Hall-Mark (404) 623-4400; Marshall (404) 923-5750.  
**ILLINOIS:** Anthem (708) 884-0200; Arrow/Schweber (708) 250-0500; Hall-Mark (312) 860-3800; Marshall (708) 490-0155; Newark (312) 784-5100.  
**INDIANA:** Arrow/Schweber (317) 299-2071; Hall-Mark (317) 872-8875; Marshall (317) 297-0483.  
**IOWA:** Arrow/Schweber (319) 395-7230.  
**KANSAS:** Arrow/Schweber (913) 541-9542; Hall-Mark (913) 888-4747; Marshall (913) 492-3121.  
**MARYLAND:** Anthem (301) 995-6640; Arrow/Schweber (301) 596-7800; Hall-Mark (301) 988-9800; Marshall (301) 622-1118; Zeus (301) 997-1118.  
**MASSACHUSETTS:** Anthem (508) 657-5170; Arrow/Schweber (508) 658-0900; Hall-Mark (508) 667-0902; Marshall (508) 658-0810; Wyle (617) 272-7300; Zeus (617) 246-8200.



**MICHIGAN: Detroit:** Arrow/Schweber (313) 462-2290; Hall-Mark (313) 416-5800; Marshall (313) 525-5850; Newark (313) 967-0600.  
**MINNESOTA:** Anthem (612) 944-5454; Arrow/Schweber (612) 941-5280; Hall-Mark (612) 881-2600; Marshall (612) 559-2211.  
**MISSOURI:** Arrow/Schweber (314) 567-6888; Hall-Mark (314) 291-5350; Marshall (314) 291-4650.  
**NEW JERSEY:** Anthem (201) 227-7960; Arrow/Schweber (201) 227-7880, (609) 596-8000; Hall-Mark (201) 515-3000, (609) 235-1900; Marshall (201) 882-0320, (609) 234-9100.  
**NEW MEXICO:** Alliance (505) 292-3360.  
**NEW YORK: Long Island:** Anthem (516) 864-6600; Arrow/Schweber (516) 231-1000; Hall-Mark (516) 737-0600; Marshall (516) 273-2424; Zeus (914) 937-7400.  
**Rochester:** Arrow/Schweber (716) 427-0300; Hall-Mark (716) 425-3300; Marshall (716) 235-7620.  
**Syracuse:** Marshall (607) 785-2345.  
**NORTH CAROLINA:** Arrow/Schweber (919) 876-3132; Hall-Mark (919) 872-0712; Marshall (919) 878-9882.  
**OHIO: Cleveland:** Arrow/Schweber (216) 248-3990; Hall-Mark (216) 349-4632; Marshall (216) 248-1788.  
**Columbus:** Hall-Mark (614) 888-3313.  
**Dayton:** Arrow/Schweber (513) 435-5563; Marshall (513) 898-4480; Zeus (513) 293-6162.  
**OKLAHOMA:** Arrow/Schweber (918) 252-7537; Hall-Mark (918) 254-6110.  
**OREGON:** Almac/Arrow (503) 629-8090; Anthem (503) 643-1114; Marshall (503) 644-5050; Wyle (503) 643-7900.  
**PENNSYLVANIA:** Anthem (215) 443-5150; Arrow/Schweber (215) 928-1800; GRS (215) 922-7037; (609) 964-8560; Marshall (412) 788-0441.  
**TEXAS: Austin:** Arrow/Schweber (512) 835-4180; Hall-Mark (512) 258-8848; Marshall (512) 837-1991; Wyle (512) 345-8853;  
**Dallas:** Anthem (214) 238-7100; Arrow/Schweber (214) 380-6464; Hall-Mark (214) 553-4300; Marshall (214) 233-5200; Wyle (214) 235-9953; Zeus (214) 783-7010;  
**Houston:** Arrow/Schweber (713) 530-4700; Hall-Mark (713) 781-6100; Marshall (713) 467-1666; Wyle (713) 879-9953.  
**UTAH:** Anthem (801) 973-8555; Arrow/Schweber (801) 973-6913; Marshall (801) 973-2288; Wyle (801) 974-9953.  
**WASHINGTON:** Almac/Arrow (206) 643-9992, Anthem (206) 483-1700; Marshall (206) 486-5747; Wyle (206) 881-1150.  
**WISCONSIN:** Arrow/Schweber (414) 792-0150; Hall-Mark (414) 797-7844; Marshall (414) 797-8400.  
**CANADA: Calgary:** Future (403) 235-5325;  
**Edmonton:** Future (403) 438-2858;  
**Montreal:** Arrow/Schweber (514) 421-7411; Future (514) 694-7710; Marshall (514) 694-8142  
**Ottawa:** Arrow/Schweber (613) 226-6903; Future (613) 820-8313.  
**Quebec:** Future (418) 897-6666.  
**Toronto:** Arrow/Schweber (416) 670-7769; Future (416) 612-9200; Marshall (416) 458-8046.  
**Vancouver:** Arrow/Schweber (604) 421-2333; Future (604) 294-1166.

## TI Die Processors

|                       |                |
|-----------------------|----------------|
| Chip Supply           | (407) 298-7100 |
| Elmo Semiconductor    | (818) 768-7400 |
| Minco Technology Labs | (512) 834-2022 |

D0892

**PACKAGING INFORMATION**

| Orderable Device  | Status <sup>(1)</sup> | Package Type | Package Drawing | Pins | Package Qty | Eco Plan <sup>(2)</sup> | Lead/Ball Finish | MSL Peak Temp <sup>(3)</sup> |
|-------------------|-----------------------|--------------|-----------------|------|-------------|-------------------------|------------------|------------------------------|
| 5962-85155132A    | ACTIVE                | LCCC         | FK              | 20   | 1           | None                    | Call TI          | Level-NC-NC-NC               |
| 5962-8515513RA    | ACTIVE                | CDIP         | J               | 20   | 1           | None                    | Call TI          | Level-NC-NC-NC               |
| 5962-8515513SA    | ACTIVE                | CFP          | W               | 20   | 1           | None                    | Call TI          | Level-NC-NC-NC               |
| 5962-85155142A    | ACTIVE                | LCCC         | FK              | 20   | 1           | None                    | Call TI          | Level-NC-NC-NC               |
| 5962-8515514RA    | ACTIVE                | CDIP         | J               | 20   | 1           | None                    | Call TI          | Level-NC-NC-NC               |
| 5962-8515514SA    | ACTIVE                | CFP          | W               | 20   | 1           | None                    | Call TI          | Level-NC-NC-NC               |
| 5962-85155152A    | ACTIVE                | LCCC         | FK              | 20   | 1           | None                    | Call TI          | Level-NC-NC-NC               |
| 5962-8515515RA    | ACTIVE                | CDIP         | J               | 20   | 1           | None                    | Call TI          | Level-NC-NC-NC               |
| 5962-8515515SA    | ACTIVE                | CFP          | W               | 20   | 1           | None                    | Call TI          | Level-NC-NC-NC               |
| 5962-85155162A    | ACTIVE                | LCCC         | FK              | 20   | 1           | None                    | Call TI          | Level-NC-NC-NC               |
| 5962-8515516RA    | ACTIVE                | CDIP         | J               | 20   | 1           | None                    | Call TI          | Level-NC-NC-NC               |
| 5962-8515516SA    | ACTIVE                | CFP          | W               | 20   | 1           | None                    | Call TI          | Level-NC-NC-NC               |
| TIBPAL16L8-10CFN  | ACTIVE                | PLCC         | FN              | 20   | 46          | None                    | Call TI          | Level-1-220-UNLIM            |
| TIBPAL16L8-10CN   | ACTIVE                | PDIP         | N               | 20   | 20          | None                    | Call TI          | Level-NC-NC-NC               |
| TIBPAL16L8-12MFKB | ACTIVE                | LCCC         | FK              | 20   | 1           | None                    | Call TI          | Level-NC-NC-NC               |
| TIBPAL16L8-12MJ   | ACTIVE                | CDIP         | J               | 20   | 1           | None                    | Call TI          | Level-NC-NC-NC               |
| TIBPAL16L8-12MJB  | ACTIVE                | CDIP         | J               | 20   | 1           | None                    | Call TI          | Level-NC-NC-NC               |
| TIBPAL16L8-12MWB  | ACTIVE                | CFP          | W               | 20   | 1           | None                    | Call TI          | Level-NC-NC-NC               |
| TIBPAL16R4-10CFN  | ACTIVE                | PLCC         | FN              | 20   | 46          | None                    | Call TI          | Level-1-220-UNLIM            |
| TIBPAL16R4-10CN   | ACTIVE                | PDIP         | N               | 20   | 20          | None                    | Call TI          | Level-NC-NC-NC               |
| TIBPAL16R4-12MFKB | ACTIVE                | LCCC         | FK              | 20   | 1           | None                    | Call TI          | Level-NC-NC-NC               |
| TIBPAL16R4-12MJ   | ACTIVE                | CDIP         | J               | 20   | 1           | None                    | Call TI          | Level-NC-NC-NC               |
| TIBPAL16R4-12MJB  | ACTIVE                | CDIP         | J               | 20   | 1           | None                    | Call TI          | Level-NC-NC-NC               |
| TIBPAL16R4-12MWB  | ACTIVE                | CFP          | W               | 20   | 1           | None                    | Call TI          | Level-NC-NC-NC               |
| TIBPAL16R6-10CFN  | ACTIVE                | PLCC         | FN              | 20   | 46          | None                    | Call TI          | Level-1-220-UNLIM            |
| TIBPAL16R6-10CN   | ACTIVE                | PDIP         | N               | 20   | 20          | None                    | Call TI          | Level-NC-NC-NC               |
| TIBPAL16R6-12MFKB | ACTIVE                | LCCC         | FK              | 20   | 1           | None                    | Call TI          | Level-NC-NC-NC               |
| TIBPAL16R6-12MJ   | ACTIVE                | CDIP         | J               | 20   | 1           | None                    | Call TI          | Level-NC-NC-NC               |
| TIBPAL16R6-12MJB  | ACTIVE                | CDIP         | J               | 20   | 1           | None                    | Call TI          | Level-NC-NC-NC               |
| TIBPAL16R6-12MWB  | ACTIVE                | CFP          | W               | 20   | 1           | None                    | Call TI          | Level-NC-NC-NC               |
| TIBPAL16R8-10CFN  | OBSOLETE              | PLCC         | FN              | 20   |             | None                    | Call TI          | Call TI                      |
| TIBPAL16R8-10CN   | OBSOLETE              | PDIP         | N               | 20   |             | None                    | Call TI          | Call TI                      |
| TIBPAL16R8-12MFKB | ACTIVE                | LCCC         | FK              | 20   | 1           | None                    | Call TI          | Level-NC-NC-NC               |
| TIBPAL16R8-12MJB  | ACTIVE                | CDIP         | J               | 20   | 1           | None                    | Call TI          | Level-NC-NC-NC               |
| TIBPAL16R8-12MWB  | ACTIVE                | CFP          | W               | 20   | 1           | None                    | Call TI          | Level-NC-NC-NC               |

<sup>(1)</sup> 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.

---

<sup>(2)</sup> Eco Plan - May not be currently available - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**None:** Not yet available Lead (Pb-Free).

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean "Pb-Free" and in addition, uses package materials that do not contain halogens, including bromine (Br) or antimony (Sb) above 0.1% of total product weight.

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

**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.

## IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

| <b>Products</b>  |                                                                    | <b>Applications</b> |                                                                          |
|------------------|--------------------------------------------------------------------|---------------------|--------------------------------------------------------------------------|
| Amplifiers       | <a href="http://amplifier.ti.com">amplifier.ti.com</a>             | Audio               | <a href="http://www.ti.com/audio">www.ti.com/audio</a>                   |
| Data Converters  | <a href="http://dataconverter.ti.com">dataconverter.ti.com</a>     | Automotive          | <a href="http://www.ti.com/automotive">www.ti.com/automotive</a>         |
| DSP              | <a href="http://dsp.ti.com">dsp.ti.com</a>                         | Broadband           | <a href="http://www.ti.com/broadband">www.ti.com/broadband</a>           |
| Interface        | <a href="http://interface.ti.com">interface.ti.com</a>             | Digital Control     | <a href="http://www.ti.com/digitalcontrol">www.ti.com/digitalcontrol</a> |
| Logic            | <a href="http://logic.ti.com">logic.ti.com</a>                     | Military            | <a href="http://www.ti.com/military">www.ti.com/military</a>             |
| Power Mgmt       | <a href="http://power.ti.com">power.ti.com</a>                     | Optical Networking  | <a href="http://www.ti.com/opticalnetwork">www.ti.com/opticalnetwork</a> |
| Microcontrollers | <a href="http://microcontroller.ti.com">microcontroller.ti.com</a> | Security            | <a href="http://www.ti.com/security">www.ti.com/security</a>             |
|                  |                                                                    | Telephony           | <a href="http://www.ti.com/telephony">www.ti.com/telephony</a>           |
|                  |                                                                    | Video & Imaging     | <a href="http://www.ti.com/video">www.ti.com/video</a>                   |
|                  |                                                                    | Wireless            | <a href="http://www.ti.com/wireless">www.ti.com/wireless</a>             |

Mailing Address: Texas Instruments  
Post Office Box 655303 Dallas, Texas 75265

Copyright © 2005, Texas Instruments Incorporated