

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

SRPS017A – D3023, MAY 1987 – REVISED DECEMBER 2010

- **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<br>INPUTS | 3-STATE<br>O OUTPUTS | REGISTERED<br>Q OUTPUTS | I/O<br>PORT<br>S |
|---------|-------------|----------------------|-------------------------|------------------|
| 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                |

## 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.

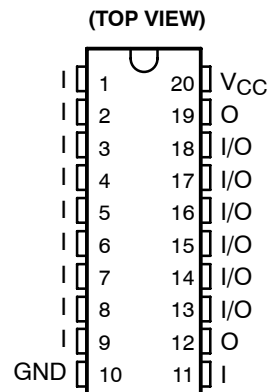
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PAL is a registered trademark of Advanced Micro Devices Inc.

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.

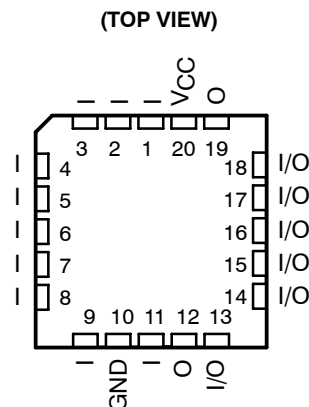


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TIBPAL16L8'  
C SUFFIX . . . J OR N PACKAGE  
M SUFFIX . . . J PACKAGE



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



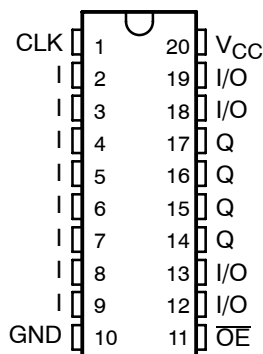
Pin assignments in operating mode

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

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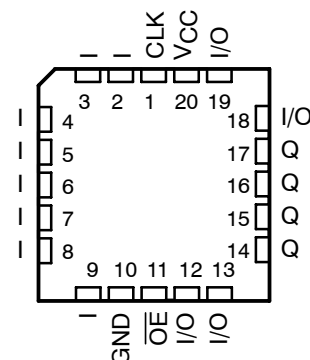
**TIBPAL16R4'**  
C SUFFIX ... J OR N PACKAGE  
M SUFFIX ... J PACKAGE

(TOP VIEW)



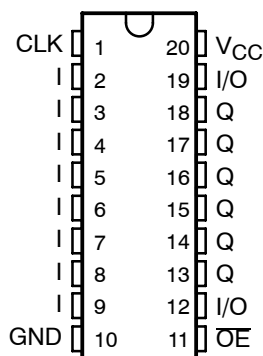
**TIBPAL16R4'**  
C SUFFIX ... FN PACKAGE  
M SUFFIX ... FK PACKAGE

(TOP VIEW)



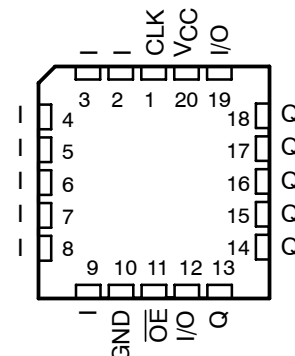
**TIBPAL16R6'**  
C SUFFIX ... J OR N PACKAGE  
M SUFFIX ... J PACKAGE

(TOP VIEW)



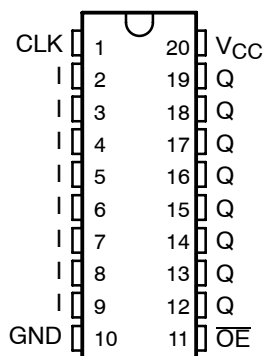
**TIBPAL16R6'**  
C SUFFIX ... FN PACKAGE  
M SUFFIX ... FK PACKAGE

(TOP VIEW)



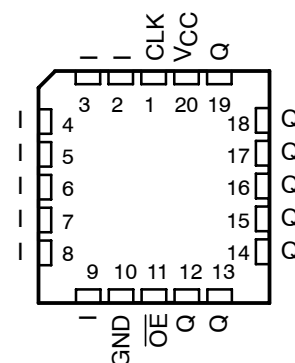
**TIBPAL16R8'**  
C SUFFIX ... J OR N PACKAGE  
M SUFFIX ... J PACKAGE

(TOP VIEW)



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

(TOP VIEW)

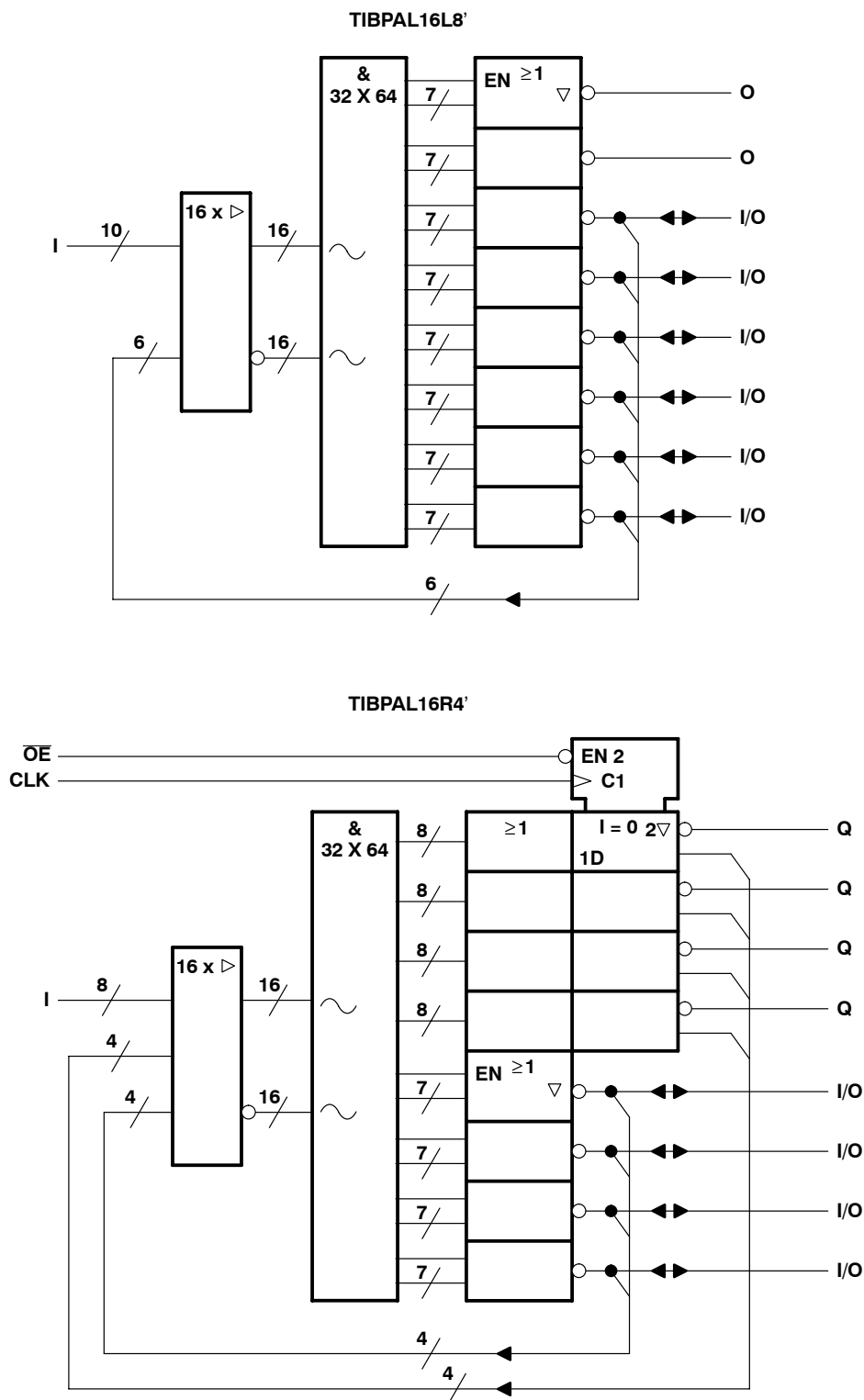


Pin assignments in operating mode

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

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**functional block diagrams (positive logic)**

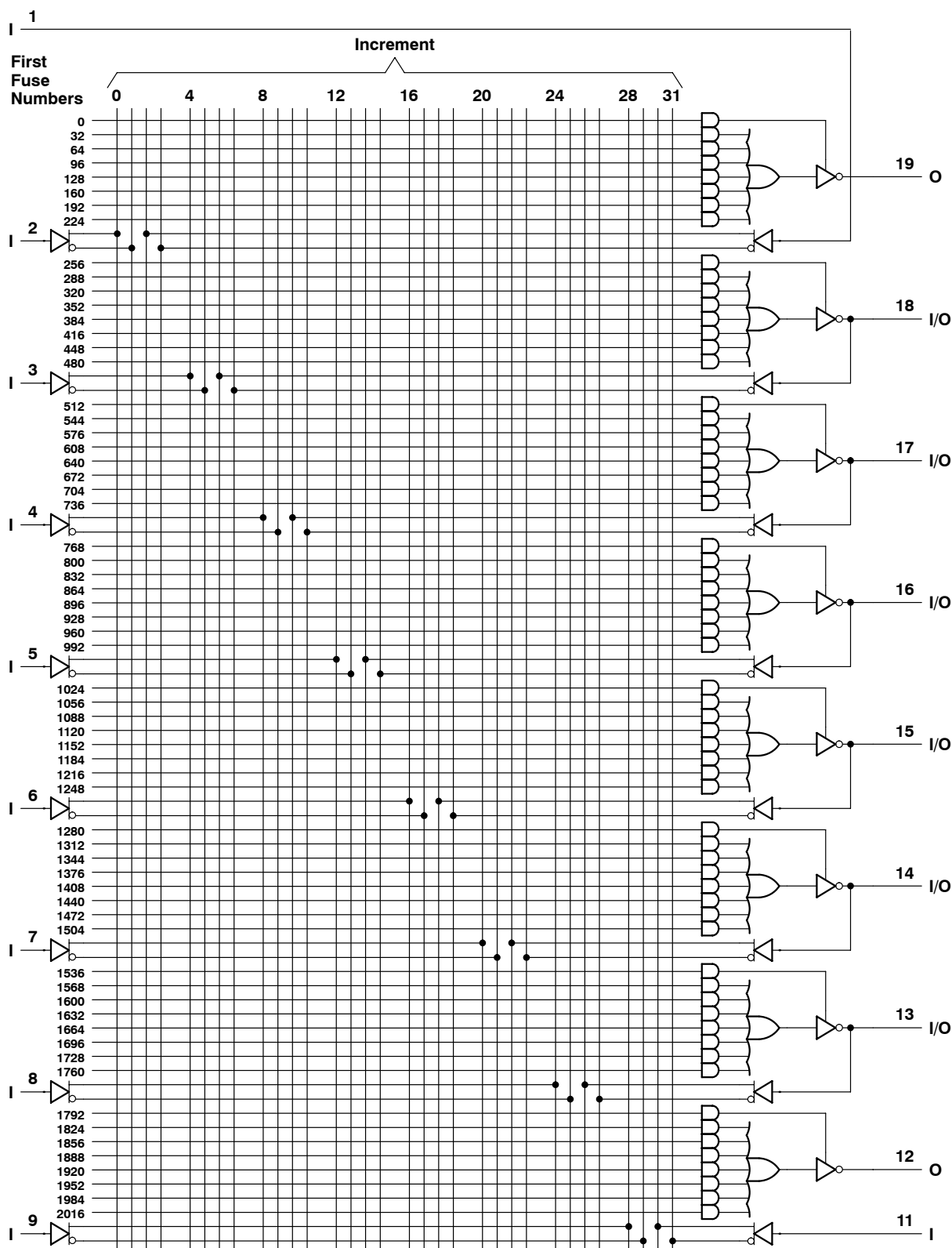




# TIBPAL16L8-10C TIBPAL16L8-12M HIGH-PERFORMANCE *IMPACT-X*™ PAL® CIRCUITS

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## logic diagram (positive logic)



Fuse number = First fuse number + Increment

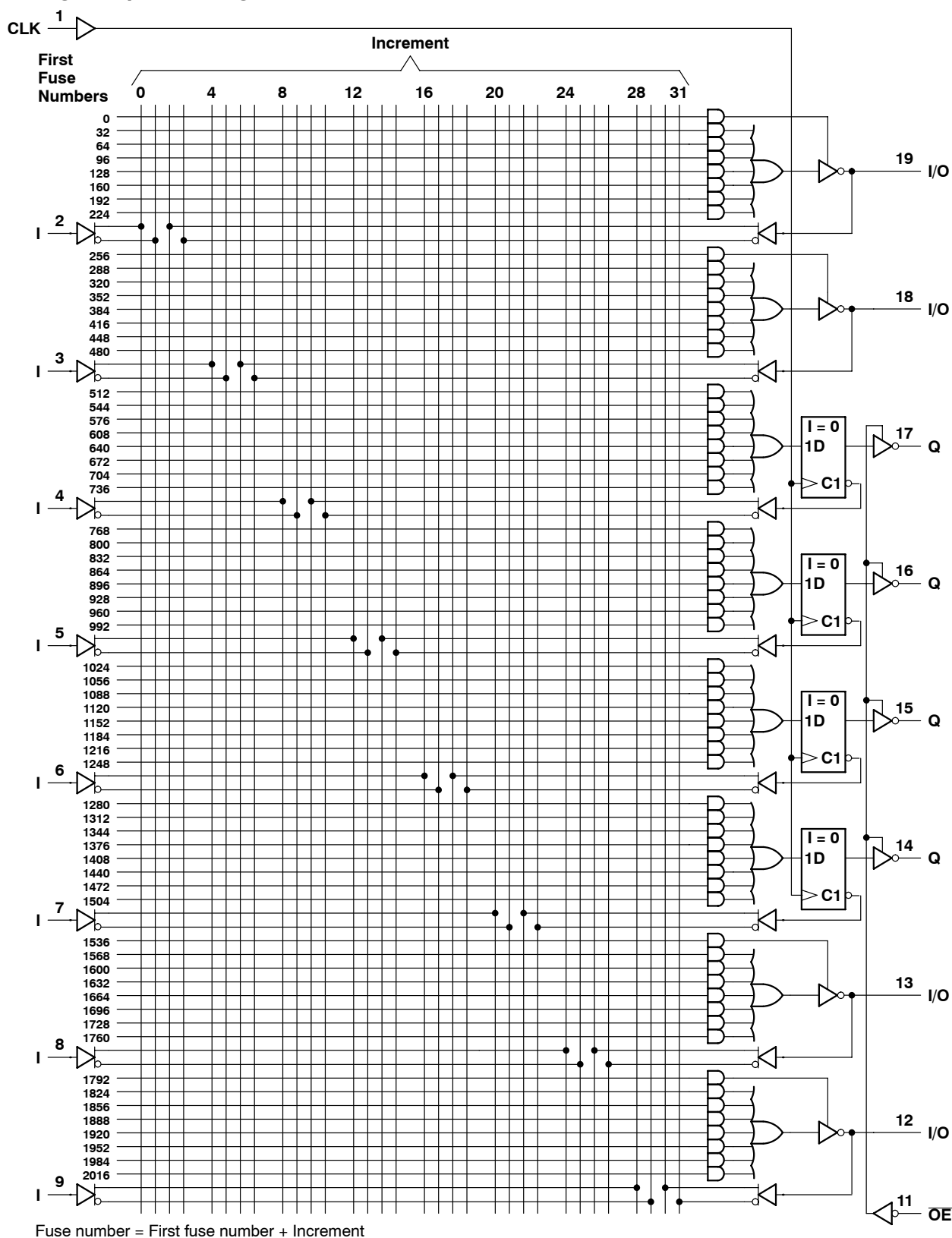
# TIBPAL16R4-10C

# TIBPAL16R4-12M

## HIGH-PERFORMANCE *IMPACT-X*™ PAL® CIRCUITS

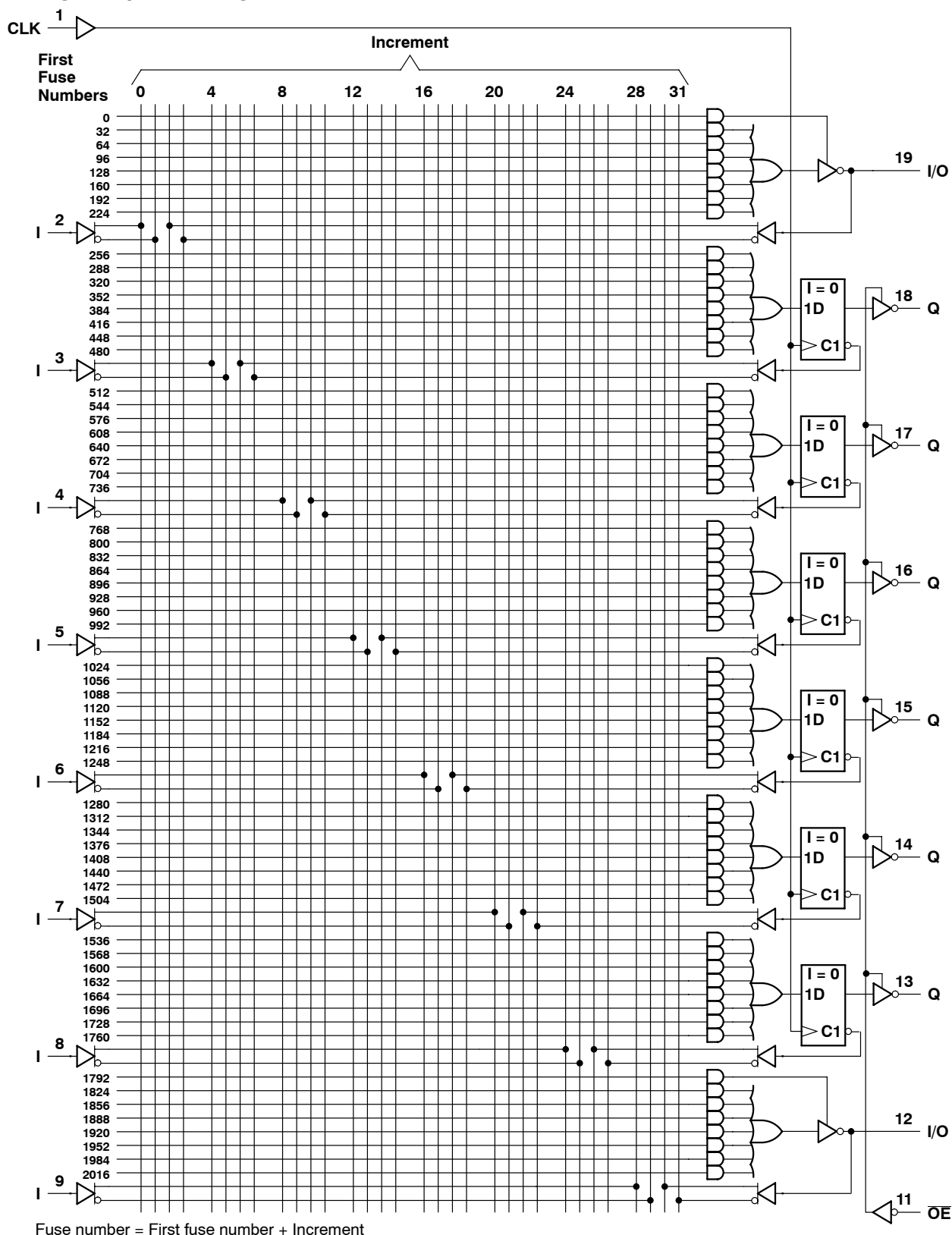
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### logic diagram (positive logic)



**TIBPAL16R6-10C****TIBPAL16R6-12M****HIGH-PERFORMANCE *IMPACT-X*™ PAL® CIRCUITS**

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**logic diagram (positive logic)**

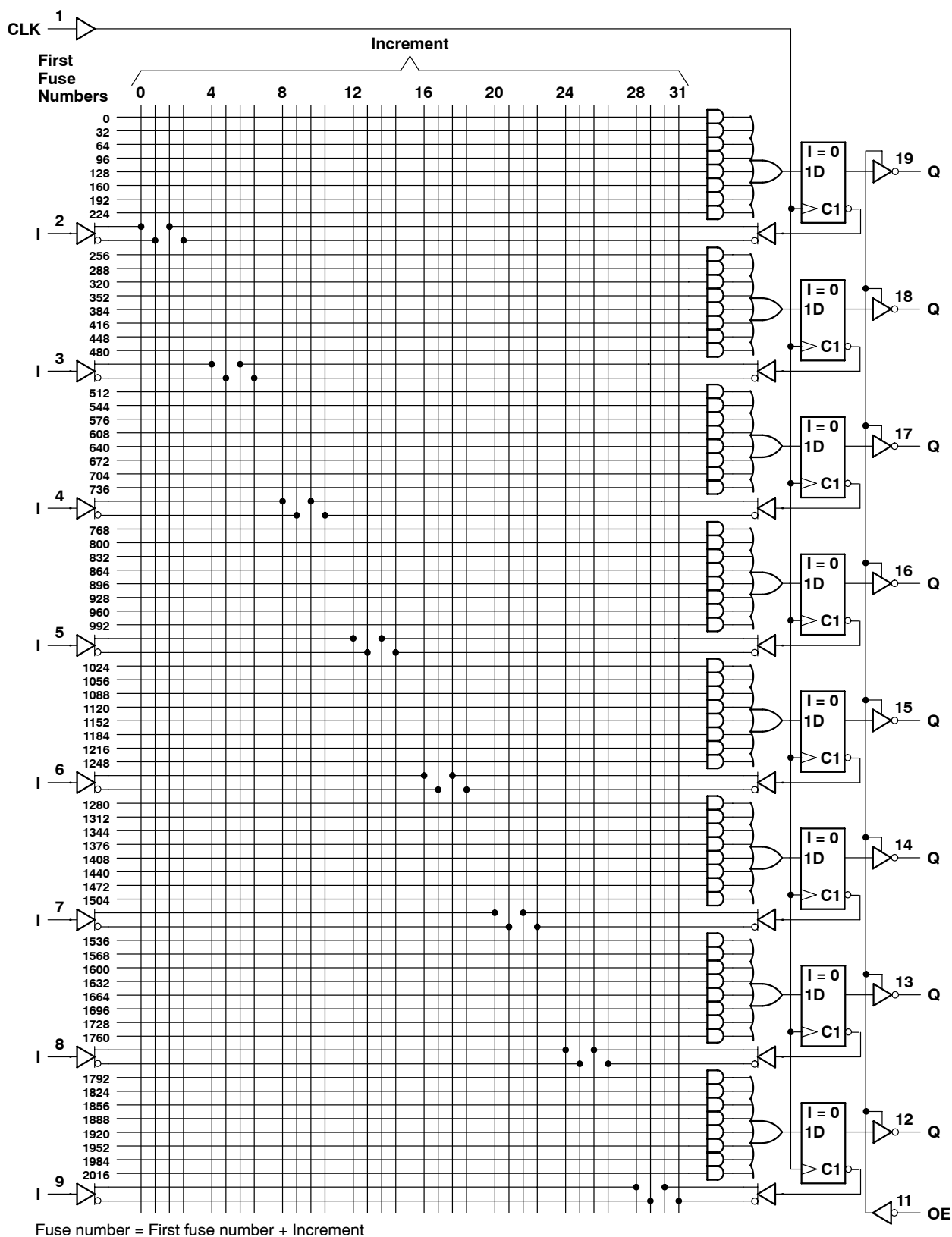
# TIBPAL16R8-10C

# TIBPAL16R8-12M

## HIGH-PERFORMANCE *IMPACT-X*™ PAL® CIRCUITS

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### logic diagram (positive logic)



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

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## 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

SRPS017A – D3023, MAY 1987 – REVISED DECEMBER 2010

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

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

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

SRPS017D – D3023, MAY 1987 – REVISED DECEMBER 2010

## 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 <sub>CC</sub>                 | Supply voltage                              |      | 4.5 | 5   | 5.5 | V    |
| V <sub>IH</sub>                 | High-level input voltage                    |      | 2   |     | 5.5 | V    |
| V <sub>IL</sub>                 | Low-level input voltage                     |      |     |     | 0.8 | V    |
| I <sub>OH</sub>                 | High-level output current                   |      |     |     | −2  | mA   |
| I <sub>OL</sub>                 | Low-level output current                    |      |     |     | 12  | mA   |
| f <sub>clock</sub> <sup>†</sup> | Clock frequency                             |      | 0   |     | 56  | MHz  |
| t <sub>w</sub>                  | Pulse duration, clock (see Note 2)          | High | 9   |     |     | ns   |
|                                 |                                             | Low  | 9   |     |     |      |
| t <sub>su</sub> <sup>†</sup>    | Setup time, input or feedback before clock↑ |      | 11  |     |     | ns   |
| t <sub>h</sub> <sup>†</sup>     | Hold time, input or feedback after clock↑   |      | 0   |     |     | ns   |
| T <sub>A</sub>                  | 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

SRPS017D – D3023, MAY 1987 – REVISED DECEMBER 2010

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

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

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

SRPS017A – D3023, MAY 1987 – REVISED DECEMBER 2010

## 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.

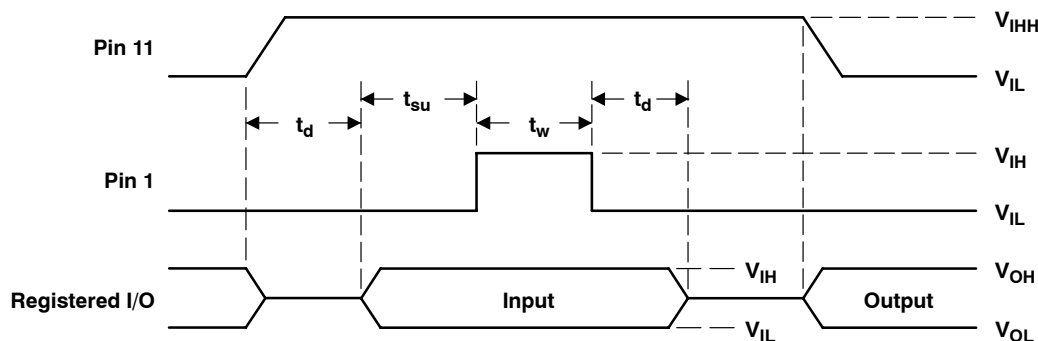


Figure 1. Preload Waveforms

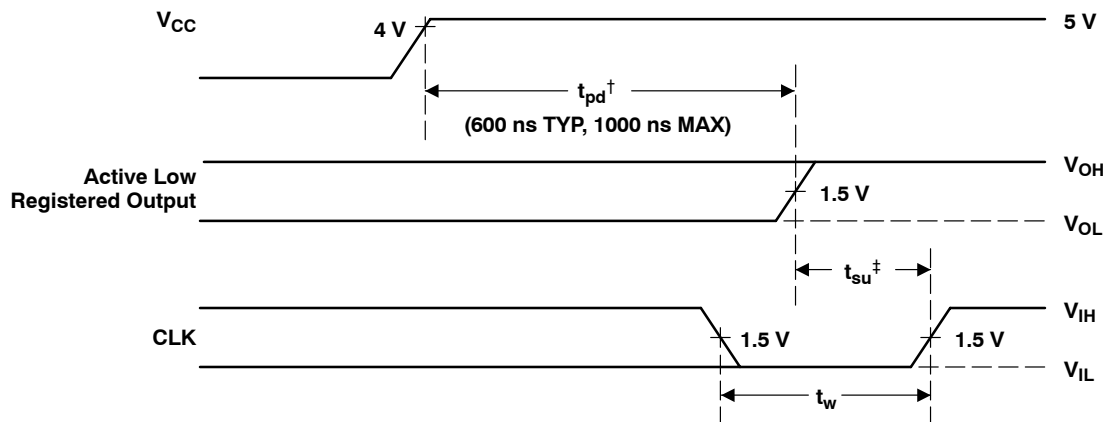
NOTE 3:  $t_d = t_{su} = t_h = 100 \text{ ns to } 1000 \text{ ns}$   $V_{IHH} = 10.25 \text{ V to } 10.75 \text{ v}$

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

SRPS017A – D3023, MAY 1987 – REVISED DECEMBER

## 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.



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

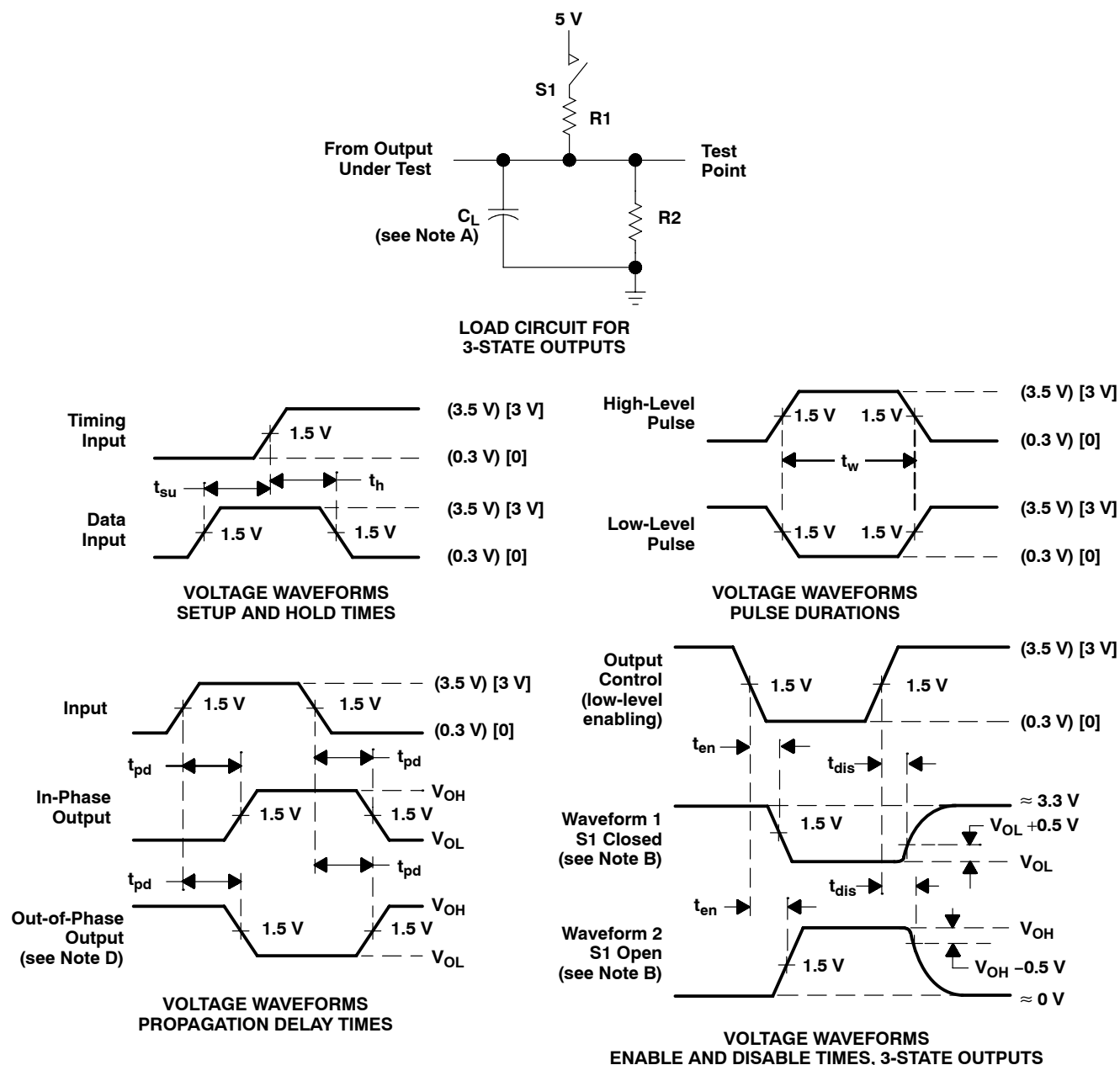
<sup>‡</sup> This is the setup time for input or feedback.

**Figure 2. Power-Up Reset Waveforms**

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

SRPS017A – D3023, MAY 1987 – REVISED DECEMBER 2010

## PARAMETER MEASUREMENT INFORMATION



- NOTES: A.  $C_L$  includes probe and jig capacitance and is 50 pF for  $t_{pd}$  and  $t_{en}$ , 5 pF for  $t_{dis}$ .  
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  $\leq$  1 MHz,  $t_r = t_f = 2$  ns, duty cycle = 50%; For M suffix, use the voltage levels indicated in brackets [ ], PRR  $\leq$  10 MHz,  $t_r$  and  $t_f \leq 2$  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

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

SRPS017 – D3023, MAY 1987 – REVISED DECEMBER 2010

## 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.

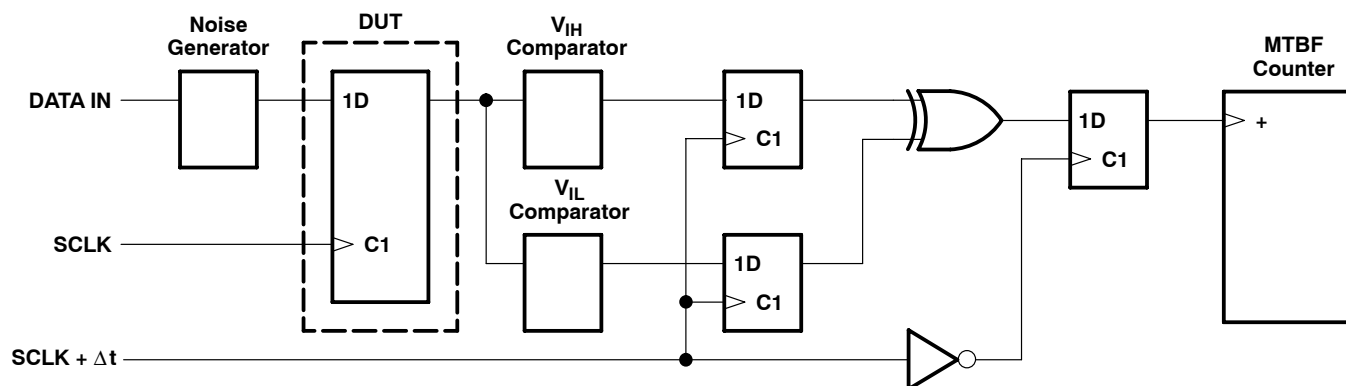


Figure 4. Metastable Evaluation Test Circuit

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.

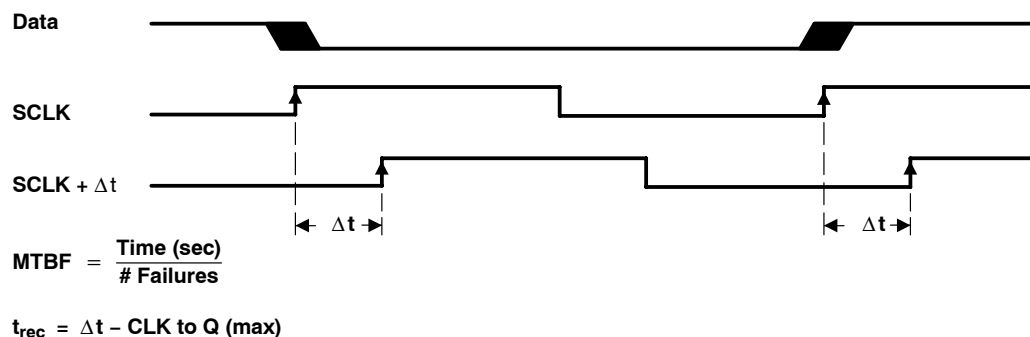
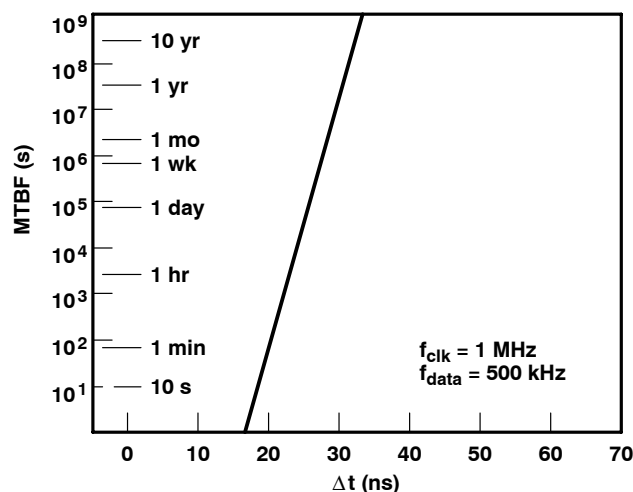


Figure 5. Timing Diagram

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

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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

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## TYPICAL CHARACTERISTICS

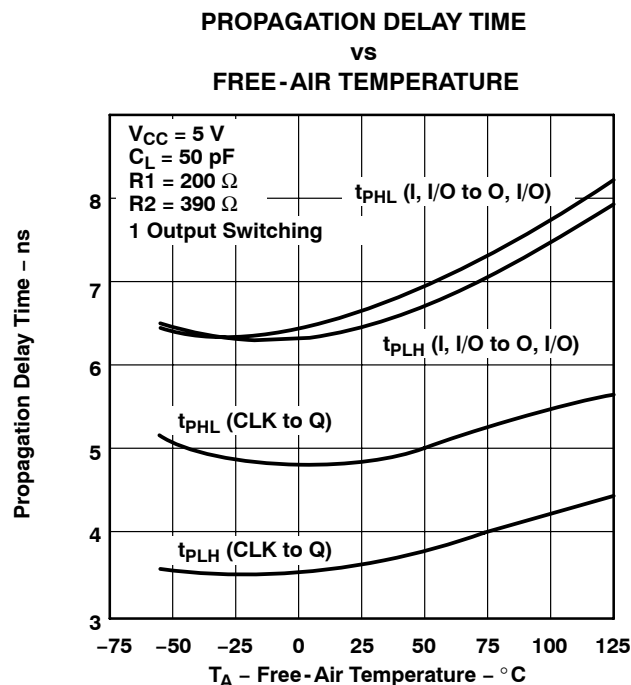


Figure 7

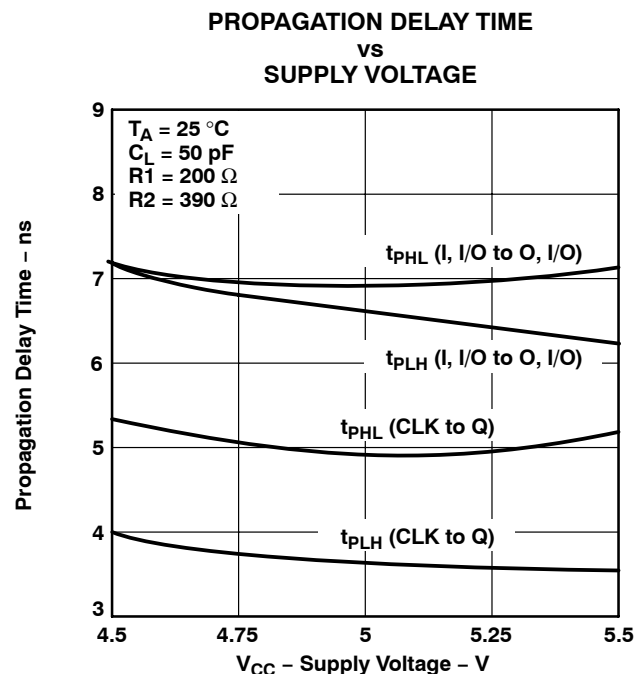


Figure 8

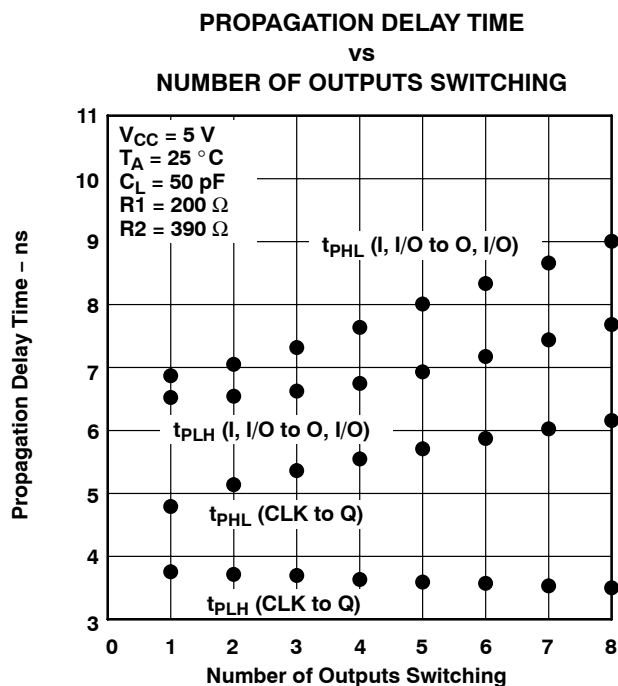
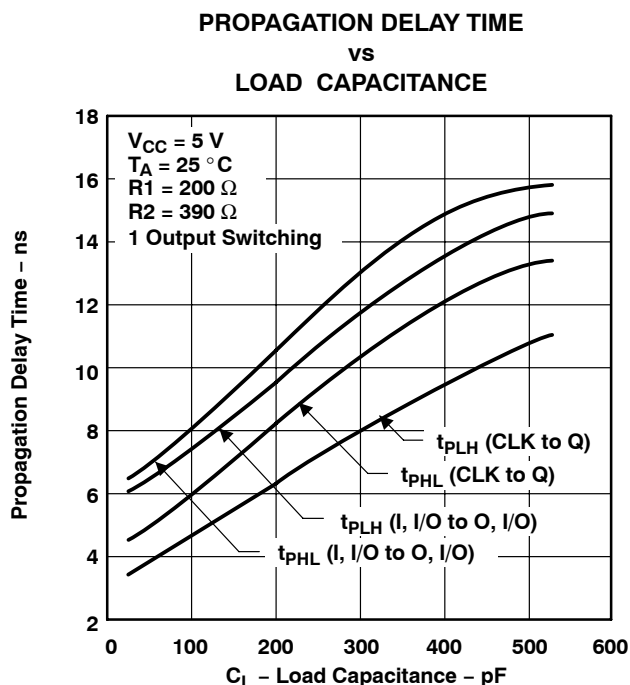


Figure 9

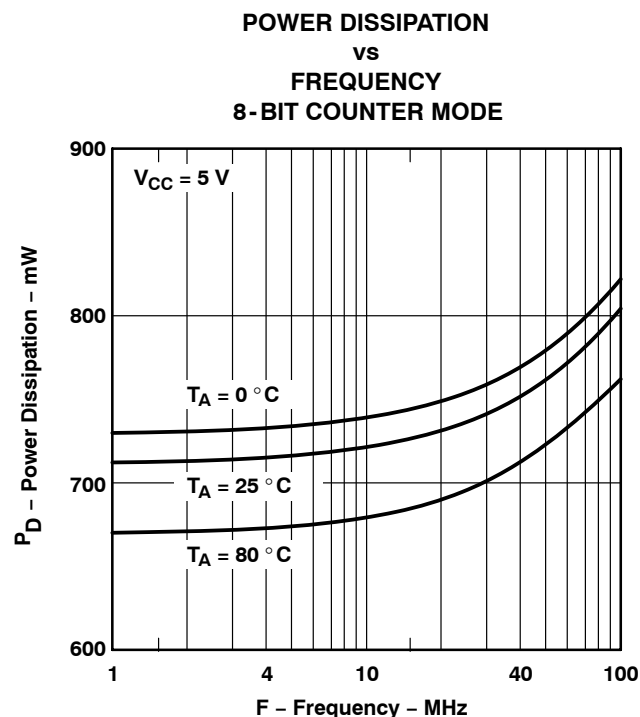
**TIBPAL16L8-10C, TIBPAL16R4-10C, TIBPAL16R6-10C, TIBPAL16R8-10C**  
**TIBPAL16L8-12M, TIBPAL16R4-12M, TIBPAL16R6-12M, TIBPAL16R8-12M**  
**HIGH-PERFORMANCE *IMPACT-X*™ *PAL*® CIRCUITS**

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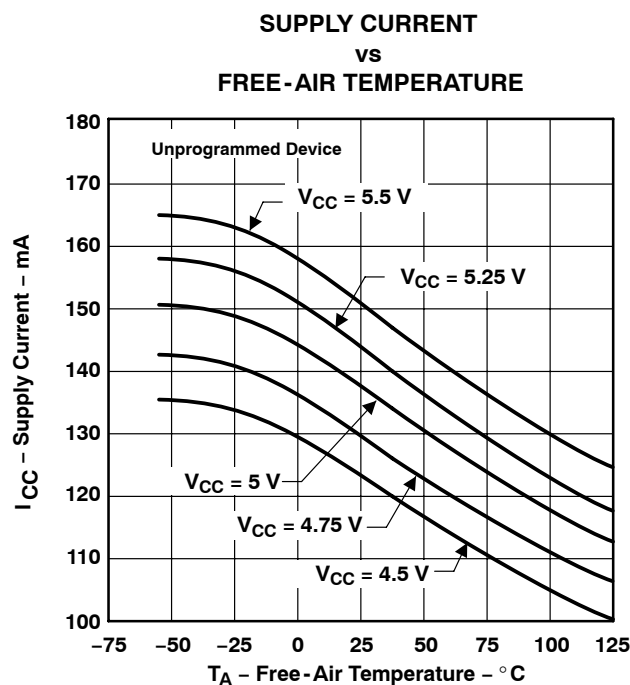
**TYPICAL CHARACTERISTICS**



**Figure 10**



**Figure 11**



**Figure 12**

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| 5962-8515513SA    | ACTIVE                | CFP          | W               | 20   | 1           | TBD                        | Call TI              | Call TI                      |                             |
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| 5962-8515514RA    | OBSOLETE              | CDIP         | J               | 20   |             | TBD                        | Call TI              | Call TI                      |                             |
| 5962-8515514SA    | OBSOLETE              | CFP          | W               | 20   |             | TBD                        | Call TI              | Call TI                      |                             |
| 5962-85155152A    | ACTIVE                | LCCC         | FK              | 20   | 1           | TBD                        | Call TI              | Call TI                      |                             |
| 5962-8515515RA    | ACTIVE                | CDIP         | J               | 20   | 1           | TBD                        | Call TI              | Call TI                      |                             |
| 5962-8515515SA    | ACTIVE                | CFP          | W               | 20   | 1           | TBD                        | Call TI              | Call TI                      |                             |
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| 5962-8515516RA    | ACTIVE                | CDIP         | J               | 20   | 1           | TBD                        | Call TI              | Call TI                      |                             |
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| TIBPAL16L8-10CN   | ACTIVE                | PDIP         | N               | 20   | 20          | Pb-Free (RoHS)             | CU NIPDAU            | N / A for Pkg Type           |                             |
| TIBPAL16L8-12MFKB | ACTIVE                | LCCC         | FK              | 20   | 1           | TBD                        | POST-PLATE           | N / A for Pkg Type           |                             |
| TIBPAL16L8-12MJ   | ACTIVE                | CDIP         | J               | 20   | 1           | TBD                        | A42                  | N / A for Pkg Type           |                             |
| TIBPAL16L8-12MJB  | ACTIVE                | CDIP         | J               | 20   | 1           | TBD                        | A42                  | N / A for Pkg Type           |                             |
| TIBPAL16L8-12MWB  | ACTIVE                | CFP          | W               | 20   | 1           | TBD                        | Call TI              | N / A for Pkg Type           |                             |
| TIBPAL16R4-10CFN  | NRND                  | PLCC         | FN              | 20   | 46          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-3-245C-168 HR          |                             |
| TIBPAL16R4-10CN   | NRND                  | PDIP         | N               | 20   | 20          | Pb-Free (RoHS)             | CU NIPDAU            | N / A for Pkg Type           |                             |
| TIBPAL16R4-12MFKB | ACTIVE                | LCCC         | FK              | 20   | 1           | TBD                        | Call TI              | Call TI                      |                             |
| TIBPAL16R4-12MJ   | ACTIVE                | CDIP         | J               | 20   | 1           | TBD                        | Call TI              | Call TI                      |                             |
| TIBPAL16R4-12MJB  | ACTIVE                | CDIP         | J               | 20   | 1           | TBD                        | Call TI              | Call TI                      |                             |
| TIBPAL16R4-12MWB  | ACTIVE                | CFP          | W               | 20   | 1           | TBD                        | Call TI              | N / A for Pkg Type           |                             |
| TIBPAL16R6-10CFN  | NRND                  | PLCC         | FN              | 20   | 46          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-3-245C-168 HR          |                             |
| TIBPAL16R6-10CN   | NRND                  | PDIP         | N               | 20   | 20          | Pb-Free (RoHS)             | CU NIPDAU            | N / A for Pkg Type           |                             |
| TIBPAL16R6-12MFKB | ACTIVE                | LCCC         | FK              | 20   | 1           | TBD                        | POST-PLATE           | N / A for Pkg Type           |                             |

| 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> | Samples (Requires Login) |
|-------------------|-----------------------|--------------|-----------------|------|-------------|-------------------------|-------------------|------------------------------|--------------------------|
| TIBPAL16R6-12MJB  | ACTIVE                | CDIP         | J               | 20   | 1           | TBD                     | A42               | N / A for Pkg Type           |                          |
| TIBPAL16R6-12MWB  | ACTIVE                | CFP          | W               | 20   | 1           | TBD                     | Call TI           | N / A for Pkg Type           |                          |
| TIBPAL16R8-10CFN  | OBSOLETE              | PLCC         | FN              | 20   |             | TBD                     | Call TI           | Call TI                      |                          |
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| TIBPAL16R8-12MFKB | OBSOLETE              | LCCC         | FK              | 20   |             | TBD                     | Call TI           | Call TI                      |                          |
| TIBPAL16R8-12MJ   | OBSOLETE              | CDIP         | J               | 20   |             | TBD                     | Call TI           | Call TI                      |                          |
| TIBPAL16R8-12MJB  | OBSOLETE              | CDIP         | J               | 20   |             | TBD                     | Call TI           | Call TI                      |                          |
| TIBPAL16R8-12MWB  | OBSOLETE              | CFP          | W               | 20   |             | TBD                     | Call TI           | Call TI                      |                          |

<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 - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**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.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

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J (R-GDIP-T\*\*)

14 LEADS SHOWN

# CERAMIC DUAL IN-LINE PACKAGE



| PINS **<br>DIM | 14                     | 16                     | 18                     | 20                     |
|----------------|------------------------|------------------------|------------------------|------------------------|
| A              | 0.300<br>(7,62)<br>BSC | 0.300<br>(7,62)<br>BSC | 0.300<br>(7,62)<br>BSC | 0.300<br>(7,62)<br>BSC |
| B MAX          | 0.785<br>(19,94)       | .840<br>(21,34)        | 0.960<br>(24,38)       | 1.060<br>(26,92)       |
| B MIN          | —                      | —                      | —                      | —                      |
| C MAX          | 0.300<br>(7,62)        | 0.300<br>(7,62)        | 0.310<br>(7,87)        | 0.300<br>(7,62)        |
| C MIN          | 0.245<br>(6,22)        | 0.245<br>(6,22)        | 0.220<br>(5,59)        | 0.245<br>(6,22)        |

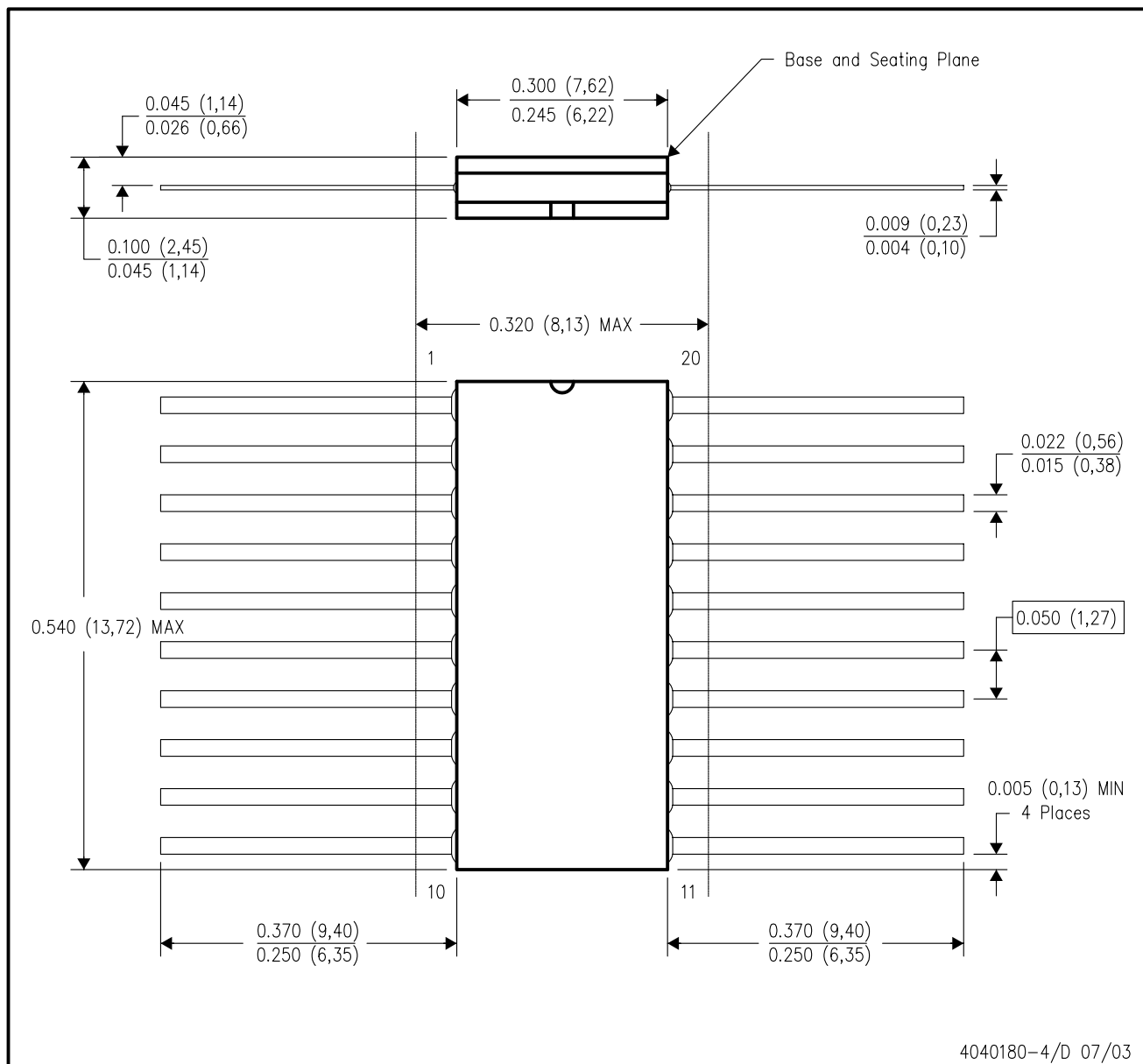


4040083/F 03/03

- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - C. This package is hermetically sealed with a ceramic lid using glass frit.
  - D. Index point is provided on cap for terminal identification only on press ceramic glass frit seal only.
  - E. Falls within MIL STD 1835 GDIP1-T14, GDIP1-T16, GDIP1-T18 and GDIP1-T20.

W (R-GDFP-F20)

CERAMIC DUAL FLATPACK



- NOTES:
- All linear dimensions are in inches (millimeters).
  - This drawing is subject to change without notice.
  - This package can be hermetically sealed with a ceramic lid using glass frit.
  - Index point is provided on cap for terminal identification only.
  - Falls within Mil-Std 1835 GDFP2-F20

FK (S-CQCC-N\*\*)

LEADLESS CERAMIC CHIP CARRIER

28 TERMINAL SHOWN



| NO. OF<br>TERMINALS<br>** | A                |                  | B                |                  |
|---------------------------|------------------|------------------|------------------|------------------|
|                           | MIN              | MAX              | MIN              | MAX              |
| 20                        | 0.342<br>(8,69)  | 0.358<br>(9,09)  | 0.307<br>(7,80)  | 0.358<br>(9,09)  |
| 28                        | 0.442<br>(11,23) | 0.458<br>(11,63) | 0.406<br>(10,31) | 0.458<br>(11,63) |
| 44                        | 0.640<br>(16,26) | 0.660<br>(16,76) | 0.495<br>(12,58) | 0.560<br>(14,22) |
| 52                        | 0.740<br>(18,78) | 0.761<br>(19,32) | 0.495<br>(12,58) | 0.560<br>(14,22) |
| 68                        | 0.938<br>(23,83) | 0.962<br>(24,43) | 0.850<br>(21,6)  | 0.858<br>(21,8)  |
| 84                        | 1.141<br>(28,99) | 1.165<br>(29,59) | 1.047<br>(26,6)  | 1.063<br>(27,0)  |



4040140/D 01/11

- NOTES:
- All linear dimensions are in inches (millimeters).
  - This drawing is subject to change without notice.
  - This package can be hermetically sealed with a metal lid.
  - Falls within JEDEC MS-004

N (R-PDIP-T\*\*)

16 PINS SHOWN

## PLASTIC DUAL-IN-LINE PACKAGE



| PINS **<br>DIM      | 14               | 16               | 18               | 20               |
|---------------------|------------------|------------------|------------------|------------------|
| A MAX               | 0.775<br>(19,69) | 0.775<br>(19,69) | 0.920<br>(23,37) | 1.060<br>(26,92) |
| A MIN               | 0.745<br>(18,92) | 0.745<br>(18,92) | 0.850<br>(21,59) | 0.940<br>(23,88) |
| MS-001<br>VARIATION | AA               | BB               | AC               | AD               |



4040049/E 12/2002

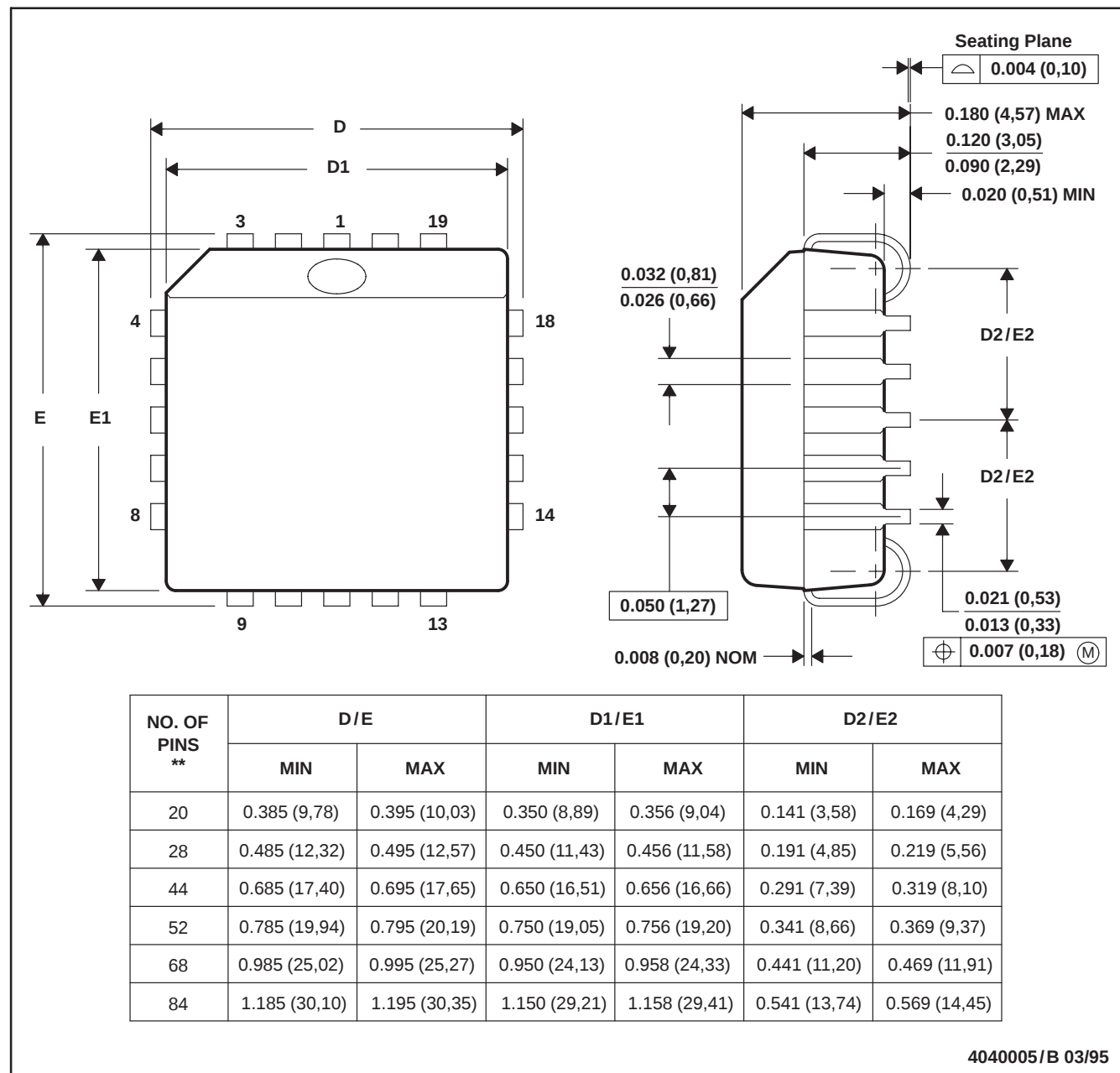
NOTES:

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

## FN (S-PQCC-J\*\*)

## PLASTIC J-LEADED CHIP CARRIER

20 PIN SHOWN



- NOTES: A. All linear dimensions are in inches (millimeters).  
 B. This drawing is subject to change without notice.  
 C. Falls within JEDEC MS-018

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|                               |                                                                                          |
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