

# 3.3 V RoboClock® Low Voltage Programmable Skew Clock Buffer

## Features

- All output pair skew <100 ps typical (250 ps max)
- 3.75 MHz to 80 MHz output operation
- User-selectable output functions:
  - Selectable skew up to 18 ns
  - Inverted and non-inverted
  - Operation at one-half and one-quarter input frequency
  - Operation at 2 × and 4 × input frequency (input as low as 3.75 MHz)
- Zero input to output delay
- 50% duty cycle outputs
- Low-voltage transistor-transistor logic (LVTTTL) outputs drive 50 Ω terminated lines
- Operates from a single 3.3 V supply
- Low operating current
- 32-pin plastic leaded chip carrier (PLCC) package
- Low cycle-to-cycle jitter (100 ps typical)

## Functional Description

The CY7B991V 3.3 V RoboClock® low-voltage programmable skew clock buffer (LVPSCB) offers user-selectable control over system clock functions. These multiple output clock drivers provide the system integrator with functions necessary to optimize the timing of high-performance computer systems. Each of the eight individual drivers – arranged in four pairs of user controllable outputs – can drive terminated transmission lines with impedances as low as 50 Ω. This delivers minimal output skews and full-swing logic levels (LVTTTL).

Each output is hardwired to one of nine delay or function configurations. Delay increments of 0.7 to 1.5 ns are determined by the operating frequency, with outputs able to skew up to ±6 time units from their nominal ‘zero’ skew position. The completely-integrated phase-locked loop (PLL) allows external load and transmission line delay effects to be canceled. When this ‘zero delay’ capability of the LVPSCB is combined with the selectable output skew functions, the user can create output-to-output delays of up to ±12 time units.

Divide-by-two and divide-by-four output functions are provided for additional flexibility in designing complex clock systems. When combined with the internal PLL, these divide functions enable distribution of a low frequency clock that is multiplied by two or four at the clock destination. This feature minimizes clock distribution difficulty, allowing maximum system clock speed and flexibility.

For a complete list of related resources, [click here](#).

## Logic Block Diagram

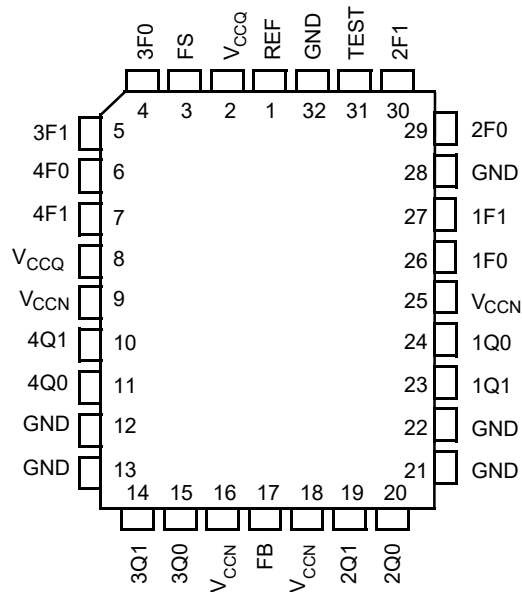


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## Pinouts

**Figure 1. 32-pin PLCC pinout**



## Pin Definitions

| Pin Name         | Pin Number             | I/O | Description   |
|------------------|------------------------|-----|---|
| REF              | 1                      | I   | Reference frequency input. This input supplies the frequency and timing against which all functional variations are measured. |
| FB               | 17                     | I   | PLL feedback input (typically connected to one of the eight outputs).   |
| FS               | 3                      | I   | Three-level frequency range select. See <a href="#">Table 1</a> .   |
| 1F0, 1F1         | 26, 27                 | I   | Three-level function select inputs for output pair 1 (1Q0, 1Q1). See <a href="#">Table 2</a> .                                |
| 2F0, 2F1         | 29, 30                 | I   | Three-level function select inputs for output pair 2 (2Q0, 2Q1). See <a href="#">Table 2</a> .                                |
| 3F0, 3F1         | 4, 5                   | I   | Three-level function select inputs for output pair 3 (3Q0, 3Q1). See <a href="#">Table 2</a> .                                |
| 4F0, 4F1         | 6, 7                   | I   | Three-level function select inputs for output pair 4 (4Q0, 4Q1). See <a href="#">Table 2</a> .                                |
| TEST             | 31                     | I   | Three-level select. See test mode section under the block diagram descriptions.   |
| 1Q0, 1Q1         | 24, 23                 | O   | Output pair 1. See <a href="#">Table 2</a> .  |
| 2Q0, 2Q1         | 20, 19                 | O   | Output pair 2. See <a href="#">Table 2</a> .  |
| 3Q0, 3Q1         | 15, 14                 | O   | Output pair 3. See <a href="#">Table 2</a> .  |
| 4Q0, 4Q1         | 11, 10                 | O   | Output pair 4. See <a href="#">Table 2</a> .  |
| V <sub>CCN</sub> | 9, 16, 18, 25          | PWR | Power supply for output drivers.  |
| V <sub>CCQ</sub> | 2, 8                   | PWR | Power supply for internal circuitry.  |
| GND              | 12, 13, 21, 22, 28, 32 | PWR | Ground.   |

## Block Diagram Description

### Phase Frequency Detector and Filter

The phase frequency detector and filter blocks accept inputs from the reference frequency (REF) input and the feedback (FB) input. They generate correction information to control the frequency of the voltage controlled oscillator (VCO). These blocks, along with the VCO, form a PLL that tracks the incoming REF signal.

### VCO and Time Unit Generator

The VCO accepts analog control inputs from the PLL filter block. It generates a frequency that is used by the time unit generator to create discrete time units, selected in the skew select matrix. The operational range of the VCO is determined by the FS control pin. The time unit ( $t_U$ ) is determined by the operating frequency of the device and the level of the FS pin as shown in Table 1.

**Table 1. Frequency Range Select and  $t_U$  Calculation<sup>[1]</sup>**

| FS <sup>[2, 3]</sup> | $f_{NOM}$ (MHz) |     | $t_U = \frac{1}{f_{NOM} \times N}$<br>where N = | Approximate<br>Frequency (MHz) At<br>Which $t_U = 1.0$ ns |
|----------------------|-----------------|-----|---|---|
|                      | Min             | Max |   |   |
| LOW                  | 15              | 30  | 44  | 22.7  |
| MID                  | 25              | 50  | 26  | 38.5  |
| HIGH                 | 40              | 80  | 16  | 62.5  |

### Skew Select Matrix

The skew select matrix is comprised of four independent sections. Each section has two low-skew, high fanout drivers (xQ0, xQ1), and two corresponding three-level function select (xF0, xF1) inputs. Table 2 shows the nine possible output functions for each section as determined by the function select inputs. All times are measured with respect to the REF input assuming that the output connected to the FB input has  $0t_U$  selected.

**Table 2. Programmable Skew Configurations<sup>[1]</sup>**

| Function Selects   |                    | Output Functions   |             |             |
|--------------------|--------------------|--------------------|-------------|-------------|
| 1F1, 2F1, 3F1, 4F1 | 1F0, 2F0, 3F0, 4F0 | 1Q0, 1Q1, 2Q0, 2Q1 | 3Q0, 3Q1    | 4Q0, 4Q1    |
| LOW                | LOW                | $-4t_U$            | Divide by 2 | Divide by 2 |
| LOW                | MID                | $-3t_U$            | $-6t_U$     | $-6t_U$     |
| LOW                | HIGH               | $-2t_U$            | $-4t_U$     | $-4t_U$     |
| MID                | LOW                | $-1t_U$            | $-2t_U$     | $-2t_U$     |
| MID                | MID                | $0t_U$             | $0t_U$      | $0t_U$      |
| MID                | HIGH               | $+1t_U$            | $+2t_U$     | $+2t_U$     |
| HIGH               | LOW                | $+2t_U$            | $+4t_U$     | $+4t_U$     |
| HIGH               | MID                | $+3t_U$            | $+6t_U$     | $+6t_U$     |
| HIGH               | HIGH               | $+4t_U$            | Divide by 4 | Inverted    |

#### Notes

- For all three state inputs, HIGH indicates a connection to  $V_{CC}$ , LOW indicates a connection to GND, and MID indicates an open connection. Internal termination circuitry holds an unconnected input to  $V_{CC}/2$ .
- The level to be set on FS is determined by the "normal" operating frequency ( $f_{NOM}$ ) of the VCO and Time Unit Generator (see Logic Block Diagram). Nominal frequency ( $f_{NOM}$ ) always appears at the outputs when they are operated in their undivided modes (see Table 2). The frequency appearing at the REF and FB inputs is  $f_{NOM}$  when the output connected to FB is undivided. The frequency of the REF and FB inputs is  $f_{NOM}/2$  or  $f_{NOM}/4$  when the part is configured for a frequency multiplication using a divided output as the FB input.
- When the FS pin is selected HIGH, the REF input must not transition upon power up until  $V_{CC}$  has reached 2.8 V.

## Test Mode

The TEST input is a three-level input. In normal system operation, this pin is connected to ground, allowing the CY7B991V to operate as explained in the [Block Diagram Description on page 4](#). For testing purposes, any of the three-level inputs can have a removable jumper to ground or be tied LOW through a 100-Ω resistor. This enables an external tester to change the state of these pins.

If the TEST input is forced to its MID or HIGH state, the device operates with its internal phase locked loop disconnected, and input levels supplied to REF directly controls all outputs. Relative output to output functions are the same as in normal mode.

In contrast with normal operation (TEST tied LOW), all outputs function based only on the connection of their own function select inputs (xF0 and xF1) and the waveform characteristics of the REF input.

**Figure 2. Typical Outputs with FB Connected to a Zero Skew Output Test Mode [4]**



**Note**

4. FB connected to an output selected for “zero” skew (that is, xF1 = xF0 = MID).

## Operational Mode Descriptions

**Figure 3. Zero Skew and Zero Delay Clock Driver**

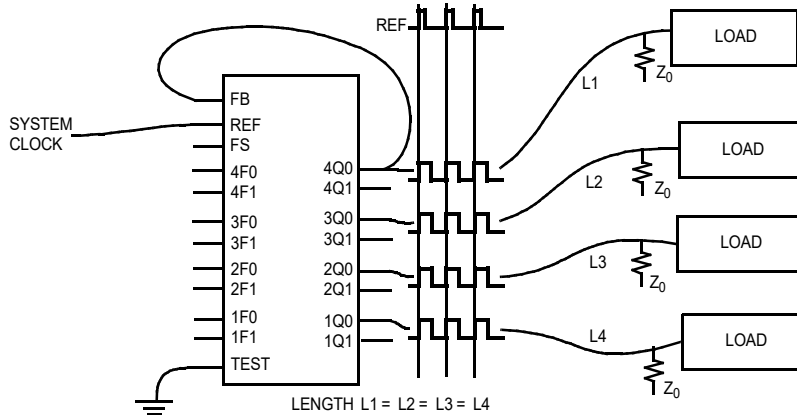


Figure 2 shows the LVPSCB configured as a zero skew clock buffer. In this mode, the CY7B991V is the basis for a low-skew clock distribution tree. When all of the function select inputs ( $\times F0$ ,  $\times F1$ ) are left open, the outputs are aligned and drive a terminated transmission line to an independent load. The FB input is tied to any output in this configuration and the operating frequency range is selected with the FS pin. The low skew specification, coupled with the ability to drive terminated transmission lines (with impedances as low as  $50 \Omega$ ), enables efficient printed circuit board design.

**Figure 4. Programmable Skew Clock Driver**

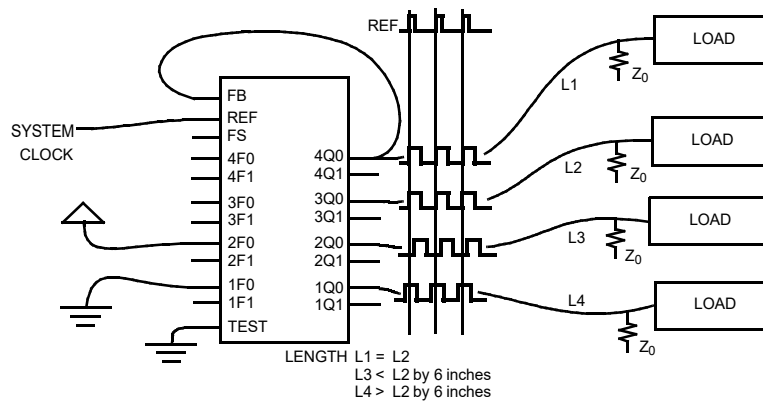


Figure 4 shows a configuration to equalize skew between metal traces of different lengths. In addition to low skew between outputs, the LVPSCB is programmed to stagger the timing of its outputs. The four groups of output pairs are each programmed to different output timing. Skew timing is adjusted over a wide range in small increments using the function select pins. In this configuration, the 4Q0 output is sent back to FB and configured for zero skew. The other three pairs of outputs are programmed to yield different skews relative to the feedback. By advancing the clock signal on the longer traces or retarding the clock signal on shorter traces, all loads receive the clock pulse at the same time.

Figure 4 shows the FB input connected to an output with 0 ns skew ( $\times F1$ ,  $\times F0 = \text{MID}$ ) selected. The internal PLL synchronizes

the FB and REF inputs and aligns their rising edges to make certain that all outputs have precise phase alignment.

Clock skews are advanced by  $\pm 6$  time units (tU) when using an output selected for zero skew as the feedback. A wider range of delays is possible if the output connected to FB is also skewed. Since “Zero Skew”,  $+tU$ , and  $-tU$  are defined relative to output groups, and the PLL aligns the rising edges of REF and FB, wider output skews are created by proper selection of the  $\times F_n$  inputs. For example, a  $+10$  tU between REF and 3Qx is achieved by connecting 1Q0 to FB and setting  $1F0 = 1F1 = \text{GND}$ ,  $3F0 = \text{MID}$ , and  $3F1 = \text{High}$ . (Since FB aligns at  $-4$  tU, and 3Qx skews to  $+6$  tU, a total of  $+10$  tU skew is realized.) Many other configurations are realized by skewing both the outputs used as the FB input and skewing the other outputs.

**Figure 5. Inverted Output Connections**



Figure 5 shows an example of the invert function of the LVPSCB. In this example the 4Q0 output is used as the FB input is programmed for invert (4F0 = 4F1 = HIGH) while the other three pairs of outputs are programmed for zero skew. When 4F0 and 4F1 are tied high, 4Q0 and 4Q1 become inverted zero phase outputs. The PLL aligns the rising edge of the FB input with the rising edge of the REF. This causes the 1Q, 2Q, and 3Q outputs to become the “inverted” outputs to the REF input. By selecting the output connected to FB, you can have two inverted and six non-inverted outputs or six inverted and two non-inverted outputs. The correct configuration is determined by the need for more (or fewer) inverted outputs. 1Q, 2Q, and 3Q outputs can also be skewed to compensate for varying trace delays independent of inversion on 4Q.

**Figure 6. Frequency Multiplier with Skew Connections**



Figure 6 shows the LVPSCB configured as a clock multiplier. The 3Q0 output is programmed to divide by four and is sent back to FB. This causes the PLL to increase its frequency until the 3Q0 and 3Q1 outputs are locked at 20 MHz, while the 1Qx and 2Qx outputs run at 80 MHz. The 4Q0 and 4Q1 outputs are programmed to divide by two that results in a 40 MHz waveform at these outputs. Note that the 20- and 40-MHz clocks fall

simultaneously and are out of phase on their rising edge. This enables the designer to use the rising edges of the 1/2 frequency and 1/4 frequency outputs without concern for rising edge skew. The 2Q0, 2Q1, 1Q0, and 1Q1 outputs run at 80 MHz and are skewed by programming their select inputs accordingly. Note that the FS pin is wired for 80 MHz operation as that is the frequency of the fastest output.

**Figure 7. Frequency Divider Connections**



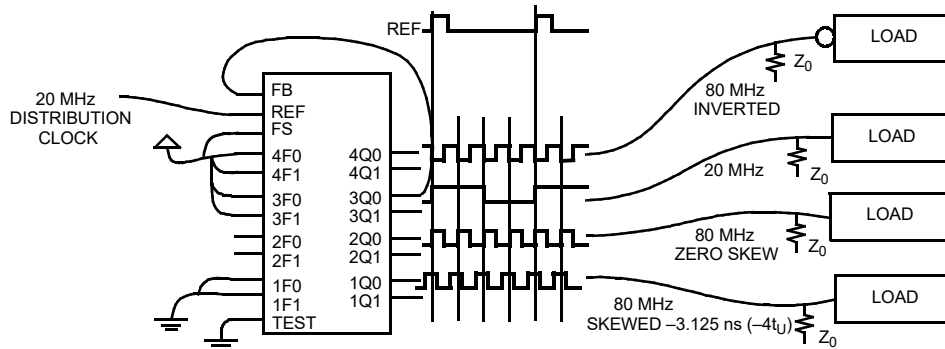
Figure 7 shows the LVPSCB in a clock divider application. 2Q0 is sent back to the FB input and programmed for zero skew. 3Qx is programmed to divide by four. 4Qx is programmed to divide by two. Note that the falling edges of the 4Qx and 3Qx outputs are aligned. This enables use of the rising edges of the 1/2 frequency and 1/4 frequency without concern for skew mismatch. The 1Qx outputs are programmed to zero skew and are aligned with the 2Qx outputs. In this example, the FS input is grounded to configure the device in the 15 to 30 MHz range since the highest frequency output is running at 20 MHz.

Figure 8 on page 8 shows some of the functions that are selectable on the 3Qx and 4Qx outputs. These include inverted outputs and outputs that offer divide-by-2 and divide-by-4 timing. An inverted output enables the system designer to clock different subsystems on opposite edges without suffering from the pulse asymmetry typical of non-ideal loading. This function enables each of the two subsystems to clock 180 degrees out of phase, but still is aligned within the skew specification.

The divided outputs offer a zero delay divider for portions of the system that divide the clock by either two or four, and still remain within a narrow skew of the “1X” clock. Without this feature, an external divider is added, and the propagation delay of the divider adds to the skew between the different clock signals.

These divided outputs, coupled with the PLL, enable the LVPSCB to multiply the clock rate at the REF input by either two or four. This mode allows the designer to distribute a low frequency clock between various portions of the system. It also locally multiplies the clock rate to a more suitable frequency, while still maintaining the low skew characteristics of the clock driver. The LVPSCB performs all of the functions described in this section at the same time. It can multiply by two and four or divide by two (and four) at the same time that it shifts its outputs over a wide range or maintains zero skew between selected outputs.

**Figure 8. Multi-Function Clock Driver**



**Figure 9. Board-to-Board Clock Distribution**



Figure 9 shows the CY7B991V connected in series to construct a zero skew clock distribution tree between boards. Delays of the downstream clock buffers are programmed to compensate for the wire length (that is, select negative skew equal to the wire delay) necessary to connect them to the master clock source, approximating a zero delay clock tree. Cascaded clock buffers accumulate low frequency jitter because of the non-ideal filtering characteristics of the PLL filter. Do not connect more than two clock buffers in a series.



## Maximum Ratings

Operating outside these boundaries may affect the performance and life of the device. These user guidelines are not tested.

|  |                  |
|--|------------------|
| Storage temperature .....                    | -65 °C to 150 °C |
| Ambient temperature with power applied ..... | -55 °C to 125 °C |
| Supply voltage to ground potential .....     | -0.5 V to +7.0 V |
| DC input voltage .....                       | -0.5 V to +7.0 V |

|   |         |
|---|---------|
| Output current into outputs (LOW) .....                   | 64 mA   |
| Static discharge voltage (MIL-STD-883, Method 3015) ..... | >2001 V |
| Latch up current .....                                    | >200 mA |

## Operating Range

| Range      | Ambient Temperature | V <sub>CC</sub> |
|------------|---------------------|-----------------|
| Commercial | 0 °C to 70 °C       | 3.3 V ± 10%     |
| Industrial | -40 °C to 85 °C     | 3.3 V ± 10%     |

## Electrical Characteristics

Over the Operating Range

| Parameter <sup>[5]</sup> | Description   | Test Conditions  | CY7B991V               |                        | Unit |    |
|--------------------------|---|--|------------------------|------------------------|------|----|
|                          |   |  | Min                    | Max                    |      |    |
| V <sub>OH</sub>          | Output HIGH voltage   | V <sub>CC</sub> = Min, I <sub>OH</sub> = -12 mA  | 2.4                    | -                      | V    |    |
| V <sub>OL</sub>          | Output LOW voltage  | V <sub>CC</sub> = Min, I <sub>OL</sub> = 35 mA   | -                      | 0.45                   | V    |    |
| V <sub>IH</sub>          | Input HIGH voltage (REF and FB inputs only)                   |  | 2.0                    | V <sub>CC</sub>        | V    |    |
| V <sub>IL</sub>          | Input LOW voltage (REF and FB inputs only)                    |  | -0.5                   | 0.8                    | V    |    |
| V <sub>IHH</sub>         | Three-level input HIGH Voltage (Test, FS, xFn) <sup>[6]</sup> | Min ≤ V <sub>CC</sub> ≤ Max.   | 0.87 × V <sub>CC</sub> | V <sub>CC</sub>        | V    |    |
| V <sub>IMM</sub>         | Three-level input MID voltage (Test, FS, xFn) <sup>[6]</sup>  | Min ≤ V <sub>CC</sub> ≤ Max.   | 0.47 × V <sub>CC</sub> | 0.53 × V <sub>CC</sub> | V    |    |
| V <sub>ILL</sub>         | Three-level input LOW voltage (Test, FS, xFn) <sup>[6]</sup>  | Min ≤ V <sub>CC</sub> ≤ Max.   | 0.0                    | 0.13 × V <sub>CC</sub> | V    |    |
| I <sub>IH</sub>          | Input HIGH leakage current (REF and FB inputs only)           | V <sub>CC</sub> = Max, V <sub>IN</sub> = Max.  | -                      | 20                     | μA   |    |
| I <sub>IL</sub>          | Input LOW leakage current (REF and FB inputs only)            | V <sub>CC</sub> = Max, V <sub>IN</sub> = 0.4 V   | -20                    | -                      | μA   |    |
| I <sub>IHH</sub>         | Input HIGH current (Test, FS, xFn)                            | V <sub>IN</sub> = V <sub>CC</sub>  | -                      | 200                    | μA   |    |
| I <sub>IMM</sub>         | Input MID current (Test, FS, xFn)                             | V <sub>IN</sub> = V <sub>CC</sub> /2   | -50                    | 50                     | μA   |    |
| I <sub>ILL</sub>         | Input LOW current (Test, FS, xFn)                             | V <sub>IN</sub> = GND  | -200                   | -                      | μA   |    |
| I <sub>OS</sub>          | Short circuit current <sup>[7]</sup>                          | V <sub>CC</sub> = Max, V <sub>OUT</sub> = GND (25 °C only)   | -200                   | -                      | mA   |    |
| I <sub>CCQ</sub>         | Operating current used by internal circuitry                  | V <sub>CCN</sub> = V <sub>CCQ</sub> = Max, All Input Selects Open  | Commercial             | -                      | 95   | mA |
|                          |   |  | Military / Industrial  | -                      | 100  | mA |
| I <sub>CCN</sub>         | Output buffer current per output pair <sup>[8]</sup>          | V <sub>CCN</sub> = V <sub>CCQ</sub> = Max, I <sub>OUT</sub> = 0 mA, Input Selects Open, f <sub>MAX</sub> | -                      | 19                     | mA   |    |

### Notes

- See the last page of this specification for Group A subgroup testing information.
- These inputs are normally wired to V<sub>CC</sub>, GND, or left unconnected (actual threshold voltages vary as a percentage of V<sub>CC</sub>). Internal termination resistors hold unconnected inputs at V<sub>CC</sub>/2. If these inputs are switched, the function and timing of the outputs glitch and the PLL requires an additional t<sub>LOCK</sub> time before all datasheet limits are achieved.
- CY7B991V is tested one output at a time, output shorted for less than one second, less than 10% duty cycle. Room temperature only.
- Total output current per output pair is approximated by the following expression that includes device current plus load current:  

$$CY7B991V: I_{CCN} = [(4 + 0.11F) + ((835 - 3F)/Z) + (.0022FC)]N \times 1.1$$
 Where  
 F = frequency in MHz  
 C = capacitive load in pF  
 Z = line impedance in ohms  
 N = number of loaded outputs; 0, 1, or 2  
 FC = F × C

**Electrical Characteristics** (continued)

Over the Operating Range

| Parameter <sup>[5]</sup> | Description                       | Test Conditions  | CY7B991V |     | Unit |
|--------------------------|-----------------------------------|--|----------|-----|------|
|                          |                                   |  | Min      | Max |      |
| PD                       | Power dissipation per output pair | $V_{CCN} = V_{CCQ} = \text{Max}$ , $I_{OUT} = 0 \text{ mA}$ ,<br>Input Selects Open, $f_{MAX}$ | –        | 104 | mW   |

**Capacitance**

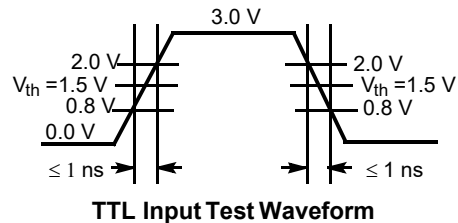
| Parameter <sup>[9, 10]</sup> | Description       | Test Conditions  | Max | Unit |
|------------------------------|-------------------|--|-----|------|
| $C_{IN}$                     | Input capacitance | $T_A = 25 \text{ }^\circ\text{C}$ , $f = 1 \text{ MHz}$ , $V_{CC} = 3.3 \text{ V}$ | 10  | pF   |

**Thermal Resistance**

| Parameter <sup>[10]</sup> | Description                              | Test Conditions   | 32-pin PLCC Package | Unit               |
|---------------------------|--|---|---------------------|--------------------|
| $\Theta_{JA}$             | Thermal resistance (junction to ambient) | Test conditions follow standard test methods and procedures for measuring thermal impedance, according to EIA/JESD51. | 44                  | $^\circ\text{C/W}$ |
| $\Theta_{JC}$             | Thermal resistance (junction to case)    |   | 26                  | $^\circ\text{C/W}$ |

**AC Test Loads and Waveforms**

Figure 10. AC Test Loads and Waveforms



**Notes**

- 9. Applies to REF and FB inputs only. Tested initially and after any design or process changes that may affect these parameters.
- 10. Tested initially and after any design or process changes that may affect these parameters.

## Switching Characteristics (-2 option)

Over the Operating Range

| Parameter <sup>[11, 12]</sup> | Description   | CY7B991V-2                        |      |       | Unit |     |
|-------------------------------|---|-----------------------------------|------|-------|------|-----|
|                               |   | Min                               | Typ  | Max   |      |     |
| f <sub>NOM</sub>              | Operating clock Frequency in MHz  | FS = LOW <sup>[11, 13]</sup>      | 15   | –     | 30   | MHz |
|                               |   | FS = MID <sup>[11, 13]</sup>      | 25   | –     | 50   |     |
|                               |   | FS = HIGH <sup>[11, 13, 14]</sup> | 40   | –     | 80   |     |
| t <sub>RPWH</sub>             | REF pulse width HIGH measured at 1/2 × V <sub>CCQ</sub> threshold               | 3.65                              | –    | –     | ns   |     |
| t <sub>RPWL</sub>             | REF pulse width LOW measured at 1/2 × V <sub>CCQ</sub> threshold                | 3.65                              | –    | –     | ns   |     |
| t <sub>U</sub>                | Programmable skew unit  | See Table 1                       |      |       |      |     |
| t <sub>SKEWPR</sub>           | Zero output matched-pair skew (XQ0, XQ1) <sup>[15, 16]</sup>                    | –                                 | 0.05 | 0.2   | ns   |     |
| t <sub>SKEW0</sub>            | Zero output skew (all outputs) <sup>[15, 17]</sup>                              | –                                 | 0.1  | 0.25  | ns   |     |
| t <sub>SKEW1</sub>            | Output skew (rise-rise, fall-fall, same class outputs) <sup>[15, 18]</sup>      | –                                 | 0.1  | 0.5   | ns   |     |
| t <sub>SKEW2</sub>            | Output skew (rise-fall, nominal-inverted, divided-divided) <sup>[15, 18]</sup>  | –                                 | 0.5  | 1.0   | ns   |     |
| t <sub>SKEW3</sub>            | Output skew (rise-rise, fall-fall, different class outputs) <sup>[15, 18]</sup> | –                                 | 0.25 | 0.5   | ns   |     |
| t <sub>SKEW4</sub>            | Output skew (rise-fall, nominal-divided, divided-inverted) <sup>[15, 18]</sup>  | –                                 | 0.5  | 0.9   | ns   |     |
| t <sub>DEV</sub>              | Device-to-device skew <sup>[19, 20]</sup>                                       | –                                 | –    | 1.25  | ns   |     |
| t <sub>PD</sub>               | Propagation delay, REF rise to FB rise  | –0.25                             | 0.0  | +0.25 | ns   |     |
| t <sub>ODCV</sub>             | Output duty cycle variation <sup>[21]</sup>                                     | –0.65                             | 0.0  | +0.65 | ns   |     |
| t <sub>PWH</sub>              | Output HIGH time deviation from 50% <sup>[22]</sup>                             | –                                 | –    | 2.0   | ns   |     |
| t <sub>PWL</sub>              | Output LOW time deviation from 50% <sup>[22]</sup>                              | –                                 | –    | 1.5   | ns   |     |
| t <sub>ORISE</sub>            | Output rise time <sup>[22, 23]</sup>  | 0.15                              | 1.0  | 1.2   | ns   |     |
| t <sub>OFALL</sub>            | Output fall time <sup>[22, 23]</sup>  | 0.15                              | 1.0  | 1.2   | ns   |     |
| t <sub>LOCK</sub>             | PLL lock time <sup>[24]</sup>   | –                                 | –    | 0.5   | ms   |     |
| t <sub>JR</sub>               | Cycle-to-cycle output jitter  | RMS <sup>[19]</sup>               | –    | –     | 25   | ps  |
|                               |   | Peak <sup>[19]</sup>              | –    | 100   | 200  | ps  |

### Notes

11. The level to be set on FS is determined by the “normal” operating frequency (f<sub>NOM</sub>) of the V<sub>CO</sub> and Time Unit Generator (see Logic Block Diagram). Nominal frequency (f<sub>NOM</sub>) always appears at the outputs when they are operated in their undivided modes (see Table 2). The frequency appearing at the REF and FB inputs is f<sub>NOM</sub> when the output connected to FB is undivided. The frequency of the REF and FB inputs is f<sub>NOM</sub>/2 or f<sub>NOM</sub>/4 when the part is configured for a frequency multiplication using a divided output as the FB input.
12. Test measurement levels for the CY7B991V are TTL levels (1.5 V to 1.5 V). Test conditions assume signal transition times of 2 ns or less and output loading as shown in the AC Test Loads and Waveforms unless otherwise specified.
13. For all three state inputs, HIGH indicates a connection to V<sub>CC</sub>, LOW indicates a connection to GND, and MID indicates an open connection. Internal termination circuitry holds an unconnected input to V<sub>CC</sub>/2.
14. When the FS pin is selected HIGH, the REF input must not transition upon power up until V<sub>CC</sub> has reached 2.8 V.
15. SKEW is defined as the time between the earliest and the latest output transition among all outputs for which the same t<sub>U</sub> delay has been selected when all are loaded with 30 pF and terminated with 50Ω to V<sub>CC</sub>/2 (CY7B991V).
16. t<sub>SKEWPR</sub> is defined as the skew between a pair of outputs (XQ0 and XQ1) when all eight outputs are selected for 0t<sub>U</sub>.
17. t<sub>SKEW0</sub> is defined as the skew between outputs when they are selected for 0t<sub>U</sub>. Other outputs are divided or inverted but not shifted.
18. There are three classes of outputs: Nominal (multiple of t<sub>U</sub> delay), Inverted (4Q0 and 4Q1 only with 4F0 = 4F1 = HIGH), and Divided (3Qx and 4Qx only in Divide-by-2 or Divide-by-4 mode).
19. Guaranteed by statistical correlation. Tested initially and after any design or process changes that may affect these parameters.
20. t<sub>DEV</sub> is the output-to-output skew between any two devices operating under the same conditions (V<sub>CC</sub> ambient temperature, air flow, etc.)
21. t<sub>ODCV</sub> is the deviation of the output from a 50% duty cycle. Output pulse width variations are included in t<sub>SKEW2</sub> and t<sub>SKEW4</sub> specifications.
22. Specified with outputs loaded with 30 pF for the CY7B991V–5 and –7 devices. Devices are terminated through 50Ω to V<sub>CC</sub>/2. t<sub>PWH</sub> is measured at 2.0 V. t<sub>PWL</sub> is measured at 0.8 V.
23. t<sub>ORISE</sub> and t<sub>OFALL</sub> measured between 0.8 V and 2.0 V.
24. t<sub>LOCK</sub> is the time that is required before synchronization is achieved. This specification is valid only after V<sub>CC</sub> is stable and within normal operating limits. This parameter is measured from the application of a new signal or frequency at REF or FB until t<sub>PD</sub> is within specified limits.

## Switching Characteristics (-5 Option)

Over the Operating Range

| Parameter <sup>[25, 26]</sup> | Description   | CY7B991V-5                    |      |      | Unit |     |
|-------------------------------|---|-------------------------------|------|------|------|-----|
|                               |   | Min                           | Typ  | Max  |      |     |
| f <sub>NOM</sub>              | Operating clock frequency in MHz  | FS = LOW <sup>[25, 27]</sup>  | 15   | –    | 30   | MHz |
|                               |   | FS = MID <sup>[25, 27]</sup>  | 25   | –    | 50   |     |
|                               |   | FS = HIGH <sup>[25, 27]</sup> | 40   | –    | 80   |     |
| t <sub>RPWH</sub>             | REF pulse width HIGH measured at 1/2 × V <sub>CCQ</sub> threshold               | 3.65                          | –    | –    | ns   |     |
| t <sub>RPWL</sub>             | REF pulse width LOW measured at 1/2 × V <sub>CCQ</sub> threshold                | 3.65                          | –    | –    | ns   |     |
| t <sub>U</sub>                | Programmable skew unit  | See <a href="#">Table 1</a>   |      |      |      |     |
| t <sub>SKEWPR</sub>           | Zero output matched-pair skew (XQ0, XQ1) <sup>[28, 29]</sup>                    | –                             | 0.1  | 0.25 | ns   |     |
| t <sub>SKEW0</sub>            | Zero output skew (all outputs) <sup>[28, 29]</sup>                              | –                             | 0.25 | 0.5  | ns   |     |
| t <sub>SKEW1</sub>            | Output skew (rise-rise, fall-fall, same class outputs) <sup>[28, 30]</sup>      | –                             | 0.6  | 0.7  | ns   |     |
| t <sub>SKEW2</sub>            | Output skew (rise-fall, nominal-inverted, divided-divided) <sup>[28, 30]</sup>  | –                             | 0.5  | 1.0  | ns   |     |
| t <sub>SKEW3</sub>            | Output skew (rise-rise, fall-fall, different class outputs) <sup>[28, 30]</sup> | –                             | 0.5  | 0.7  | ns   |     |
| t <sub>SKEW4</sub>            | Output skew (rise-fall, nominal-divided, divided-inverted) <sup>[28, 30]</sup>  | –                             | 0.5  | 1.0  | ns   |     |
| t <sub>DEV</sub>              | Device-to-device skew <sup>[32, 33]</sup>                                       | –                             | –    | 1.25 | ns   |     |
| t <sub>PD</sub>               | Propagation delay, REF rise to FB rise  | –0.5                          | 0.0  | +0.5 | ns   |     |
| t <sub>ODCV</sub>             | Output duty cycle variation <sup>[34]</sup>                                     | –1.0                          | 0.0  | +1.0 | ns   |     |
| t <sub>PWH</sub>              | Output HIGH time deviation from 50% <sup>[35]</sup>                             | –                             | –    | 2.5  | ns   |     |
| t <sub>PWL</sub>              | Output LOW time deviation from 50% <sup>[35]</sup>                              | –                             | –    | 3    | ns   |     |
| t <sub>ORISE</sub>            | Output rise time <sup>[35, 36]</sup>  | 0.15                          | 1.0  | 1.5  | ns   |     |
| t <sub>OFALL</sub>            | Output fall time <sup>[35, 36]</sup>  | 0.15                          | 1.0  | 1.5  | ns   |     |
| t <sub>LOCK</sub>             | PLL lock time <sup>[36]</sup>   | –                             | –    | 0.5  | ms   |     |
| t <sub>JR</sub>               | Cycle-to-cycle output jitter  | RMS <sup>[32]</sup>           | –    | –    | 25   | ps  |
|                               |   | Peak-to-peak <sup>[32]</sup>  | –    | –    | 200  | ps  |

### Notes

25. The level to be set on FS is determined by the “normal” operating frequency (f<sub>NOM</sub>) of the V<sub>CO</sub> and Time Unit Generator (see [Logic Block Diagram](#)). Nominal frequency (f<sub>NOM</sub>) always appears at the outputs when they are operated in their undivided modes (see [Table 2](#)). The frequency appearing at the REF and FB inputs is f<sub>NOM</sub> when the output connected to FB is undivided. The frequency of the REF and FB inputs is f<sub>NOM</sub>/2 or f<sub>NOM</sub>/4 when the part is configured for a frequency multiplication using a divided output as the FB input.
26. Test measurement levels for the CY7B991V are TTL levels (1.5 V to 1.5 V). Test conditions assume signal transition times of 2 ns or less and output loading as shown in the AC Test Loads and Waveforms unless otherwise specified.
27. For all three state inputs, HIGH indicates a connection to V<sub>CC</sub>, LOW indicates a connection to GND, and MID indicates an open connection. Internal termination circuitry holds an unconnected input to V<sub>CC</sub>/2.
28. t<sub>SKEWPR</sub> is defined as the skew between a pair of outputs (XQ0 and XQ1) when all eight outputs are selected for 0t<sub>U</sub>.
29. t<sub>SKEW0</sub> is defined as the skew between outputs when they are selected for 0t<sub>U</sub>. Other outputs are divided or inverted but not shifted.
30. t<sub>DEV</sub> is the output-to-output skew between any two devices operating under the same conditions (V<sub>CC</sub> ambient temperature, air flow, etc.)
31. C<sub>L</sub> = 0 pF. For C<sub>L</sub> = 30 pF, t<sub>SKEW0</sub> = 0.35 ns.
32. SKEW is defined as the time between the earliest and the latest output transition among all outputs for which the same t<sub>U</sub> delay has been selected when all are loaded with 30 pF and terminated with 50Ω to V<sub>CC</sub>/2 (CY7B991V).
33. t<sub>ODCV</sub> is the deviation of the output from a 50% duty cycle. Output pulse width variations are included in t<sub>SKEW2</sub> and t<sub>SKEW4</sub> specifications.
34. Specified with outputs loaded with 30 pF for the CY7B991V–5 and –7 devices. Devices are terminated through 50Ω to V<sub>CC</sub>/2. t<sub>PWH</sub> is measured at 2.0 V. t<sub>PWL</sub> is measured at 0.8 V.
35. t<sub>ORISE</sub> and t<sub>OFALL</sub> measured between 0.8 V and 2.0 V.
36. t<sub>LOCK</sub> is the time that is required before synchronization is achieved. This specification is valid only after V<sub>CC</sub> is stable and within normal operating limits. This parameter is measured from the application of a new signal or frequency at REF or FB until t<sub>PD</sub> is within specified limits.

## Switching Characteristics (-7 Option)

Over the Operating Range

| Parameter <sup>[37, 38]</sup> | Description   | CY7B991V-7                    |     |      | Unit |     |
|-------------------------------|---|-------------------------------|-----|------|------|-----|
|                               |   | Min                           | Typ | Max  |      |     |
| f <sub>NOM</sub>              | Operating clock Frequency in MHz  | FS = LOW <sup>[37, 39]</sup>  | 15  | –    | 30   | MHz |
|                               |   | FS = MID <sup>[37, 39]</sup>  | 25  | –    | 50   |     |
|                               |   | FS = HIGH <sup>[37, 39]</sup> | 40  | –    | 80   |     |
| t <sub>RPWH</sub>             | REF pulse width HIGH measured at 1/2 × V <sub>CCQ</sub> threshold               | 3.65                          | –   | –    | ns   |     |
| t <sub>RPWL</sub>             | REF pulse width LOW measured at 1/2 × V <sub>CCQ</sub> threshold                | 3.65                          | –   | –    | ns   |     |
| t <sub>U</sub>                | Programmable skew unit  | See <a href="#">Table 1</a>   |     |      |      |     |
| t <sub>SKEWPR</sub>           | Zero output matched pair skew (XQ0, XQ1) <sup>[40, 41]</sup>                    | –                             | 0.1 | 0.25 | ns   |     |
| t <sub>SKEW0</sub>            | Zero output skew (All Outputs) <sup>[40, 42]</sup>                              | –                             | 0.3 | 0.75 | ns   |     |
| t <sub>SKEW1</sub>            | Output skew (rise-rise, fall-fall, same class outputs) <sup>[43, 44]</sup>      | –                             | 0.6 | 1.0  | ns   |     |
| t <sub>SKEW2</sub>            | Output skew (rise-fall, nominal-inverted, divided-divided) <sup>[40, 45]</sup>  | –                             | 1.0 | 1.5  | ns   |     |
| t <sub>SKEW3</sub>            | Output skew (rise-rise, fall-fall, different class outputs) <sup>[40, 45]</sup> | –                             | 0.7 | 1.2  | ns   |     |
| t <sub>SKEW4</sub>            | Output skew (rise-fall, nominal-divided, divided-inverted) <sup>[40, 45]</sup>  | –                             | 1.2 | 1.7  | ns   |     |
| t <sub>DEV</sub>              | Device-to-device skew <sup>[43, 46]</sup>                                       | –                             | –   | 1.65 | ns   |     |
| t <sub>PD</sub>               | Propagation delay, REF rise to FB rise  | –0.7                          | 0.0 | +0.7 | ns   |     |
| t <sub>ODCV</sub>             | Output duty cycle variation <sup>[46]</sup>                                     | –1.2                          | 0.0 | +1.2 | ns   |     |
| t <sub>PWH</sub>              | Output HIGH time deviation from 50% <sup>[47]</sup>                             | –                             | –   | 3    | ns   |     |
| t <sub>PWL</sub>              | Output LOW time deviation from 50% <sup>[47]</sup>                              | –                             | –   | 3.5  | ns   |     |
| t <sub>ORISE</sub>            | Output rise time <sup>[47, 48]</sup>  | 0.15                          | 1.5 | 2.5  | ns   |     |
| t <sub>OFALL</sub>            | Output fall time <sup>[47, 48]</sup>  | 0.15                          | 1.5 | 2.5  | ns   |     |
| t <sub>LOCK</sub>             | PLL lock time <sup>[49]</sup>   | –                             | –   | 0.5  | ms   |     |
| t <sub>JR</sub>               | Cycle-to-cycle output jitter  | RMS <sup>[50]</sup>           | –   | –    | 25   | ps  |
|                               |   | Peak-to-peak <sup>[50]</sup>  | –   | –    | 200  | ps  |

### Notes

37. The level to be set on FS is determined by the "normal" operating frequency (f<sub>NOM</sub>) of the V<sub>CO</sub> and Time Unit Generator (see [Logic Block Diagram](#)). Nominal frequency (f<sub>NOM</sub>) always appears at the outputs when they are operated in their undivided modes (see [Table 2](#)). The frequency appearing at the REF and FB inputs is f<sub>NOM</sub> when the output connected to FB is undivided. The frequency of the REF and FB inputs is f<sub>NOM</sub>/2 or f<sub>NOM</sub>/4 when the part is configured for a frequency multiplication using a divided output as the FB input.
38. Test measurement levels for the CY7B991V are TTL levels (1.5 V to 1.5 V). Test conditions assume signal transition times of 2 ns or less and output loading as shown in the AC Test Loads and Waveforms unless otherwise specified.
39. For all three state inputs, HIGH indicates a connection to V<sub>CC</sub>, LOW indicates a connection to GND, and MID indicates an open connection. Internal termination circuitry holds an unconnected input to V<sub>CC</sub>/2.
40. t<sub>SKEWPR</sub> is defined as the skew between a pair of outputs (XQ0 and XQ1) when all eight outputs are selected for 0t<sub>U</sub>.
41. t<sub>SKEW0</sub> is defined as the skew between outputs when they are selected for 0t<sub>U</sub>. Other outputs are divided or inverted but not shifted.
42. C<sub>L</sub> = 0 pF. For C<sub>L</sub> = 30 pF, t<sub>SKEW0</sub> = 0.35 ns.
43. SKEW is defined as the time between the earliest and the latest output transition among all outputs for which the same t<sub>U</sub> delay has been selected when all are loaded with 30 pF and terminated with 50Ω to V<sub>CC</sub>/2 (CY7B991V).
44. There are three classes of outputs: Nominal (multiple of t<sub>U</sub> delay), Inverted (4Q0 and 4Q1 only with 4F0 = 4F1 = HIGH), and Divided (3Qx and 4Qx only in Divide-by-2 or Divide-by-4 mode).
45. t<sub>DEV</sub> is the output-to-output skew between any two devices operating under the same conditions (V<sub>CC</sub> ambient temperature, air flow, etc.)
46. t<sub>ODCV</sub> is the deviation of the output from a 50% duty cycle. Output pulse width variations are included in t<sub>SKEW2</sub> and t<sub>SKEW4</sub> specifications.
47. Specified with outputs loaded with 30 pF for the CY7B991V-5 and -7 devices. Devices are terminated through 50Ω to V<sub>CC</sub>/2. t<sub>PWH</sub> is measured at 2.0 V. t<sub>PWL</sub> is measured at 0.8 V.
48. t<sub>ORISE</sub> and t<sub>OFALL</sub> measured between 0.8 V and 2.0 V.
49. t<sub>LOCK</sub> is the time that is required before synchronization is achieved. This specification is valid only after V<sub>CC</sub> is stable and within normal operating limits. This parameter is measured from the application of a new signal or frequency at REF or FB until t<sub>PD</sub> is within specified limits.
50. Guaranteed by statistical correlation. Tested initially and after any design or process changes that may affect these parameters.

### AC Timing Diagrams



### Ordering Information

| Speed (ps)     | Ordering Code  | Package Type                | Operating Range |
|----------------|----------------|-----------------------------|-----------------|
| <b>Pb-free</b> |                |                             |                 |
| 250            | CY7B991V-2JXC  | 32-pin PLCC                 | Commercial      |
|                | CY7B991V-2JXCT | 32-pin PLCC – Tape and Reel | Commercial      |
| 500            | CY7B991V-5JXC  | 32-pin PLCC                 | Commercial      |
|                | CY7B991V-5JXCT | 32-pin PLCC – Tape and Reel | Commercial      |
|                | CY7B991V-5JXI  | 32-pin PLCC                 | Industrial      |
|                | CY7B991V-5JXIT | 32-pin PLCC – Tape and Reel | Industrial      |
| 750            | CY7B991V-7JXC  | 32-pin PLCC                 | Commercial      |
|                | CY7B991V-7JXCT | 32-pin PLCC – Tape and Reel | Commercial      |

### Ordering Code Definitions



Package Diagram

Figure 11. 32-pin PLCC (0.453 x 0.553 Inches) J32 Package Outline, 51-85002



51-85002 \*E



## Acronyms

Table 3. Acronyms Used in this Document

| Acronym | Description                                |
|---------|--|
| CMOS    | Complementary Metal Oxide Semiconductor    |
| FB      | Feedback                                   |
| LVPSCB  | Low-Voltage Programmable Skew Clock Buffer |
| LVTTTL  | Low-Voltage Transistor-Transistor Logic    |
| PLL     | Phase-Locked Loop                          |
| PLCC    | Plastic Leaded Chip Carrier                |
| RF      | Reference Frequency                        |
| RMS     | Root Mean Square                           |
| VCO     | Voltage Controlled Oscillator              |

## Document Conventions

### Units of Measure

Table 4. Units of Measure

| Symbol | Unit of Measure |
|--------|-----------------|
| °C     | degree Celsius  |
| kΩ     | kiloohm         |
| μA     | microampere     |
| μs     | microsecond     |
| mA     | milliampere     |
| ms     | millisecond     |
| mW     | milliwatt       |
| MHz    | megahertz       |
| ns     | nanosecond      |
| Ω      | ohm             |
| pF     | picofarad       |
| ps     | picosecond      |
| V      | volt            |
| W      | watt            |

**Document History Page**

| Document Title: CY7B991V, 3.3 V RoboClock® Low Voltage Programmable Skew Clock Buffer |         |                 |                 |   |
|---|---------|-----------------|-----------------|---|
| Document Number: 38-07141   |         |                 |                 |   |
| Revision  | ECN     | Orig. of Change | Submission Date | Description of Change   |
| **  | 110250  | SZV             | 12/17/2001      | Change from Specification number: 38-00641 to 38-07141.   |
| *A  | 293239  | RGL             | 11/29/2004      | Updated <b>Features</b> :<br>Removed "Jitter < 200 ps peak-to-peak (< 25 ps RMS)".<br>Added "Jitter 100 ps (typical)".<br>Updated <b>Switching Characteristics (-2 option)</b> :<br>Added typical value of $t_{JR}$ parameter as "100 ps" corresponding to "Peak".<br>Updated <b>Ordering Information</b> :<br>Updated part numbers.  |
| *B  | 1199925 | KVM / AESA      | 06/29/2007      | Removed "Switching Characteristics (-2 option)".<br>Updated <b>Ordering Information</b> :<br>No change in part numbers.<br>Changed format only.   |
| *C  | 1286064 | AESA            | 07/18/2007      | Change status from Preliminary to Final.  |
| *D  | 2584293 | AESA            | 10/10/2008      | Added <b>Switching Characteristics (-2 option)</b> .<br>Updated to new template.  |
| *E  | 2761988 | CXQ             | 09/10/2009      | Updated <b>Test Mode</b> :<br>Replaced "100W resistor" with "100Ω resistor".<br>Updated <b>Ordering Information</b> :<br>No change in part numbers.<br>Replaced "Pb" with "pin" in "Package Type" column.   |
| *F  | 2905834 | CXQ             | 04/06/2010      | Updated <b>Ordering Information</b> :<br>Removed inactive part numbers CY7B991V-5JC, CY7B991V-5JCT, CY7B991V-7JC and CY7B991V-7JCT.<br>Updated <b>Package Diagram</b> .   |
| *G  | 3041840 | CXQ             | 09/29/2010      | Fixed various format and typographical errors.<br>Updated <b>Pinouts</b> :<br>Updated <b>Figure 1</b> (Fixed pin 8 label).<br>Updated <b>Pin Definitions</b> :<br>Added "Pin Number" column.<br>Updated <b>Electrical Characteristics</b> :<br>Removed values from "Max" column of $I_{LL}$ and $I_{OS}$ parameters and added the same values in "Min" column.<br>Removed note "These inputs are normally wired to $V_{CC}$ , GND, or left unconnected (actual threshold voltages vary as a percentage of $V_{CC}$ ). Internal termination resistors hold unconnected inputs at $V_{CC}/2$ . If these inputs are switched, the function and timing of the outputs may glitch and the PLL may require an additional $t_{LOCK}$ time before all datasheet limits are achieved." and its reference in "Description" column of PD parameter.<br>Completing Sunset Review. |
| *H  | 4161003 | CINM            | 10/16/2013      | Updated <b>Package Diagram</b> :<br>spec 51-85002 – Changed revision from *C to *D.<br>Updated to new template.<br>Completing Sunset Review.  |
| *I  | 4598452 | TAVA            | 12/16/2014      | Updated <b>Functional Description</b> :<br>Added "For a complete list of related resources, <a href="#">click here</a> ." at the end.<br>Added <b>AC Timing Diagrams</b> .  |

Document History Page (continued)

| Document Title: CY7B991V, 3.3 V RoboClock® Low Voltage Programmable Skew Clock Buffer |         |                 |                 |   |
|---|---------|-----------------|-----------------|---|
| Document Number: 38-07141   |         |                 |                 |   |
| Revision  | ECN     | Orig. of Change | Submission Date | Description of Change   |
| *J  | 4644120 | TAVA            | 01/28/2015      | Updated <a href="#">Switching Characteristics (-2 option)</a> :<br>Updated description of $t_{RPWH}$ and $t_{RPWL}$ parameters.<br>Changed minimum value of $t_{RPWH}$ parameter from 5 ns to 3.65 ns.<br>Changed minimum value of $t_{RPWL}$ parameter from 5 ns to 3.65 ns.<br>Updated <a href="#">Switching Characteristics (-5 Option)</a> :<br>Updated description of $t_{RPWH}$ and $t_{RPWL}$ parameters.<br>Changed minimum value of $t_{RPWH}$ parameter from 5 ns to 3.65 ns.<br>Changed minimum value of $t_{RPWL}$ parameter from 5 ns to 3.65 ns.<br>Updated <a href="#">Switching Characteristics (-7 Option)</a> :<br>Updated description of $t_{RPWH}$ and $t_{RPWL}$ parameters.<br>Changed minimum value of $t_{RPWH}$ parameter from 5 ns to 3.65 ns.<br>Changed minimum value of $t_{RPWL}$ parameter from 5 ns to 3.65 ns.<br>Updated <a href="#">Package Diagram</a> :<br>spec 51-85002 – Changed revision from *D to *E. |
| *K  | 5276098 | PSR             | 05/18/2016      | Updated <a href="#">Electrical Characteristics</a> :<br>Updated Note 8 (Replaced “FC = F < C” with “FC = F × C”).<br>Added <a href="#">Thermal Resistance</a> .<br>Updated to new template.   |
| *L  | 5507104 | PAWK            | 11/02/2016      | Updated to new template.<br>Completing Sunset Review.   |
| *M  | 6011930 | PAWK            | 01/03/2018      | Updated <a href="#">Ordering Information</a> :<br>Updated part numbers.<br>Updated to new template.   |

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