

# TLC2942

## HIGH-PERFORMANCE DUAL PHASE-LOCKED LOOP BUILDING BLOCK

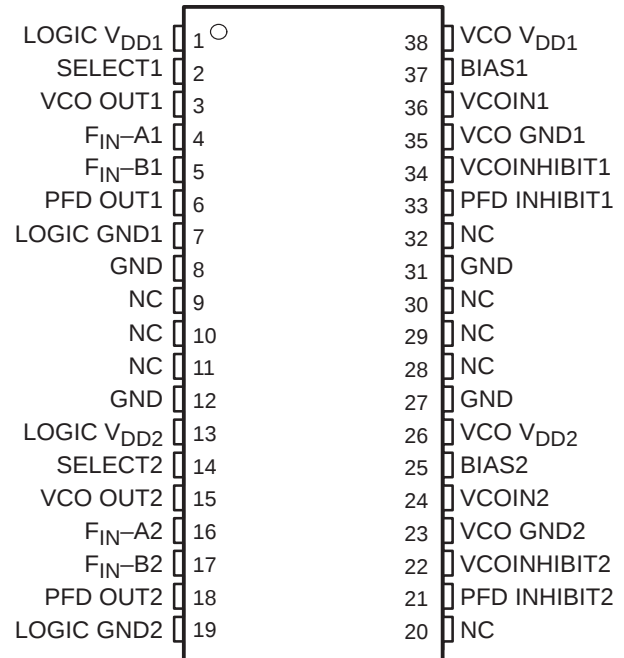
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- Dual TLC2932 by Multichip Module (MCM) Technology
- Voltage-Controlled Oscillator (VCO) Section:
  - Complete Oscillator Using Only One External Bias Resistor ( $R_{BIAS}$ )
  - Recommended Lock Frequency Range:
    - 22 MHz to 50 MHz ( $V_{DD} = 5\text{ V} \pm 5\%$ ,  $T_A = -20^\circ\text{C}$  to  $75^\circ\text{C}$ ,  $\times 1$  Output)
    - 11 MHz to 25 MHz ( $V_{DD} = 5\text{ V} \pm 5\%$ ,  $T_A = -20^\circ\text{C}$  to  $75^\circ\text{C}$ ,  $\times 1/2$  Output)
  - Output Frequency . . .  $\times 1$  and  $\times 1/2$  Selectable
- Includes a High-Speed Edge-Triggered Phase Frequency Detector (PFD) With Internal Charge Pump
- Independent VCO, PFD Power-Down Mode

### description

The TLC2942 is a multichip module product that uses two TLC2932 chips. The TLC2932 chip is composed of a voltage-controlled oscillator and an edge-triggered phase frequency detector. The oscillation frequency range of each VCO is set by an external bias resistor ( $R_{BIAS}$ ) and each VCO output can be a  $\times 1$  or  $\times 1/2$  output frequency. Each high speed PFD with internal charge pump detects the phase difference between the reference frequency input and signal frequency input from the external counter. The VCO and the PFD have inhibit functions that can be used as a power-down mode. The high-speed and stable oscillation capability of the TLC2932 makes the TLC2942 suitable for use in dual high-performance phase-locked loop (PLL) systems.

DB PACKAGE  
(TOP VIEW)



NC – No internal connection

AVAILABLE OPTIONS

| $T_A$                                     | PACKAGE            |
|-------------------------------------------|--------------------|
|                                           | SMALL OUTLINE (DB) |
| $-20^\circ\text{C}$ to $75^\circ\text{C}$ | TLC2942IDB         |



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**TEXAS  
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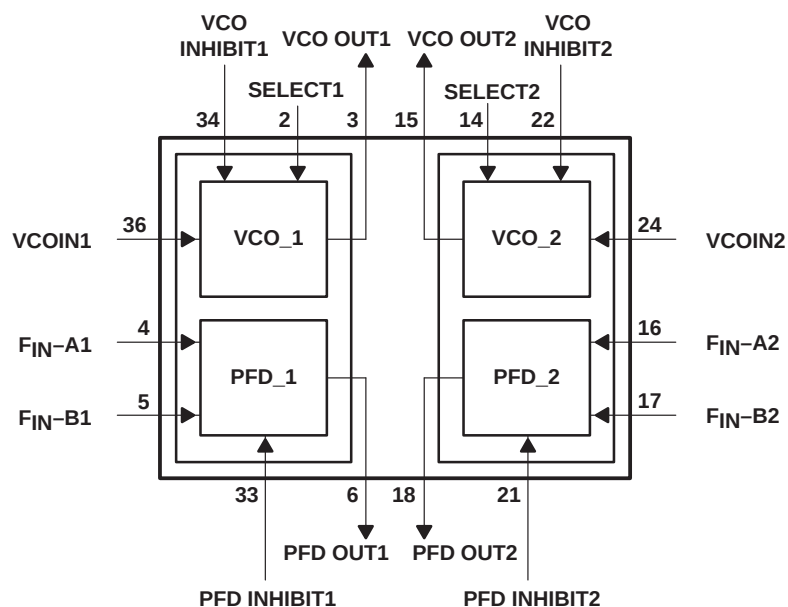
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### functional block diagram



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### Terminal Functions

| TERMINAL<br>NAME       | NO.                                    | I/<br>O | DESCRIPTION                                                                                                                                                                                                                                    |
|------------------------|----------------------------------------|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| BIAS1                  | 37                                     | I       | VCO1 bias supply. An external resistor (R <sub>BIAS1</sub> ) between VCO V <sub>DD1</sub> and BIAS1 supplies bias for adjusting the oscillation frequency range.                                                                               |
| BIAS2                  | 25                                     | I       | VCO2 bias supply. An external resistor (R <sub>BIAS2</sub> ) between VCO V <sub>DD2</sub> and BIAS2 supplies bias for adjusting the oscillation frequency range.                                                                               |
| F <sub>IN</sub> -A1    | 4                                      | I       | Input reference frequency 1. The frequency f(REF IN)1 is applied to F <sub>IN</sub> -A1.                                                                                                                                                       |
| F <sub>IN</sub> -A2    | 16                                     | I       | Input reference frequency 2. The frequency f(REF IN)2 is applied to F <sub>IN</sub> -A2.                                                                                                                                                       |
| F <sub>IN</sub> -B1    | 5                                      | I       | Input for VCO1 external counter output frequency f(F <sub>IN</sub> -B)1. F <sub>IN</sub> -B1 is nominally provided from the external counter (see Figure 28).                                                                                  |
| F <sub>IN</sub> -B2    | 17                                     | I       | Input for VCO2 external counter output frequency f(F <sub>IN</sub> -B)2. F <sub>IN</sub> -B2 is nominally provided from the external counter (see Figure 28).                                                                                  |
| GND                    | 8, 12,<br>27,31                        |         | Ground                                                                                                                                                                                                                                         |
| LOGIC V <sub>DD1</sub> | 1                                      |         | Logic1 supply voltage. LOGIC V <sub>DD1</sub> supplies voltage to internal logic 1. LOGIC V <sub>DD1</sub> should be separate from the other supply lines to reduce cross-coupling between power supplies.                                     |
| LOGIC V <sub>DD2</sub> | 13                                     |         | Logic2 supply voltage. LOGIC V <sub>DD2</sub> supplies voltage to internal logic 2. LOGIC V <sub>DD2</sub> should be separate from the other supply lines to reduce cross-coupling between power supplies.                                     |
| LOGIC GND1             | 7                                      |         | Ground for the internal logic 1                                                                                                                                                                                                                |
| LOGIC GND2             | 19                                     |         | Ground for the internal logic 2                                                                                                                                                                                                                |
| NC                     | 9, 10, 11,<br>20, 28,<br>29, 30,<br>32 |         | No internal connection                                                                                                                                                                                                                         |
| PFD INHIBIT1           | 33                                     | I       | PFD inhibit 1 control. When PFD INHIBIT1 is high, PFD OUT1 is in the high-impedance state (see Table 4).                                                                                                                                       |
| PFD INHIBIT2           | 21                                     | I       | PFD inhibit 2 control. When PFD INHIBIT2 is high, PFD OUT2 is in the high-impedance state (see Table 5).                                                                                                                                       |
| PFD OUT1               | 6                                      | O       | PFD1 output. When the PFD INHIBIT1 is high, PFD OUT1 is in the high-impedance state.                                                                                                                                                           |
| PFD OUT2               | 18                                     | O       | PFD2 output. When the PFD INHIBIT2 is high, PFD OUT2 is in the high-impedance state.                                                                                                                                                           |
| SELECT1                | 2                                      | I       | VCO1 output frequency select. When SELECT1 is high, the VCO1 output frequency is $\times 1/2$ and when SELECT1 is low, the output frequency is $\times 1$ (see Table 1).                                                                       |
| SELECT2                | 14                                     | I       | VCO2 output frequency select. When SELECT2 is high, the VCO2 output frequency is $\times 1/2$ and when SELECT2 is low, the output frequency is $\times 1$ (see Table 1).                                                                       |
| VCO GND1               | 35                                     |         | Ground for VCO1                                                                                                                                                                                                                                |
| VCO GND2               | 23                                     |         | Ground for VCO2                                                                                                                                                                                                                                |
| VCOINHIBIT1            | 34                                     | I       | VCO1 inhibit control. When VCOINHIBIT1 is high, VCO OUT1 is low (see Table 2).                                                                                                                                                                 |
| VCOINHIBIT2            | 22                                     | O       | VCO2 inhibit control. When VCOINHIBIT2 is high, VCO OUT2 is low (see Table 3).                                                                                                                                                                 |
| VCO OUT1               | 3                                      | O       | VCO1 output. When VCOINHIBIT1 is high, VCO OUT1 is low.                                                                                                                                                                                        |
| VCO OUT2               | 15                                     |         | VCO2 output. When VCOINHIBIT2 is high, VCO OUT2 is low.                                                                                                                                                                                        |
| VCO V <sub>DD1</sub>   | 38                                     |         | VCO1 supply voltage. VCO V <sub>DD1</sub> supplies voltage for VCO1. VCO V <sub>DD1</sub> should be separated from LOGIC V <sub>DD1</sub> and LOGIC V <sub>DD2</sub> and VCO V <sub>DD2</sub> to reduce cross-coupling between power supplies. |
| VCO V <sub>DD2</sub>   | 26                                     |         | VCO2 supply voltage. VCO V <sub>DD2</sub> supplies voltage for VCO2. VCO V <sub>DD2</sub> should be separated from LOGIC V <sub>DD1</sub> and LOGIC V <sub>DD2</sub> and VCO V <sub>DD1</sub> to reduce cross-coupling between power supplies. |
| VCOIN1                 | 36                                     | I       | VCO1 control voltage input. Nominally the external loop filter output1 connects to VCOIN1 to control VCO1 oscillation frequency.                                                                                                               |
| VCOIN2                 | 24                                     | I       | VCO2 control voltage input. Nominally the external loop filter output2 connects to VCOIN2 to control VCO2 oscillation frequency.                                                                                                               |



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### detailed description

#### multichip module

The TLC2942 is a multichip module (MCM) product that uses two TLC2932 chips. A newly developed lead frame for TLC2942IBD is specially shaped and cut in the package to electrically isolate one chip from another. The two chips are completely independent from each other to perform the best stable oscillation and locking. If asynchronous locking operation is required for these two PLL blocks, each TLC2942 VCO and PFD can achieve the same stability as the single chip TLC2932IPW.

Three NC terminals are on both sides of the package between chip1 and chip2 due to the lead frame shape. To avoid performance degradation, special attention is needed for each PLL block PCB layout especially for supply voltage lines and GND patterns.

#### voltage-controlled oscillator (VCO)

VCO1 and VCO2 have the same typical characteristics. Each VCO oscillation frequency is determined by an external resistor ( $R_{BIAS}$ ) connected between each VCO  $V_{DD}$  and BIAS terminals. The oscillation frequency and range depends on this register value. The bias resistor value for the minimum temperature coefficient is nominally 3.3 k $\Omega$  with  $V_{DD}$  = 3 V and nominally 2.2 k $\Omega$  with  $V_{DD}$  = 5 V. For the lock frequency range refer to the recommended operating conditions. Figure 1 shows the typical frequency variation and VCO control voltage.

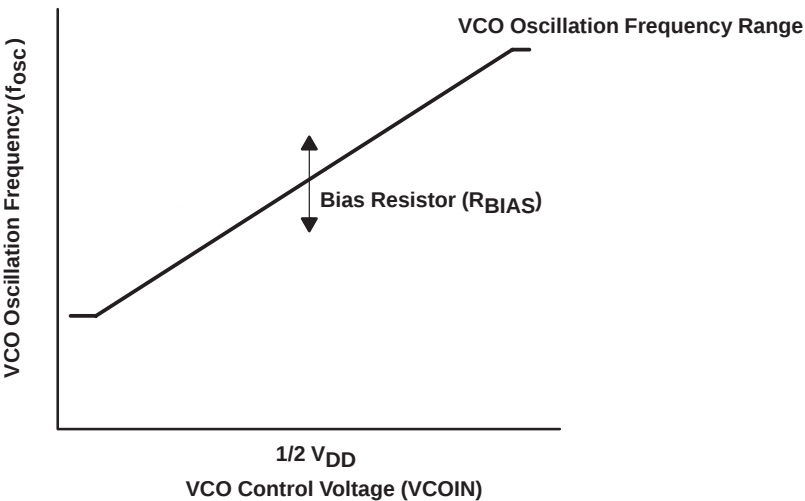


Figure 1. VCO1 and VCO2 Oscillation Frequency

#### VCO output frequency 1/2 divider

SELECT1 and SELECT2 select between  $f_{osc}$  and  $1/2 f_{osc}$  for the VCO output frequencies as shown in Table 1.

Table 1. SELECT1 and SELECT2 Function Table

| SELECT1 | VCO1 OUTPUT FREQUENCY | SELECT2 | VCO2 OUTPUT FREQUENCY |
|---------|-----------------------|---------|-----------------------|
| Low     | $f_{osc1}$            | Low     | $f_{osc2}$            |
| High    | $1/2 f_{osc1}$        | High    | $1/2 f_{osc2}$        |

### VCO inhibit function

Each VCO has an externally controlled inhibit function that inhibits the VCO output. The VCO oscillation is stopped during a high level on VCOINHIBIT, so the high level can also be used as the power-down mode. The VCO output maintains a low level during the power-down mode (see Table 2 and Table 3).

**Table 2. VCO1 Inhibit Function**

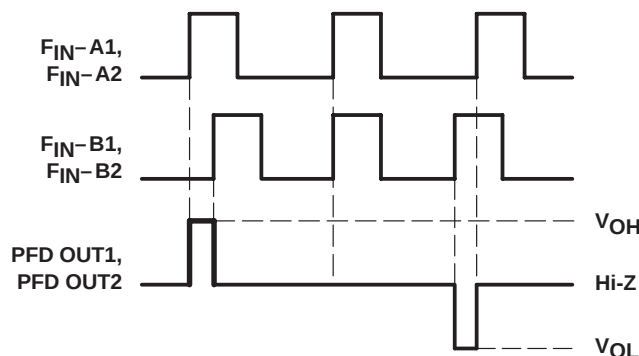
| VCOINHIBIT1 | VCO1 OSCILLATOR | VCO OUT1 | VCO1 I <sub>DD</sub> |
|-------------|-----------------|----------|----------------------|
| Low         | Active          | Active   | Normal               |
| High        | Stop            | Low      | Power Down           |

**Table 3. VCO2 Inhibit Function**

| VCOINHIBIT2 | VCO2 OSCILLATOR | VCO OUT2 | VCO2 I <sub>DD</sub> |
|-------------|-----------------|----------|----------------------|
| Low         | Active          | Active   | Normal               |
| High        | Stop            | Low      | Power Down           |

### PFD operation

The PFD is a high-speed, edge-triggered detector with an internal charge pump. The PFD detects the phase difference between two frequency inputs supplied to F<sub>IN</sub>-A and F<sub>IN</sub>-B as shown in Figure 2. Nominally the reference is supplied to F<sub>IN</sub>-A, and the frequency from the external counter output is fed to F<sub>IN</sub>-B.



**Figure 2. PFD Function Timing Chart**

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PFD output control

A high level on PFD INHIBIT places the PFD OUT in the high-impedance state and the PFD stops phase detection as shown in Table 4 and Table 5. A high level on PFD INHIBIT also can be used as the power-down mode for the PFD.

Table 4. PFD1 Inhibit Function

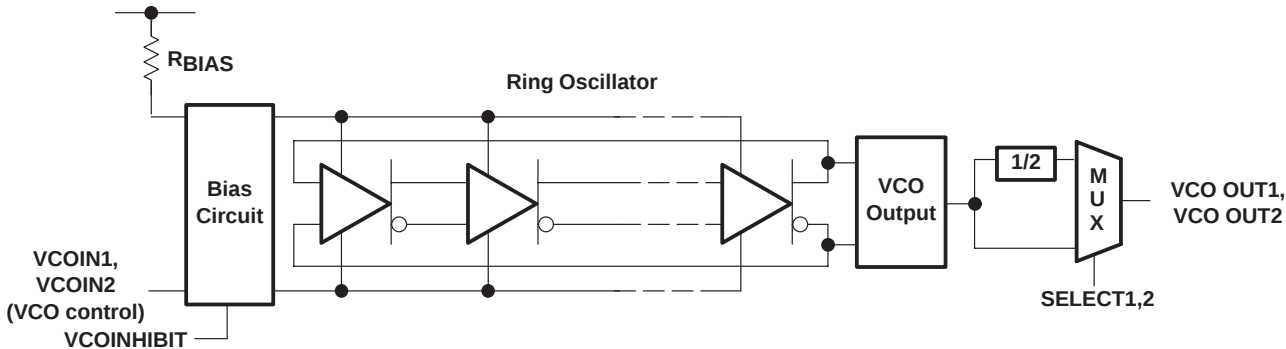
| PFD INHIBIT1 | DETECTION | PFD OUT1 | PFD1 I <sub>DD</sub> |
|--------------|-----------|----------|----------------------|
| Low          | Active    | Active   | Normal               |
| High         | Stop      | Hi-Z     | Power Down           |

Table 5. PFD2 Inhibit Function Table

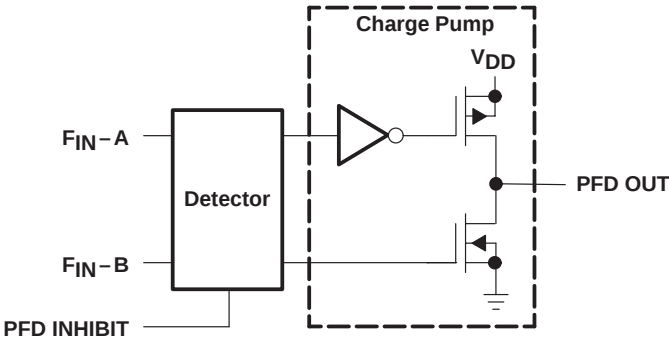
| PFD INHIBIT2 | DETECTION | PFD OUT2 | PFD2 I <sub>DD</sub> |
|--------------|-----------|----------|----------------------|
| Low          | Active    | Active   | Normal               |
| High         | Stop      | Hi-Z     | Power Down           |

schematics

VCO block schematic (VCO1, VCO2)



PFD block schematic (PFD1, PFD2)



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### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)<sup>†</sup>

|                                                                                         |                            |
|-----------------------------------------------------------------------------------------|----------------------------|
| Supply voltage (each supply), $V_{DD}$ (see Note 1)                                     | 7 V                        |
| Input voltage range (each input), $V_I$ (see Note 1)                                    | –0.5 V to $V_{DD} + 0.5$ V |
| Input current (each input), $I_I$                                                       | ±20 mA                     |
| Output current (each output), $I_O$                                                     | ±20 mA                     |
| Continuous total power dissipation, at (or below) $T_A = 25^\circ\text{C}$ (see Note 2) | 1160 mW                    |
| Operating free-air temperature range, $T_A$                                             | –20°C to 75°C              |
| Storage temperature range, $T_{stg}$                                                    | –65°C to 150°C             |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds                            | 260°C                      |

<sup>†</sup> Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions for extended periods may affect device reliability.

NOTES: 1. All voltage values are with respect to network GND.

2. For operation above 25°C free-air temperature, derate linearly at the rate of 9.3 mW/°C.

### recommended operating conditions

|                                                           |                | MIN  | NOM | MAX      | UNIT |
|-----------------------------------------------------------|----------------|------|-----|----------|------|
| Supply voltage, $V_{DD}$ (each supply, see Note 3)        | $V_{DD} = 3$ V | 2.85 | 3   | 3.15     | V    |
|                                                           | $V_{DD} = 5$ V | 4.75 | 5   | 5.25     |      |
| Input voltage, $V_I$ , (all inputs except VCOIN1, VCOIN2) |                | 0    |     | $V_{DD}$ | V    |
| Output current, $I_O$ (each output)                       |                | 0    |     | ±2       | mA   |
| VCO control voltage at each VCOIN1, VCOIN2                |                | 0.9  |     | $V_{DD}$ | V    |
| Lock frequency, (each VCO) (×1 output)                    | $V_{DD} = 3$ V | 14   |     | 21       | MHz  |
|                                                           | $V_{DD} = 5$ V | 22   |     | 50       |      |
| Lock frequency, (each VCO) (×1/2 output)                  | $V_{DD} = 3$ V | 7    |     | 10.5     | MHz  |
|                                                           | $V_{DD} = 5$ V | 11   |     | 25       |      |
| Bias resistor, (each BIAS), $R_{BIAS1}$ , $R_{BIAS2}$     | $V_{DD} = 3$ V | 2.2  | 3.3 | 4.3      | kΩ   |
|                                                           | $V_{DD} = 5$ V | 1.5  | 2.2 | 3.3      |      |
| Operating temperature, $T_A$                              |                | –20  |     | 75       | °C   |

NOTE 3: It is recommended that LOGIC  $V_{DD1}$  and VCO  $V_{DD1}$  or LOGIC  $V_{DD2}$  and VCO  $V_{DD2}$  should be at the same voltage and separated from each other.

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### VCO1, VCO2 electrical characteristics, $V_{DD} = 3\text{ V}$ , $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER            |                                          | TEST CONDITIONS                               | MIN | TYP  | MAX     | UNIT             |
|----------------------|------------------------------------------|-----------------------------------------------|-----|------|---------|------------------|
| $V_{OH}$             | High-level output voltage                | $I_{OH} = -2\text{ mA}$                       | 2.4 |      |         | V                |
| $V_{OL}$             | Low-level output voltage                 | $I_{OL} = 2\text{ mA}$                        |     |      | 0.3     | V                |
| $V_{IT}$             | Input threshold voltage                  | SELECT1, SELECT2,<br>VCOINHIBIT2, VCOINHIBIT1 | 0.9 | 1.5  | 2.1     | V                |
| $I_I$                | Input current                            | SELECT1, SELECT2,<br>VCOINHIBIT2, VCOINHIBIT1 |     |      | $\pm 1$ | $\mu\text{A}$    |
| $Z_i(\text{VCOIN})$  | Input impedance                          | VCOIN2, VCOIN1                                |     | 10   |         | $\text{M}\Omega$ |
| $I_{DD}(\text{INH})$ | VCO supply current (inhibit) (each chip) | See Note 4                                    |     | 0.01 | 1       | $\mu\text{A}$    |
| $I_{DD}(\text{VCO})$ | VCO supply current (each chip)           | See Note 5                                    |     | 5    | 15      | $\text{mA}$      |

NOTES: 4. The current into VCO  $V_{DD}$  and LOGIC  $V_{DD}$  when VCOINHIBIT =  $V_{DD}$ , and the PFD is inhibited.

5. The current into VCO  $V_{DD}$  and LOGIC  $V_{DD}$  when VCOIN =  $1/2 V_{DD}$ ,  $R_{BIAS} = 3.3\text{ k}\Omega$ , VCOINHIBIT = GND, and the PFD is inhibited.

### PFD1, PFD2 electrical characteristic, $V_{DD} = 3\text{ V}$ , $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER            |                                         | TEST CONDITIONS                                          | MIN | TYP | MAX     | UNIT             |
|----------------------|-----------------------------------------|----------------------------------------------------------|-----|-----|---------|------------------|
| $V_{OH}$             | High-level output voltage               | $I_{OH} = -2\text{ mA}$                                  | 2.7 |     |         | V                |
| $V_{OL}$             | Low-level output voltage                | $I_{OL} = 2\text{ mA}$                                   |     |     | 0.2     | V                |
| $I_{OZ}$             | High-impedance output current           | PFD INHIBIT = high,<br>$V_O = V_{DD}$ or GND             |     |     | $\pm 1$ | $\mu\text{A}$    |
| $V_{IH}$             | High-level input voltage                | $F_{IN-A1}$ , $F_{IN-B1}$ ,<br>$F_{IN-A2}$ , $F_{IN-B2}$ | 2.7 |     |         | V                |
| $V_{IL}$             | Low-level input voltage                 | $F_{IN-A1}$ , $F_{IN-B1}$ ,<br>$F_{IN-A2}$ , $F_{IN-B2}$ |     |     | 0.5     | V                |
| $V_{IT}$             | Input threshold voltage                 | PFD INHIBIT2, PFD INHIBIT1                               | 0.9 | 1.5 | 2.1     | V                |
| $C_i$                | Input capacitance                       | $F_{IN-A1}$ , $F_{IN-B1}$ ,<br>$F_{IN-A2}$ , $F_{IN-B2}$ |     | 5   |         | pF               |
| $Z_i$                | Input impedance                         | $F_{IN-A1}$ , $F_{IN-B1}$ ,<br>$F_{IN-A2}$ , $F_{IN-B2}$ |     | 10  |         | $\text{M}\Omega$ |
| $I_{DD}(Z)$          | High-impedance state PFD supply current | See Note 6                                               |     | 0.1 | 1       | $\mu\text{A}$    |
| $I_{DD}(\text{PFD})$ | PFD supply current                      | See Note 7                                               |     | 0.1 | 1.5     | $\text{mA}$      |

NOTES: 6. The current into LOGIC  $V_{DD}$ , when  $F_{IN-A}$  and  $F_{IN-B} = \text{GND}$ , PFD INHIBIT =  $V_{DD}$ , no load, and VCO OUT is inhibited.

7. The current into LOGIC  $V_{DD}$  when  $F_{IN-A}$  and  $F_{IN-B} = 1\text{ MHz}$  with  $V_{I(PP)} = 3\text{ V}$  rectangular wave, PFD INHIBIT = GND, no load, and VCO OUT is inhibited.

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### VCO1, VCO2 operating characteristics, $V_{DD} = 3\text{ V}$ , $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER                                                           | TEST CONDITIONS                                                                                                                           | MIN | TYP  | MAX | UNIT                |
|---------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|-----|------|-----|---------------------|
| $f_{osc}$ Operating oscillation frequency                           | $R_{BIAS1}, R_{BIAS2} = 3.3\text{ k}\Omega$ ,<br>$V_{COIN1}, V_{COIN2} = 1/2 V_{DD}$                                                      | 15  | 19   | 23  | MHz                 |
| $t_{s(fosc)}$ Time to stable oscillation                            | See Note 8                                                                                                                                |     |      | 10  | $\mu\text{s}$       |
| $t_r$ Rise time                                                     | $C_L = 15\text{ pF}$ , See Figure 3                                                                                                       |     | 7    | 14  | ns                  |
|                                                                     | $C_L = 50\text{ pF}$ , See Figure 3                                                                                                       |     | 14   |     |                     |
| $t_f$ Fall time                                                     | $C_L = 15\text{ pF}$ , See Figure 3                                                                                                       |     | 6    | 12  | ns                  |
|                                                                     | $C_L = 50\text{ pF}$ , See Figure 3                                                                                                       |     | 10   |     |                     |
| Duty cycle at VCO OUT                                               | $R_{BIAS1}, R_{BIAS2} = 3.3\text{ k}\Omega$ ,<br>$V_{COIN1}, V_{COIN2} = 1/2 V_{DD}$                                                      | 45% | 50%  | 55% |                     |
| $\alpha(f_{osc})$ Temperature coefficient of oscillation frequency  | $R_{BIAS1}, R_{BIAS2} = 3.3\text{ k}\Omega$ ,<br>$V_{COIN1}, V_{COIN2} = 1/2 V_{DD}$ ,<br>$T_A = -20^\circ\text{C}$ to $75^\circ\text{C}$ |     | 0.04 |     | $\%/^\circ\text{C}$ |
| $k_{SVS(fosc)}$ Supply voltage coefficient of oscillation frequency | $R_{BIAS1}, R_{BIAS2} = 3.3\text{ k}\Omega$ ,<br>$V_{COIN1}, V_{COIN2} = 1.5\text{ V}$ ,<br>$V_{DD} = 2.85\text{ V}$ to $3.15\text{ V}$   |     | 0.02 |     | $\%/mV$             |
| Jitter absolute (see Note 9)                                        | $R_{BIAS1} = 3.3\text{ k}\Omega$                                                                                                          |     | 100  |     | ps                  |

NOTES: 8. The time period to stabilize the VCO oscillation frequency after VCOINHIBIT is changed to a low level.

9. The LPF circuit is shown in Figure 28 with calculated values listed in Table 9. Jitter performance is highly dependent on circuit layout and external device characteristics. The jitter specification was made with a carefully designed PCB with no device socket.

### PFD1, PFD2 operating characteristics, $V_{DD} = 3\text{ V}$ , $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER                                         | TEST CONDITIONS                     | MIN | TYP | MAX | UNIT |
|---------------------------------------------------|-------------------------------------|-----|-----|-----|------|
| $f_{max}$ Maximum operating frequency             |                                     | 20  |     |     | MHz  |
| $t_{PLZ}$ PFD output disable time from low level  | See Figures 4 and 5 and Table 4     |     | 21  | 50  | ns   |
| $t_{PHZ}$ PFD output disable time from high level |                                     |     | 23  | 50  |      |
| $t_{PZL}$ PFD output enable time to low level     |                                     |     | 11  | 30  | ns   |
| $t_{PZH}$ PFD output enable time to high level    |                                     |     | 10  | 30  |      |
| $t_r$ Rise time                                   | $C_L = 15\text{ pF}$ , See Figure 4 |     | 2.3 | 10  | ns   |
| $t_f$ Fall time                                   |                                     |     | 2.1 | 10  | ns   |



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### VCO1, VCO2 electrical characteristics, $V_{DD} = 5\text{ V}$ , $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER            |                                          | TEST CONDITIONS                               | MIN | TYP  | MAX     | UNIT             |
|----------------------|------------------------------------------|-----------------------------------------------|-----|------|---------|------------------|
| $V_{OH}$             | High-level output voltage                | $I_{OH} = -2\text{ mA}$                       | 4   |      |         | V                |
| $V_{OL}$             | Low-level output voltage                 | $I_{OL} = 2\text{ mA}$                        |     |      | 0.5     | V                |
| $V_{IT}$             | Input threshold voltage                  | SELECT1, SELECT2,<br>VCOINHIBIT1, VCOINHIBIT2 | 1.5 | 2.5  | 3.5     | V                |
| $I_I$                | Input current                            | SELECT1, SELECT2,<br>VCOINHIBIT1, VCOINHIBIT2 |     |      | $\pm 1$ | $\mu\text{A}$    |
| $Z_i(\text{VCOIN})$  | Input impedance                          | VCOIN1, VCOIN2                                |     | 10   |         | $\text{M}\Omega$ |
| $I_{DD}(\text{INH})$ | VCO supply current (inhibit) (each chip) | See Note 4                                    |     | 0.01 | 1       | $\mu\text{A}$    |
| $I_{DD}(\text{VCO})$ | VCO supply current (each chip)           | See Note 10                                   |     | 15   | 35      | $\text{mA}$      |

NOTES: 4. The current into VCO  $V_{DD}$  and LOGIC  $V_{DD}$  when VCOINHIBIT =  $V_{DD}$ , and the PFD is inhibited.

10. The current into VCO  $V_{DD}$  and LOGIC  $V_{DD}$  when VCOIN =  $1/2 V_{DD}$ ,  $R_{BIAS} = 2.2\text{ k}\Omega$ , VCOINHIBIT = GND, and the PFD is inhibited.

### PFD1, PFD2 electrical characteristics, $V_{DD} = 5\text{ V}$ , $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER            |                                         | TEST CONDITIONS                                             | MIN | TYP  | MAX     | UNIT             |
|----------------------|-----------------------------------------|-------------------------------------------------------------|-----|------|---------|------------------|
| $V_{OH}$             | High-level output voltage               | $I_{OH} = 2\text{ mA}$                                      | 4.5 |      |         | V                |
| $V_{OL}$             | Low-level output voltage                | $I_{OL} = 2\text{ mA}$                                      |     |      | 0.2     | V                |
| $I_{OZ}$             | High-impedance output current           | PFD INHIBIT1, PFD INHIBIT2 = high,<br>$V_O = V_{DD}$ or GND |     |      | $\pm 1$ | $\mu\text{A}$    |
| $V_{IH}$             | High-level input voltage                | $F_{IN-A1}$ , $F_{IN-B1}$ ,<br>$F_{IN-A2}$ , $F_{IN-B2}$    | 4.5 |      |         | V                |
| $V_{IL}$             | Low-level input voltage                 | $F_{IN-A1}$ , $F_{IN-B1}$ ,<br>$F_{IN-A2}$ , $F_{IN-B2}$    |     |      | 1       | V                |
| $V_{IT}$             | Input threshold voltage                 | PFD INHIBIT2,<br>PFD INHIBIT1                               | 1.5 | 2.5  | 3.5     | V                |
| $C_i$                | Input capacitance                       | $F_{IN-A1}$ , $F_{IN-B1}$ ,<br>$F_{IN-A2}$ , $F_{IN-B2}$    |     | 5    |         | pF               |
| $Z_i$                | Input impedance                         | $F_{IN-A1}$ , $F_{IN-B1}$ ,<br>$F_{IN-A2}$ , $F_{IN-B2}$    |     | 10   |         | $\text{M}\Omega$ |
| $I_{DD}(Z)$          | High-impedance state PFD supply current | See Note 6                                                  |     | 0.1  | 1       | $\mu\text{A}$    |
| $I_{DD}(\text{PFD})$ | PFD supply current (each chip)          | See Note 11                                                 |     | 0.15 | 3       | $\text{mA}$      |

NOTES: 6. The current into LOGIC  $V_{DD}$ , when  $F_{IN-A}$  and  $F_{IN-B} = \text{GND}$ , PFD INHIBIT =  $V_{DD}$ , no load, and VCO OUT is inhibited.

11. The current into LOGIC  $V_{DD}$  when  $F_{IN-A}$  and  $F_{IN-B} = 1\text{ MHz}$  with  $V_{I(PP)} = 5\text{-V}$  rectangular wave, PFD INHIBIT = GND, no load, and VCO OUT is inhibited.



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### VCO1, VCO2 operating characteristics, $V_{DD} = 5\text{ V}$ , $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER                                                           | TEST CONDITIONS                                                                                                                               | MIN | TYP   | MAX | UNIT                |
|---------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|-----|-------|-----|---------------------|
| $f_{osc}$ Operating oscillation frequency                           | $R_{BIAS1}, R_{BIAS2} = 2.2\text{ k}\Omega$ ,<br>$V_{COIN1}, V_{COIN2} = 1/2 V_{DD}$                                                          | 32  | 41    | 50  | MHz                 |
| $t_{s(fosc)}$ Time to stable oscillation                            | See Note 8                                                                                                                                    |     |       | 10  | $\mu\text{s}$       |
| $t_r$ Rise time                                                     | $C_L = 15\text{ pF}$ , See Figure 3                                                                                                           |     | 5.5   | 10  | ns                  |
|                                                                     | $C_L = 50\text{ pF}$ , See Figure 3                                                                                                           |     | 8     |     |                     |
| $t_f$ Fall time                                                     | $C_L = 15\text{ pF}$ , See Figure 3                                                                                                           |     | 5     | 10  | ns                  |
|                                                                     | $C_L = 50\text{ pF}$ , See Figure 3                                                                                                           |     | 6     |     |                     |
| Duty cycle at VCO OUT                                               | $R_{BIAS1}, R_{BIAS2} = 2.2\text{ k}\Omega$ ,<br>$V_{COIN1}, V_{COIN2} = 1/2 V_{DD}$                                                          | 45% | 50%   | 55% |                     |
| $\alpha(f_{osc})$ Temperature coefficient of oscillation frequency  | $R_{BIAS1}, R_{BIAS2} = 2.2\text{ k}\Omega$ ,<br>$V_{COIN1}, V_{COIN2} = 1/2 V_{DD}$ ,<br>$T_{ope} = -20^\circ\text{C}$ to $75^\circ\text{C}$ |     | 0.06  |     | $\%/^\circ\text{C}$ |
| $k_{SVS(fosc)}$ Supply voltage coefficient of oscillation frequency | $R_{BIAS1}, R_{BIAS2} = 2.2\text{ k}\Omega$ ,<br>$V_{COIN1}, V_{COIN2} = 2.5\text{ V}$ ,<br>$V_{DD} = 4.75\text{ V}$ to $5.25\text{ V}$       |     | 0.006 |     | $\%/mV$             |
| Jitter absolute (see Note 9)                                        | $R_{BIAS1} = 3.3\text{ k}\Omega$                                                                                                              |     | 100   |     | ps                  |

NOTES: 8. The time period to stabilize the VCO oscillation frequency after VCOINHIBIT is changed to a low level.

9. The LPF circuit is shown in Figure 28 with calculated values listed in Table 9. Jitter performance is highly dependent on circuit layout and external device characteristics. The jitter specification was made with a carefully designed PCB with no device socket.

### PFD1, PFD2 operating characteristics, $V_{DD} = 5\text{ V}$ , $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER                                         | TEST CONDITIONS                     | MIN | TYP | MAX | UNIT |
|---------------------------------------------------|-------------------------------------|-----|-----|-----|------|
| $f_{max}$ Maximum operating frequency             |                                     | 40  |     |     | MHz  |
| $t_{PLZ}$ PFD output disable time from low level  | See Figures 4 and 5 and Table 4     |     | 21  | 40  | ns   |
| $t_{PHZ}$ PFD output disable time from high level |                                     |     | 20  | 40  |      |
| $t_{PZL}$ PFD output enable time to low level     |                                     |     | 7.3 | 20  | ns   |
| $t_{PZH}$ PFD output enable time to high level    |                                     |     | 6.5 | 20  |      |
| $t_r$ Rise time                                   | $C_L = 15\text{ pF}$ , See Figure 4 |     | 2.3 | 10  | ns   |
| $t_f$ Fall time                                   |                                     |     | 1.7 | 10  | ns   |



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### PARAMETER MEASUREMENT INFORMATION

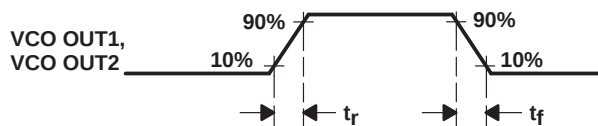
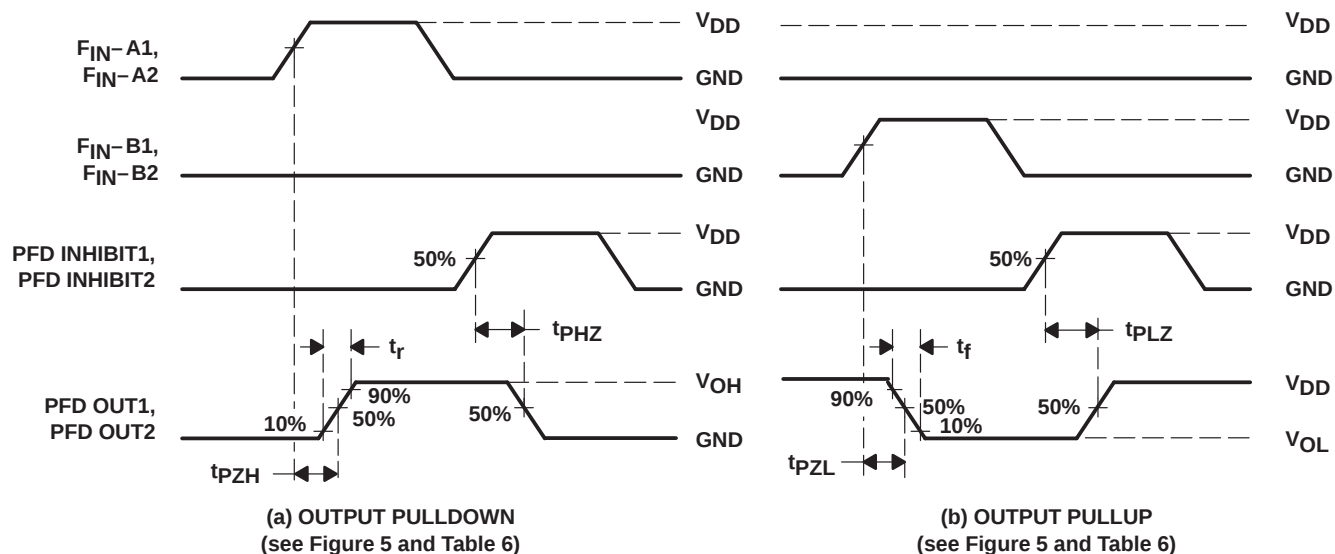


Figure 3. VCO Output Voltage Waveform



†  $F_{IN-A}$  and  $F_{IN-B}$  are for reference phase only, not for timing.

Figure 4. PFD Output Voltage Waveform

Table 6. PFD1 and PDF2 Output Test Conditions

| PARAMETER | $R_L$        | $C_L$ | $S_1$ | $S_2$ |
|-----------|--------------|-------|-------|-------|
| $t_{PZH}$ | 1 k $\Omega$ | 15 pF | Open  | Close |
| $t_{PHZ}$ |              |       |       |       |
| $t_r$     |              |       |       |       |
| $t_{PZL}$ |              |       | Close | Open  |
| $t_{PLZ}$ |              |       |       |       |
| $t_f$     |              |       |       |       |

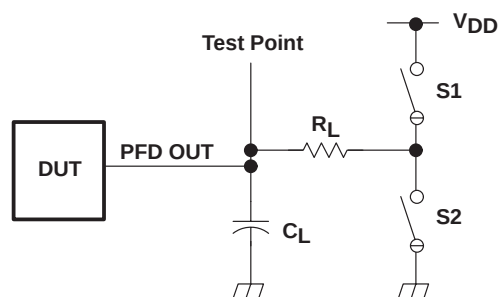


Figure 5. PFD1 and PFD2 Output Test Conditions

## TYPICAL CHARACTERISTICS

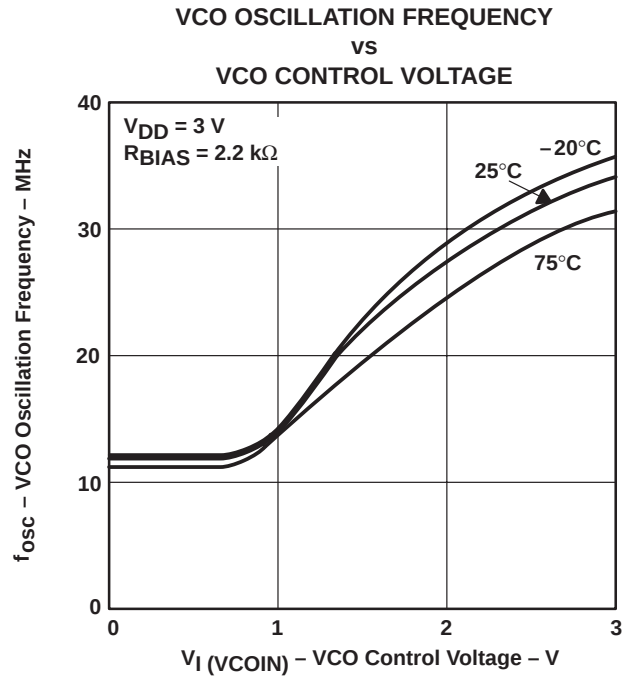


Figure 6

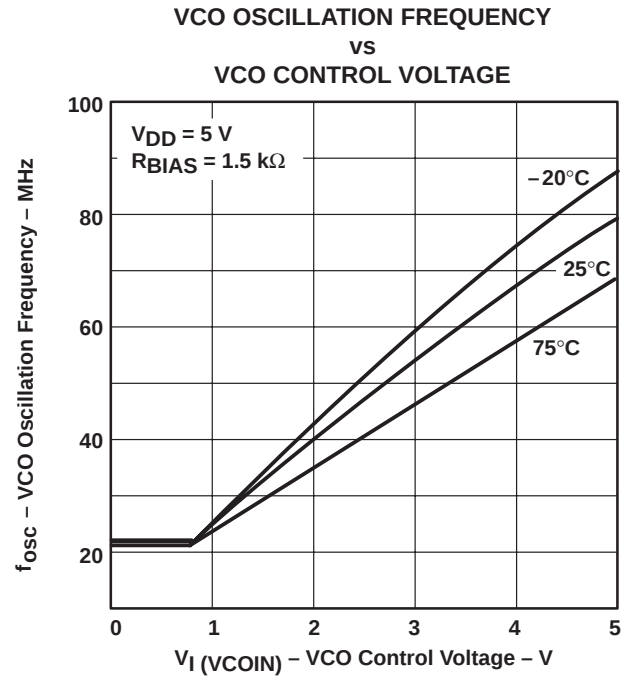


Figure 7

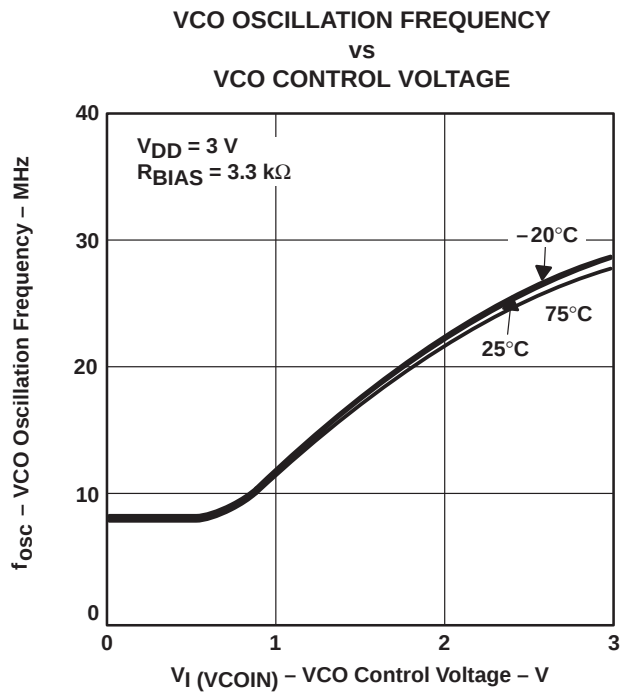


Figure 8

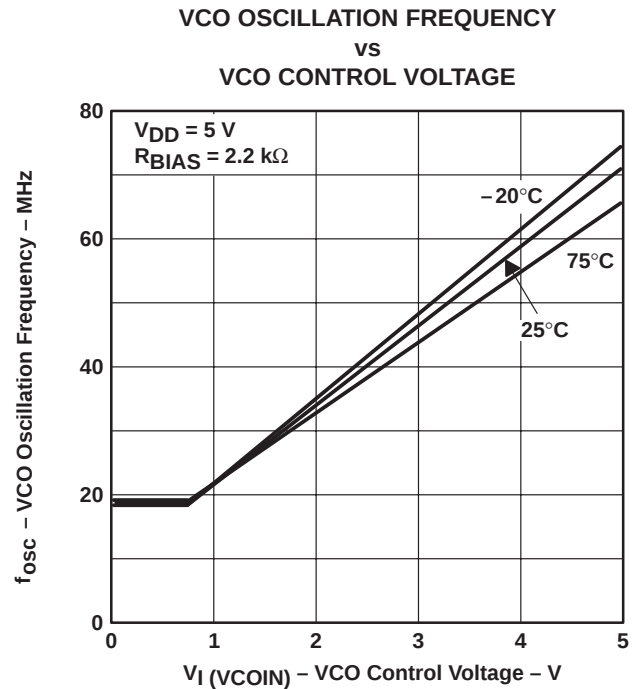


Figure 9

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### TYPICAL CHARACTERISTICS

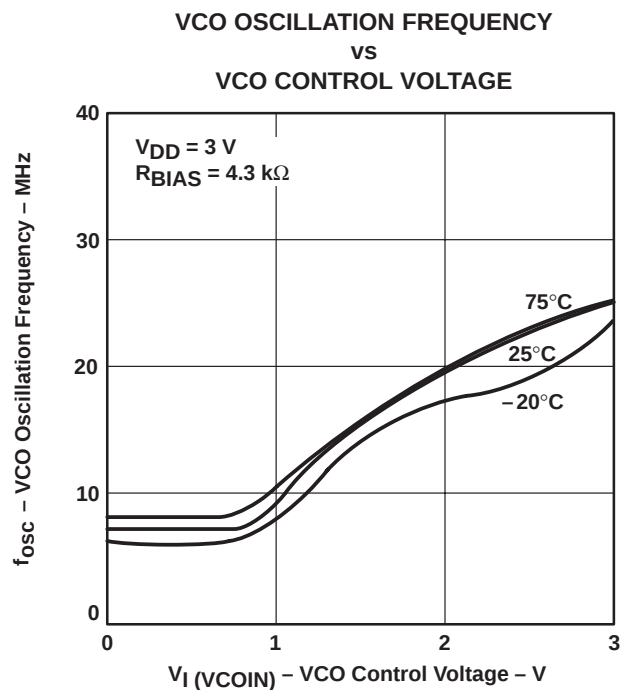


Figure 10

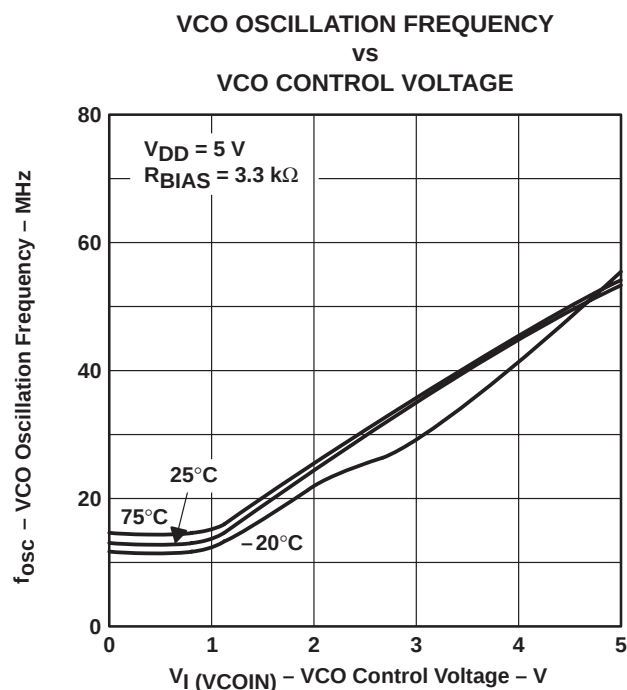


Figure 11

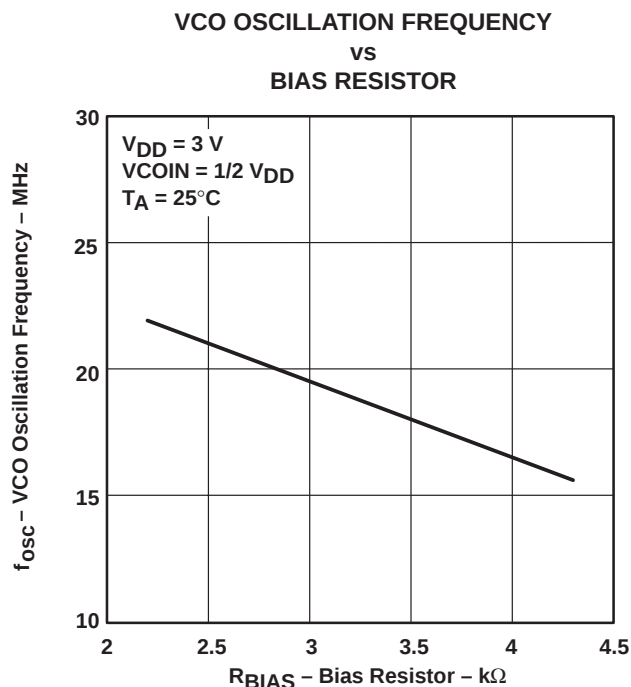


Figure 12

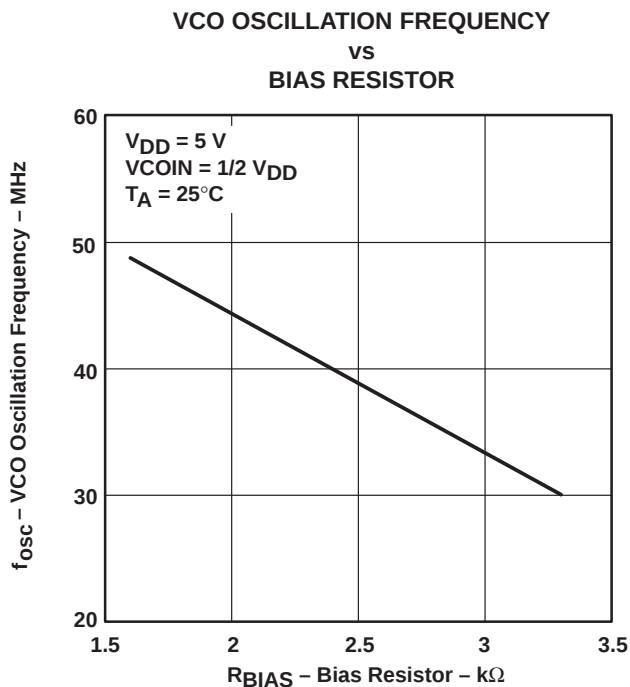


Figure 13

### TYPICAL CHARACTERISTICS

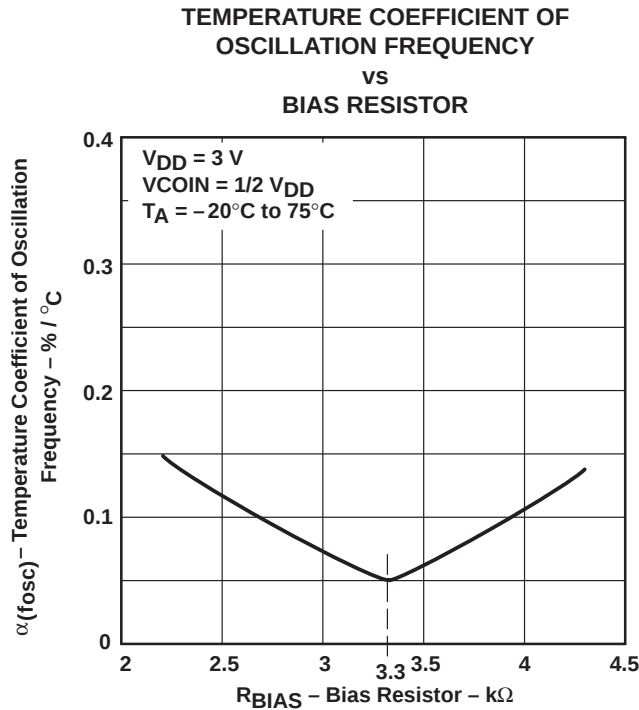


Figure 14

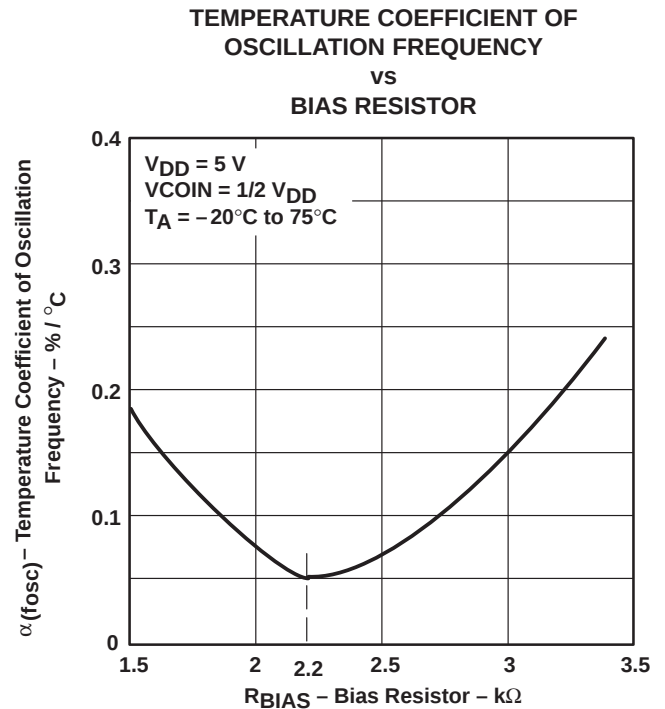


Figure 15

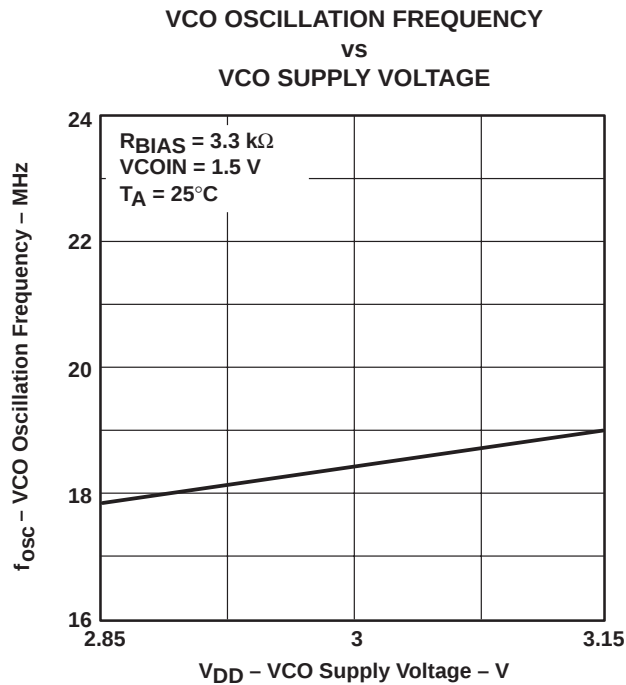


Figure 16

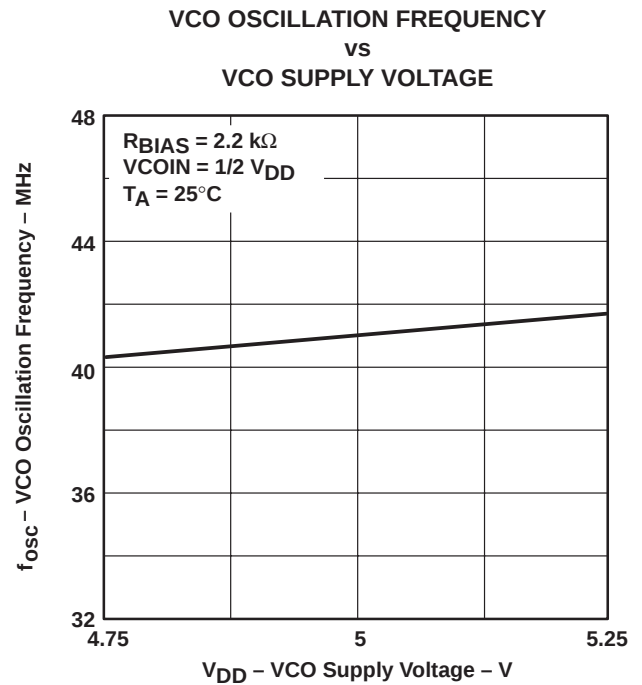


Figure 17

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### TYPICAL CHARACTERISTICS

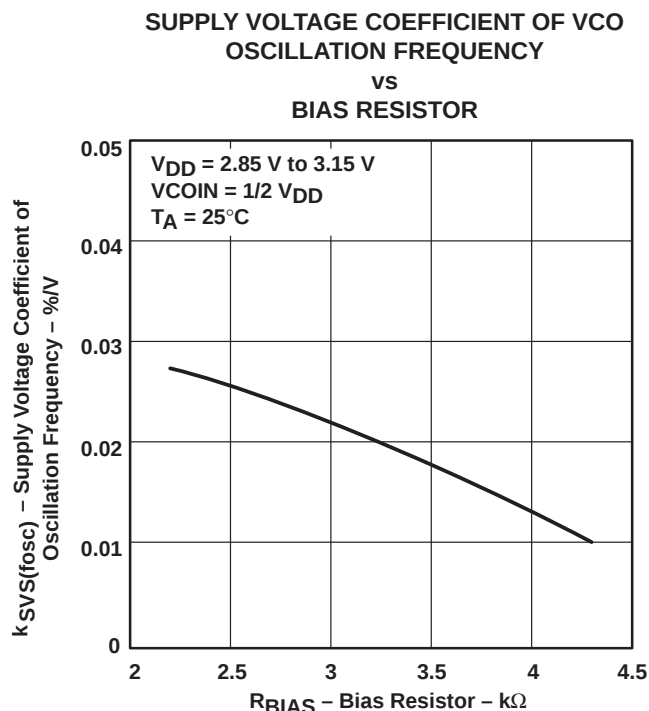


Figure 18

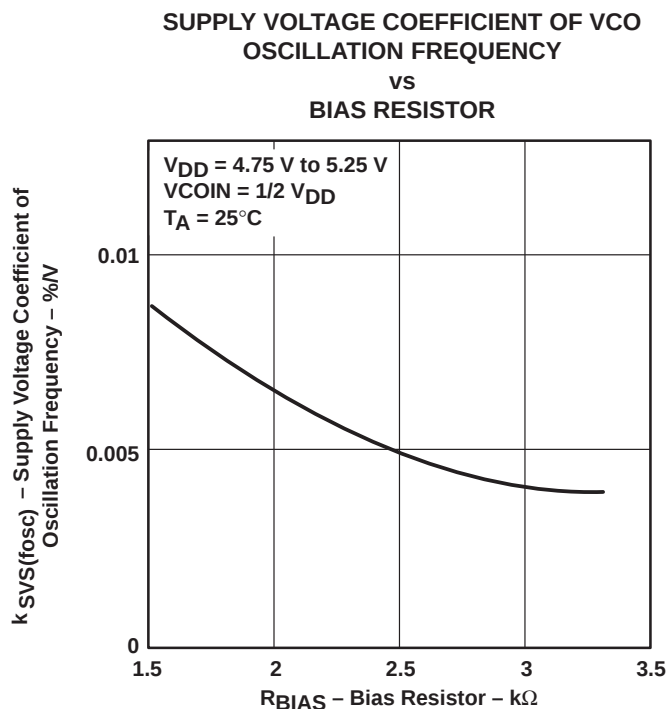


Figure 19

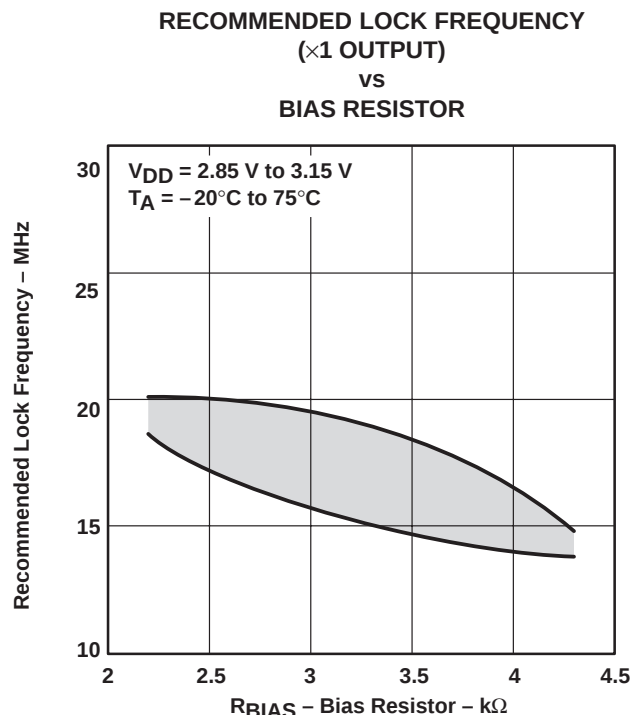


Figure 20

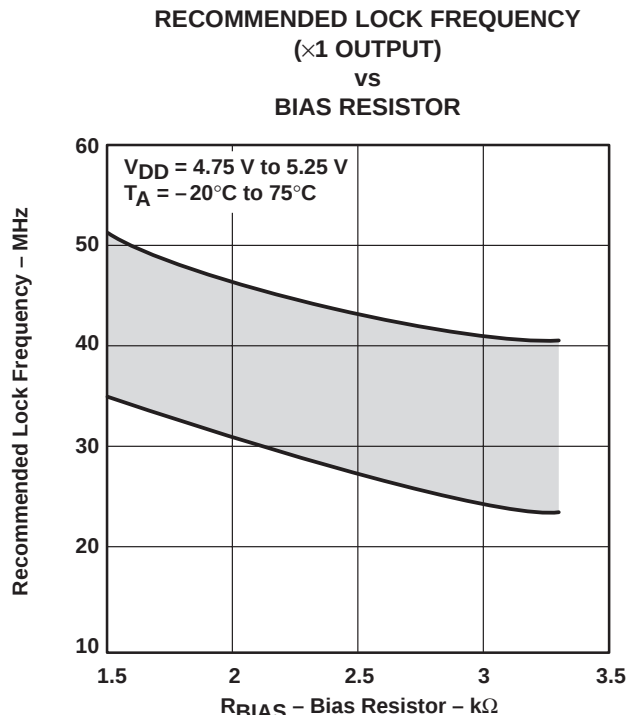


Figure 21

## TYPICAL CHARACTERISTICS

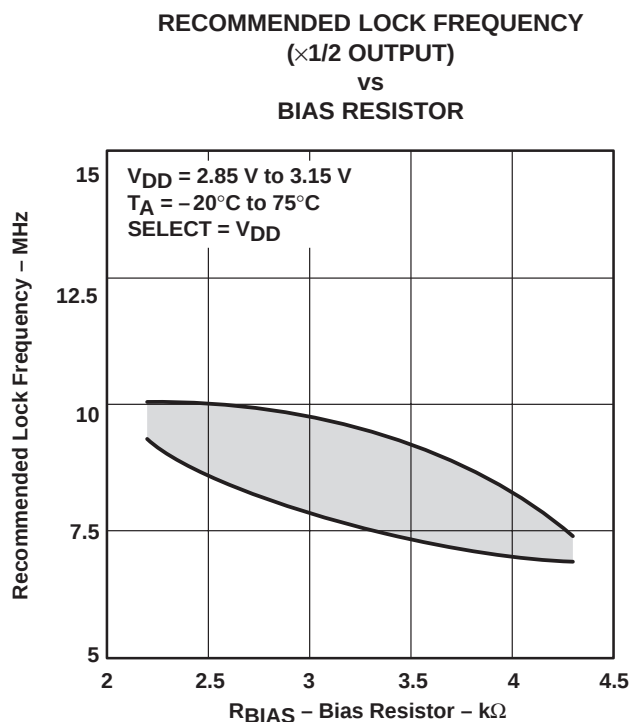


Figure 22

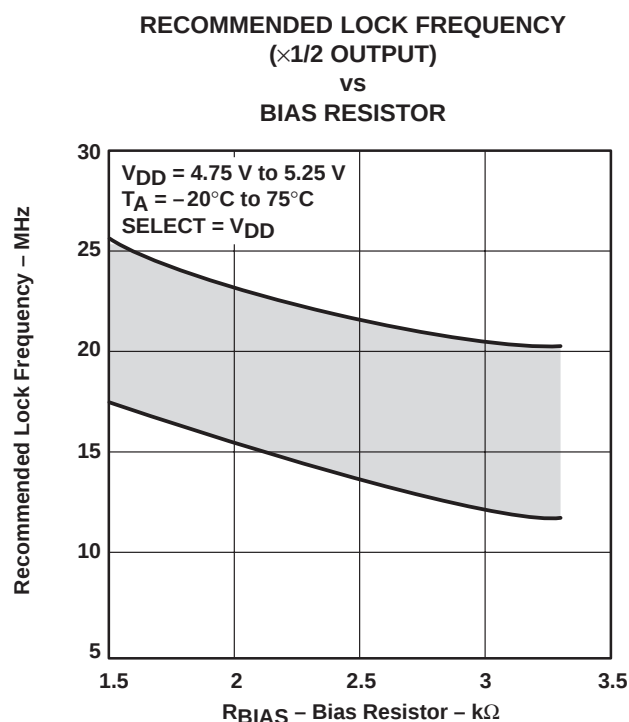


Figure 23

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## HIGH-PERFORMANCE DUAL PHASE-LOCKED LOOP BUILDING BLOCK

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### APPLICATION INFORMATION

#### gain of VCO and PFD

Figure 24 is a block diagram of the PLL. The divider N value depends on the input frequency and the desired VCO output frequency according to the system application requirements. The  $K_p$  and  $K_v$  values are obtained from the operating characteristics of the device as shown in Figure 24.  $K_p$  is defined from the phase detector  $V_{OL}$  and  $V_{OH}$  specifications and the equation shown in Figure 24(b).  $K_v$  is defined from Figures 8, 9, 10, and 11 as shown in Figure 24(c).

The parameters for the block diagram with the units are as follows:

- $K_v$  : VCO gain (rad/s/V)
- $K_p$  : PFD gain (V/rad)
- $K_f$  : LPF gain (V/V)
- $K_N$  : countdown divider gain (1/N)

#### external counter

When a large N counter is required by the application, there is a possibility that the PLL response becomes slow due to the counter response delay time. In the case of a high frequency application, the counter delay time should be accounted for in the overall PLL design.

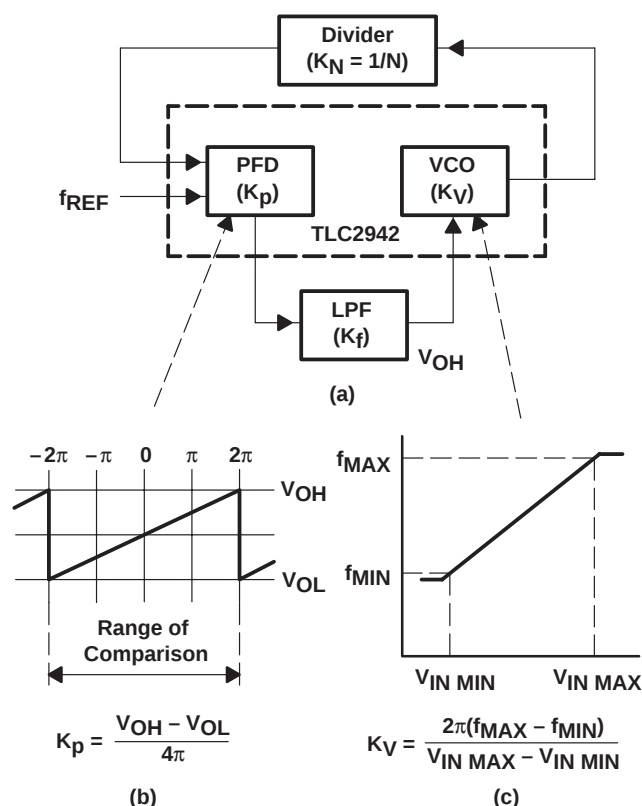


Figure 24. Example of a PLL Block Diagram

#### R<sub>BIAS</sub>

The external bias resistor sets the VCO center frequency with  $1/2 V_{DD}$  applied to the VCOIN terminal. However, for optimum temperature performance, a resistor value of 3.3 k $\Omega$  with a 3-V supply, or a resistor value of 2.5 k $\Omega$  for a 5-V supply is recommended. For the most accurate results, a metal-film resistor is the better choice, but a carbon-composition resistor can be used with excellent results also. A 0.22- $\mu$ F capacitor should be connected from the BIAS terminal to ground as close to the device terminals as possible.

#### hold-in range

From the technical literature, the maximum hold-in range for an input frequency step for the three types of filter configurations shown in Figure 25 is as follows:

$$\Delta\omega_H \approx 0.8 (K_p) (K_v) (K_f(\infty)) \quad (1)$$

Where

$K_f(\infty)$  = the filter transfer function value at  $\omega = \infty$

## APPLICATION INFORMATION

### low-pass-filter (LPF) configurations

Many excellent references are available that include detailed design information about LPFs and they should be consulted for additional information. Lag-lead filters or active filters are often used. Examples of LPFs are shown in Figure 25. When the active filter of Figure 25(c) is used, the reference should be applied to  $F_{IN-B}$  because of the amplifier inversion. Also, in practical filter implementations, C2 is used as additional filtering at the VCO input. The value of C2 should be equal to or less than one-tenth the value of C1.

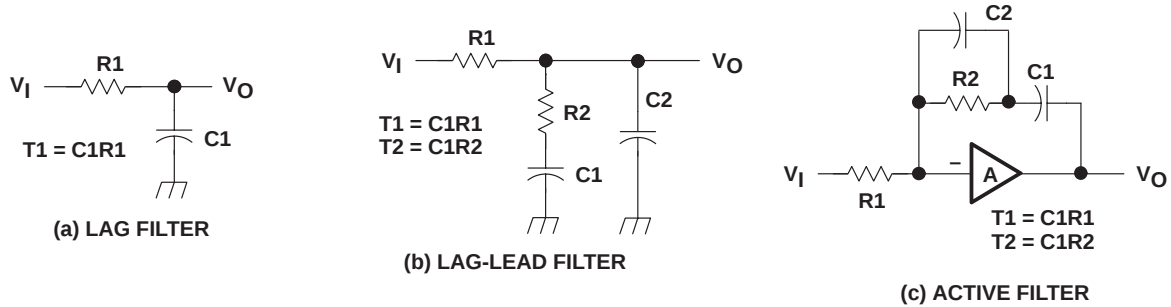


Figure 25. LPF Examples for PLL

### the passive filter

The transfer function for the low-pass filter shown in Figure 25(b) is:

$$\frac{V_O}{V_{IN}} = \frac{1 + s \cdot T_2}{1 + s \cdot (T_1 + T_2)} \quad (2)$$

Where

$$T_1 = R_1 \cdot C_1 \text{ and } T_2 = R_2 \cdot C_1$$

Using this filter makes the closed loop PLL system a type 1 second-order system. The response curves of this system to a unit step are shown in Figure 26.

### the active filter

When using the active filter shown in Figure 25(c), the phase detector inputs must be reversed since the filter adds an additional inversion. Therefore, the input reference frequency should be applied to the  $F_{IN-B}$  terminal and the output of the VCO divider should be applied to the input reference terminal,  $F_{IN-A}$ .

The transfer function for the active filter shown in Figure 25(c) is:

$$F(s) = \frac{1 + s \cdot R_2 \cdot C_1}{s \cdot R_1 \cdot C_1} \quad (3)$$

Using this filter makes the closed loop PLL system a type 2 second-order system. The response curves of this system to a unit step are shown in Figure 27.

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### APPLICATION INFORMATION

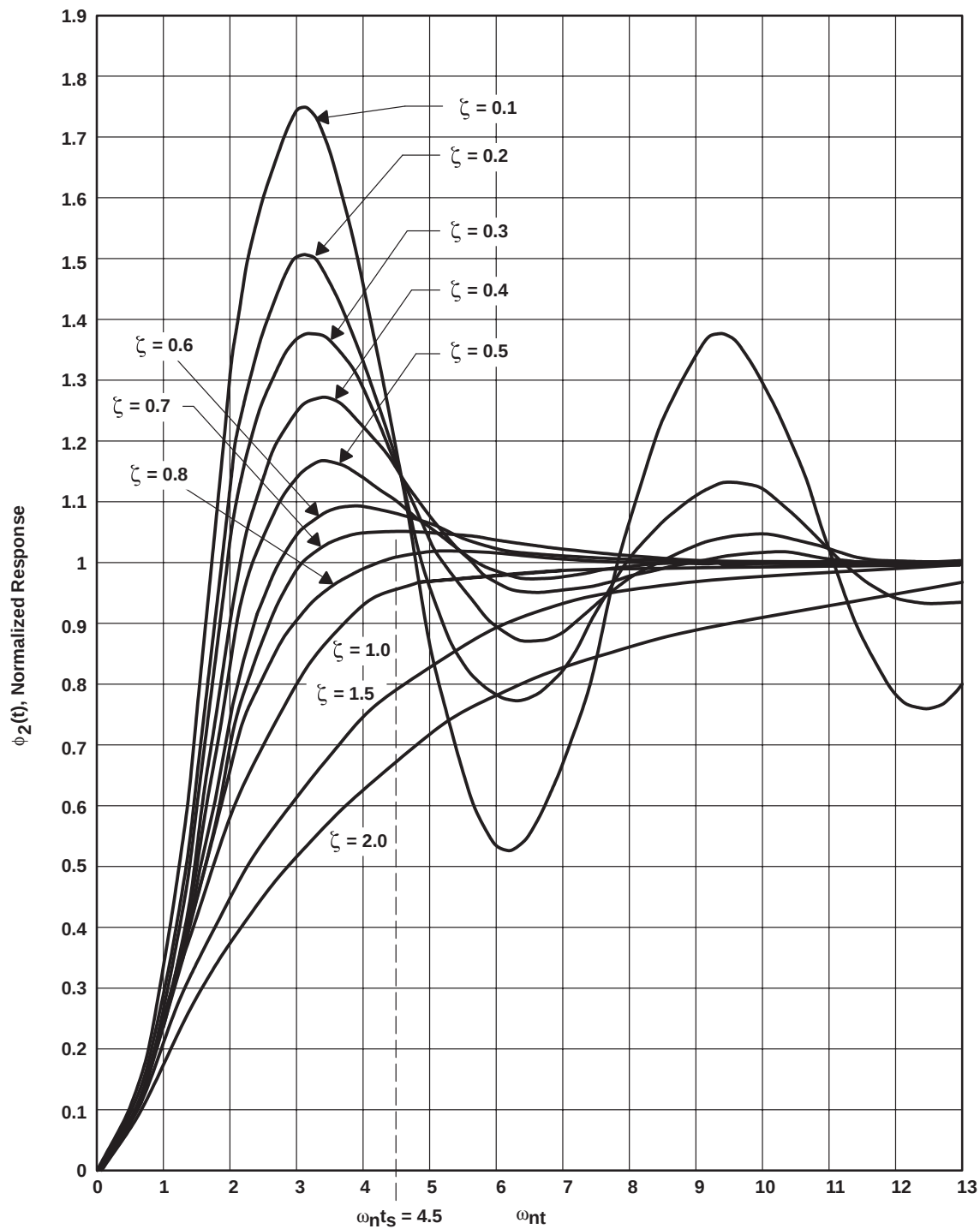


Figure 26. Type 1 Second-Order Step Response

APPLICATION INFORMATION

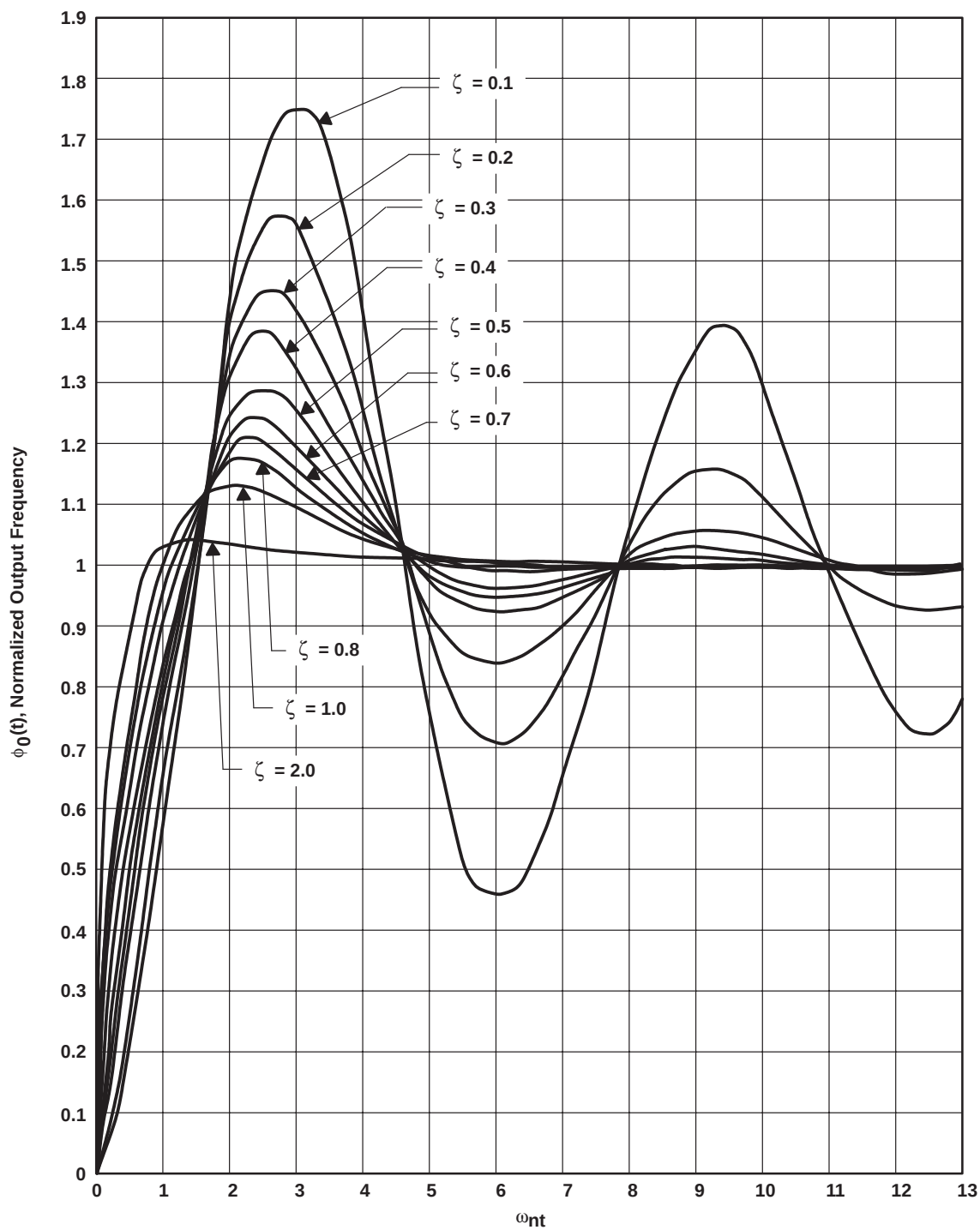


Figure 27. Type 2 Second-Order Step Response

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### APPLICATION INFORMATION

#### basic design example

The following design example presupposes that the input reference frequency and the required frequency of the VCO are within the respective ranges of the device.

Assume the loop has to have a 100- $\mu$ s settling time ( $t_s$ ) with a countdown divider N value = 8. Using the Type 1, second-order response curves of Figure 26, a value of 4.5 radians is selected for  $\omega_n t_s$  with a damping factor of 0.7. This selection gives a good combination for settling time, accuracy, and loop gain margin. The initial parameters are summarized in Table 7. The loop constants,  $K_V$  and  $K_P$ , are calculated from the data sheet specifications and Table 8 shows these values.

The natural loop frequency is calculated as follows:

Since

$$\omega_n t_s = 4.5 \quad (4)$$

Then

$$\omega_n = \frac{4.5}{100 \mu s} = 45 \text{ k-radians/sec}$$

**Table 7. Design Parameters**

| PARAMETER                            | SYMBOL       | VALUE | UNITS   |
|--------------------------------------|--------------|-------|---------|
| Divider value                        | N            | 8     |         |
| Lockup time                          | t            | 100   | $\mu$ s |
| Radian value to selected lockup time | $\omega_n t$ | 4.5   | rad     |
| Damping factor                       | $\zeta$      | 0.7   |         |

**Table 8. Device Specifications**

| PARAMETER    | SYMBOL | VALUE    | UNITS    |
|--------------|--------|----------|----------|
| VCO gain     |        | 76.6     | Mrad/V/s |
| $f_{MAX}$    | $K_V$  | 70       | MHz      |
| $f_{MIN}$    |        | 20       | MHz      |
| $V_{IN MAX}$ |        | 5        | V        |
| $V_{IN MIN}$ |        | 0.9      | V        |
| PFD gain     | $K_P$  | 0.342357 | V/rad    |

Using the low-pass filter in Figure 25(b) and divider N value, the transfer function for phase and frequency are shown in equations 5 and 6. Note that the transfer function for phase differs from the transfer function for frequency by only the divider N value. The difference arises from the fact that the feedback for phase is unity while the feedback for frequency is 1/N.

Hence, transfer function of Figure 24 (a) for phase is:

$$\frac{\Phi_2(s)}{\Phi_1(s)} = \frac{K_P \cdot K_V}{N \cdot (T_1 + T_2)} \left[ \frac{1 + s \cdot T_2}{s^2 + s \left[ 1 + \frac{K_P \cdot K_V \cdot T_2}{N \cdot (T_1 + T_2)} \right] + \frac{K_P \cdot K_V}{N \cdot (T_1 + T_2)}} \right] \quad (5)$$

## APPLICATION INFORMATION

and the transfer function for frequency is:

$$\frac{F_{OUT}(s)}{F_{REF}(s)} = \frac{K_p \cdot K_V}{(T1 + T2)} \left[ \frac{1 + s \cdot T2}{s^2 + s \cdot \left[ 1 + \frac{K_p \cdot K_V \cdot T2}{N \cdot (T1 + T2)} \right] + \frac{K_p \cdot K_V}{N \cdot (T1 + T2)}} \right] \quad (6)$$

The standard two-pole denominator is  $D = s^2 + 2 \zeta \omega_n s + \omega_n^2$  and comparing the coefficients of the denominator of equation 5 and 6 with the standard two-pole denominator gives the following results:

$$\omega_n = \sqrt{\frac{K_p \cdot K_V}{N \cdot (T1 + T2)}} \quad (7)$$

Solving for  $T1 + T2$

$$T1 + T2 = \frac{K_p \cdot K_V}{N \cdot \omega_n^2}$$

and by using this value for  $T1 + T2$  in equation 7 the damping factor is:

$$\zeta = \frac{\omega_n}{2} \cdot \left( T2 + \frac{N}{K_p \cdot K_V} \right) \quad (8)$$

solving for  $T2$ :

$$T2 = \frac{2 \zeta}{\omega_n} - \frac{N}{K_p \cdot K_V} \quad (9)$$

then by substituting for  $T2$  in equation 7 and solving for  $T1$  as given in equation 10:

$$T1 = \frac{K_V \cdot K_p}{N \cdot \omega_n^2} - \frac{2 \zeta}{\omega_n} + \frac{N}{K_p \cdot K_V} \quad (10)$$

From the circuit constants and the initial design parameters then:

$$R1 = \left[ \frac{K_p \cdot K_V}{\omega_n^2 \cdot N} - \frac{2 \zeta}{\omega_n} + \frac{N}{K_p \cdot K_V} \right] \frac{1}{C1} \quad (11)$$

$$R2 = \left[ \frac{2 \zeta}{\omega_n} - \frac{N}{K_p \cdot K_V} \right] \frac{1}{C1} \quad (12)$$

**APPLICATION INFORMATION**

The capacitor, C1, is usually chosen between 1  $\mu\text{F}$  and 0.1  $\mu\text{F}$  to allow for reasonable resistor values and physical capacitor size. In this example, C1 is chosen to be 0.1  $\mu\text{F}$  and the corresponding R1 and R2 calculated values are listed in Table 9.

**Table 9. Calculated Values**

| PARAMETER                 | SYMBOL     | VALUE | UNITS         |
|---------------------------|------------|-------|---------------|
| Natural angular frequency | $\omega_n$ | 45000 | rad/sec       |
| $K = (K_V \cdot K_p)/N$   |            | 3.277 | Mrad/sec      |
| Lag-lead filter           |            |       |               |
| Calculated value          | R1         | 15870 | $\Omega$      |
| Nearest standard value    |            | 16000 |               |
| Calculated value          | R2         | 308   | $\Omega$      |
| Nearest standard value    |            | 300   |               |
| Selected value            | C1         | 0.1   | $\mu\text{F}$ |

The evaluation and operation schematic for the TLC2942I is shown in Figure 28.



### Figure 28. Evaluation and Operation Schematic

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### APPLICATION INFORMATION

#### PCB layout considerations

The TLC2942I contains high frequency analog oscillators; therefore, very careful breadboarding and printed-circuit-board (PCB) layout is required for evaluation.

The following design recommendations benefit the TLC2942I user:

- External analog and digital circuitry should be physically separated and shielded as much as possible to reduce system noise.
- RF breadboarding or RF PCB techniques should be used throughout the evaluation and production process.
- Wide ground leads or a ground plane should be used on the PCB layouts to minimize parasitic inductance and resistance. The ground plane is the better choice for noise reduction.
- LOGIC  $V_{DD}$  and VCO  $V_{DD}$  should be separate PCB traces and connected to the best filtered supply point available in the system to minimize supply cross-coupling.
- VCO  $V_{DD}$  to GND and LOGIC  $V_{DD}$  to GND should be decoupled with a 0.1- $\mu$ F capacitor placed as close as possible to the appropriate device terminals.
- The no-connection (NC) terminal on the package should be connected to GND.



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# TLC2942 HIGH-PERFORMANCE DUAL PHASE-LOCKED LOOP BUILDING BLOCK

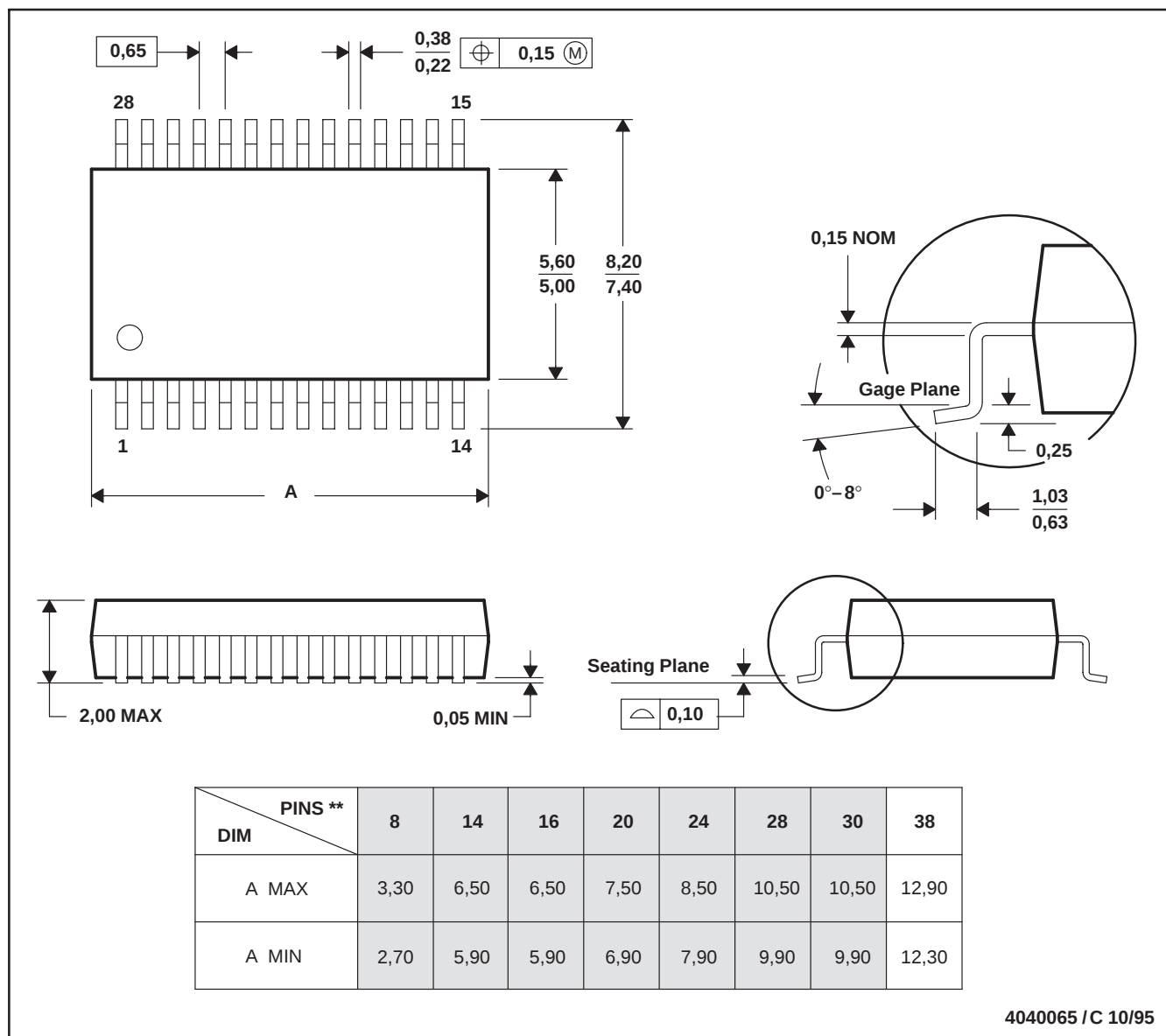
SLAS146B – NOVEMBER 1996 – REVISED JUNE 1997

## MECHANICAL DATA

DB (R-PDSO-G\*\*)

PLASTIC SMALL-OUTLINE PACKAGE

28 PIN SHOWN



- NOTES: A. All linear dimensions are in millimeters.  
 B. This drawing is subject to change without notice.  
 C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.  
 D. Falls within JEDEC MO-150

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