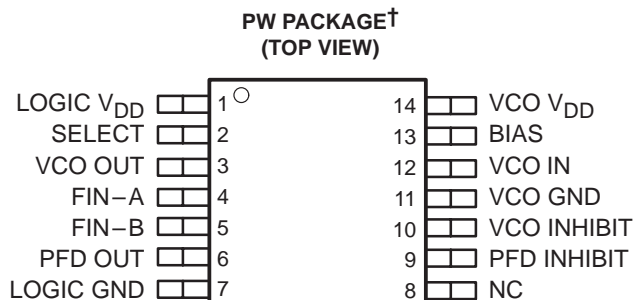


# TLC2932 HIGH-PERFORMANCE PHASE-LOCKED LOOP

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- **Voltage-Controlled Oscillator (VCO) Section:**
  - Complete Oscillator Using Only One External Bias Resistor ( $R_{BIAS}$ )
  - Lock Frequency:
    - 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
- **Phase-Frequency Detector (PFD) Section Includes a High-Speed Edge-Triggered Detector With Internal Charge Pump**
- Independent VCO, PFD Power-Down Mode
- Thin Small-Outline Package (14 terminal)
- CMOS Technology
- Typical Applications:
  - Frequency Synthesis
  - Modulation/Demodulation
  - Fractional Frequency Division
- Application Report Available†
- CMOS Input Logic Level

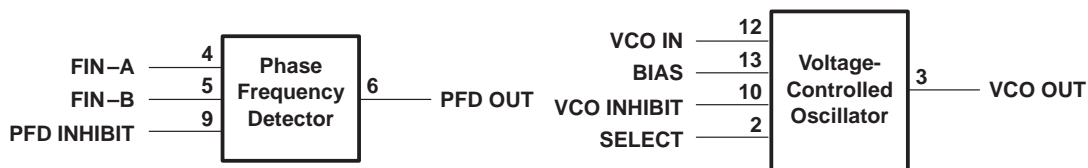


† Available in tape and reel only and ordered as the TLC2932IPWLE.  
NC – No internal connection

## description

The TLC2932 is designed for phase-locked-loop (PLL) systems and is composed of a voltage-controlled oscillator (VCO) and an edge-triggered-type phase frequency detector (PFD). The oscillation frequency range of the VCO is set by an external bias resistor ( $R_{BIAS}$ ). The VCO has a 1/2 frequency divider at the output stage. The high-speed PFD with internal charge pump detects the phase difference between the reference frequency input and signal frequency input from the external counter. Both the VCO and the PFD have inhibit functions, which can be used as a power-down mode. The TLC2932 is suitable for use as a high-performance PLL due to the high speed and stable oscillation capability of the device.

## functional block diagram



### AVAILABLE OPTIONS

$T_A$	PACKAGE
	SMALL OUTLINE (PW)
$-20^\circ\text{C}$ to $75^\circ\text{C}$	TLC2932IPWLE



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

† TLC2932 Phase-Locked-Loop Building Block With Analog Voltage-Controlled Oscillator and Phase Frequency Detector (SLAA011).

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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# TLC2932

## HIGH-PERFORMANCE PHASE-LOCKED LOOP

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### Terminal Functions

TERMINAL NAME	NO.	I/O	DESCRIPTION
FIN–A	4	I	Input reference frequency $f_{(REF\ IN)}$ is applied to FIN–A.
FIN–B	5	I	Input for VCO external counter output frequency $f_{(FIN-B)}$ . FIN–B is nominally provided from the external counter.
LOGIC GND	7		GND for the internal logic.
LOGIC $V_{DD}$	1		Power supply for the internal logic. This power supply should be separate from VCO $V_{DD}$ to reduce cross-coupling between supplies.
NC	8		No internal connection.
PFD INHIBIT	9	I	PFD inhibit control. When PFD INHIBIT is high, PFD output is in the high-impedance state, see Table 3.
PFD OUT	6	O	PFD output. When the PFD INHIBIT is high, PFD output is in the high-impedance state.
BIAS	13	I	Bias supply. An external resistor ( $R_{BIAS}$ ) between VCO $V_{DD}$ and BIAS supplies bias for adjusting the oscillation frequency range.
SELECT	2	I	VCO output frequency select. When SELECT is high, the VCO output frequency is $\times 1/2$ and when low, the output frequency is $\times 1$ , see Table 1.
VCO IN	12	I	VCO control voltage input. Nominally the external loop filter output connects to VCO IN to control VCO oscillation frequency.
VCO INHIBIT	10	I	VCO inhibit control. When VCO INHIBIT is high, VCO OUT is low (see Table 2).
VCO GND	11		GND for VCO.
VCO OUT	3	O	VCO output. When the VCO INHIBIT is high, VCO output is low.
VCO $V_{DD}$	14		Power supply for VCO. This power supply should be separated from LOGIC $V_{DD}$ to reduce cross-coupling between supplies.

### detailed description

#### VCO oscillation frequency

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

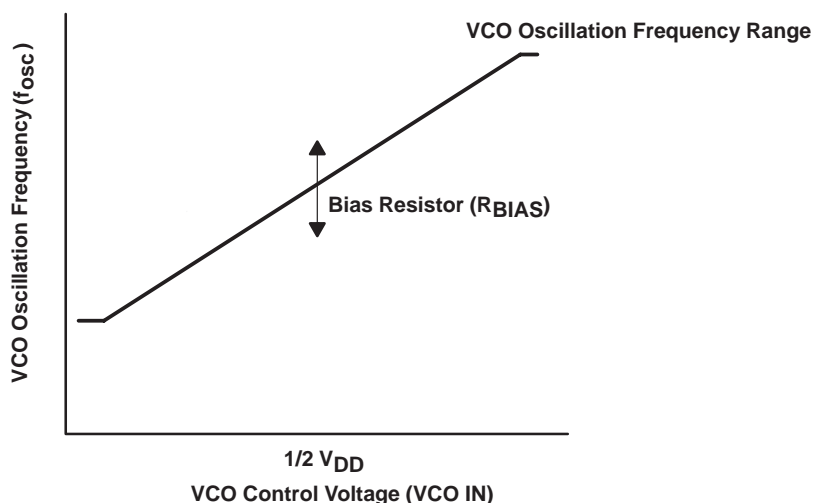


Figure 1. VCO Oscillation Frequency

### VCO output frequency 1/2 divider

The TLC2932 SELECT terminal sets the  $f_{osc}$  or  $1/2 f_{osc}$  VCO output frequency as shown in Table 1. The  $1/2 f_{osc}$  output should be used for minimum VCO output jitter.

**Table 1. VCO Output 1/2 Divider Function**

SELECT	VCO OUTPUT
Low	$f_{osc}$
High	$1/2 f_{osc}$

### VCO inhibit function

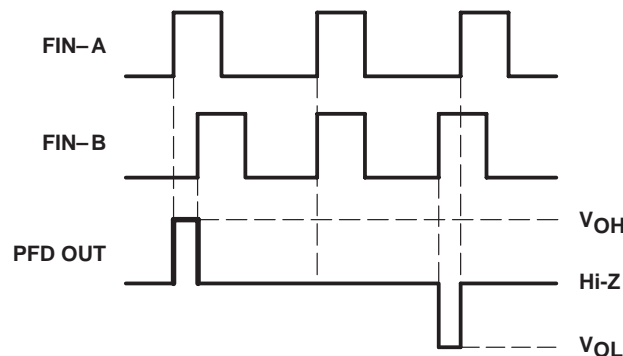
The VCO has an externally controlled inhibit function which inhibits the VCO output. A high level on the VCO INHIBIT terminal stops the VCO oscillation and powers down the VCO. The output maintains a low level during the power-down mode, refer to Table 2.

**Table 2. VCO Inhibit Function**

VCO INHIBIT	VCO OSCILLATOR	VCO OUTPUT	$I_{DD}(VCO)$
Low	Active	Active	Normal
High	Stopped	Low level	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 FIN-A and FIN-B as shown in Figure 2. Nominally the reference is supplied to FIN-A, and the frequency from the external counter output is fed to FIN-B.



**Figure 2. PFD Function Timing Chart**

### PFD output control

A high level on the PFD INHIBIT terminal places the PFD output in the high-impedance state and the PFD stops phase detection as shown in Table 3. A high level on the PFD INHIBIT terminal also can be used as the power-down mode for the PFD.

**Table 3. VCO Output Control Function**

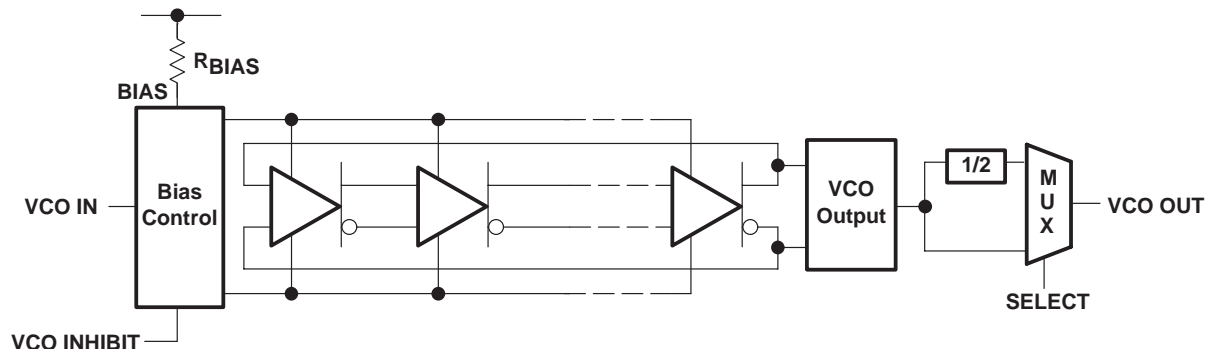
PFD INHIBIT	DETECTION	PFD OUTPUT	$I_{DD}(PFD)$
Low	Active	Active	Normal
High	Stopped	Hi-Z	Power Down

# TLC2932 HIGH-PERFORMANCE PHASE-LOCKED LOOP

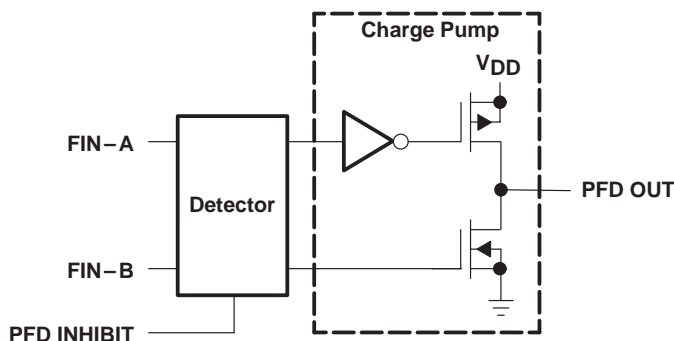
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## schematics

### VCO block schematic



### PFD block schematic



## absolute maximum ratings†

Supply voltage (each supply), V <sub>DD</sub> (see Note 1)	7 V
Input voltage range (each input), V <sub>I</sub> (see Note 1)	-0.5 V to V <sub>DD</sub> + 0.5 V
Input current (each input), I <sub>I</sub>	±20 mA
Output current (each output), I <sub>O</sub>	±20 mA
Continuous total power dissipation, at (or below) T <sub>A</sub> = 25°C (see Note 2)	700 mW
Operating free-air temperature range, T <sub>A</sub>	-20°C to 75°C
Storage temperature range, T <sub>stg</sub>	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

† 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 beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated 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 5.6 mW/°C.

## recommended operating conditions

PARAMETER		MIN	NOM	MAX	UNIT
Supply voltage, $V_{DD}$ (each supply, see Note 3)	$V_{DD} = 3\text{ V}$	2.85	3	3.15	V
	$V_{DD} = 5\text{ V}$	4.75	5	5.25	
Input voltage, $V_I$ (inputs except VCO IN)		0		$V_{DD}$	V
Output current, $I_O$ (each output)		0		$\pm 2$	mA
VCO control voltage at VCO IN		0.9		$V_{DD}$	V
Lock frequency ( $\times 1$ output)	$V_{DD} = 3\text{ V}$	14		21	MHz
	$V_{DD} = 5\text{ V}$	22		50	
Lock frequency ( $\times 1/2$ output)	$V_{DD} = 3\text{ V}$	7		10.5	MHz
	$V_{DD} = 5\text{ V}$	11		25	
Bias resistor, $R_{BIAS}$	$V_{DD} = 3\text{ V}$	2.2	3.3	4.3	k $\Omega$
	$V_{DD} = 5\text{ V}$	1.5	2.2	3.3	

NOTE 3: It is recommended that the logic supply terminal (LOGIC  $V_{DD}$ ) and the VCO supply terminal (VCO  $V_{DD}$ ) should be at the same voltage and separated from each other.

## electrical characteristics over recommended operating free-air temperature range, $V_{DD} = 3\text{ V}$ (unless otherwise noted)

### VCO section

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 at SELECT, VCO INHIBIT		0.9	1.5	2.1	V
$I_I$	Input current at SELECT, VCO INHIBIT	$V_I = V_{DD}$ or GND			$\pm 1$	$\mu\text{A}$
$Z_i(\text{VCO IN})$	Input impedance	$V_{CO\ IN} = 1/2 V_{DD}$		10		M $\Omega$
$I_{DD}(\text{INH})$	VCO supply current (inhibit)	See Note 4		0.01	1	$\mu\text{A}$
$I_{DD}(\text{VCO})$	VCO supply current	See Note 5		5	15	mA

NOTES: 4. Current into VCO  $V_{DD}$ , when VCO INHIBIT =  $V_{DD}$ , PFD is inhibited.

5. Current into VCO  $V_{DD}$ , when VCO IN =  $1/2 V_{DD}$ ,  $R_{BIAS} = 3.3\text{ k}\Omega$ , VCO INHIBIT = GND, and PFD is inhibited.

### PFD section

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-state output current	PFD INHIBIT = high, $V_I = V_{DD}$ or GND			$\pm 1$	$\mu\text{A}$
$V_{IH}$	High-level input voltage at FIN-A, FIN-B		2.7			V
$V_{IL}$	Low-level input voltage at FIN-A, FIN-B				0.5	V
$V_{IT}$	Input threshold voltage at PFD INHIBIT		0.9	1.5	2.1	V
$C_i$	Input capacitance at FIN-A, FIN-B			5		pF
$Z_i$	Input impedance at FIN-A, FIN-B			10		M $\Omega$
$I_{DD}(Z)$	High-impedance-state PFD supply current	See Note 6		0.01	1	$\mu\text{A}$
$I_{DD}(\text{PFD})$	PFD supply current	See Note 7		0.1	1.5	mA

NOTES: 6. Current into LOGIC  $V_{DD}$ , when FIN-A, FIN-B = GND, PFD INHIBIT =  $V_{DD}$ , no load, and VCO OUT is inhibited.

7. Current into LOGIC  $V_{DD}$ , when FIN-A, FIN-B = 1 MHz ( $V_{I(\text{PP})} = 3\text{ V}$ , rectangular wave), NC = GND, no load, and VCO OUT is inhibited.

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operating characteristics over recommended operating free-air temperature range,  $V_{DD} = 3\text{ V}$  (unless otherwise noted)

### VCO section

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$f_{osc}$	Operating oscillation frequency	$R_{BIAS} = 3.3\text{ k}\Omega$ , VCO IN = $1/2 V_{DD}$	15	19	23	MHz
$t_s(f_{osc})$	Time to stable oscillation (see Note 8)	Measured from VCO INHIBIT↓			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		$R_{BIAS} = 3.3\text{ k}\Omega$ , VCO IN = $1/2 V_{DD}$ .	45%	50%	55%	
$\alpha(f_{osc})$	Temperature coefficient of oscillation frequency	$R_{BIAS} = 3.3\text{ k}\Omega$ , VCO IN = $1/2 V_{DD}$ , $T_A = -20^\circ\text{C}$ to $75^\circ\text{C}$		0.04		$\%/^\circ\text{C}$
$k_{SVS}(f_{osc})$	Supply voltage coefficient of oscillation frequency	$R_{BIAS} = 3.3\text{ k}\Omega$ , VCO IN = 1.5 V, $V_{DD} = 2.85\text{ V}$ to $3.15\text{ V}$		0.02		$\%/mV$
Jitter absolute (see Note 9)		$R_{BIAS} = 3.3\text{ k}\Omega$		100		ps

- NOTES: 8. The time period to the stable VCO oscillation frequency after the VCO INHIBIT terminal is changed to a low level.  
 9. The low-pass-filter (LPF) circuit is shown in Figure 28 with calculated values listed in Table 7. 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.

### PFD section

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



**electrical characteristics over recommended operating free-air temperature range,  $V_{DD} = 5\text{ V}$  (unless otherwise noted)**

**VCO section**

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 at SELECT, VCO INHIBIT		1.5	2.5	3.5	V
$I_I$	Input current at SELECT, VCO INHIBIT	$V_I = V_{DD}$ or GND			$\pm 1$	$\mu\text{A}$
$Z_i(\text{VCO IN})$	Input impedance	$\text{VCO IN} = 1/2 V_{DD}$		10		$\text{M}\Omega$
$I_{DD}(\text{INH})$	VCO supply current (inhibit)	See Note 4		0.01	1	$\mu\text{A}$
$I_{DD}(\text{VCO})$	VCO supply current	See Note 5		15	35	mA

- NOTES: 4. Current into VCO  $V_{DD}$ , when VCO INHIBIT =  $V_{DD}$ , and PFD is inhibited.  
5. Current into VCO  $V_{DD}$ , when VCO IN =  $1/2 V_{DD}$ ,  $R_{BIAS} = 3.3\text{ k}\Omega$ , VCO INHIBIT = GND, and PFD is inhibited.

**PFD section**

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-state output current	PFD INHIBIT = high, $V_I = V_{DD}$ or GND			$\pm 1$	$\mu\text{A}$
$V_{IH}$	High-level input voltage at FIN-A, FIN-B		4.5			V
$V_{IL}$	Low-level input voltage at FIN-A, FIN-B				1	V
$V_{IT}$	Input threshold voltage at PFD INHIBIT		1.5	2.5	3.5	V
$C_i$	Input capacitance at FIN-A, FIN-B			5		pF
$Z_i$	Input impedance at FIN-A, FIN-B			10		$\text{M}\Omega$
$I_{DD}(\text{Z})$	High-impedance-state PFD supply current	See Note 6		0.01	1	$\mu\text{A}$
$I_{DD}(\text{PFD})$	PFD supply current	See Note 7		0.15	3	mA

- NOTES: 6. Current into LOGIC  $V_{DD}$ , when FIN-A, FIN-B = GND, PFD INHIBIT =  $V_{DD}$ , no load, and VCO OUT is inhibited.  
7. Current into LOGIC  $V_{DD}$ , when FIN-A, FIN-B = 1 MHz ( $V_{I(\text{PP})} = 5\text{ V}$ , rectangular wave), PFD INHIBIT = GND, no load, and VCO OUT is inhibited.

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operating characteristics over recommended operating free-air temperature range,  $V_{DD} = 5\text{ V}$  (unless otherwise noted)

### VCO section

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$f_{osc}$	Operating oscillation frequency	$R_{BIAS} = 2.2\text{ k}\Omega$ , $VCO\ IN = 1/2\ V_{DD}$	30	41	52	MHz
$t_s(f_{osc})$	Time to stable oscillation (see Note 8)	Measured from VCO INHIBIT↓			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		$R_{BIAS} = 2.2\text{ k}\Omega$ , $VCO\ IN = 1/2\ V_{DD}$	45%	50%	55%	
$\alpha(f_{osc})$	Temperature coefficient of oscillation frequency	$R_{BIAS} = 2.2\text{ k}\Omega$ , $VCO\ IN = 1/2\ V_{DD}$ , $T_A = -20^\circ\text{C}$ to $75^\circ\text{C}$		0.06		$\%/^\circ\text{C}$
$k_{SVS}(f_{osc})$	Supply voltage coefficient of oscillation frequency	$R_{BIAS} = 2.2\text{ k}\Omega$ , $VCO\ IN = 2.5\text{ V}$ , $V_{DD} = 4.75\text{ V}$ to $5.25\text{ V}$		0.006		$\%/mV$
Jitter absolute (see Note 9)		$R_{BIAS} = 2.2\text{ k}\Omega$		100		ps

NOTES: 8: The time period to the stable VCO oscillation frequency after the VCO INHIBIT terminal is changed to a low level.  
 9: The LPF circuit is shown in Figure 28 with calculated values listed in Table 7. 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.

### PFD section

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



PARAMETER MEASUREMENT INFORMATION

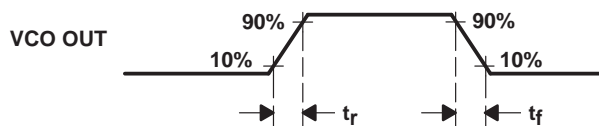
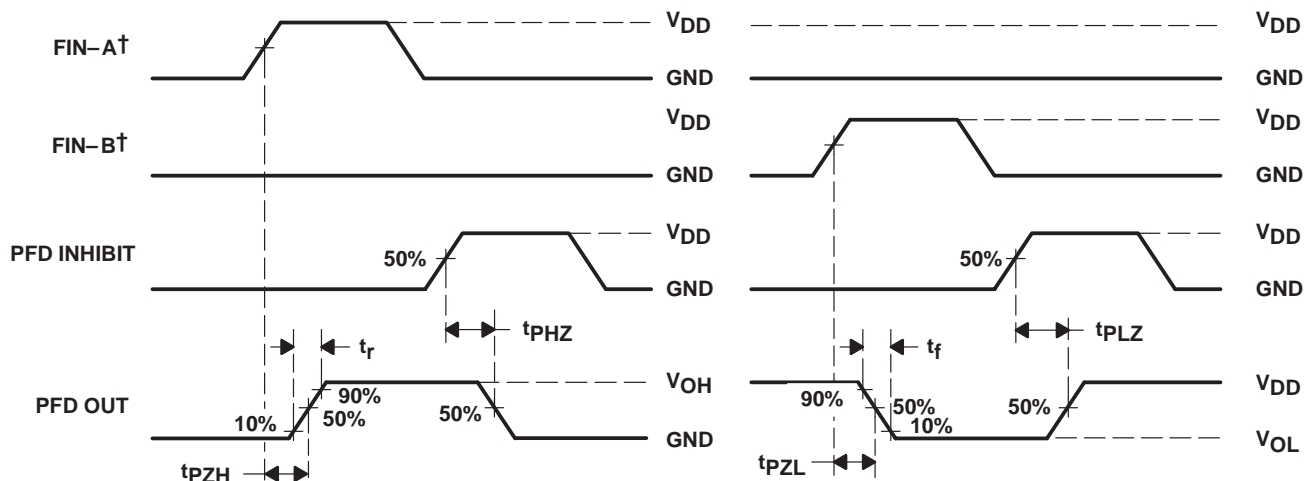


Figure 3. VCO Output Voltage Waveform



(a) OUTPUT PULLDOWN  
(see Figure 5 and Table 4)

(b) OUTPUT PULLUP  
(see Figure 5 and Table 4)

† FIN-A and FIN-B are for reference phase only, not for timing.

Figure 4. PFD Output Voltage Waveform

Table 4. PFD Output Test Conditions

PARAMETER	R <sub>L</sub>	C <sub>L</sub>	S <sub>1</sub>	S <sub>2</sub>
t <sub>PZH</sub>	1 kΩ	15 pF	Open	Close
t <sub>PHZ</sub>				
t <sub>r</sub>			Close	Open
t <sub>PZL</sub>				
t <sub>PLZ</sub>			Close	Open
t <sub>f</sub>				

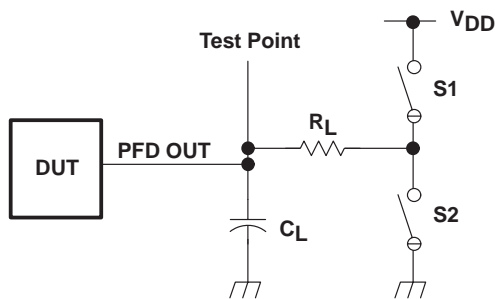


Figure 5. PFD Output Test Conditions

TYPICAL CHARACTERISTICS

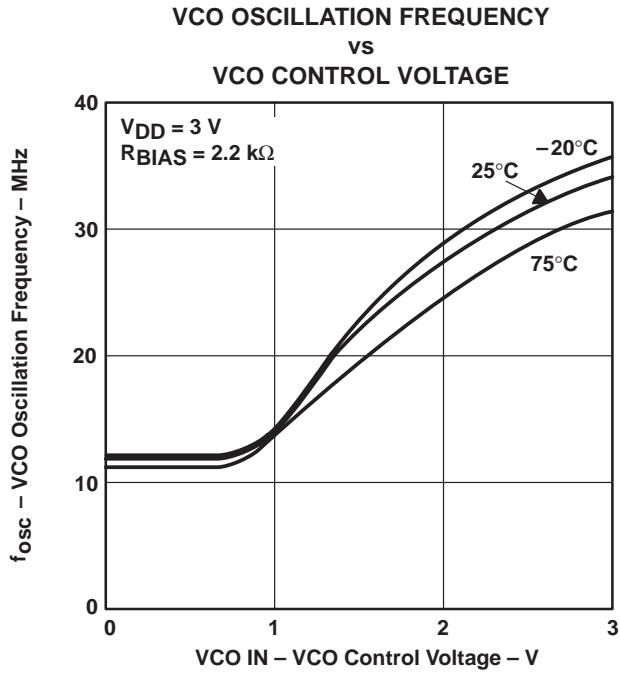


Figure 6

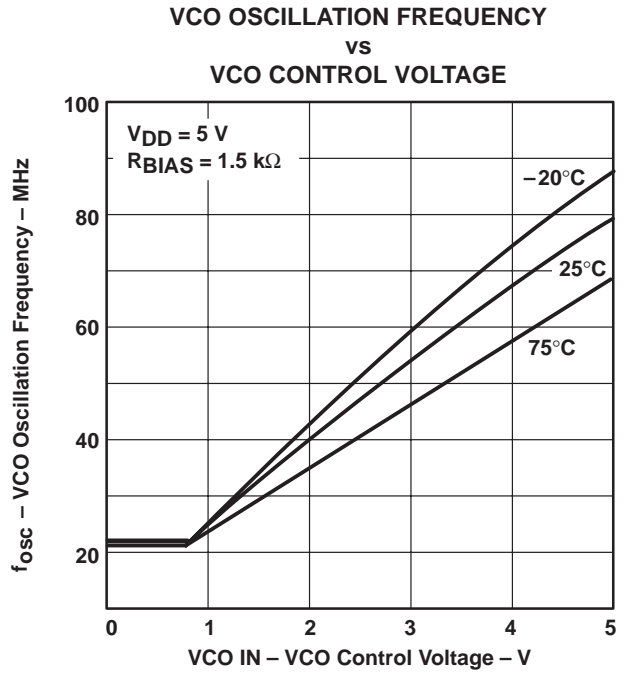


Figure 7

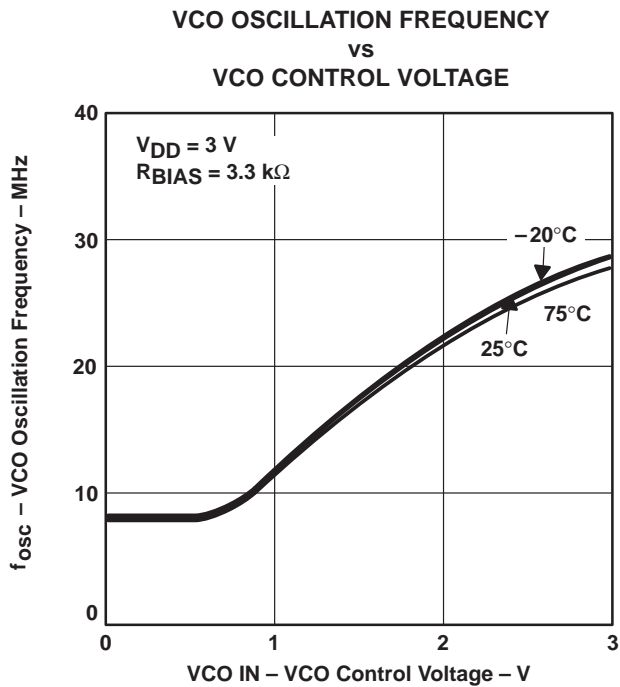


Figure 8

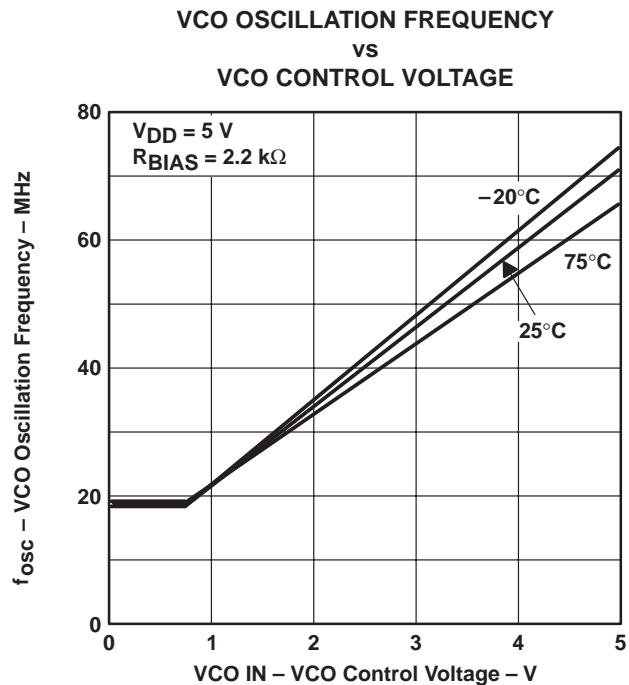


Figure 9

TYPICAL CHARACTERISTICS

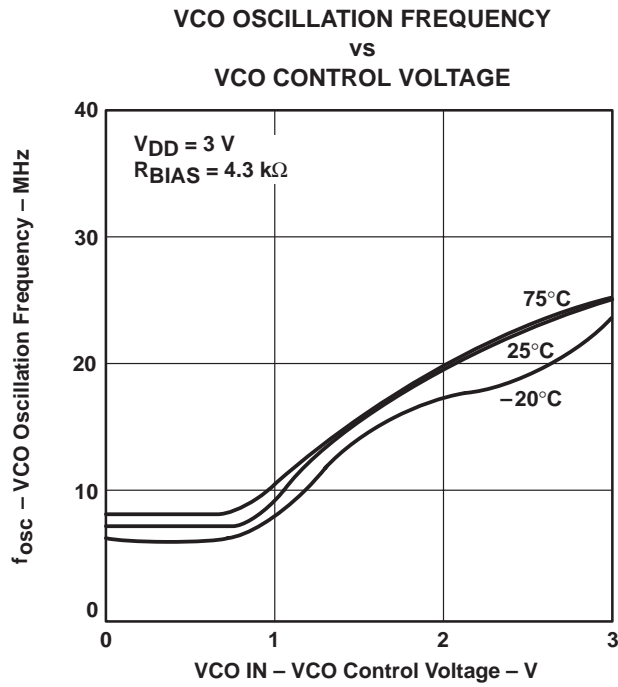


Figure 10

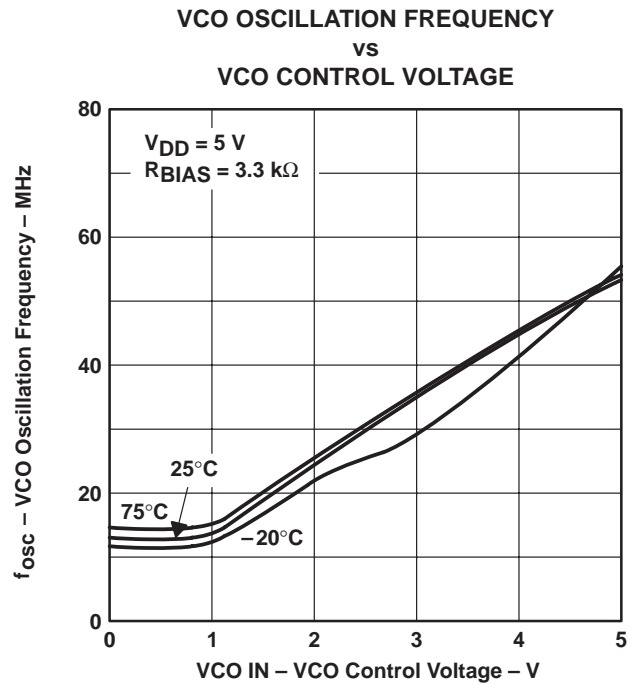


Figure 11

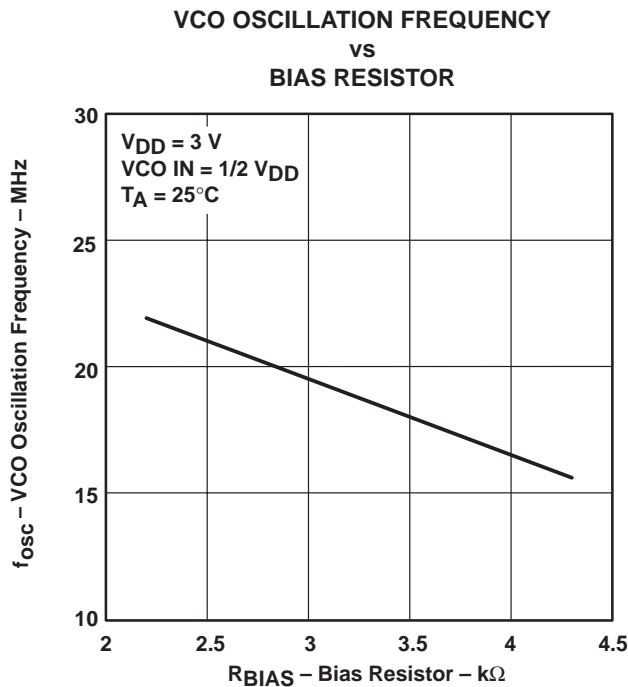


Figure 12

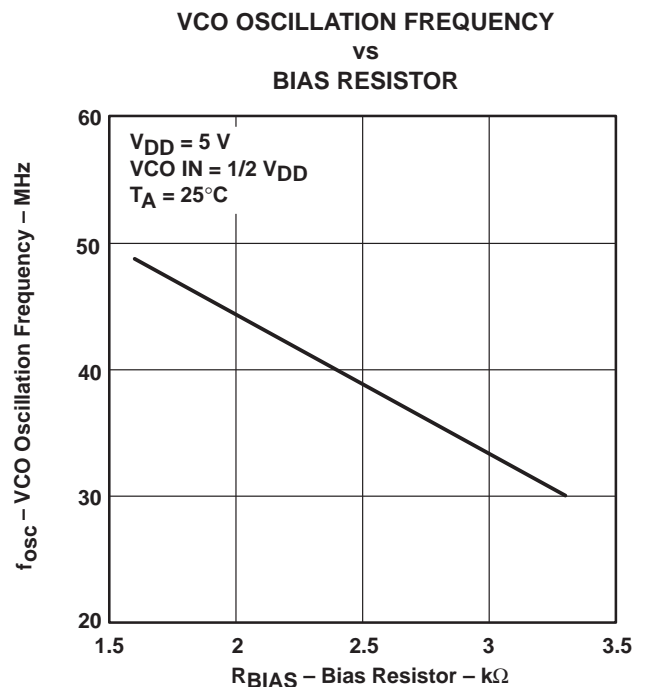


Figure 13

# TLC2932 HIGH-PERFORMANCE PHASE-LOCKED LOOP

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## TYPICAL CHARACTERISTICS

TEMPERATURE COEFFICIENT OF  
OSCILLATION FREQUENCY  
vs  
BIAS RESISTOR

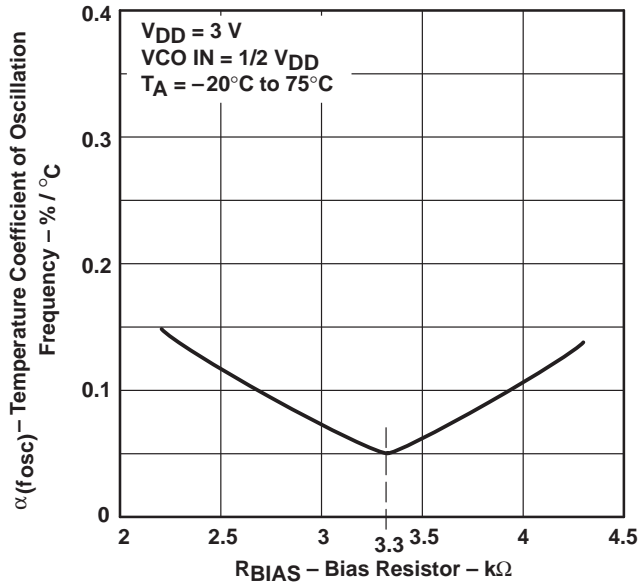


Figure 14

TEMPERATURE COEFFICIENT OF  
OSCILLATION FREQUENCY  
vs  
BIAS RESISTOR

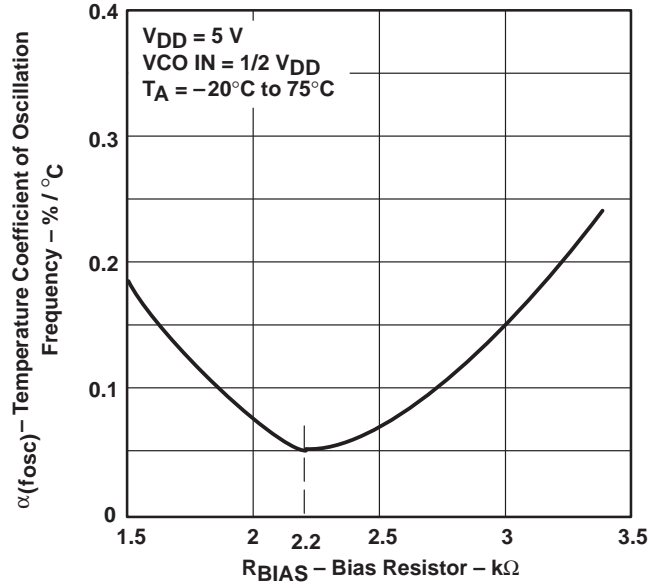


Figure 15

VCO OSCILLATION FREQUENCY  
vs  
VCO SUPPLY VOLTAGE

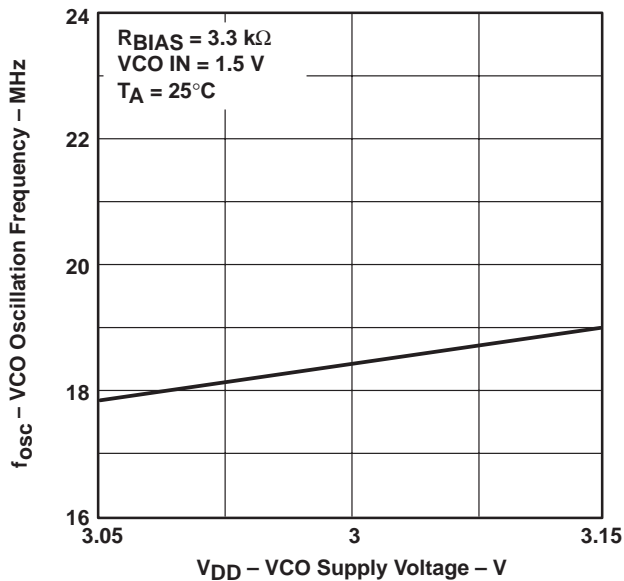


Figure 16

VCO OSCILLATION FREQUENCY  
vs  
VCO SUPPLY VOLTAGE

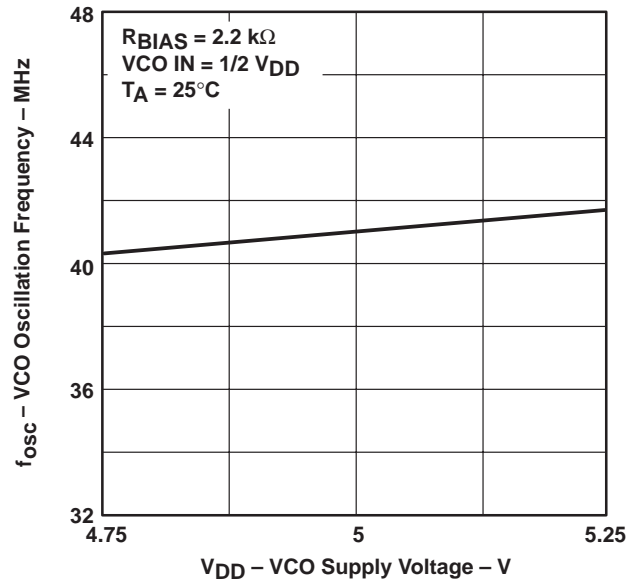


Figure 17



TYPICAL CHARACTERISTICS

SUPPLY VOLTAGE COEFFICIENT OF VCO  
OSCILLATION FREQUENCY

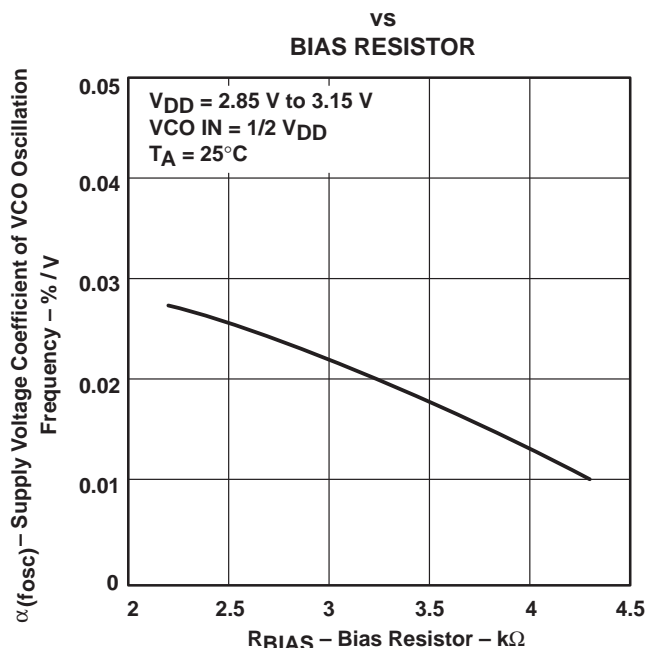


Figure 18

SUPPLY VOLTAGE COEFFICIENT OF VCO  
OSCILLATION FREQUENCY

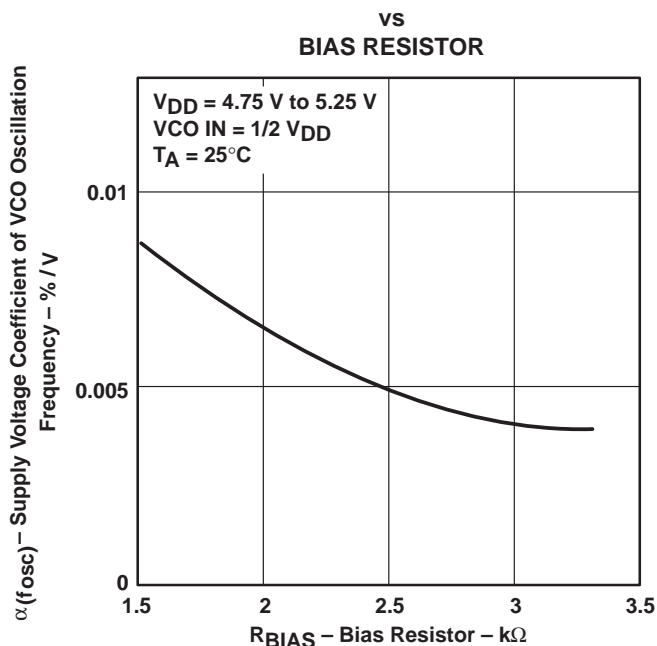


Figure 19

RECOMMENDED LOCK FREQUENCY

( $\times 1$  OUTPUT)

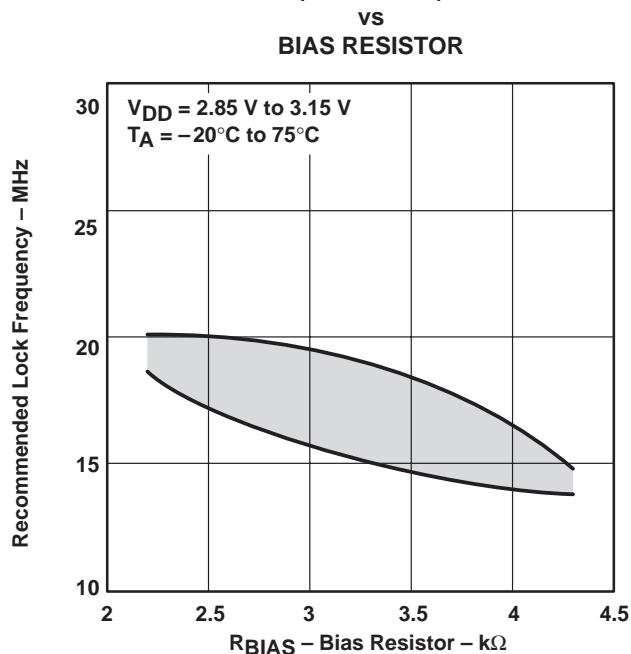


Figure 20

RECOMMENDED LOCK FREQUENCY

( $\times 1$  OUTPUT)

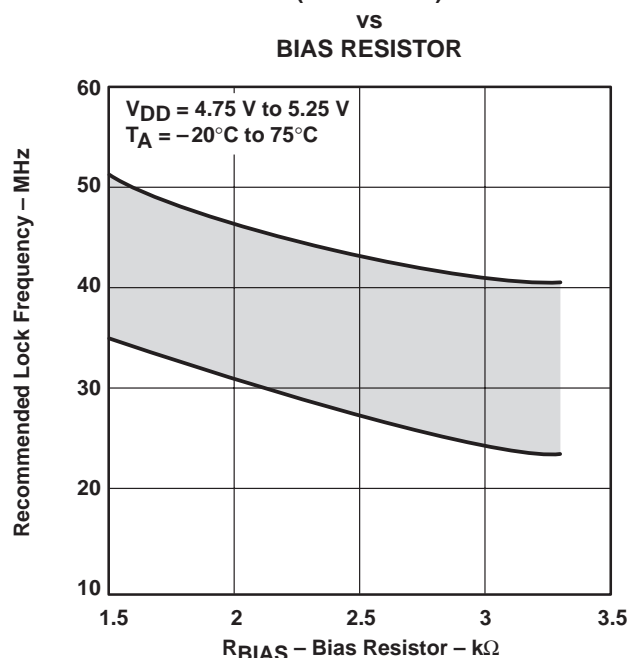


Figure 21

APPLICATION INFORMATION

RECOMMENDED LOCK FREQUENCY  
( $\times 1/2$  OUTPUT)  
vs  
BIAS RESISTOR

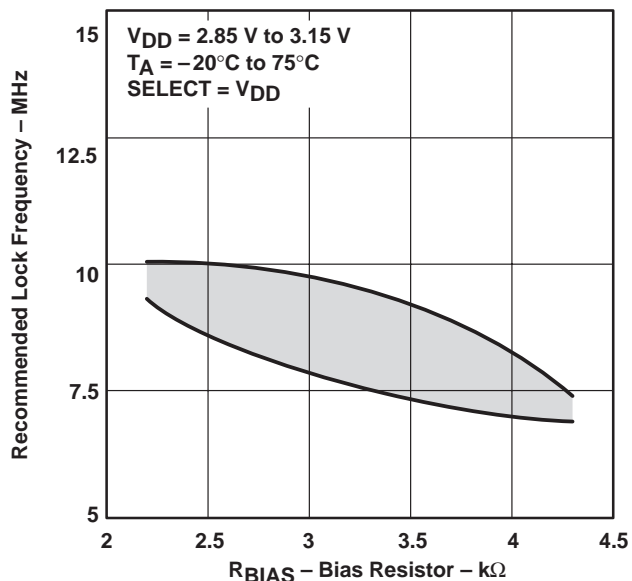


Figure 22

RECOMMENDED LOCK FREQUENCY  
( $\times 1/2$  OUTPUT)  
vs  
BIAS RESISTOR

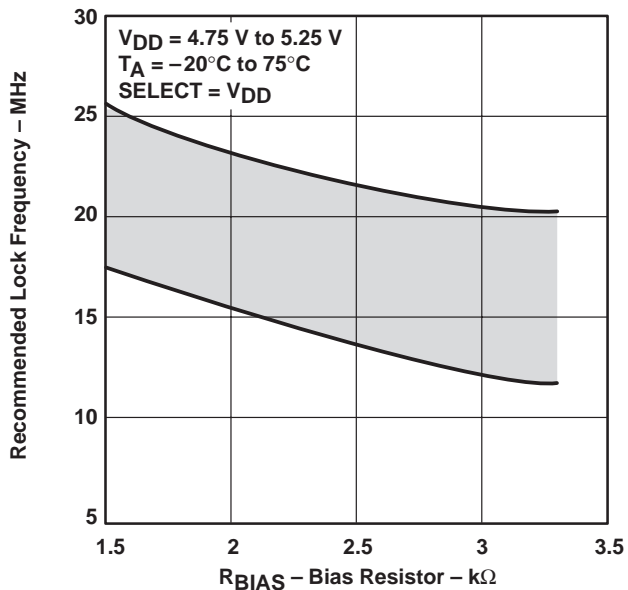


Figure 23

APPLICATION INFORMATION

gain of VCO and PFD

Figure 24 is a block diagram of the PLL. The countdown 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)
- $K_N$  : count down 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.

$R_{BIAS}$

The external bias resistor sets the VCO center frequency with  $1/2 V_{DD}$  applied to the VCO IN terminal. However, for optimum temperature performance, a resistor value of 3.3 k $\Omega$  with a 3-V supply and 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:

$$\Delta\omega_H \approx 0.8 (K_p) (K_V) (K_f(\infty))$$

Where

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

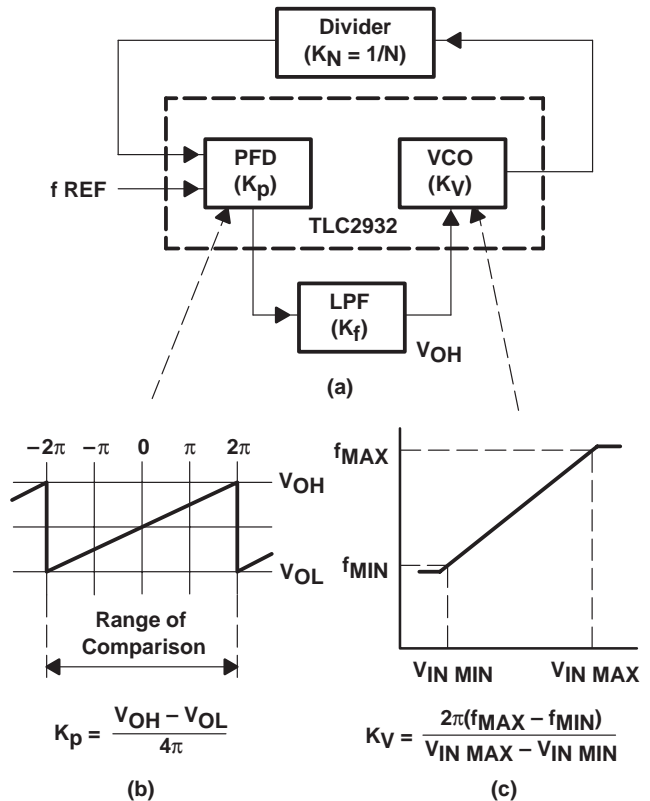


Figure 24. Example of a PLL Block Diagram

APPLICATION INFORMATION

low-pass-filter (LPF) configurations

Many excellent references are available that include detailed design information about LPFs and 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 FIN-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.

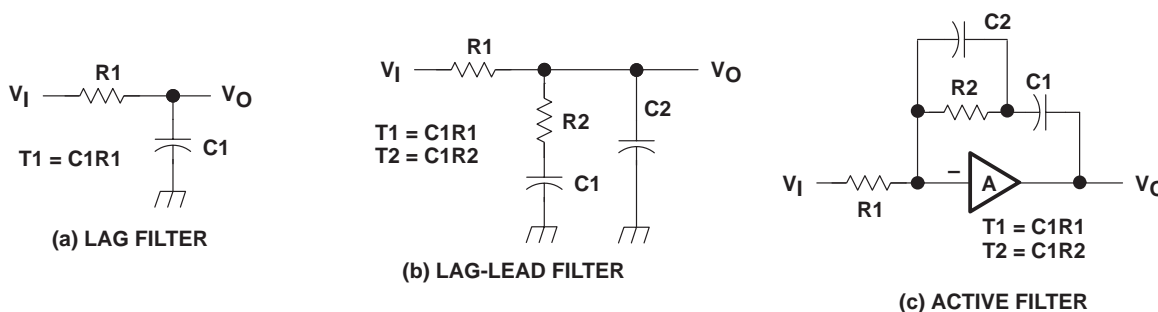


Figure 25. LPF Examples for PLL

the passive filter

The transfer function for the lag-lead filter shown in Figure 25(b) is;

$$\frac{V_O}{V_{IN}} = \frac{1 + s \cdot T2}{1 + s \cdot (T1 + T2)}$$

Where

$$T1 = R1 \cdot C1 \text{ and } T2 = R2 \cdot C1$$

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

the active filter

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

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

$$F(s) = \frac{1 + s \cdot R2 \cdot C1}{s \cdot R1 \cdot C1}$$

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

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.

## APPLICATION INFORMATION

### basic design example (continued)

Assume the loop has to have a 100  $\mu\text{s}$  settling time ( $t_s$ ) with a countdown  $N = 8$ . 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 5. The loop constants,  $K_V$  and  $K_P$ , are calculated from the data sheet specifications and Table 6 shows these values.

The natural loop frequency is calculated as follows:

Since

$$\omega_n t_s = 4.5$$

Then

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

**Table 5. Design Parameters**

PARAMETER	SYMBOL	VALUE	UNITS
Division factor	N	8	
Lockup time	t	100	$\mu\text{s}$
Radian value to selected lockup time	$\omega_n t$	4.5	rad
Damping factor	$\zeta$	0.7	

**Table 6. Device Specifications**

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

**Table 7. 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	$\mu\text{F}$

# TLC2932 HIGH-PERFORMANCE PHASE-LOCKED LOOP

SLAS097E – SEPTEMBER 1994 – REVISED MAY 1997

## APPLICATION INFORMATION

Using the low-pass filter in Figure 25(b) and divider ratio N, the transfer function for phase and frequency are shown in equations 1 and 2. Note that the transfer function for phase differs from the transfer function for frequency by only the divider value N. 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

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

and the transfer function for frequency is

$$\frac{F_{OUT}(s)}{F_{REF}(s)} = \frac{K_p \cdot K_V}{(T_1 + T_2)} \left[ \frac{1 + s \cdot T_2}{s^2 + s \cdot \left[ 1 + \frac{K_p \cdot K_V \cdot T_2}{N \cdot (T_1 + T_2)} \right] + \frac{K_p \cdot K_V}{N \cdot (T_1 + T_2)}} \right] \quad (2)$$

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 1 and 2 with the standard two-pole denominator gives the following results.

$$\omega_n = \sqrt{\frac{K_p \cdot K_V}{N \cdot (T_1 + T_2)}}$$

Solving for  $T_1 + T_2$

$$T_1 + T_2 = \frac{K_p \cdot K_V}{N \cdot \omega_n^2} \quad (3)$$

and by using this value for  $T_1 + T_2$  in equation 3 the damping factor is

$$\zeta = \frac{\omega_n}{2} \cdot \left( T_2 + \frac{N}{K_p \cdot K_V} \right)$$

solving for  $T_2$

$$T_2 = \frac{2 \zeta}{\omega_n} - \frac{N}{K_p \cdot K_V}$$

then by substituting for  $T_2$  in equation 3

$$T_1 = \frac{K_V \cdot K_p}{N \cdot \omega_n^2} - \frac{2 \zeta}{\omega_n} + \frac{N}{K_p \cdot K_V}$$

### APPLICATION INFORMATION

From the circuit constants and the initial design parameters then

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

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

The capacitor, C1, is usually chosen between 1  $\mu$ F and 0.1  $\mu$ F to allow for reasonable resistor values and physical capacitor size. In this example, C1 is chosen to be 0.1  $\mu$ F and the corresponding R1 and R2 calculated values are listed in Table 7.

APPLICATION INFORMATION

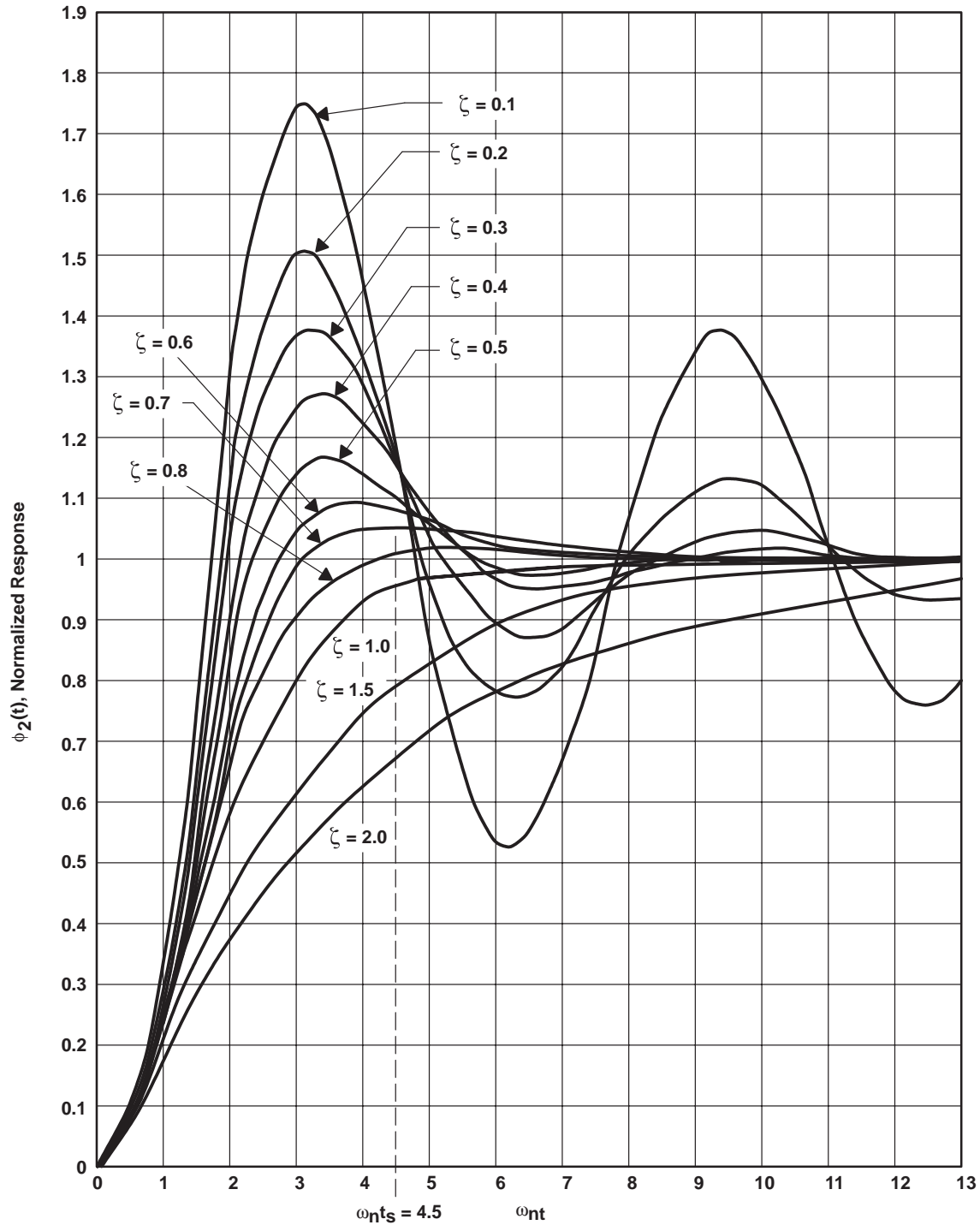


Figure 26. Type 1 Second-Order Step Response

APPLICATION INFORMATION

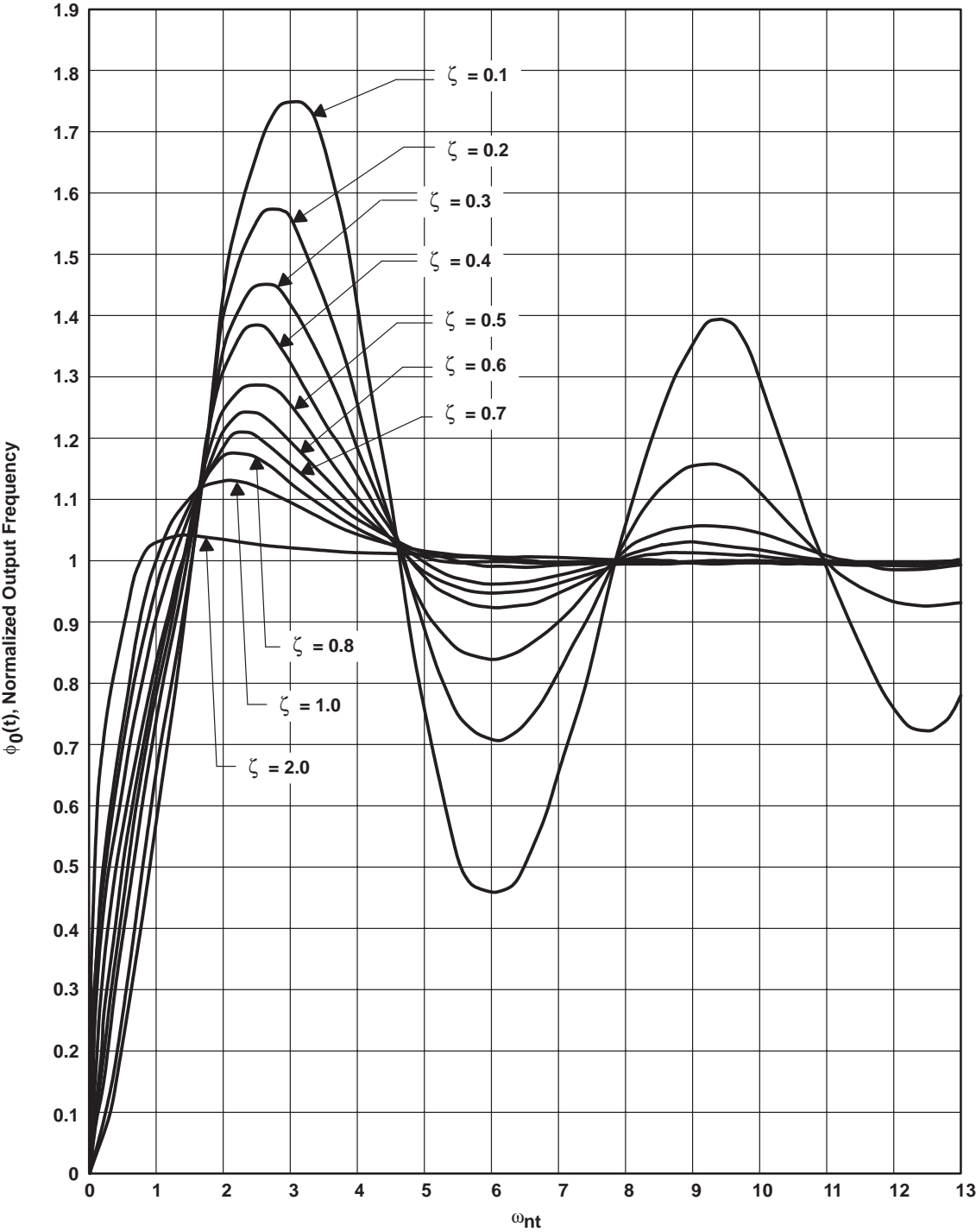


Figure 27. Type 2 Second-Order Step Response



TLC2932  
HIGH-PERFORMANCE PHASE-LOCKED LOOP

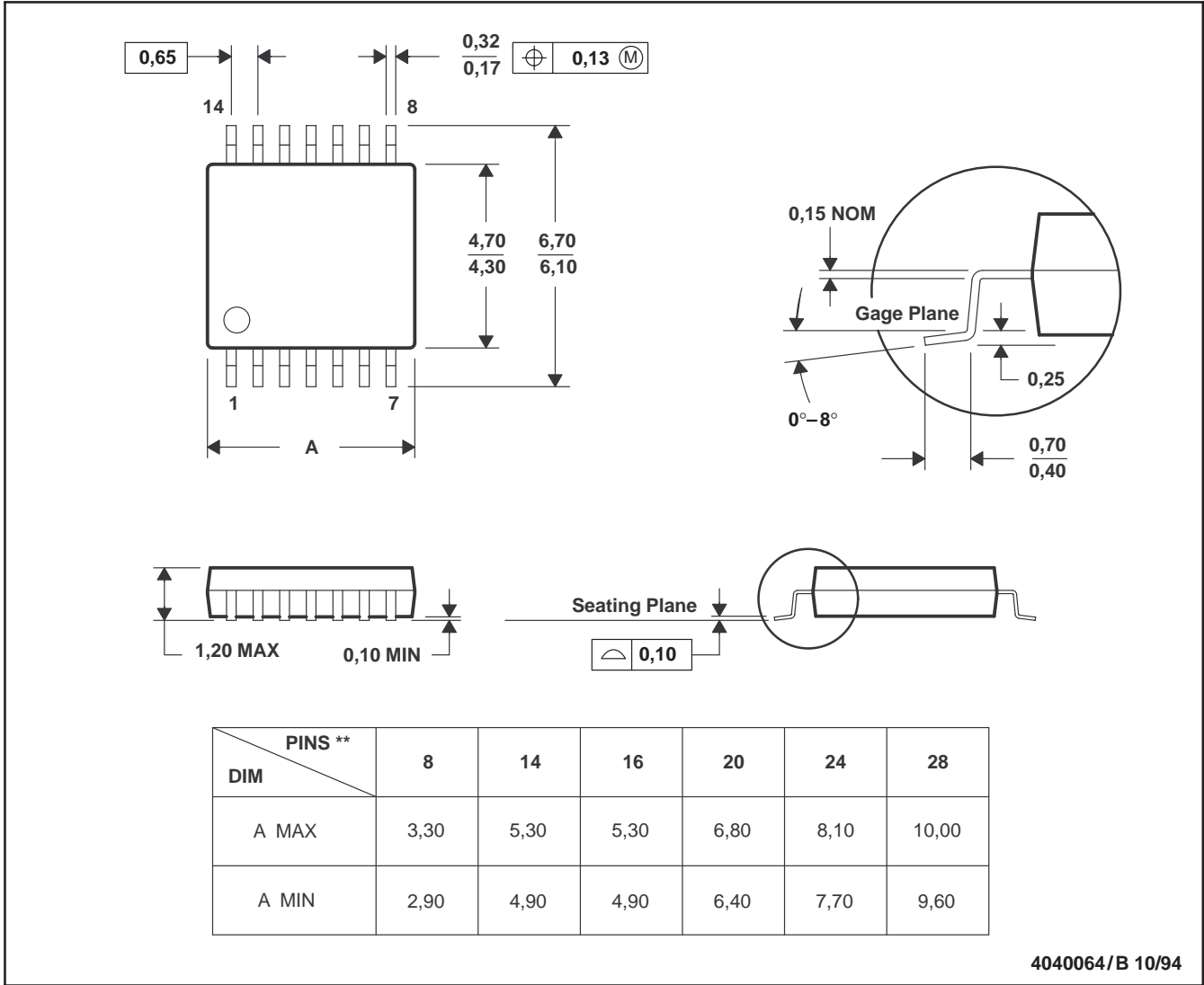
SLAS097E – SEPTEMBER 1994 – REVISED MAY 1997

MECHANICAL DATA

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

PLASTIC SMALL-OUTLINE PACKAGE

14 PIN SHOWN



4040064/B 10/94

- 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.

**PACKAGING INFORMATION**

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/Ball Finish	MSL Peak Temp <sup>(3)</sup>
TLC2932IPW	NRND	TSSOP	PW	14	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC2932IPWG4	ACTIVE	TSSOP	PW	14	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC2932IPWLE	OBSOLETE	TSSOP	PW	14		TBD	Call TI	Call TI
TLC2932IPWR	NRND	TSSOP	PW	14	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC2932IPWRG4	ACTIVE	TSSOP	PW	14	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM

<sup>(1)</sup> The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

<sup>(2)</sup> Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

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

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

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