

# PE9704

## Product Description

Peregrine's PE9704 is a high-performance integer-N PLL capable of frequency synthesis up to 3.0 GHz. The device is designed for superior phase noise performance while providing an order of magnitude reduction in current consumption, when compared with existing commercial space PLLs.

The PE9704 features a  $\div 10/11$  dual modulus prescaler, counters, and a phase comparator as shown in Figure 1. Counter values are programmable through a serial interface, and can also be directly hard wired.

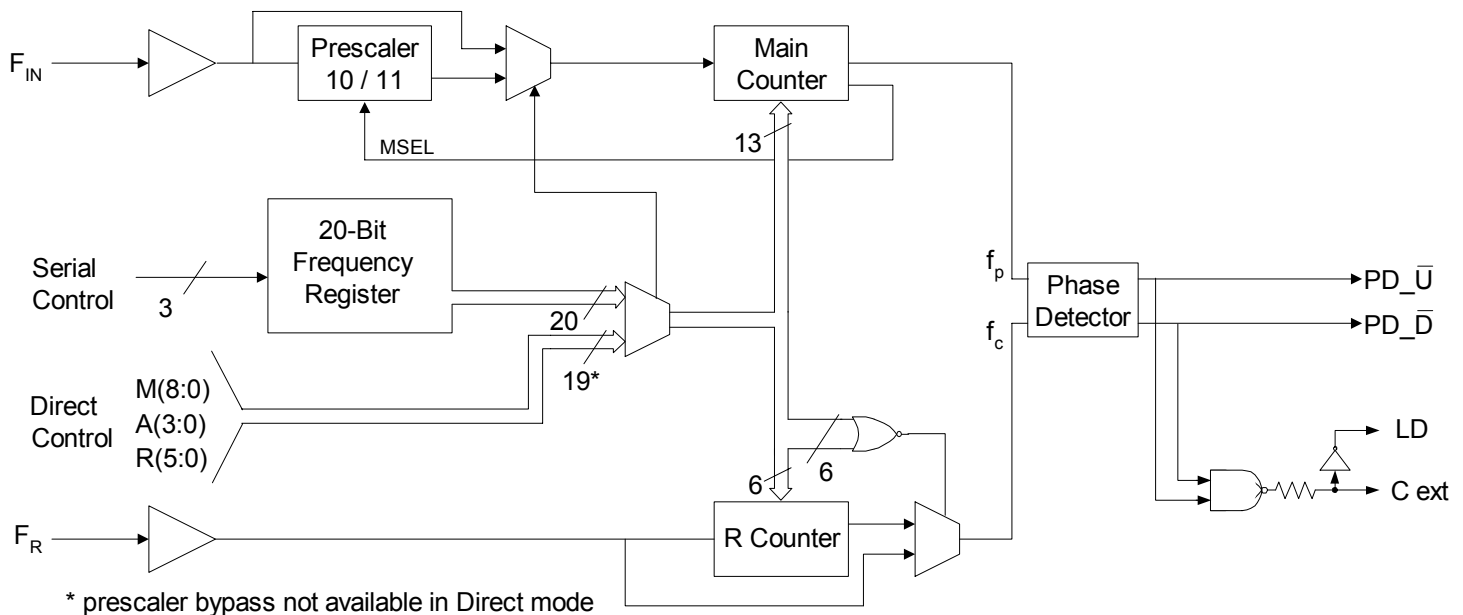
The PE9704 is optimized for commercial space applications. Single Event Latch-up (SEL) is physically impossible and Single Event Upset (SEU) is better than  $10^{-9}$  errors per bit / day. Fabricated in Peregrine's patented UTSi® (Ultra Thin Silicon) CMOS technology, the PE9704 offers excellent RF performance and intrinsic radiation tolerance.

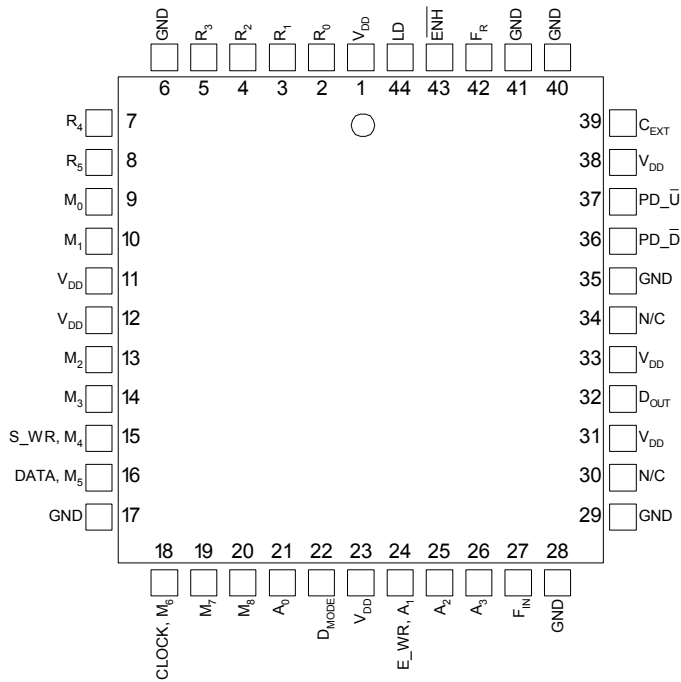
## 3.0 GHz Integer-N PLL for Rad Hard Applications

### Features

- 3.0 GHz operation
- $\div 10/11$  dual modulus prescaler
- Phase detector output
- Serial interface or hardwired programmable
- Ultra-low phase noise
- SEU <  $10^{-9}$  errors / bit-day
- 100 Krad (Si) total dose
- 44-lead CQFJ

Figure 1. Block Diagram



**Figure 2. Pin Configuration**

**Table 1. Pin Descriptions**

Pin No.	Pin Name	Interface Mode	Type	Description
1	V <sub>DD</sub>	Both	(Note 1)	Power supply input. Input may range from 2.85 V to 3.15 V. Bypassing recommended.
2	R <sub>0</sub>	Direct	Input	R Counter bit0
3	R <sub>1</sub>	Direct	Input	R Counter bit1
4	R <sub>2</sub>	Direct	Input	R Counter bit2
5	R <sub>3</sub>	Direct	Input	R Counter bit3
6	GND	Both	(Note 1)	Ground
7	R <sub>4</sub>	Direct	Input	R Counter bit4
8	R <sub>5</sub>	Direct	Input	R Counter bit5 (MSB)
9	M <sub>0</sub>	Direct	Input	M Counter bit0
10	M <sub>1</sub>	Direct	Input	M Counter bit1
11	V <sub>DD</sub>	Both	(Note 1)	Same as pin 1
12	V <sub>DD</sub>	Both	(Note 1)	Same as pin 1
13	M <sub>2</sub>	Direct	Input	M Counter bit2
14	M <sub>3</sub>	Direct	Input	M Counter bit3
15	S_WR	Serial	Input	Frequency register load enable input. Buffered data is transferred to the frequency register on S_WR rising edge.
	M <sub>4</sub>	Direct	Input	M Counter bit4
16	DATA	Serial	Input	Binary serial data input. Data is entered LSB first, and is clocked serially into the 20-bit frequency control register (E_WR "low") or the 8-bit enhancement register (E_WR "high") on the rising edge of CLOCK.

Pin No.	Pin Name	Interface Mode	Type	Description
	M <sub>5</sub>	Direct	Input	M Counter bit5
17	GND	Both		Ground
18	CLOCK	Serial	Input	Clock input. Data is clocked serially into either the 20-bit primary register (E_WR "low") or the 8-bit enhancement register (E_WR "high") on the rising edge of CLOCK.
	M <sub>6</sub>	Direct	Input	M Counter bit6
19	M <sub>7</sub>	Direct	Input	M Counter bit7
20	M <sub>8</sub>	Direct	Input	M Counter bit8 (MSB)
21	A <sub>0</sub>	Direct	Input	A Counter bit0
22	D <sub>MODE</sub>	Both	Input	Selects direct interface mode (D <sub>MODE</sub> =1) or serial interface mode (D <sub>MODE</sub> =0)
23	V <sub>DD</sub>	Both	(Note 1)	Same as pin 1
24	E_WR	Serial	Input	Enhancement register write enable. While E_WR is "high", DATA can be serially clocked into the enhancement register on the rising edge of CLOCK.
	A <sub>1</sub>	Direct	Input	A Counter bit1.
25	A <sub>2</sub>	Direct	Input	A Counter bit2
26	A <sub>3</sub>	Direct	Input	A Counter bit3 (MSB)
27	F <sub>IN</sub>	Both	Input	RF prescaler input from the VCO. 3.0 GHz maximum frequency.
28	GND	Both		Ground.
29	GND	Both		Ground.
30	N/C			No connect.
31	V <sub>DD</sub>	Both	(Note 1)	Same as pin 1
32	D <sub>OUT</sub>	Serial	Output	Data Out. The Main Counter output, R Counter output, or dual modulus prescaler select (MSEL) can be routed to D <sub>OUT</sub> through enhancement register programming.
33	V <sub>DD</sub>	Both	(Note 1)	Same as pin 1
34	N/C			No connect.
35	GND	Both		Ground.
36	PD <sub>̄</sub>	Both	Output	PD <sub>̄</sub> pulses down when f <sub>p</sub> leads f <sub>c</sub> .
37	PD <sub>̄</sub>	Both		PD <sub>̄</sub> pulses down when f <sub>c</sub> leads f <sub>p</sub> .
38	V <sub>DD</sub>	Both	(Note 1)	Same as pin 1
39	C <sub>EXT</sub>	Both	Output	Logical "NAND" of PD <sub>̄</sub> and PD <sub>̄</sub> , passed through an on-chip, 2 kΩ series resistor. Connecting C <sub>EXT</sub> to an external capacitor will low pass filter the input to the inverting amplifier used for driving LD.
40	GND	Both		Ground
41	GND	Both		Ground
42	F <sub>R</sub>	Both	Input	Reference frequency input
43	ENH	Both	Output, OD	Enhancement mode. When asserted low ("0"), enhancement register bits are functional.
44	LD	Serial	Output	Lock detect output, the open-drain logical inversion of C <sub>EXT</sub> . When the loop is locked, LD is high impedance; otherwise LD is a logic low ("0").

**Note 1:** V<sub>DD</sub> pins 1, 11, 12, 23, 31, 33, 35, and 38 are connected by diodes and must be supplied with the same positive voltage level.

**Note 2:** All digital input pins have 70 kΩ pull-down resistors to ground.

**Table 2. Absolute Maximum Ratings**

Symbol	Parameter/Conditions	Min	Max	Units
$V_{DD}$	Supply voltage	-0.3	4.0	V
$V_i$	Voltage on any input	-0.3	$V_{DD} + 0.3$	V
$I_i$	DC into any input	-10	+10	mA
$I_o$	DC into any output	-10	+10	mA
$T_{stg}$	Storage temperature range	-65	150	°C

**Table 3. Operating Ratings**

Symbol	Parameter/Conditions	Min	Max	Units
$V_{DD}$	Supply voltage	2.85	3.15	V
$T_A$	Operating ambient temperature range	-40	85	°C

**Table 4. ESD Ratings**

Symbol	Parameter/Conditions	Level	Units
$V_{ESD}$	ESD voltage (Human Body Model) – Note 1	1000	V

**Note 1:** Periodically sampled, not 100% tested. Tested per MIL-STD-883, M3015 C2

### Electrostatic Discharge (ESD) Precautions

When handling this UTSi device, observe the same precautions that you would use with other ESD-sensitive devices. Although this device contains circuitry to protect it from damage due to ESD, precautions should be taken to avoid exceeding the rating specified in Table 4.

### Latch-Up Avoidance

Unlike conventional CMOS devices, UTSi CMOS devices are immune to latch-up.

**Table 5. DC Characteristics**

$V_{DD} = 3.0\text{ V}$ ,  $-40^\circ\text{ C} < T_A < 85^\circ\text{ C}$ , unless otherwise specified

Symbol	Parameter	Conditions	Min	Typ	Max	Units
$I_{DD}$	Operational supply current; Prescaler disabled Prescaler enabled	$V_{DD} = 2.85\text{ to }3.15\text{ V}$		10 24	31	mA mA
Digital Inputs: All except $F_R$ , $F_{IN}$ (all digital inputs have 70k ohm pull-up resistors)						
$V_{IH}$	High level input voltage	$V_{DD} = 2.85\text{ to }3.15\text{ V}$	$0.7 \times V_{DD}$			V
$V_{IL}$	Low level input voltage	$V_{DD} = 2.85\text{ to }3.15\text{ V}$			$0.3 \times V_{DD}$	V
$I_{IH}$	High level input current	$V_{IH} = V_{DD} = 3.15\text{ V}$			+70	$\mu\text{A}$
$I_{IL}$	Low level input current	$V_{IL} = 0, V_{DD} = 3.15\text{ V}$	-1			$\mu\text{A}$
Reference Divider input: $F_R$						
$I_{IHR}$	High level input current	$V_{IH} = V_{DD} = 3.15\text{ V}$			+100	$\mu\text{A}$
$I_{ILR}$	Low level input current	$V_{IL} = 0, V_{DD} = 3.15\text{ V}$	-100			$\mu\text{A}$
Counter and phase detector outputs: $f_c, f_p$ .						
$V_{OLD}$	Output voltage LOW	$I_{out} = 6\text{ mA}$			0.4	V
$V_{OHD}$	Output voltage HIGH	$I_{out} = -3\text{ mA}$	$V_{DD} - 0.4$			V
Lock detect outputs: $C_{EXT}, LD$						
$V_{OLC}$	Output voltage LOW, $C_{EXT}$	$I_{out} = 100\ \mu$			0.4	V
$V_{OHC}$	Output voltage HIGH, $C_{EXT}$	$I_{out} = -100\ \mu$	$V_{DD} - 0.4$			V
$V_{OLLD}$	Output voltage LOW, LD	$I_{out} = 6\text{ mA}$			0.4	V

**Table 6. AC Characteristics**
 $V_{DD} = 3.0\text{ V}$ ,  $-40^{\circ}\text{ C} < T_A < 85^{\circ}\text{ C}$ , unless otherwise specified

Symbol	Parameter	Conditions	Min	Max	Units
Control Interface and Latches (see Figures 1 and 3)					
$f_{\text{Clk}}$	CLOCK Serial data clock frequency	(Note 1)		10	MHz
$t_{\text{ClkH}}$	CLOCK Serial clock HIGH time		30		ns
$t_{\text{ClkL}}$	CLOCK Serial clock LOW time		30		ns
$t_{\text{DSU}}$	DATA set-up time after CLOCK rising edge		10		ns
$t_{\text{DHLD}}$	DATA hold time after CLOCK rising edge		10		ns
$t_{\text{PW}}$	S_WR pulse width		30		ns
$t_{\text{CWR}}$	CLOCK rising edge to S_WR rising edge.		30		ns
$t_{\text{CE}}$	CLOCK falling edge to E_WR transition		30		ns
$t_{\text{WRC}}$	S_WR falling edge to CLOCK rising edge.		30		ns
$t_{\text{EC}}$	E_WR transition to CLOCK rising edge		30		ns
$t_{\text{MDO}}$	MSEL data out delay after $F_{\text{IN}}$ rising edge	$C_L = 12\text{ pf}$		8	ns
Main Divider (Including Prescaler)					
$F_{\text{IN}}$	Operating frequency		500	3000	MHz
$P_{\text{Fin}}$	Input level range	External AC coupling	-5	5	dBm
Main Divider (Prescaler Bypassed)					
$F_{\text{IN}}$	Operating frequency		50	300	MHz
$P_{\text{Fin}}$	Input level range	External AC coupling	-5	5	dBm
Reference Divider					
$F_{\text{R}}$	Operating frequency	(Note 3)		100	MHz
$P_{\text{Fr}}$	Reference input power (Note 2)	Single-ended input	-2		dBm
Phase Detector					
$f_c$	Comparison frequency	(Note 3)		20	MHz

**Note 1:** Fclk is verified during the functional pattern test. Serial programming sections of the functional pattern are clocked at 10 MHz to verify Fclk specification.

**Note 2:** CMOS logic levels can be used to drive reference input if DC coupled. Voltage input needs to be a minimum of  $0.5V_{p-p}$ .

**Note 3:** Parameter is guaranteed through characterization only and is not tested.

## Functional Description

The PE9704 consists of a prescaler, counters, a phase detector, and control logic. The dual modulus prescaler divides the VCO frequency by either 10 or 11, depending on the value of the modulus select. Counters “R” and “M” divide the reference and prescaler output, respectively, by integer values stored in a 20-bit register. An additional counter (“A”) is used in the modulus select logic. The phase-frequency detector generates up and down frequency control signals. The control logic includes a selectable chip interface. Data can be written via a serial bus or hardwired directly to the pins. There are also various operational and test modes and a lock detect output.

### Main Counter Chain

#### Normal Operating Mode

Setting the PB control bit “low” enables the ÷10/11 prescaler. The main counter chain then divides the RF input frequency ( $F_{IN}$ ) by an integer derived from the values in the “M” and “A” counters.

In this mode, the output from the main counter chain ( $f_p$ ) is related to the VCO frequency ( $F_{IN}$ ) by the following equation:

$$f_p = F_{IN} / [10 \times (M + 1) + A] \quad (1)$$

where  $A \leq M + 1$ ,  $1 \leq M \leq 511$

When the loop is locked,  $F_{IN}$  is related to the reference frequency ( $F_R$ ) by the following equation:

$$F_{IN} = [10 \times (M + 1) + A] \times (F_R / (R+1)) \quad (2)$$

where  $A \leq M + 1$ ,  $1 \leq M \leq 511$

A consequence of the upper limit on A is that  $F_{IN}$  must be greater than or equal to  $90 \times (F_R / (R+1))$  to obtain contiguous channels. The A counter can accept values as high as 15, but in typical operation it will cycle from 0 to 9 between increments in M.

Programming the M counter with the minimum allowed value of “1” will result in a minimum M counter divide ratio of “2”.

#### Prescaler Bypass Mode

Setting the frequency control register bit PB “high” allows  $F_{IN}$  to bypass the ÷10/11 prescaler. In this mode, the prescaler and A counter are powered down, and the input VCO frequency is divided by the M counter directly. This mode is only available when using the serial port to set the frequency control bits. The following equation relates  $F_{IN}$  to the reference frequency  $F_R$ :

$$F_{IN} = (M + 1) \times (F_R / (R+1)) \quad (3)$$

where  $1 \leq M \leq 511$

### Reference Counter

The reference counter chain divides the reference frequency  $F_R$  down to the phase detector comparison frequency  $f_c$ .

The output frequency of the 6-bit R Counter is related to the reference frequency by the following equation:

$$f_c = F_R / (R + 1) \quad (4)$$

where  $0 \leq R \leq 63$

Note that programming R with “0” will pass the reference frequency ( $F_R$ ) directly to the phase detector.

## Register Programming

### Serial Interface Mode

Serial Interface Mode is selected by setting the  $D_{MODE}$  input “low”.

While the  $E\_WR$  input is “low”, serial data (DATA input),  $B_0$  to  $B_{19}$ , is clocked into a buffer register on the rising edge of  $CLOCK$ , LSB ( $B_0$ ) first. The contents from this buffer register are transferred into the frequency control register on the rising edge of  $S\_WR$  according to the timing diagram shown in Figure 3. This data controls the counters as shown in Table 7.

While the  $E\_WR$  input is “high”, serial data (DATA input),  $B_0$  to  $B_7$ , is clocked into a buffer register on the rising edge of  $CLOCK$ , LSB ( $B_0$ ) first. The

contents from this buffer register are transferred into the enhancement register on the falling edge of  $E\_WR$  according to the timing diagram shown in Figure 3. After the falling edge of  $E\_WR$ , the data provides control bits as shown in Table 8. These bits are active when the  $Enh$  input is “low”.

### Direct Interface Mode

Direct Interface Mode is selected by setting the  $D_{MODE}$  input “high”. In this mode, the counter values are set directly at external pins as shown in Table 7 and Figure 2. All frequency control register bits are addressable except  $PB$  (it is not possible to bypass the  $\div 10/11$  dual modulus prescaler in Direct Mode).

**Table 7. Frequency Register Programming**

Interface Mode	$\overline{Enh}$	$D_{MODE}$	$R_5$	$R_4$	$M_8$	$M_7$	$PB$	$M_6$	$M_5$	$M_4$	$M_3$	$M_2$	$M_1$	$M_0$	$R_3$	$R_2$	$R_1$	$R_0$	$A_3$	$A_2$	$A_1$	$A_0$
Serial*	1	0	$B_0$	$B_1$	$B_2$	$B_3$	$B_4$	$B_5$	$B_6$	$B_7$	$B_8$	$B_9$	$B_{10}$	$B_{11}$	$B_{12}$	$B_{13}$	$B_{14}$	$B_{15}$	$B_{16}$	$B_{17}$	$B_{18}$	$B_{19}$
Direct	1	1	$R_5$	$R_4$	$M_8$	$M_7$	0	$M_6$	$M_5$	$M_4$	$M_3$	$M_2$	$M_1$	$M_0$	$R_3$	$R_2$	$R_1$	$R_0$	$A_3$	$A_2$	$A_1$	$A_0$

\* Data is clocked serially on  $CLOCK$  rising edge while  $E\_WR$  is “low” and transferred to frequency register on  $S\_WR$  rising edge.

↑  
LSB (first in)

↑  
MSB (last in)

**Table 8. Enhancement Register Programming**

Interface Mode	$\overline{Enh}$	$D_{MODE}$	Reserved*	Reserved*	fp output	Power down	Counter load	MSEL output	fc output	Reserved*
Serial**	0	X	$B_0$	$B_1$	$B_2$	$B_3$	$B_4$	$B_5$	$B_6$	$B_7$

\* Program to 0

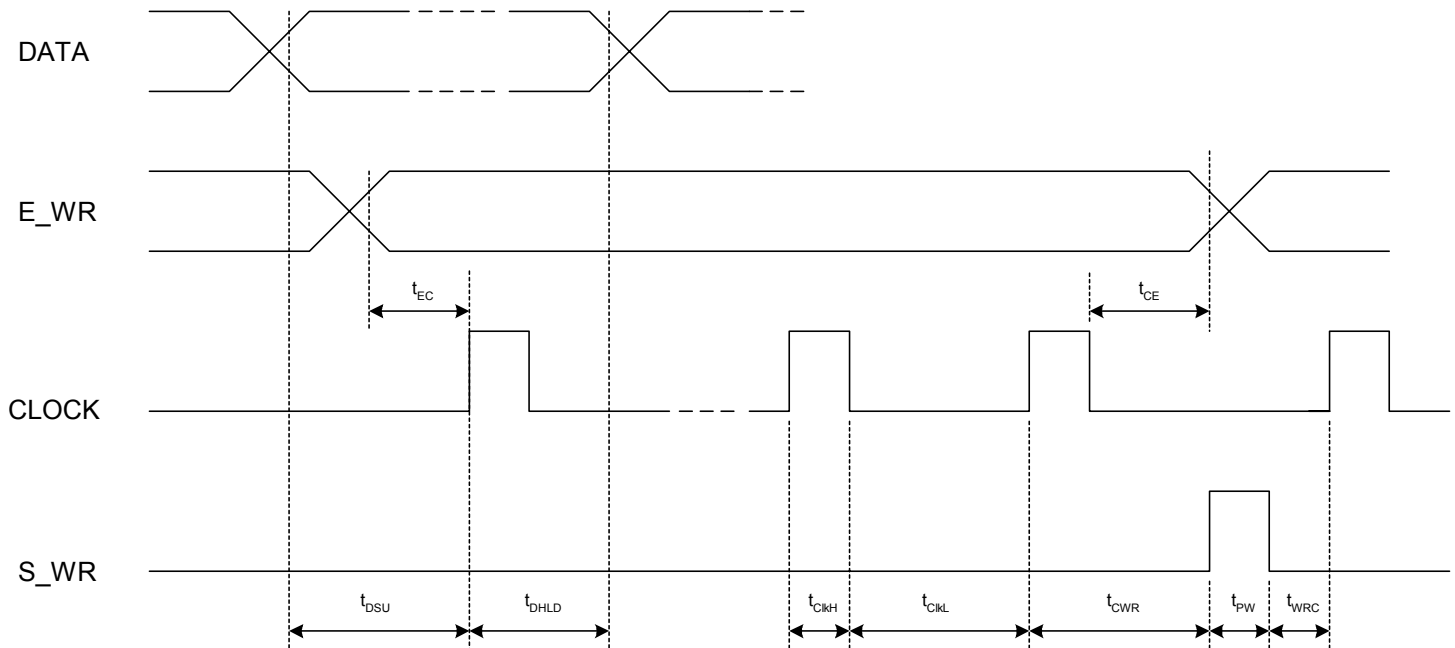
\* Data is clocked serially on  $CLOCK$  rising edge while  $E\_WR$  is “low” and transferred to frequency register on  $S\_WR$  rising edge.

↑  
LSB (first in)

↑  
MSB (last in)



**Figure 3. Serial Interface Mode Timing Diagram**



### Enhancement Register

The functions of the enhancement register bits are shown below. All bits are active high. Operation is undefined if more than one output is sent to  $D_{OUT}$ .

**Table 9. Enhancement Register Bit Functionality**

Bit Function		Description
Bit 0	Reserved**	
Bit 1	Reserved**	
Bit 2	$f_p$ output	Drives the M counter output onto the $D_{OUT}$ output.
Bit 3	Power down	Power down of all functions except programming interface.
Bit 4	Counter load	Immediate and continuous load of counter programming.
Bit 5	MSEL output	Drives the internal dual modulus prescaler modulus select (MSEL) onto the $D_{OUT}$ output.
Bit 6	$f_c$ output	Drives the R counter output onto the $D_{OUT}$ output
Bit 7	Reserved**	

\*\* Program to 0

## Phase Detector Outputs

The phase detector is triggered by rising edges from the main counter ( $f_p$ ) and the reference counter ( $f_c$ ). It has two outputs,  $PD_{\bar{U}}$  and  $PD_{\bar{D}}$ . If the divided VCO leads the divided reference in phase or frequency ( $f_p$  leads  $f_c$ ),  $PD_{\bar{D}}$  pulses “low”. If the divided reference leads the divided VCO in phase or frequency ( $f_c$  leads  $f_p$ ),  $PD_{\bar{U}}$  pulses “low”. The width of either pulse is directly proportional to phase offset between the two input signals,  $f_p$  and  $f_c$ . The phase detector gain is 430 mV / radian.

$PD_{\bar{U}}$  and  $PD_{\bar{D}}$  are designed to drive an active loop filter which controls the VCO tune voltage.  $PD_{\bar{U}}$  pulses result in an increase in VCO frequency and  $PD_{\bar{D}}$  results in a decrease in VCO frequency.

Software tools for designing the active loop filter can be found at Peregrine’s web site ([www.peregrine-semi.com](http://www.peregrine-semi.com)).

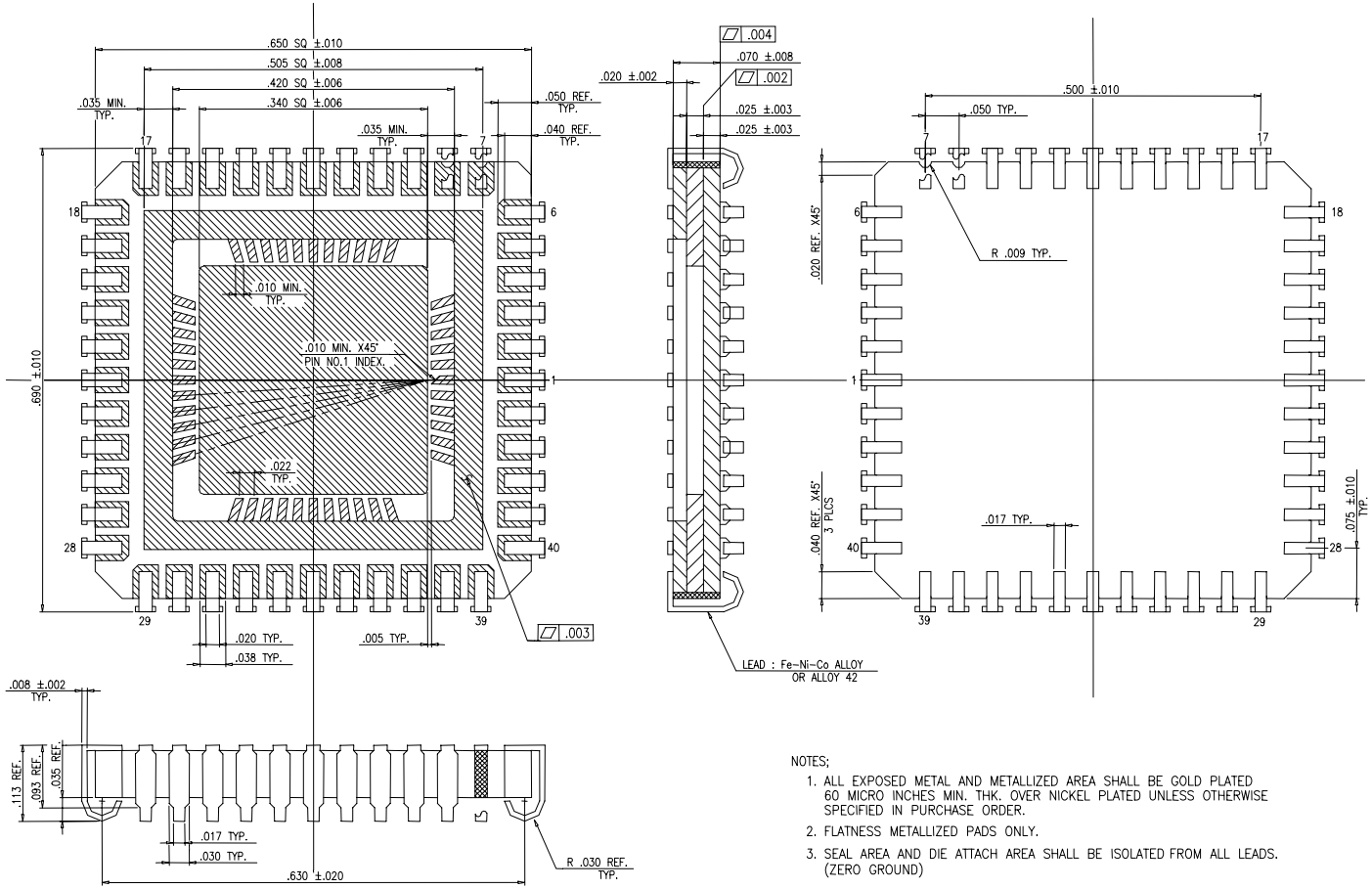
## Lock Detect Output

A lock detect signal is provided at pin LD, via the pin  $C_{EXT}$  (see Figure 1).  $C_{EXT}$  is the logical “NAND” of  $PD_{\bar{U}}$  and  $PD_{\bar{D}}$  waveforms, driven through a series 2k ohm resistor. Connecting  $C_{EXT}$  to an external shunt capacitor provides integration of this signal.

The  $C_{EXT}$  signal is then sent to the LD pin through an internal inverting comparator with an open drain output. Thus LD is an “AND” function of  $PD_{\bar{U}}$  and  $PD_{\bar{D}}$ .

### Figure 4. Package Drawing

44-lead CQFJ



All dimensions are in mils

Table 10. Ordering Information

Order Code	Part Marking	Description	Package	Shipping Method
9704-01	PE9704 ES	Engineering Samples	44-pin CQFJ	40 units / Tray
9704-11	PE9704	Flight Units	44-pin CQFJ	40 units / Tray
9704-00	PE9704 EK	Evaluation Kit		1 / Box