

Product Description

Peregrine's PE97632 is a high performance fractional-N PLL capable of frequency synthesis up to 3.5 GHz. The device is designed for superior phase noise performance while providing an order of magnitude reduction in current consumption, when compared with the existing commercial space PLLs.

The PE97632 features a 10/11 dual modulus prescaler, counters, a delta sigma modulator, and a phase comparator as shown in Figure 1. Counter values are programmable through either a serial interface or directly hard-wired.

The PE97632 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 UltraCMOS™ technology, the PE97632 offers excellent RF performance and intrinsic radiation tolerance.

3.5 GHz Delta-Sigma modulated Fractional-N Frequency Synthesizer for Low Phase Noise Applications

Features

- 3.5 GHz operation
- $\div 10/11$ dual modulus prescaler
- Phase detector output
- Serial or Direct mode access
- Frequency selectivity: Comparison frequency / 2^{18}
- Low power — 40 mA at 3.3 V
- Rad-Hard
- Ultra-low phase noise
- 68-lead CQFJ

Figure 1. Block Diagram

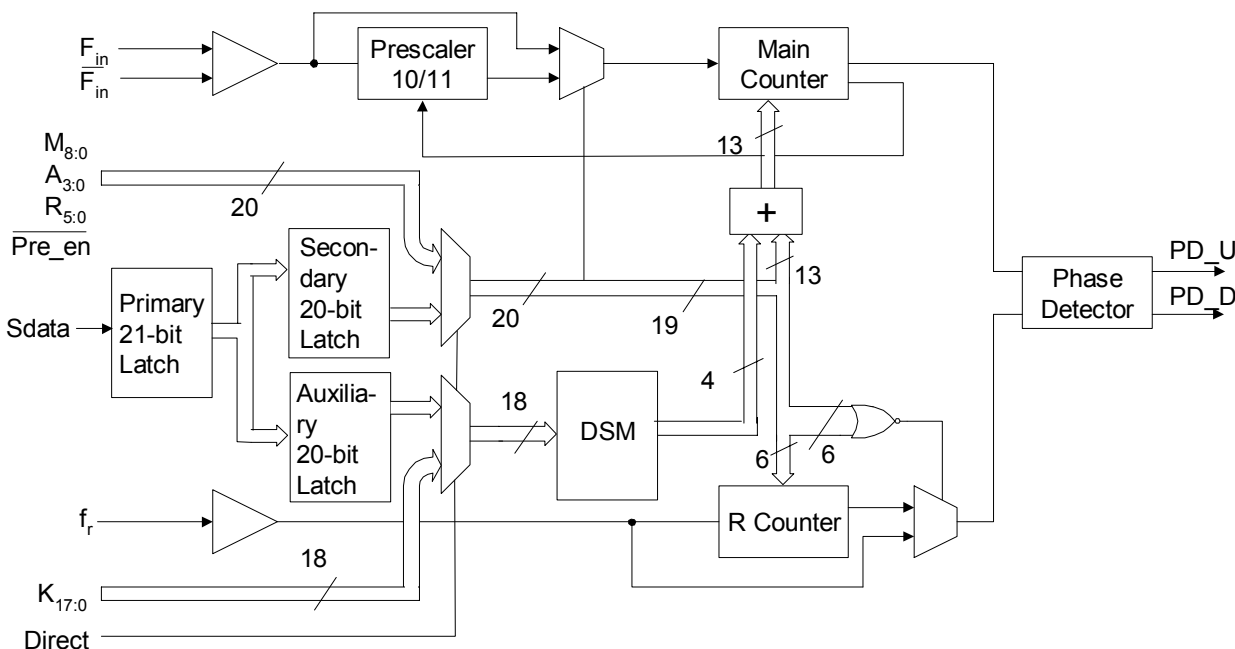


Figure 2. Pin Configuration and package photo

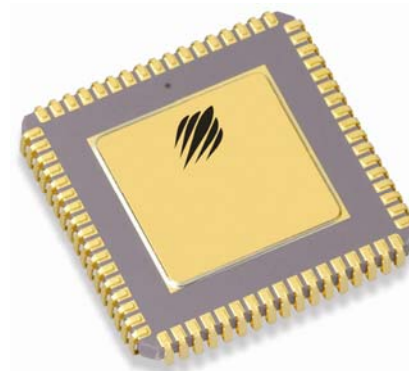
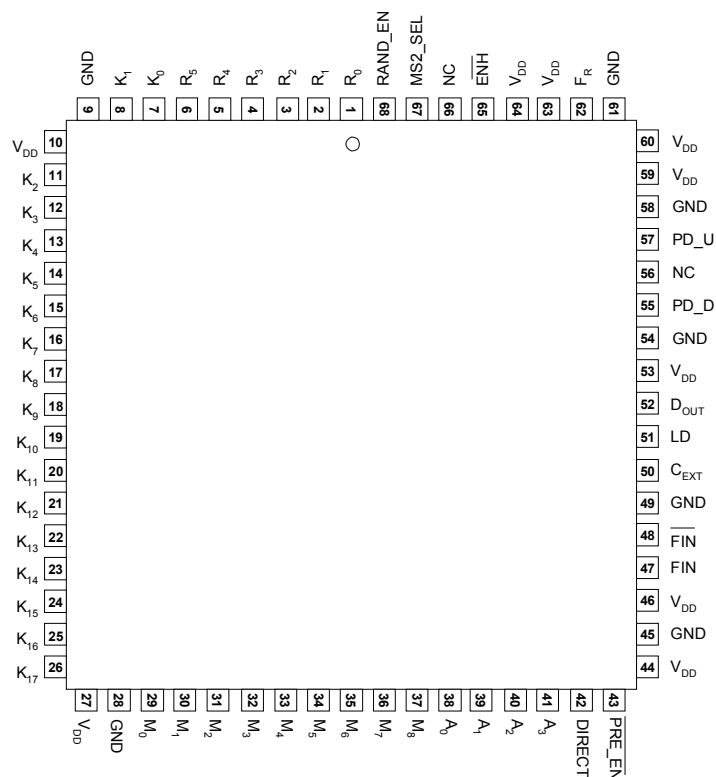


Table 1. Pin Descriptions

Pin No.	Pin Name	Valid Mode	Type	Description
1	R ₀	Direct	Input	R Counter bit0 (LSB).
2	R ₁	Direct	Input	R Counter bit1.
3	R ₂	Direct	Input	R Counter bit2.
4	R ₃	Direct	Input	R Counter bit3.
5	R ₄	Direct	Input	R Counter bit4.
6	R ₅	Direct	Input	R Counter bit5 (MSB).
7	K ₀	Direct	Input	K Counter bit0 (LSB).
8	K ₁	Direct	Input	K Counter bit1.
9	GND		Downbond	Ground
10	V _{DD}		(Note 1)	Digital core V _{DD} .
11	K ₂	Direct	Input	K Counter bit2.
12	K ₃	Direct	Input	K Counter bit3.
13	K ₄	Direct	Input	K Counter bit4.
14	K ₅	Direct	Input	K Counter bit5.
15	K ₆	Direct	Input	K Counter bit6.

Pin No.	Pin Name	Valid Mode	Type	Description
16	K ₇	Direct	Input	K Counter bit7.
17	K ₈	Direct	Input	K Counter bit8.
18	K ₉	Direct	Input	K Counter bit9.
19	K ₁₀	Direct	Input	K Counter bit10.
20	K ₁₁	Direct	Input	K Counter bit11.
21	K ₁₂	Direct	Input	K Counter bit12.
22	K ₁₃	Direct	Input	K Counter bit13.
23	K ₁₄	Direct	Input	K Counter bit14.
24	K ₁₅	Direct	Input	K Counter bit15.
25	K ₁₆	Direct	Input	K Counter bit16.
26	K ₁₇	Direct	Input	K Counter bit17 (MSB).
27	V _{DD}		(Note 1)	Digital core V _{DD} .
28	GND		Downbond	Ground
29	M ₀	Direct	Input	M Counter bit0 (LSB).
30	M ₁	Direct	Input	M Counter bit1.
31	M ₂	Direct	Input	M Counter bit2.
32	M ₃	Direct	Input	M Counter bit3.
33	M ₄	Direct	Input	M Counter bit4.
	S_WR	Serial	Input	Serial load enable input. While S_WR is "low", Sdata can be serially clocked. Primary register data are transferred to the secondary register on S_WR rising edge.
34	M ₅	Direct	Input	M Counter bit5.
	SDATA	Serial	Input	Binary serial data input. Input data entered MSB first.
35	M ₆	Direct	Input	M Counter bit6.
	SCLK	Serial	Input	Serial clock input. SDATA is clocked serially into the 21-bit primary register (E_WR "low") or the 8-bit enhancement register (E_WR "high") on the rising edge of Sclk.
36	M ₇	Direct	Input	M Counter bit7.
37	M ₈	Direct	Input	M Counter bit8 (MSB).
38	A ₀	Direct	Input	A Counter bit0 (LSB).
39	A ₁	Direct	Input	A Counter bit1.
	E_WR	Serial	Input	Enhancement register write enable. While E_WR is "high", Sdata can be serially clocked into the enhancement register on the rising edge of Sclk.
40	A ₂	Direct	Input	A Counter bit2.
41	A ₃	Direct	Input	A Counter bit3 (MSB).
42	DIRECT	Both	Input	Direct mode select. "High" enables direct mode. "Low" enables serial mode.
43	Pre_en	Direct	Input	Prescaler enable, active "low". When "high", Fin bypasses the prescaler.
44	V _{DD}		(Note 1)	Digital core V _{DD} .
45	GND		Downbond	Ground

Pin No.	Pin Name	Valid Mode	Type	Description
46	V _{DD}		(Note 1)	Prescaler V _{DD} .
47	F _{in}	Both	Input	Prescaler input from the VCO. 3.5 GHz max frequency.
48	$\overline{F_{in}}$	Both	Input	Prescaler complementary input. A bypass capacitor should be placed as close as possible to this pin and be connected in series with a 50 Ω resistor directly to the ground plane.
49	GND		Downbond	Ground
50	CEXT	Both	Output	Logical "NAND" of PD_U and PD_D terminated through an on chip, 2 k Ω series resistor. Connecting Cext to an external capacitor will low pass filter the input to the inverting amplifier used for driving LD.
51	LD	Both	Output	Lock detect and open drain logical inversion of CEXT. When the loop is in lock, LD is high impedance, otherwise LD is a logic low ("0").
52	D _{OUT}	Both	Output	Data out function, enabled in enhancement mode.
53	V _{DD}		(Note 1)	Output driver/V _{DD} .
54	GND		Downbond	Ground
55	PD_D	Both	Output	PD_D pulses down when f _p leads f _c .
56	NC	Both		No Connect
57	PD_U	Both	Output	PD_U pulses down when f _c leads f _p .
58	GND		Downbond	Ground
59	V _{DD}		(Note 1)	Output driver/V _{DD} .
60	V _{DD}		(Note 1)	Phase detector V _{DD} .
61	GND		Downbond	Ground
62	f _r	Both	Input	Reference frequency input.
63	V _{DD}		(Note 1)	Reference V _{DD} .
64	V _{DD}		(Note 1)	Digital core V _{DD} .
	GND		Downbond	Ground
65	$\overline{ENH}$	Both	Input	Enhancement mode. When asserted low ("0"), enhancement register bits are functional.
66	NC	Both		No Connect
67	MS2_SEL	Both	Input	MASH 1-1 select. "High" selects MASH 1-1 mode. "Low" selects the MASH 1-1-1 mode.
68	RND_SEL	Both	Input	K register LSB toggle enable. "1" enables the toggling of LSB. This is equivalent to having an additional bit for the LSB of K register. The frequency offset as a result of enabling this bit is the phase detector comparison frequency / 2 ¹⁹ .

Note 1: All V_{DD} pins are connected by diodes and must be supplied with the same positive voltage level.

Note 2: All digital input pins have 70 k Ω 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	3.45	V
T_A	Operating ambient temperature range	-40	85	°C

Table 4. ESD Ratings

Symbol	Parameter/Conditions	Level	Units
VESD	ESD Voltage Human Body Model on all pins except pin 52 (Note:1)	1000	V
	ESD Voltage Human Body Model on pin 52 (Notes 1 and 2)	300	V

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

Note 2: Pin 52 is a test pin only. It is not used in normal operation.

Electrostatic Discharge (ESD) Precautions

When handling this UltraCMOS™ 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, UltraCMOS™ devices are immune to latch-up.

Table 5. DC Characteristics
 $V_{DD} = 3.30\text{ V}$, $-40^{\circ}\text{C} < T_A < 85^{\circ}\text{C}$, Unless otherwise specified

Symbol	Parameter	Conditions	Min	Typ	Max	Units
I _{DD}	Operational supply current;	V _{DD} = 2.85 to 3.45 V				
	Prescaler enabled			40		mA
I _{DD}	Operational supply current;	V _{DD} = 2.85 to 3.45 V		15		mA
	Prescaler disabled					
All Digital inputs: K[17:0], R[5:0], M[8:0], A[3:0], Direct, $\overline{\text{Pre_en}}$, Rand_en, M2_sel, $\overline{\text{Enh}}$ (contains a 70 kΩ pull-down resistor)						
V _{IH}	High level input voltage	V _{DD} = 2.85 to 3.45 V	0.7 x V _{DD}			V
V _{IL}	Low level input voltage	V _{DD} = 2.85 to 3.45 V			0.3 x Vdd	V
I _{IH}	High level input current	V _{IH} = V _{DD} = 3.45 V			100	μA
I _{IL}	Low level input current	V _{IL} = 0, V _{DD} = 3.45 V	-1			μA
Reference Divider input: f _r						
I _{IHR}	High level input current	V _{IH} = V _{DD} = 3.45 V			100	μA
I _{ILR}	Low level input current	V _{IL} = 0, V _{DD} = 3.45 V	-100			μA
Counter and phase detector outputs: PD_D, PD_U						
V _{OLD}	Output voltage LOW	I _{out} = 6 mA			0.4	V
V _{OHD}	Output voltage HIGH	I _{out} = -3 mA	V _{DD} - 0.4			V
Digital test outputs: Dout						
V _{OLD}	Output voltage LOW	I _{out} = 200 μA			0.4	V
V _{OHD}	Output voltage HIGH	I _{out} = -200 μA	V _{DD} - 0.4			V
Lock detect outputs: (Cext, LD)						
V _{OLC}	Output voltage LOW, Cext	I _{out} = 0.1 mA			0.4	V
V _{OHC}	Output voltage HIGH, Cext	I _{out} = -0.1 mA	V _{DD} - 0.4			V
V _{OLLD}	Output voltage LOW, LD	I _{out} = 1 mA			0.4	V

Table 6. AC Characteristics

$V_{DD} = 3.30\text{ V}$ $-40^{\circ}\text{C} < T_A < 85^{\circ}\text{C}$, Unless otherwise specified

Symbol	Parameter	Conditions	Min	Typ	Max	Units
Control Interface and Latches (see Figures 3, 4)						
f _{Clk}	Serial data clock frequency	(Note 1)			10	MHz
t _{ClkH}	Serial clock HIGH time		30			ns
t _{ClkL}	Serial clock LOW time		30			ns
t _{DSU}	Sdata set-up time to Sclk rising edge		10			ns
t _{DHLD}	Sdata hold time after Sclk rising edge		10			ns
t _{PW}	S_WR pulse width		30			ns
t _{CWR}	Sclk rising edge to S_WR rising edge		30			ns
t _{CE}	Sclk falling edge to E_WR transition		30			ns
t _{WRC}	S_WR falling edge to Sclk rising edge		30			ns
t _{EC}	E_WR transition to Sclk rising edge		30			ns
Main Divider (Including Prescaler) (Note 4)						
P _{Fin}	Input level range	External AC coupling 275 MHz ≤ Freq ≤ 3200MHz	-5		5	dBm
		External AC coupling 3.2 GHz < Freq ≤ 3.5 GHz 3.15 V ≤ VDD ≤ 3.45 V	0		5	dBm
Main Divider (Prescaler Bypassed) (Note 4)						
F _{in}	Operating frequency		50		300	MHz
P _{Fin}	Input level range	External AC coupling	-5		5	dBm
Reference Divider						
f _r	Operating frequency	(Note 3)			100	MHz
P _{fr}	Reference input power (Note 2)	Single ended input	-2			dBm
Phase Detector						
f _c	Comparison frequency	(Note 3)			50	MHz
SSB Phase Noise (F _{in} = 1.9 GHz, f _r = 20 MHz, f _c = 20 MHz, LBW = 50 kHz, V _{DD} = 3.3 V, Temp = 25° C) (Note 4)						
Φ _N	Phase Noise	100 Hz Offset		-89		dBc/Hz
Φ _N	Phase Noise	1 kHz Offset		-96		dBc/Hz
Φ _N	Phase Noise	10 kHz Offset		-101		dBc/Hz
SSB Phase Noise (F _{in} = 1.9 GHz, f _r = 20 MHz, f _c = 20 MHz, LBW = 50 kHz, V _{DD} = 3.0 V, Temp = 25° C) (Note 4)						
Φ _N	Phase Noise	100 Hz Offset		-84		dBc/Hz
Φ _N	Phase Noise	1 kHz Offset		-92		dBc/Hz
Φ _N	Phase Noise	10 kHz Offset		-100		dBc/Hz

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 0.5 Vp-p. For optimum phase noise performance, the reference input falling edge rate should be faster than 80mV/ns.

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

Note 4: Parameter below are not tested for die sales. These parameters are verified during the element

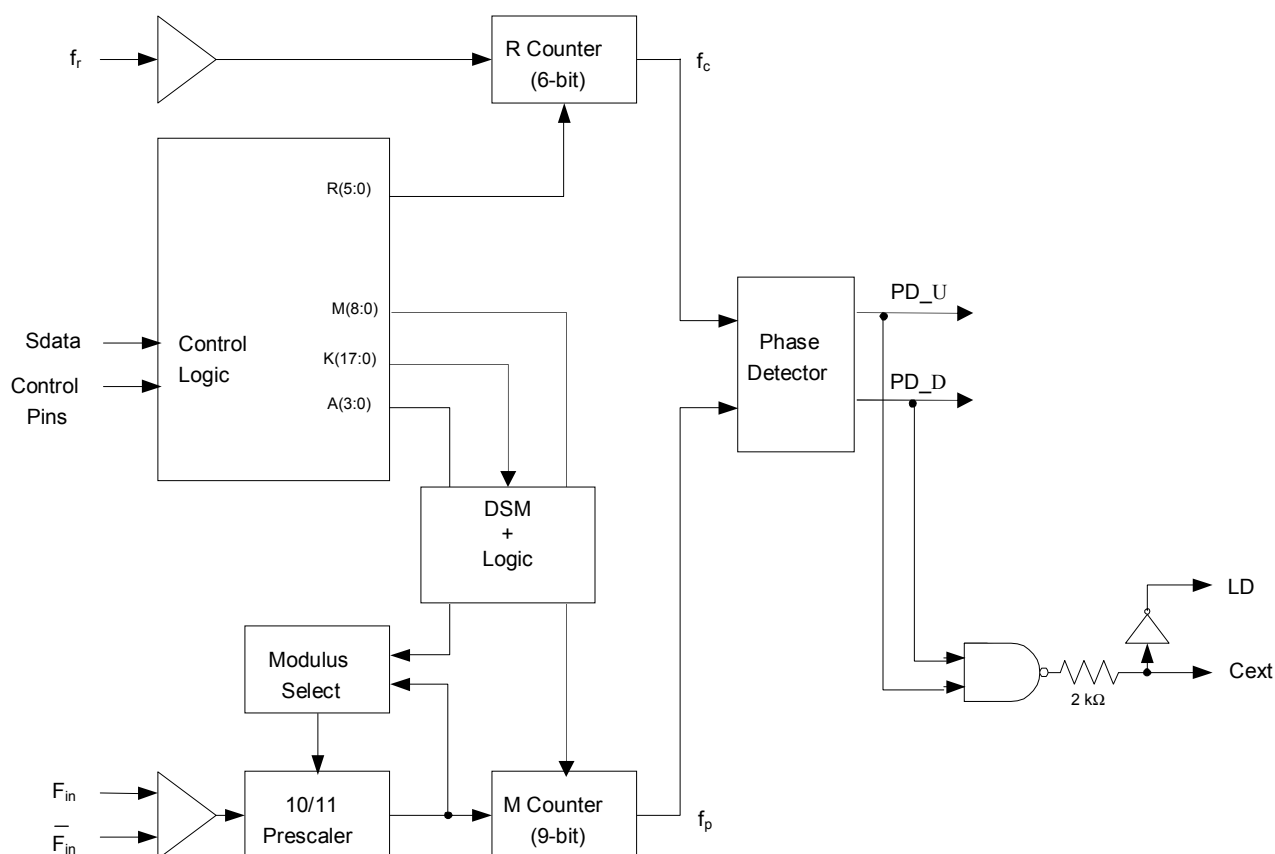
Functional Description

The PE97632 consists of a prescaler, counters, an 18-bit delta-sigma modulator (DSM) and a phase detector. 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 DSM

modulates the “A” counter outputs in order to achieve the desired fractional step.

The phase-frequency detector generates up and down frequency control signals. Data is written into the internal registers via the three wire serial bus. There are also various operational and test modes and a lock detect output.

Figure 3. Functional Block Diagram



Main Counter Chain

Normal Operating Mode

Setting the Pre_en control bit “low” enables the ÷10/11 prescaler. The main counter chain then divides the RF input frequency (F_{in}) by an integer or fractional number derived from the values in the “M”, “A” counters and the DSM input word K. The accumulator size is 18 bit, so the fractional value is fixed from the ratio $K/2^{18}$. There is an additional bit in the DSM that acts like an extra bit (19th bit). This bit is enabled by asserting the pin RAND_SEL to “high”. Enabling this bit has the benefit of reducing the spurious levels. However, a small frequency offset will occur. This positive frequency offset is calculated with the following equation.

$$f_{offset} = (f_r / (R + 1)) / 2^{19} \quad (1)$$

All of the following equations do not take into account this frequency offset. If this offset is important to a specific frequency plan, appropriate account needs to be taken.

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

$$f_p = F_{in} / [10 \times (M + 1) + A + K/2^{18}] \quad (2)$$

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:

$$F_{in} = [10 \times (M + 1) + A + K/2^{18}] \times (f_r / (R+1)) \quad (3)$$

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 Pre_en “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. The following equation relates F_{in} to the reference frequency f_r :

$$F_{in} = (M + 1) \times (f_r / (R+1)) \quad (4)$$

where $1 \leq M \leq 511$

(*) Only integer mode

In frequency bypass mode, neither A counter or K counter is used. Therefore, only integer-N operation is possible.

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:

$$f_c = f_r / (R + 1) \quad (5)$$

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

While the E_WR input is “low” and the S_WR input is “low”, serial input data (Sdata input), B_0 to B_{20} , are clocked serially into the primary register on the rising edge of Sclk, MSB (B_0) first. The LSB is used as address bit. When “0”, the contents from the primary register are transferred into the secondary register on the rising edge of either S_WR according to the timing diagrams shown in Figure 4. When “1”, data is transferred to the auxiliary register according to the same timing diagram. The secondary register is used to program the various counters, while the auxiliary register is used to program the DSM.

Data are transferred to the counters as shown in Table 8 on page 10.

While the E_WR input is “high” and the S_WR input is “low”, serial input data (Sdata input), B₀ to B₇, are clocked serially into the enhancement register on the rising edge of Sclk, MSB (B₀) first. The enhancement register is double buffered to prevent inadvertent control changes during serial loading, with buffer capture of the serially entered data performed on the falling edge of E_WR according to the timing diagram shown in Figure 4. After the falling edge of E_WR, the data provide control bits as shown in Table 9 on page 10 will have their bit functionality enabled by asserting the Enh input “low”.

Direct Interface Mode

Direct Interface Mode is selected by setting the “Direct” input “high”.

Counter control bits are set directly at the pins as shown in Table 7 and Table 8.

Table 7. Secondary Register Programming

Interface Mode	Enh	R ₅	R ₄	M ₈	M ₇	Pre_en	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	Addr
Direct	1	R ₅	R ₄	M ₈	M ₇	Pre_en	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	X
Serial*	1	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	0

*Serial data clocked serially on Sclk rising edge while E_WR “low” and captured in secondary register on S_WR rising edge.

↑
MSB (first in)

↑
(last in) LSB

Table 8. Auxiliary Register Programming

Interface Mode	Enh	K ₁₇	K ₁₆	K ₁₅	K ₁₄	K ₁₃	K ₁₂	K ₁₁	K ₁₀	K ₉	K ₈	K ₇	K ₆	K ₅	K ₄	K ₃	K ₂	K ₁	K ₀	Rsrv	Rsrv	Addr
Direct	1	K ₁₇	K ₁₆	K ₁₅	K ₁₄	K ₁₃	K ₁₂	K ₁₁	K ₁₀	K ₉	K ₈	K ₇	K ₆	K ₅	K ₄	K ₃	K ₂	K ₁	K ₀	X	X	X
Serial*	1	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	1

*Serial data clocked serially on Sclk rising edge while E_WR “low” and captured in secondary register on S_WR rising edge.

↑
MSB (first in)

↑
(last in) LSB

Table 9. Enhancement Register Programming

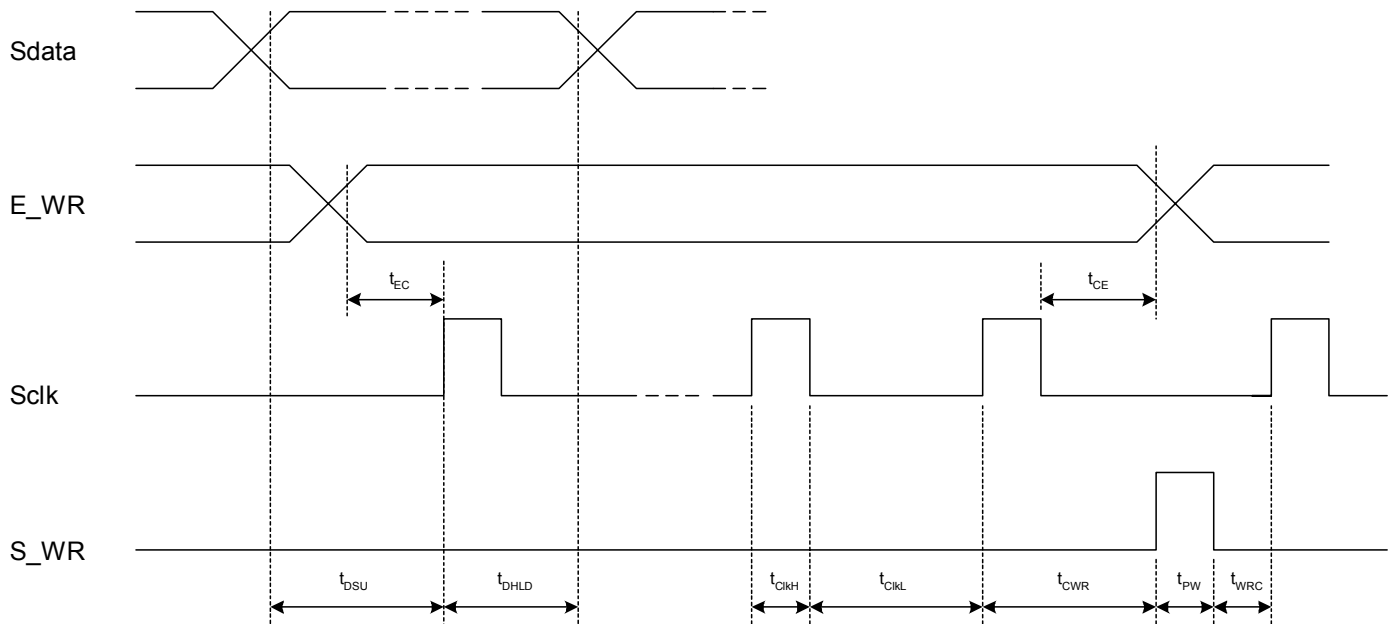
Interface Mode	Enh	Reserved	Reserved	f _p output	Power Down	Counter load	MSEL output	f _c output	LD Disable
Serial*	0	B ₀	B ₁	B ₂	B ₃	B ₄	B ₅	B ₆	B ₇

*Serial data clocked serially on Sclk rising edge while E_WR “high” and captured in the double buffer on E_WR falling edge.

↑
MSB (first in)

↑
(last in) LSB

Figure 4. Serial Interface Mode Timing Diagram



Enhancement Register

The functions of the enhancement register bits are shown below with all bits active “high”.

Table 10. Enhancement Register Bit Functionality

Bit Function		Description
Bit 0	Reserve **	Reserved.
Bit 1	Reserve **	Reserved.
Bit 2	f_p output	Drives the M counter output onto the Dout 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 Dout output.
Bit 6	f_c output	Drives the reference counter output onto the Dout output.
Bit 7	LD Disable	Disables the LD pin for quieter operation.

** Program to 0

Phase Detector

The phase detector is triggered by rising edges from the main Counter (f_p) and the reference counter (f_c). It has two outputs, namely PD_U, and PD_D. If the divided VCO leads the divided reference in phase or frequency (f_p leads f_c), PD_D pulses “low”. If the divided reference leads the divided VCO in phase or frequency (f_c leads f_p), PD_U pulses “low”. The width of either pulse is directly proportional to phase offset between the two input signals, f_p and f_c .

For the UP and DOWN mode, PD_U and PD_D drive an active loop filter which controls the VCO tune voltage. The phase detector gain is equal to $VDD / 2 \pi$.

PD_U pulses cause an increase in VCO frequency and PD_D pulses cause a decrease in VCO frequency, for a positive K_v VCO.

A lock detect output, LD is also provided, via the pin Cext. Cext is the logical “NAND” of PD_U and PD_D waveforms, which is driven through a series 2 k Ω resistor. Connecting Cext to an external shunt capacitor provides low pass filtering of this signal. Cext also drives the input of an internal inverting comparator with an open drain output. Thus LD is an “AND” function of PD_U and PD_D.

Figure 5. Typical Phase Noise

A typical phase noise plot is shown below. “Trace 1” is the smoothed average, and “Trace 2” is the raw data.

Test Conditions: A typical phase noise plot is shown below. “Trace 1” is the smoothed average, and “Trace 2” is the raw data. Test Conditions: $F_{out} = 1.9204$ GHz in MASH 1-1 mode, $F_{comparison} = 20$ MHz, $V_{DD} = 3.3$ V, Temp = 25 C, Loop bandwidth = 50 kHz.

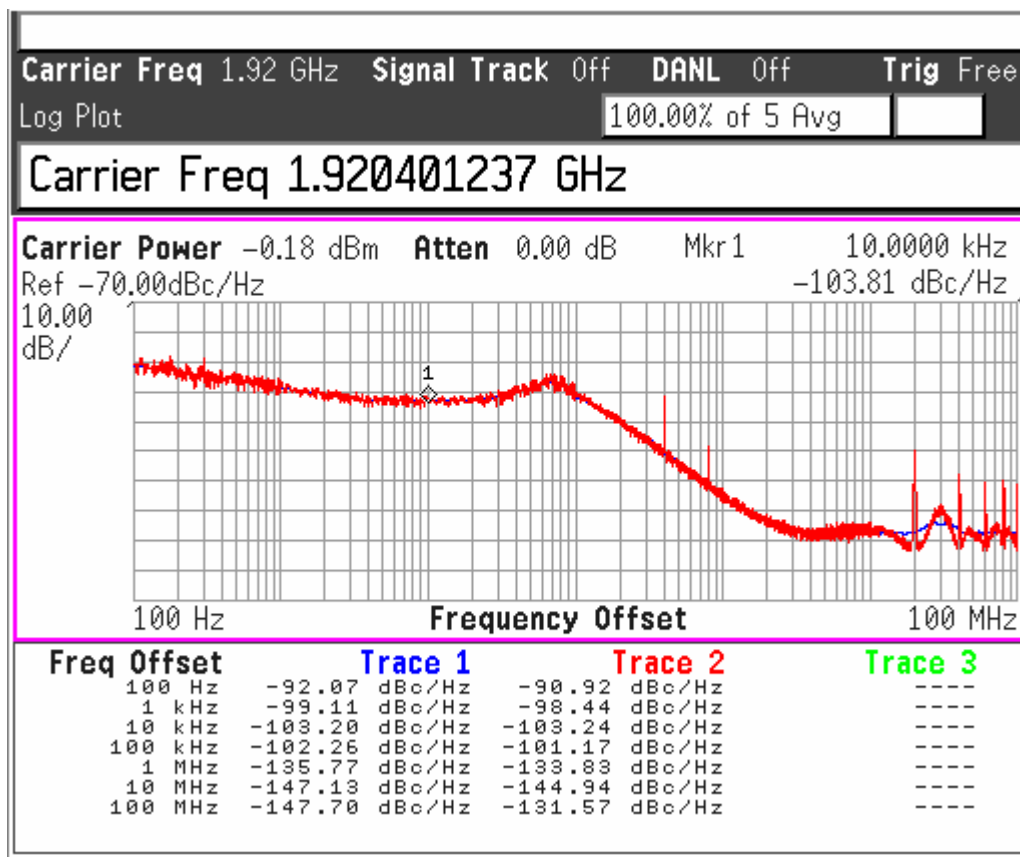


Figure 6. Typical Spurious Plot

Test Conditions: Frequency step = 400 KHz, Loop bandwidth = 50 kHz, Fout = 1.9204 GHz,
Fcomparison = 20 MHz, MASH 1-1, V_{DD} = 3.3 V, Temp = 25C.

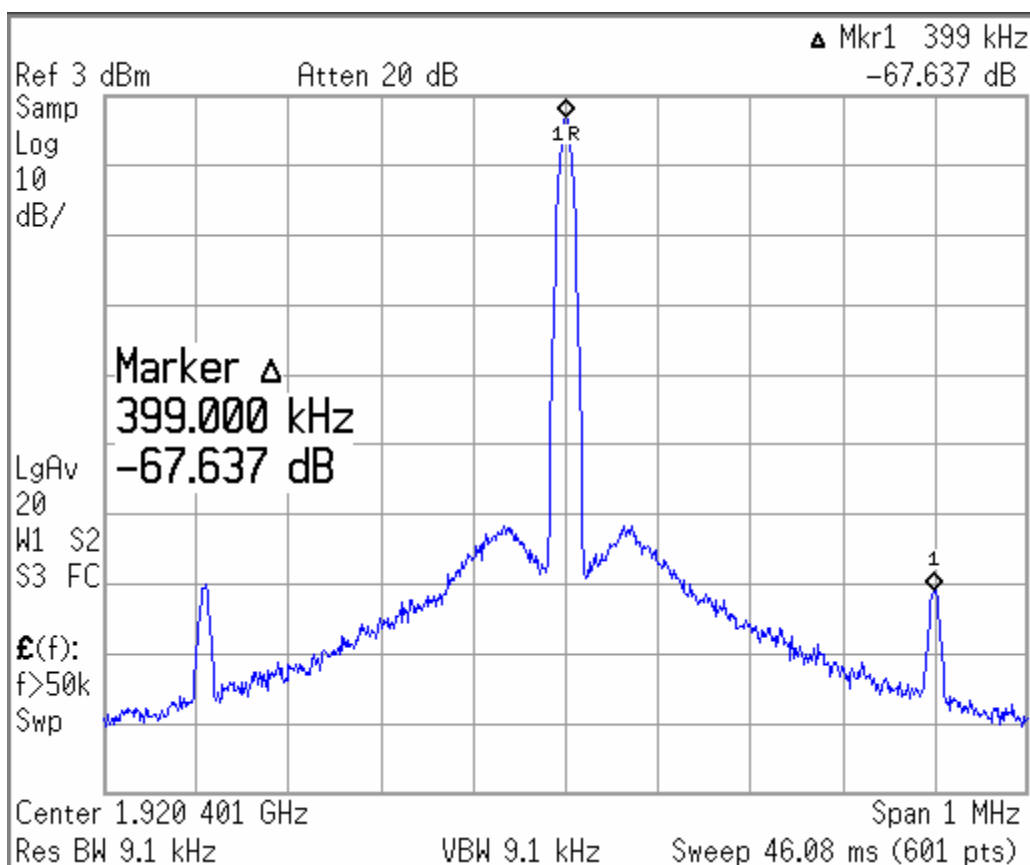


Figure 7. Package Drawing

Package dimensions: 68-lead CQFJ

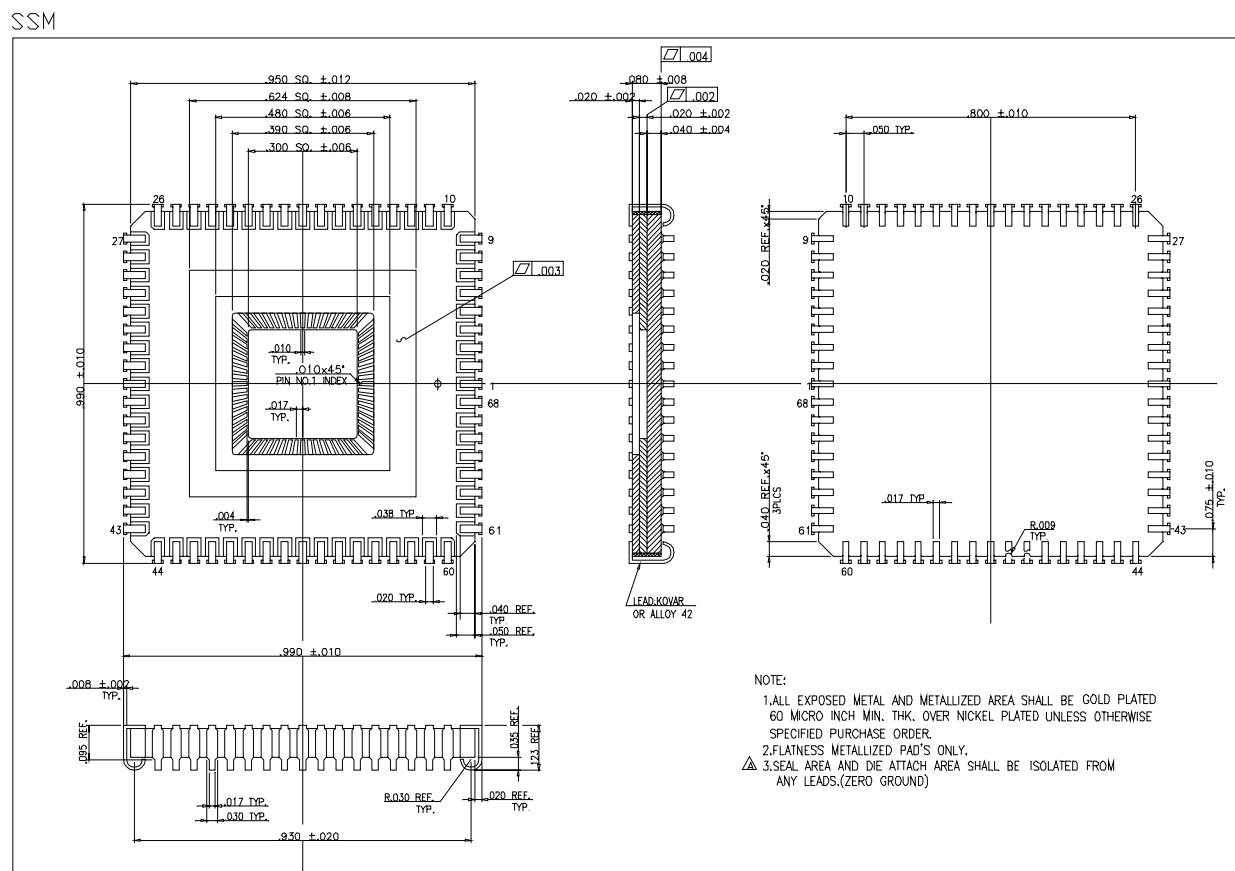


Table 11. Ordering Information

Order Code	Part Marking	Description	Packaging	Shipping Method
97632-01	PE97632 ES	Engineering Samples	68-lead CQFJ	Tray
97632-11	PE97632	Flight Units	68-lead CQFJ	Tray
97632-00		Evaluation Kit		1/Box

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