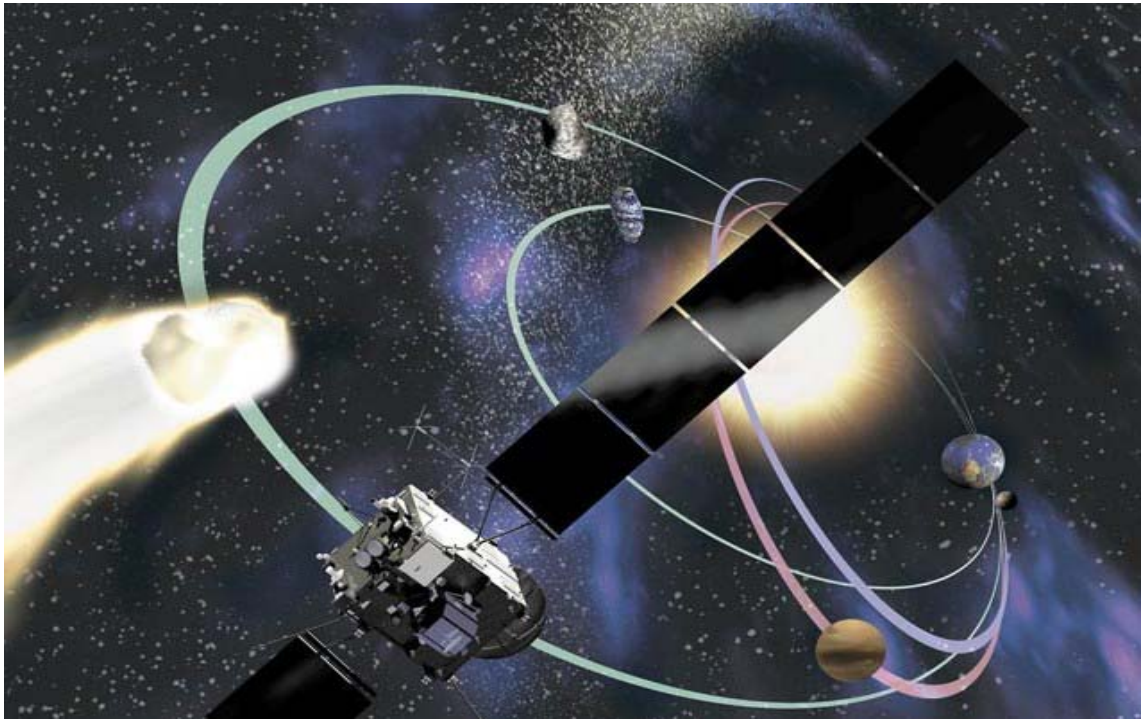
Peregrine Semiconductor

ESCCON 2011: The experience in expanding Operations in Europe and the business Roadmap

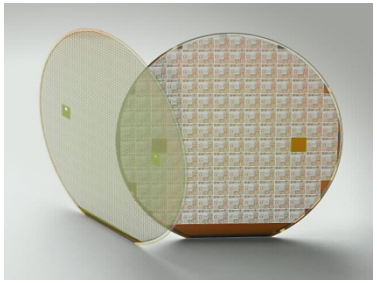


March 16, 2011

Ron Reedy
Pascal Le Bohec

Peregrine Semiconductor Corporation

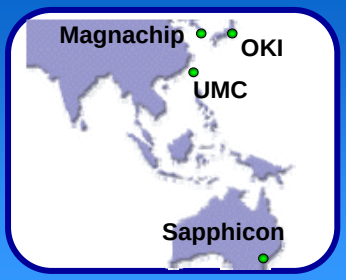
- Patent holder for UltraCMOS™ Technology, a CMOS SOI process fabricated on an insulating sapphire substrate
  - Design methodology inventions including HaRP™ and DuNE™ Technologies
- Strong position in Mobile Wireless and Broadband industries with nearly **180** complementary RFIC products:
  - Switches, Digital Attenuators, PLLs, Prescalers and Mixers
- Design Centers support engineering excellence
  - San Diego, CA
  - Arlington Heights, IL
  - Nashua, NH
  - Aix-En-Provence, France
- Fabless manufacturing model with multiple wafer fabrication sources
  - Silanna Australia
  - Strategic partnership with OKI (Japan)
  - World-class Asian Foundries
- Founded 1990; Headquarters in San Diego, CA USA
- 200 Employees worldwide



Solid UltraCMOS™ Supply Chain

Sapphire Supply

- 3 multinational qualified suppliers
- Peregrine consumes ~6% of the worlds sapphire wafers
- 33% 5 YR CAGR forecasted for world sapphire wafer demand



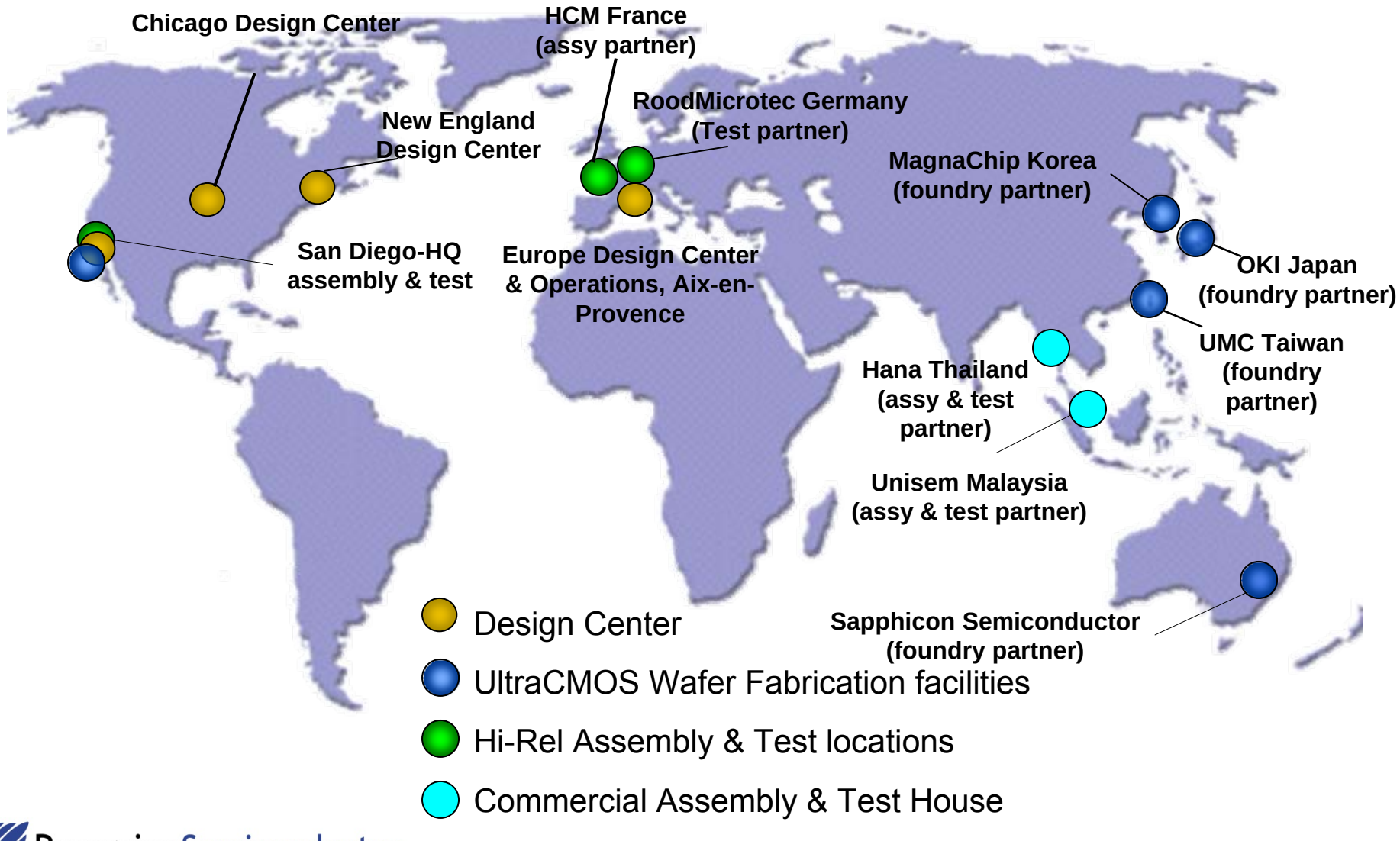
Foundry Model

- 4 qualified CMOS foundry suppliers
- 0.5µm, 0.35µm and 0.25µm processes qualified
- Scalable and near unlimited capacity
- 150mm in production, 200mm in development

Backend

- Proprietary high volume UltraCMOS™ backend processing
- Replicated in San Diego, Malaysia, Thailand
- **High reliability European operations**
- KGD Die, Plastic, Ceramic packaging

Fabless manufacturing on a global basis



Why Silicon on Sapphire?

World's Best Semiconductor Technology + World's Best Substrate Material

Silicon CMOS

- Silicon CMOS is, without question, the optimum technology for building semiconductor devices
- CMOS provides:
  - Highest manufacturability
  - Lowest cost; highest yields
  - Lowest power consumption
  - Most capability for integration
  - Greatest design tools support

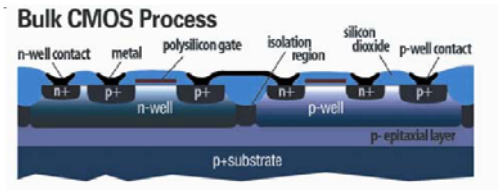
Sapphire

- With outstanding electrical and thermal properties, the highest performance microwave circuits have always been built upon a substrate of ceramic *alumina* (Al_2O_3)
- Sapphire is the crystalline form of alumina
- Same outstanding physical properties of ceramic alumina and enables the deposition of an ultra-thin layer of monocrystalline silicon

UltraCMOS™

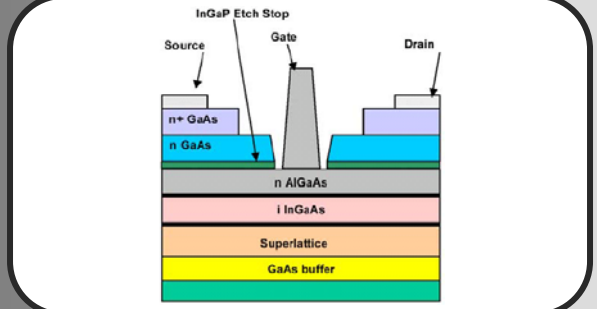
UltraCMOS™ Integrates Best In Class Performance +

Bulk CMOS



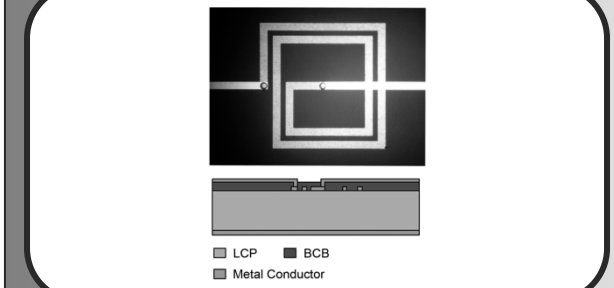
- Monolithic Integration
  - Manufacturable
  - Transferrable
  - Repeatable
  - Scaleable

Gallium Arsenide



- RF Power Applications
  - Good linearity
  - High mobility
  - High power handling
  - Good isolation

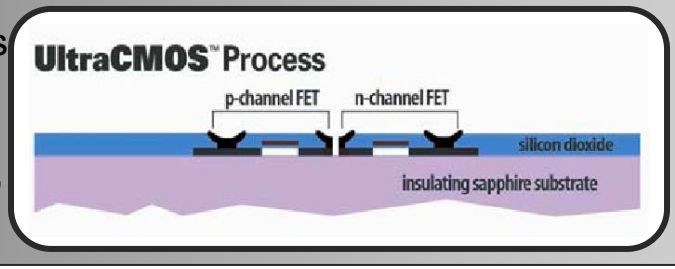
Integrated Passive Device



- Passive Integration
  - Miniaturized passive blocks
  - Minimized parasitics
  - Lithographic interconnect

UltraCMOS™

- All positive attributes of CMOS
- All positive attributes of GaAs
- All positive attributes of IPD
- Additional Unique Properties, best SEU/SEL in industry



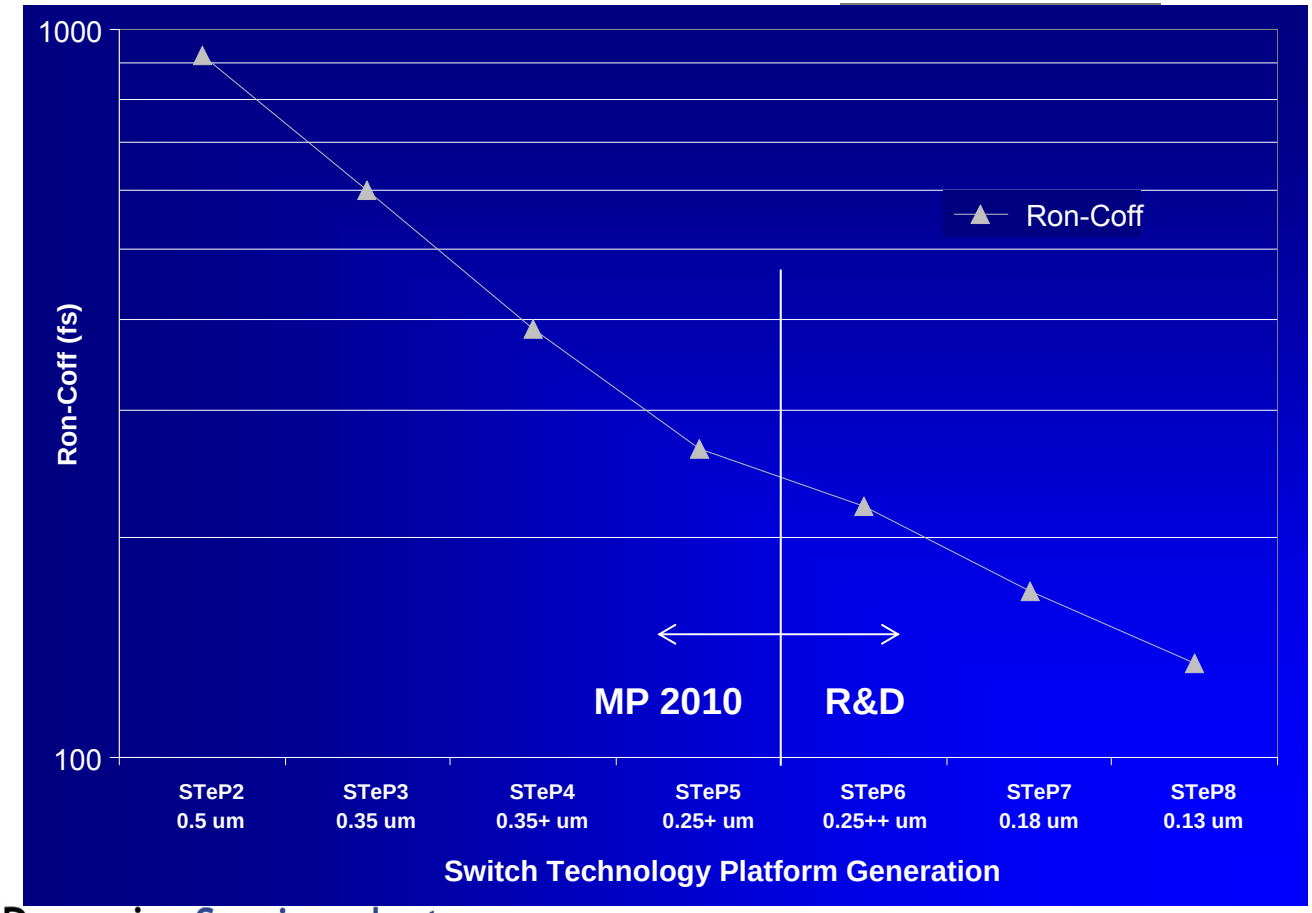
+ Broadband Linearity
+ Unprecedented Isolation
+ High ESD Handling
+ Onboard Memory - EEPROM

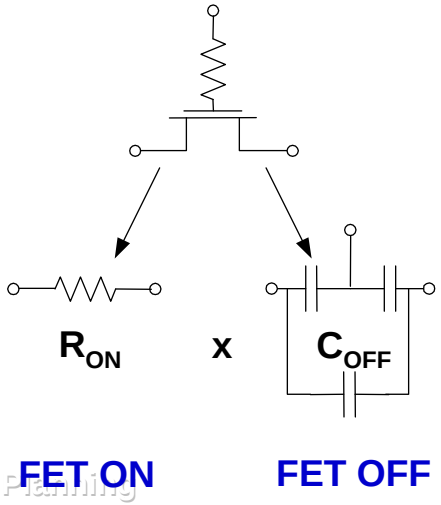
Impact of Technology Scaling

Gate length, um	0.5	0.25	0.18 enh
fT, GHz	20	50	75
fMAX, GHz	50	90	110
IP3, dBm	35	unk	unk
Ron-Coff, ps	900	400	180
kgates/mm2	5	50	100
Proven IP Blocks	~50	<10	N/A
Products (@2 GHz)			
PLL SBN	-218	-225*	-230*
Sw IL	0.6	0.4	0.2
Sw IMD3	-110	-110*	-110*
PA PAE (Sat), %	N/A	55	60*
PA PAE (Lin), %	N/A	45	55*
* simulated			

Peregrine Technology Roadmap

- Ron-Coff is key figure of merit for RFFE switch products
- Most of RFFE is a switch
- LNA NF and g_m improve with gate length



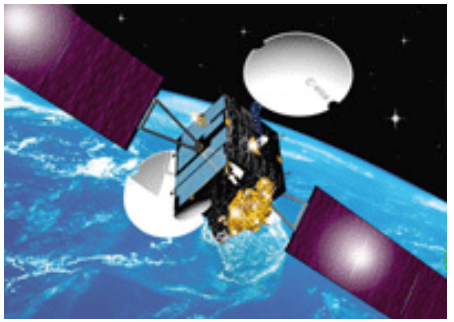


Changing High-Performance RF Across Multiple Vertical Markets

Cellular Handsets and Basestations

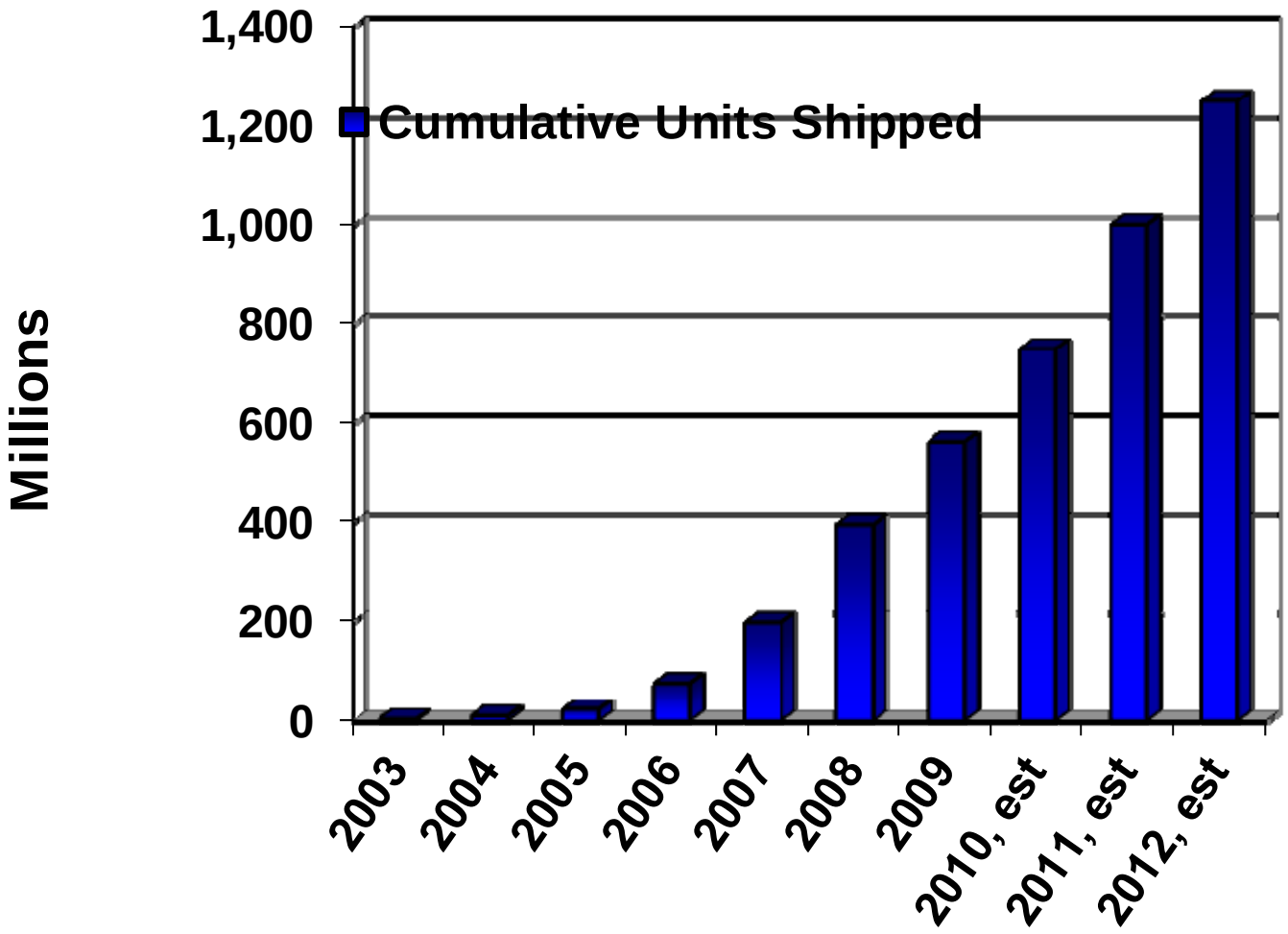
Wired & Wireless Broadband, CA/HDTV

High-Reliability Space/Mil, Auto, Medical



UltraCMOS Technology is Now Mainstream

- More than 800 million units shipped to-date
- Never obsoleted a production process or space product



Deep Space and Satellite End Markets

Radiation Tolerant

Technology tolerant to radiation environments

Total Dose
100 KRads(Si) (& greater if need be)

Single Event Latch-Up
Guaranteed Immunity

Single Event Upset (SEU)
Exceptional Natural Tolerance

Single Event Transient Effects
Not Observed To Date

Neutron Effects
(Displacement Damage) CMOS Insensitive

Dose Rate (Gamma Dot)
Highly Tolerant

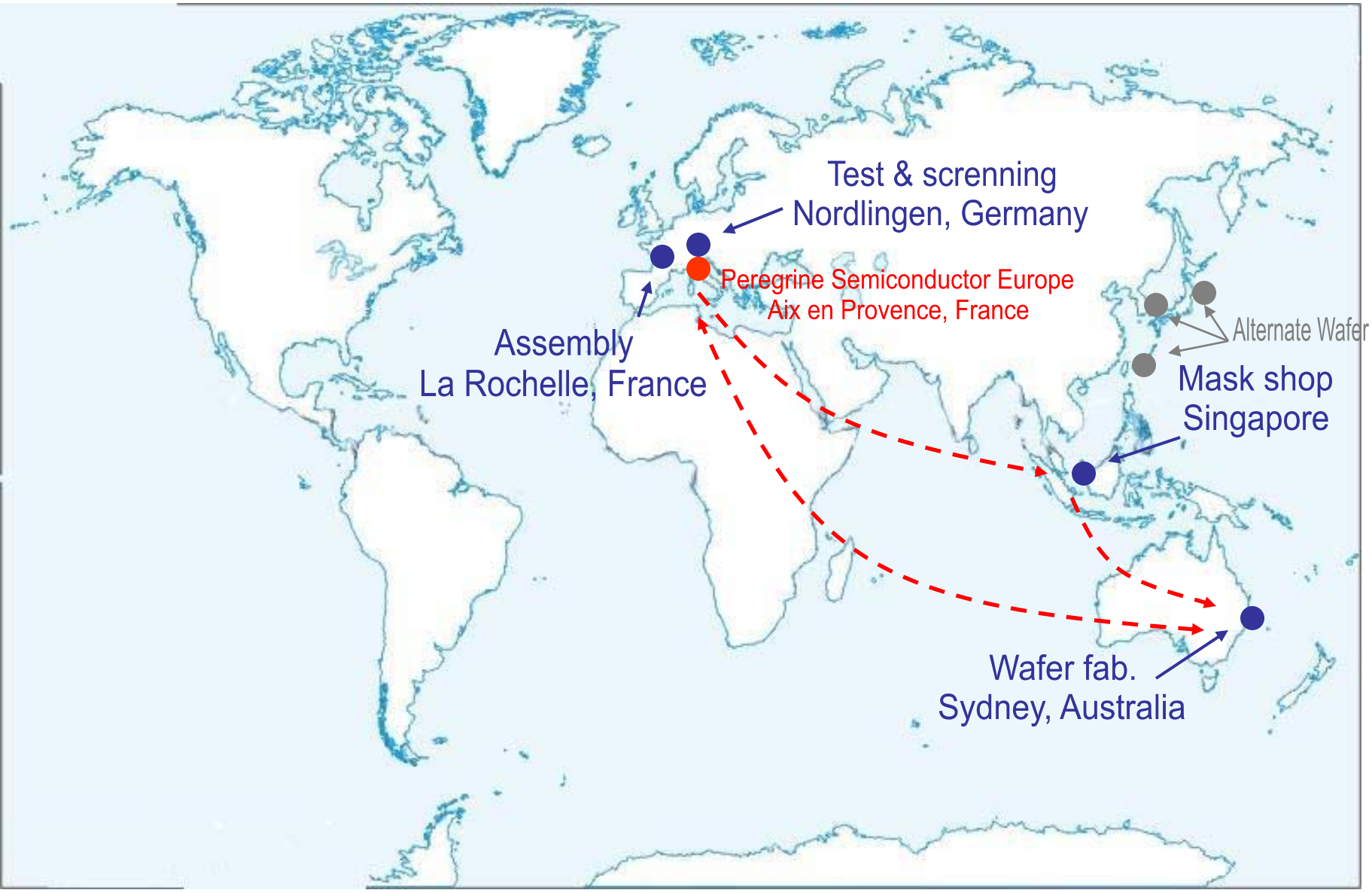
Peregrine Semiconductor support to Hi-Rel Market

- Global company
  - Supporting customers around the world with a variety of products and services since 15 years with high success
  - Global design and manufacturing locations
  - Peregrine is interested in expanding European footprint to support local markets
- Peregrine Hi-Rel markets
  - Great support from European customers
    - Peregrine's product developments have historically been driven by European customers in both Hi-Rel and commercial markets
    - More than 90% of Peregrine's new products have been defined with European customers
  - Unique advantages of UltraCMOS™
    - Integration
    - Radiation hardness
  - Understanding of market requirements
  - Roadmap for long-term success

Peregrine Europe Operation: key factors for success

- European Team in place with more than 50 years experience in development and production of Space products.
  - First Space ASICs design in 1984
  - Digital, Mixed-Mode, RF skills
  - Establishment and Management of Space BU with European Supplier
    - No support needed from Peregrine Hi-Rel US
- Strong relationship and support from ESA (ECI Phase 1 contract)
  - Thanks to Laurent Marchand (ESA) & Jean Luc Roux (CNES)
- Production flow based on well established ESA SCC9000 system.
  - First product qualified through this flow is Peregrine Fractional PLL PE33632 (3.5GHz)
- Strong support from Space Systems Manufacturers.
  - Production flow has been audited and approved
  - Need for more products has been expressed
- High quality subcontractors and efficient management

Peregrine Semiconductor Europe ESCC flow



Peregrine Semiconductor Europe Activities

Peregrine Semiconductor Europe – France

- Overall Program Management
- Product development & Design
- Full documentation set up
- Quality assurance

Mask Shop (Singapore)

- Mask

Foundry (Australia)

Silanna

- Wafer processing
- WAT/WLR
- Backgrinding

HCM – France

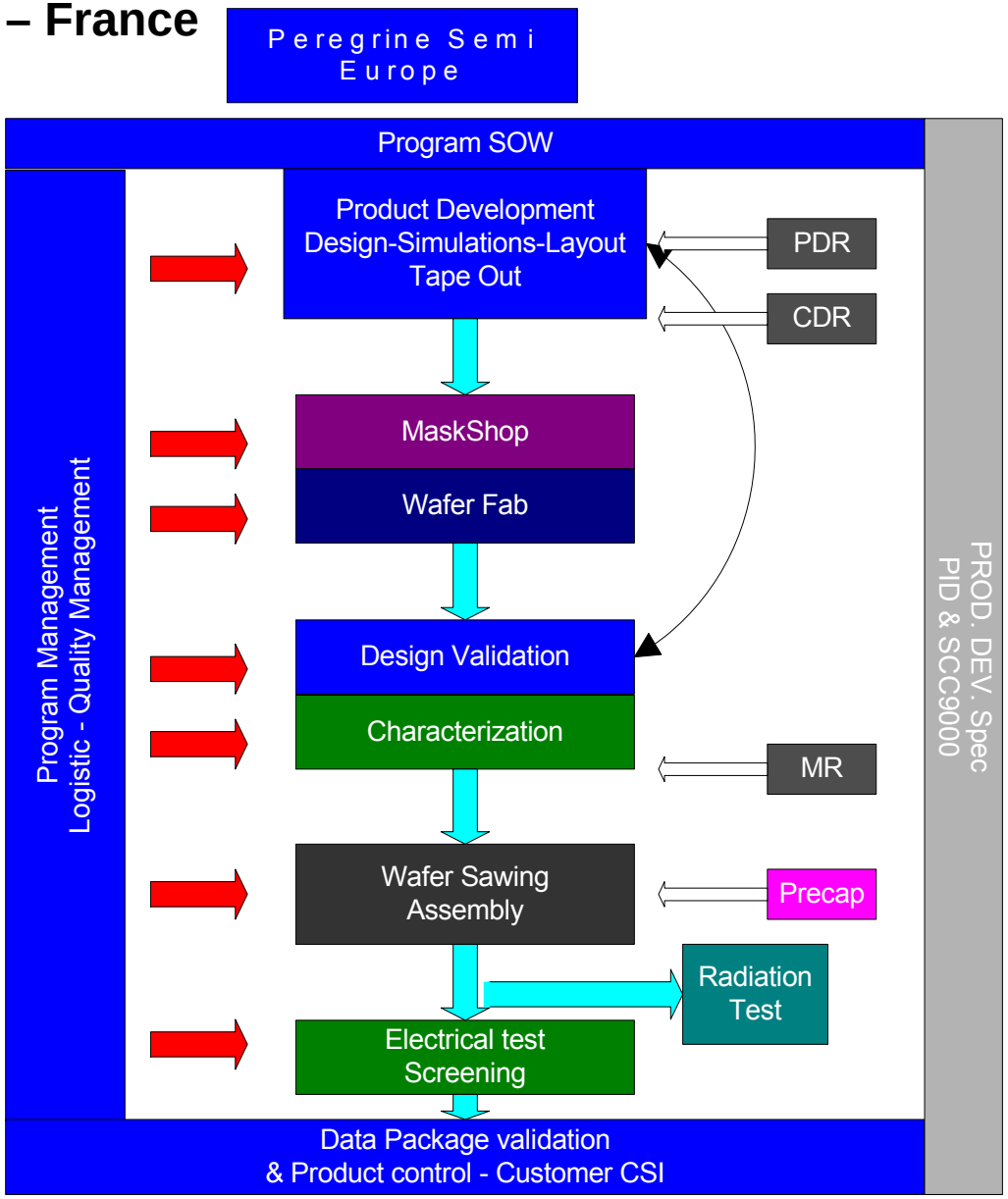
HCM

- Wafer sawing
- Assembly (Packaging and bonding)
- Mechanical screening
  - Thermal cycles
  - PIND test
  - Leakages

ROODMICROTEC – Germany

RoodMicrotec

- Wafer probe
- Electrical test
  - DC, AC, RF and PN
- Electrical screening (Burn in, Life test,…)
- Qualification and Periodic Tests



Wafer Sawing

- Equipment :
- Four 8’’ Disco sawing machines
- Wafer mounting on adhesive/UV films on frames
- Deionised water station / CO2 Bubbler
- Materials : Silicon, GaAs, Ceramic, Glass, Sapphire, SOS, SiC, GaN, Etc..

Packaging

HCM Hybritech Composants MicroElectroniques

ISO 9001 BUREAU VERITAS Certification

1/ Die attach

Adhesive

Eutectic

Soft solder

High temperature solder up to 300°C

Cyanate ester/Silver glass

Etc.

2/ Bonding

- Thermosonic / ball bonding
  - Gold wire
  - 15 to 80 µm
  - Down to 35 µm pitch
- Ultrasonic / wedge bonding
  - Aluminium / gold wire
  - 25 to 500 µm
  - Ribbon
  - Down to 50 µm pitch

3/ Sealing/Potting

- For ceramic or plastic packages:
  - Hermetic (tin/gold alloy)
  - Adhesive
  - Resin
  - Silicon
- For metal packages:
  - Electric
  - Seam Welding

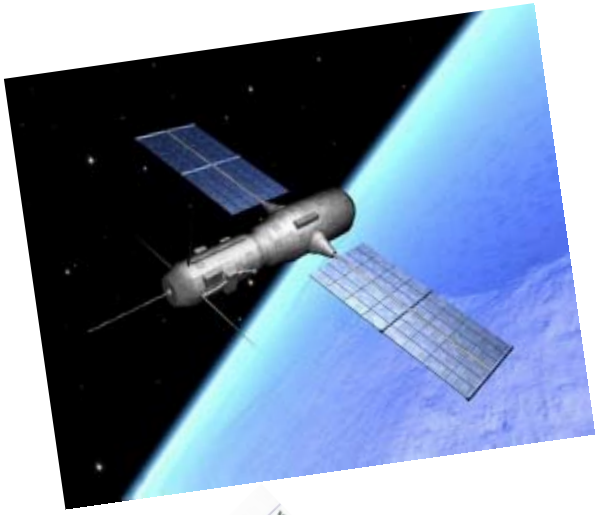
* Mainly used for space applications

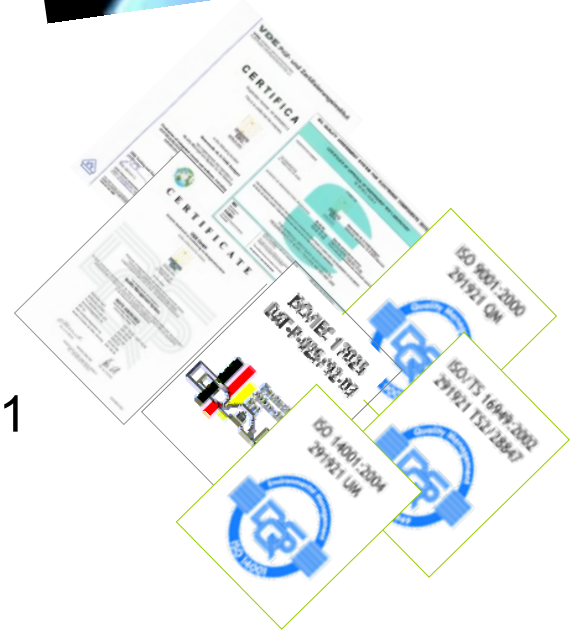
Testing & Screening

RoodMicrotec
powerful solutions

The leading independent European company for semiconductor testing and quality services like:

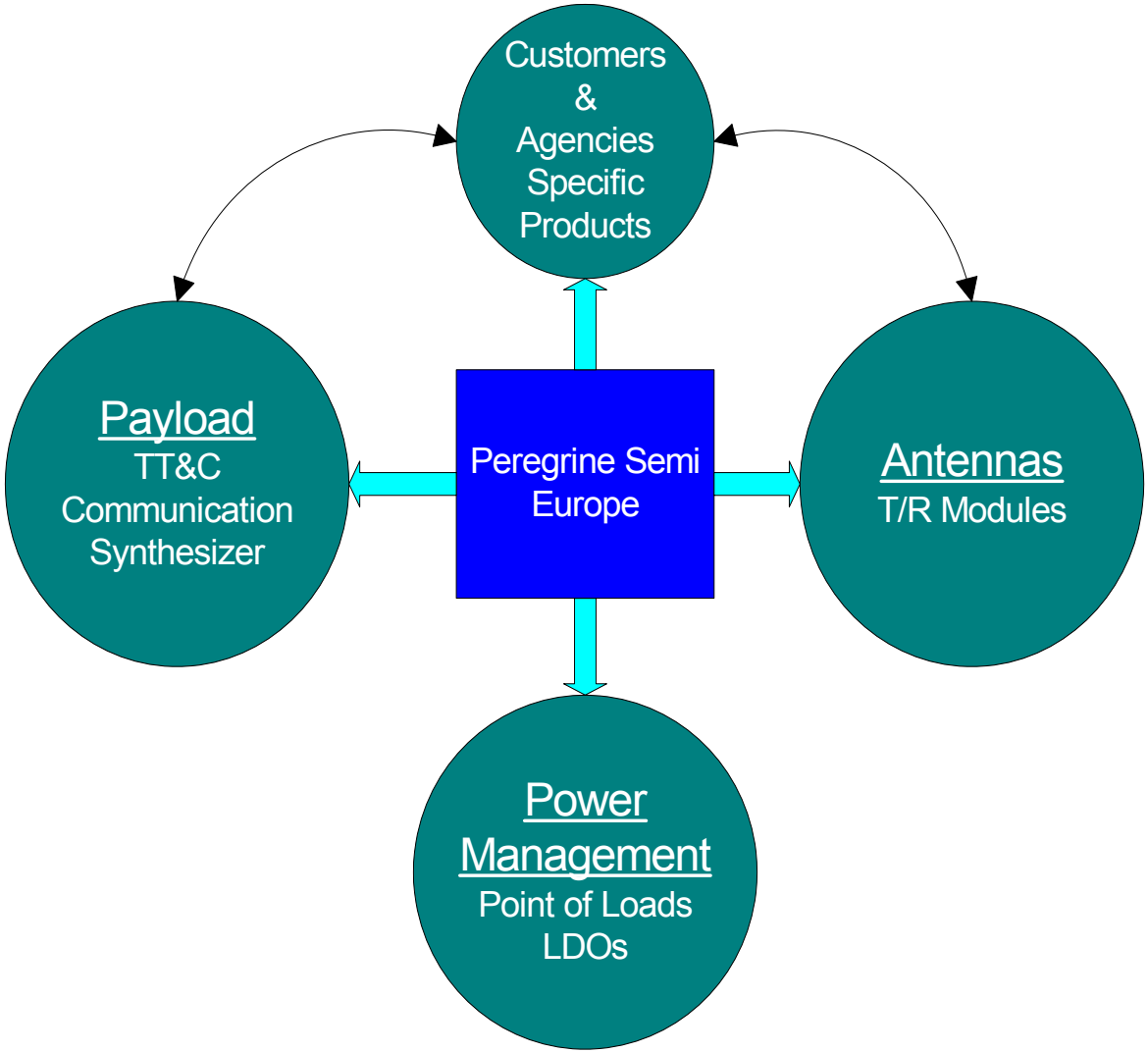
- Test Engineering
  (Soft-Hardware development)
- Monitoring Burn-in
- Electrical Test of
  Mixed Signal, Analog, Digital, Opto, RF ICs
- Integrated Supply Chain Management
- Evaluation tests / up screenings
- Qualification acc. ESCC Standard
- Failure- Technological Analysis
- Reliability Consulting, ESD evaluation
- Approved acc. ISO TS 16949, ISO 17025, ISO 14001





Applications target

Business Roadmap: Applications



Business Roadmap: Products/Applications

- Best class **Phase Locked Loop (PLL)**
- Reference on the market
  - Qualified PE33632 Fractional PLL (ECI contract)
  - Continuous Phase Noise improvement
  - **VCO integration**
- Other functions
  - **Digital Step Attenuators** (ECI contract)
  - **Digital Variable Gain Amplifiers**
  - **Switches**
  - **Mixers**

Payload
TT&C
Communication
Synthesizer

- **Phase Shifters**
- **Digital Step Attenuators**
- **Switches (SPDT, SP4T, …)**
- **Drain Switches**
- **Fully integrated Core Chip** (Full function except LNA & PAs)

Antennas
T/R Modules

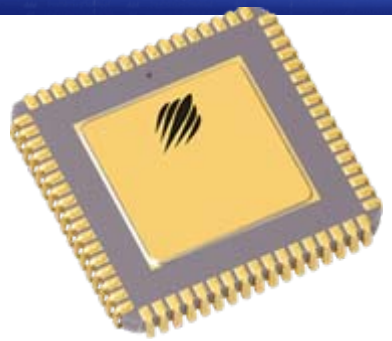
- **DC/DC 2A, 6A, 10A**
- **LDOs**

Power Management
Point of Loads
LDOs

Current Production and On going development

PE33632 Fractional N PLL (ECI 1 - QPL March 2011)

- 3500 MHz operation
- Ultra-Low Phase Noise: -216 dBc/Hz
- Low power 40 mA at 3.3 V
- ÷10/11 dual modulus prescaler
- Phase detector output
- Serial or Direct mode access
- Frequency selectivity: Comparison frequency / 2^{18}
- 1000 V ESD Protection
- 100 Krads (Si) Total dose
- Packaged in 68-lead CQFJ



Peregrine Semiconductor

Product Specification

PE33632

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

Features

- 3.5 GHz operation
- ÷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
- Ultra-low phase noise
- 68-lead CQFJ

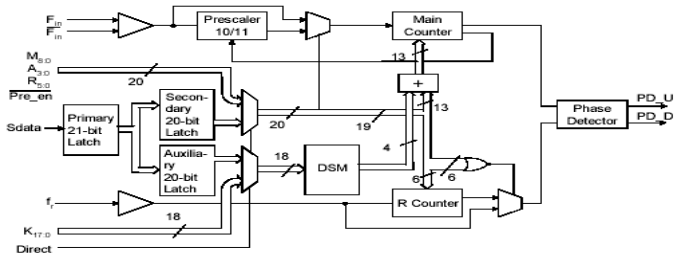
Product Description

Peregrine's PE33632 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 PLLs.

The PE33632 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 PE33632 is manufactured on Peregrine's UltraCMOS™ process, a patented variation of silicon-on-insulator (SOI) technology on a sapphire substrate, offering the performance of GaAs with the economy and integration of conventional CMOS.

Figure 1. Block Diagram

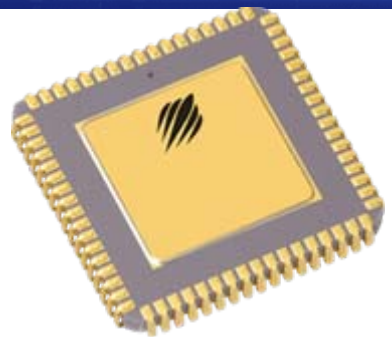


Document No. 70-02xx-01 | www.psemi.com

©2009 Peregrine Semiconductor Corp. All rights reserved.

PE33362 Integer-N PLL (EPPL)

- 3500 MHz operation
- Ultra-Low Phase Noise: -216 dBc/Hz
- Low Power: 45 mA at 3.3 V
- ÷10/11 dual modulus prescaler
- Internal phase detector
- Serial, Parallel or Direct Mode Access
- 1000 V ESD Protection
- 100 Krads (Si) total dose
- Packaged in a 44-lead CQFJ



Peregrine Semiconductor

Product Specification

PE33362

3500 MHz UltraCMOS™ Integer-N PLL

Features

- Low Power - 45 mA at 3.3V
- 3500 MHz operation
- ÷10/11 dual modulus prescaler
- Internal phase detector
- Serial, parallel or hardwired programmable
- Ultra-Low Phase Noise: -216 dBc/Hz
- Packaged in a 44-lead CQFJ

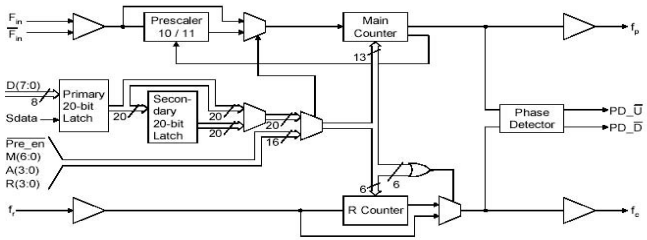
Product Description

Peregrine's PE33362 is a high-performance integer-N PLL capable of frequency synthesis up to 3500 MHz. The device is designed for superior phase noise performance while providing an order of magnitude reduction in current consumption, when compared with existing commercial PLLs.

The PE33362 features a 10/11 dual modulus prescaler, counters and a phase comparator as shown in Figure 1. Counter values are programmable through either a serial or parallel interface and can also be directly hard wired.

The PE33362 is manufactured on Peregrine's UltraCMOS™ process, a patented variation of silicon-on-insulator (SOI) technology on a sapphire substrate, offering the performance of GaAs with the economy and integration of conventional CMOS.

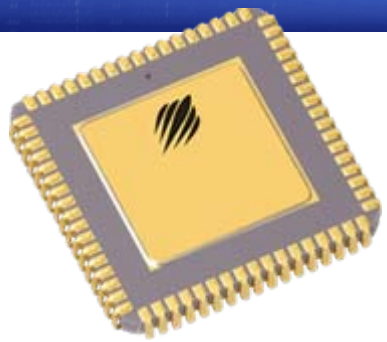
Figure 1. Block Diagram



©2009 Peregrine Semiconductor Corp. All rights reserved.

PE33382 Integer N PLL (EPPL)

- Low Power: 45 mA Typical
- Ultra-Low Phase Noise: -216 dBc/Hz
- 3500 MHz operation
- ÷10/11 dual modulus prescaler
- 1000 V ESD Protection
- Phase detector output
- Serial interface or hardwired programmable
- 100 Krad (Si) total dose
- Packaged in a 44-lead CQFJ



Peregrine Semiconductor

Advance Information

PE33382

3500 MHz UltraCMOS™ Integer-N PLL

Features

- Low Power: 45 mA Typical
- 3500 MHz operation
- ÷10/11 dual modulus prescaler
- Phase detector output
- Serial interface or hardwired programmable
- Ultra-Low Phase Noise: -216 dBc/Hz
- Packaged in a 44-lead CQFJ

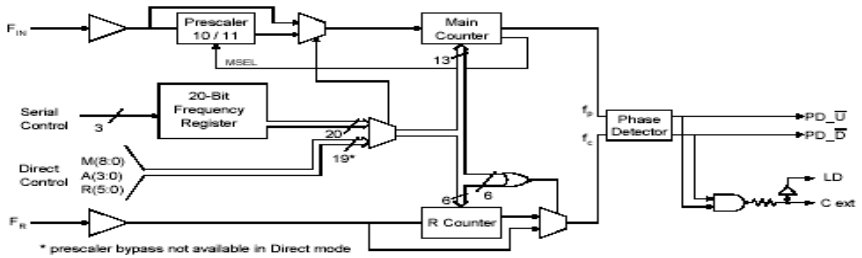
Product Description

Peregrine's PE33382 is a high-performance integer-N PLL capable of frequency synthesis up to 3500 MHz. The device is designed for superior phase noise performance while providing an order of magnitude reduction in current consumption, when compared with existing commercial PLLs.

The PE33382 features a ÷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 PE33382 is manufactured on Peregrine's UltraCMOS™ process, a patented variation of silicon-on-insulator (SOI) technology on a sapphire substrate, offering the performance of GaAs with the economy and integration of conventional CMOS.

Figure 1. Block Diagram



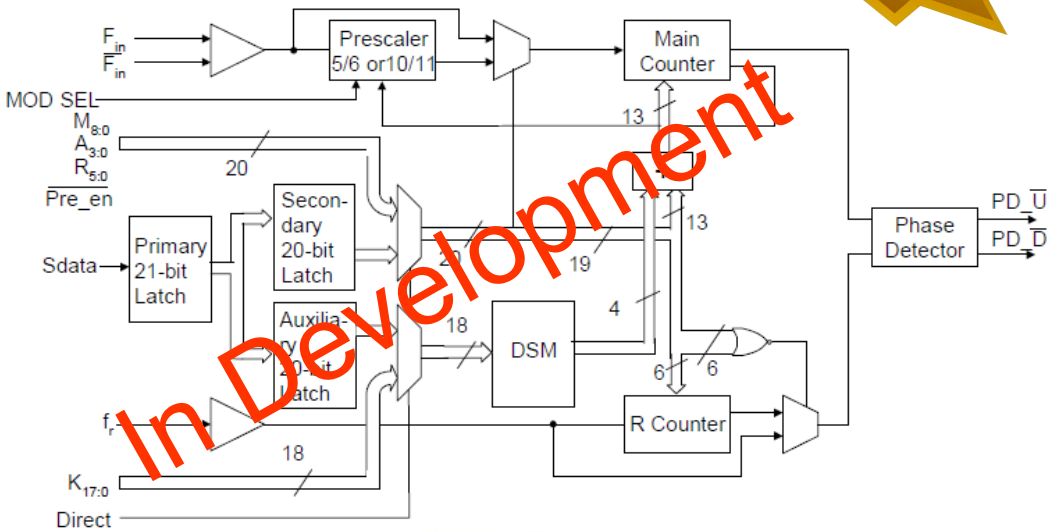
Document No. 70-02xx-01 | www.psemi.com

©2009 Peregrine Semiconductor Corp. All rights reserved.

PE33642 4.0GHz Fractional-N PLL

- 4.0 GHz operation
- Ultra-Low Phase Noise: -221 dBc/Hz
- Low Power: 50 mA at 2.5V
- Selectable prescaler modulus of 5/6 or 10/11
- Internal phase detector
- Serial or hard-wire programmable
- Frequency selectivity: Comparison frequency/2^{18}
- SEU < 10^{-9} errors / bit-day
- 100 Krad (Si) total dose
- Packaged in a 64-lead CQFP
- 1000 V ESD Protection

Ultra-low Phase Noise

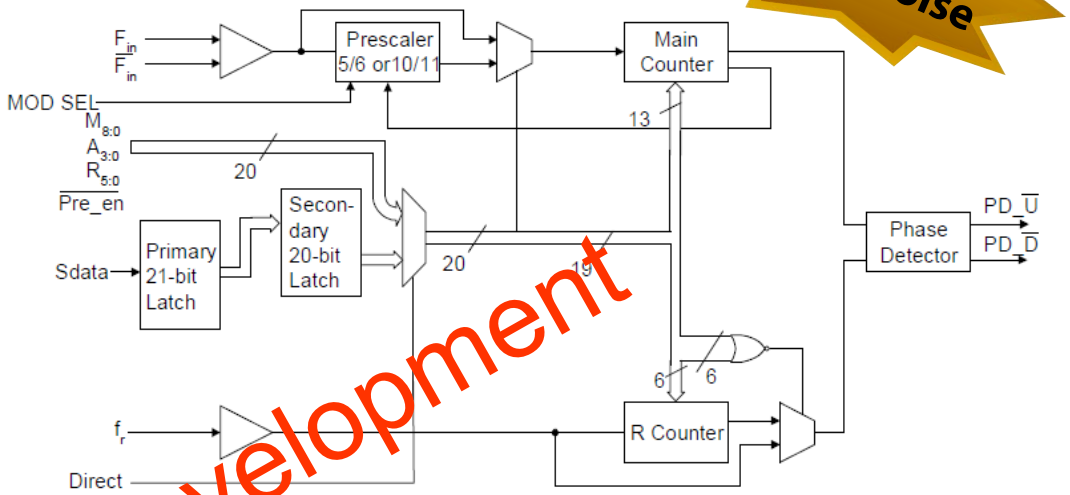


64-Lead CQFP Package

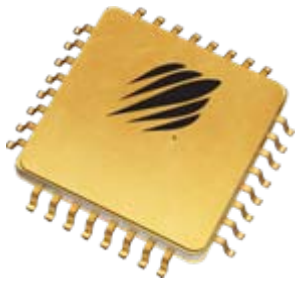
PE33242 4.0 GHz Integer-N PLL

- 4.0 GHz operation
- Ultra-Low Phase Noise: -221 dBc/Hz
- Low Power: 50 mA at 2.5V
- Selectable prescaler modulus of 5/6 or 10/11
- Internal phase detector
- Serial or hard-wire programmable
- SEU < 10^{-9} errors / bit-day
- 100 Krad (Si) total dose
- Packaged in a 44-lead CQFJ
- 1000 V ESD Protection
- 100 Krad (Si) total dose

Ultra-low Phase Noise



In Development



44-Lead CQFP Package

PE43751/43752 7-Bit Digital Step Attenuator (ECI 2)

- **High Linearity**
  - +34 dBm peak P1 dB typical
  - +52 dBm IIP3 typical
  - Flat performance from 1 MHz to 3 GHz
- **Market Leading Accuracy**
  - 31.75dB attenuation range with 0.25dB steps
  - 63.5dB attenuation range with 0.5dB steps
- **3V Supply voltage**
- **Parallel & serial logic control**
- **Low Insertion Loss (1.5 dB)**
- **No coupling caps if RF I/O remains at 0 VDC**
- **High ESD rating**
- **Available as RF Tested Die**

Peregrine Semiconductor

50 Ω RF Digital Attenuator
7-bit, 31.75 dB, 9 kHz - 6000 MHz
Vss_{EXT} option

Features

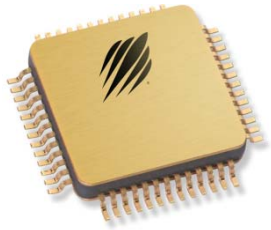
- HaRP™-enhanced UltraCMOS™ device
- Attenuation options: 0.25 dB, 0.5 dB, or 1.0 dB steps to 31.75 dB
  - 0.25 dB monotonicity for ≤ 4.0 GHz
  - 0.5 dB monotonicity for ≤ 5.0 GHz
  - 1 dB monotonicity for ≤ 6.0 GHz
- High linearity: Typical +59 dBm IIP3
- Excellent low-frequency performance
- Optional External Vss Control (Vss_{EXT})
- 3.3 V or 5.0 V Power Supply Voltage
- Fast switch settling time
- Programming Modes:
  - Direct Parallel
  - Latched Parallel
  - Serial-Addressable: Program up to eight addresses 000 - 111
- High-attenuation state @ power-up (PUP)
- CMOS Compatible
- No DC blocking capacitors required

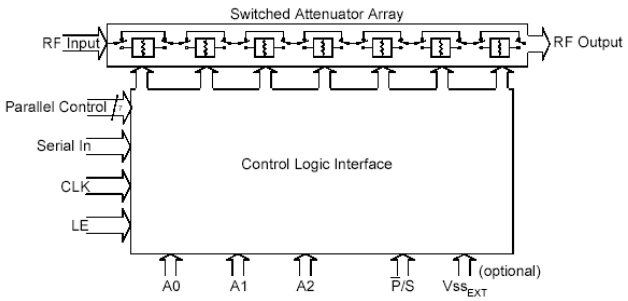
Product Description

The PE43703 is a HaRP™-enhanced, high linearity, 7-bit RF Digital Step Attenuator (DSA). This highly versatile DSA covers a 31.75 dB attenuation range in 0.25 dB, 0.5 dB, or 1.0 dB steps. The customer can choose which step size and associated specifications are best suited for their application. The Peregrine 50Ω RF DSA provides multiple CMOS control interfaces and an optional external Vss feature. It maintains high attenuation accuracy over frequency and temperature and exhibits very low insertion loss and low power consumption. Performance does not change with V_{DD} due to on-board regulator. This next generation Peregrine DSA is available in a 5x5 mm 32-lead QFN footprint.

The PE43703 is manufactured on Peregrine's UltraCMOS™ process, a patented variation of silicon-on-insulator (SOI) technology on a sapphire substrate, offering the performance of GaAs with the economy and integration of conventional CMOS.

Development





PE52100 – Triple Digital Variable Gain Amplifier

- 60 - 200 MHz operation
- 27dB Gain per Stage
- Attenuator Dynamic Range: 31.5dB per Stage
- Attenuator Step accuracy better than 0.1dB
- IF amplifier Output P1dB: 8dBm
- Noise Figure at minimum attenuation: +4.5dB
- Output IP3 +18dBm
- 1000 V ESD Protection
- Rad-Hard
- Packaged 52-lead CQFP

Peregrine Semiconductor

Product Concept

Digital Variable Gain Amplifier

60-200 MHz IF frequency amplifier for Hi-Rel Applications

UltraCMOS™ Triple Digital Variable Gain Amplifier

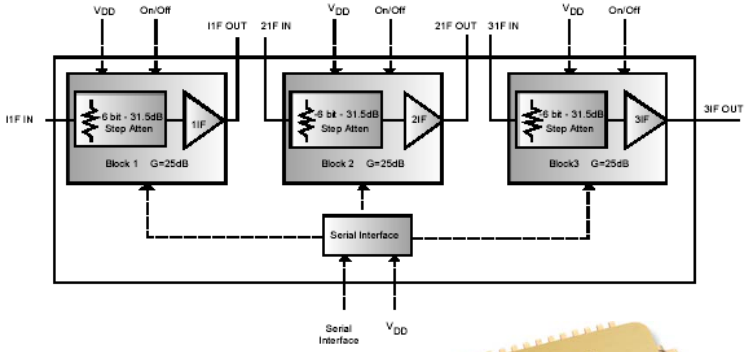
General Description

The Digital Variable Gain Amplifier is a 60-200 MHz IF subsystem. All three gain stages can be cascaded but the total maximum gain cannot exceed 60 dB after substracting any on-chip digital attenuator loss and off-chip inter-stage loss. 3-wire on-chip programmable serial-control attenuators are used as variable gain elements. The device can be used to drive an off-chip peripheral with up to +8 dBm (50 Ohms).

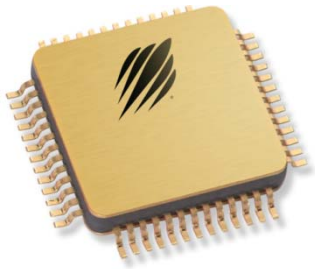
Screening of the Digital Variable Gain Amplifier is available for Hi-Rel applications . Fabricated in Peregrine's patented UltraCMOS™ technology, this part offers high linearity and low distortion.

Product Features

- Gain: +26dB per stage
- Noise Figure at min. attenuation: 5.0 dB
- IF amplifier output P1dB = 8 dBm
- Output IP3 higher than +18 dBm
- Harmonics: <–30 dBc at +3 dBm output power
- Attenuator Dynamic Range: 31.5 dB per stage
- Attenuator Step Accuracy better than 0.1 dB
- 60-200 MHz Operation

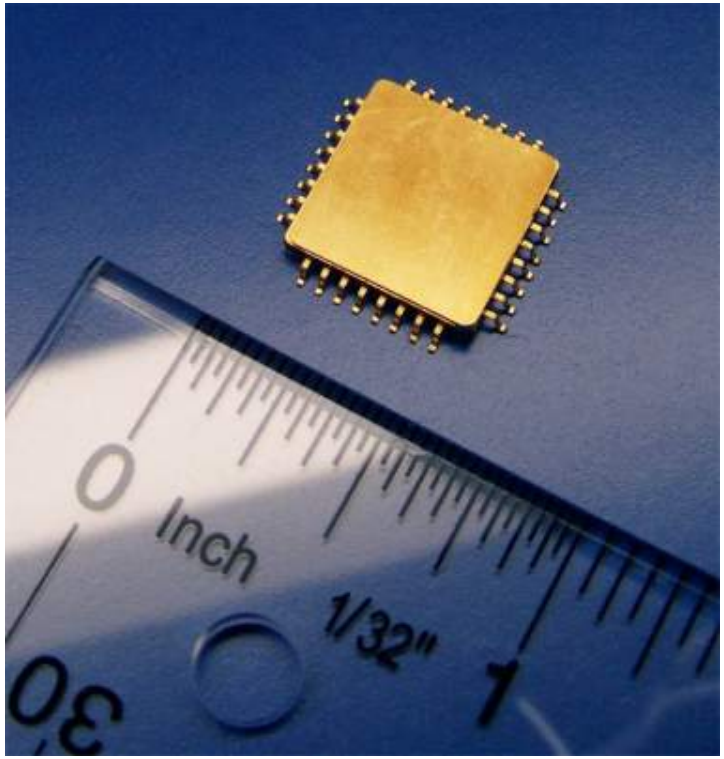


The Digital Variable Gain Amplifier is composed of 3 identical and independent blocks plus a common serial Interface. Each block includes a 6 bit step attenuator and an amplifier. For each block there are accessible I/O pins, a dedicated V_{DD} pin and a dedicated power down pin for the ON/OFF function. Only the serial interface (DATA, CLK, ENABLE) is common to all blocks. Each block exhibits the same electrical performance.



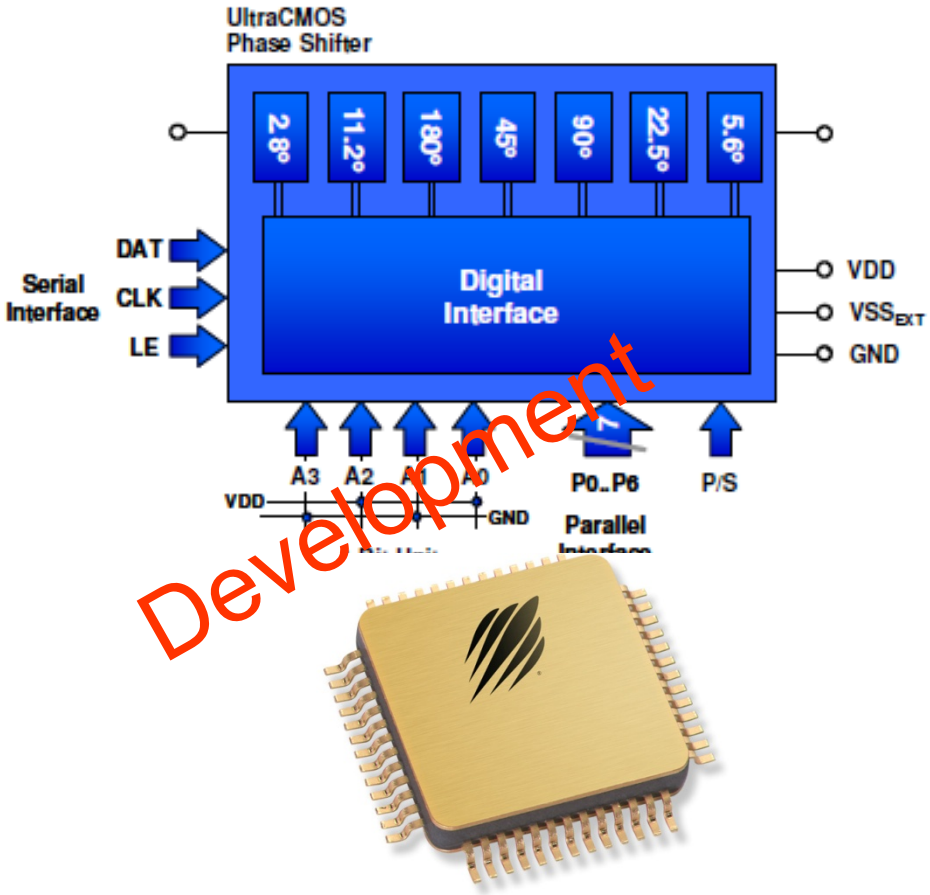
DC-DC Converter: Monolithic Point of Load

- 93% Peak Efficiency
- Better than 1% Accuracy
- Monolithic Design with integrated Power MOSFETs & Control Logic
- 4.5 – 6 V Input (VIN)
- VIN– 1 V Output
- 2A, 6A, 10A
- SYNC function, 100 kHz – 5 MHz lock range with selectable 500kHz / 1MHz free running frequency at no sync
- Current mode control, pulse-by-pulse current limit, current sharing enabled and (N+K) redundancy
- Adjustable Soft-Start
- SEL Immune
- Single Event Effects do not interrupt Power delivery
- 100 Krads (Si) Total Dose



PE892277: 7-Bits L-Band Phase Shifter

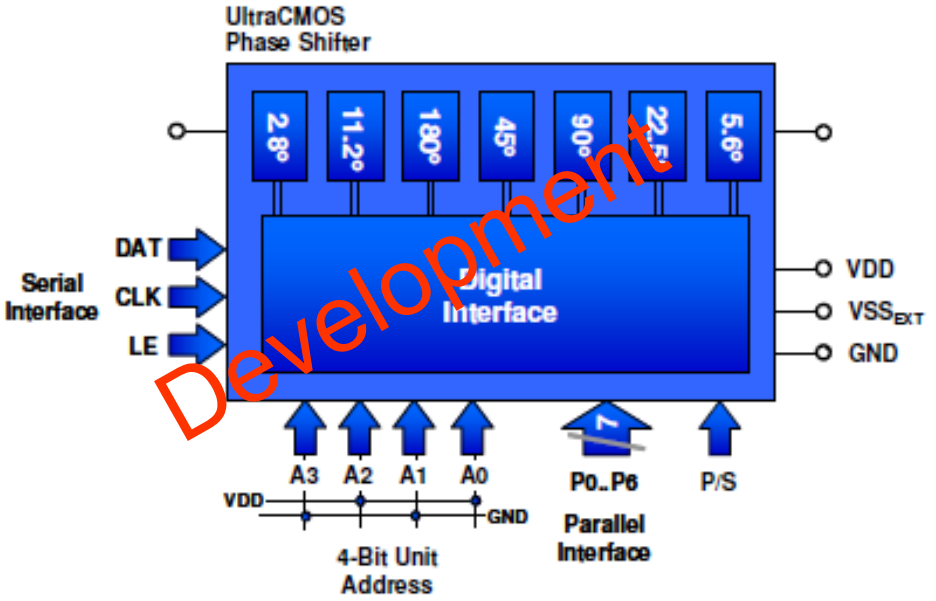
- **1.2 – 1.4 GHz Operation**
- Phase Range: 360 deg 7-Bit
  - 180, 90, 45, 22.5,11.2, 5.6, 2.8 degree bits (LSB)
- Low power : 70 µA at 3.3 V
- Low insertion loss: 4 dB
- Linearity: 50 dBm min
- Fast Settling Time: < 200 ns
- RMS Phase Error: 1 degree
- RMS Amplitude Error: 0.2 dB
- 1000 V ESD Protection
- Rad-Hard
- 32-lead Ceramic Package



Q1'11: Kick-off → Q2'11 → Q3'11 → Q4'11: ES &CS → Q1'12: Production

PE892371: 7-Bit S-Band Phase Shifter

- **2.7 – 3.7 GHz Operation**
- Phase Range: 360 deg 7-Bit
  - 180, 90, 45, 22.5,11.2, 5.6, 2.8 degree bits
- Low power : 70 µA at 3.3 V
- Low insertion loss: < 5 dB
- Linearity: 50 dBm min
- Fast Settling Time: < 200 ns
- RMS Phase Error: < 1 degree
- RMS Amplitude Error: 0.2 dB
- 1000 V ESD Protection
- Rad-Hard
- 32-lead Ceramic Package



PE99311/PE99315: Low-Power and High-Power Positive LDO

Parameters	PE99311 Low-Power LDO	PE99315 High Power LDO
Maximum Power, PWRMAX	100mW	1W
Rated Output Current	100mA	1000mA
Current Limit (max)	150mA	1.5A
IOUT(Shutdown) @ VIN(max)	10uA	100uA
Input Voltage Range	2.3 - 3.6V	2.3 - 3.6V
PSRR DC	80dB	80dB
PSRR 1MHz	40dB	40dB
Programmable Output Voltage	1 to Vin	1 to Vin
Total Ionizing Dose	100 KRad	100 Krad

Conclusion

- Peregrine Semiconductor Europe is developing advanced RF products for Space applications which comply with European Customers requirements as well as European Space Agency system
- Various new products will be introduced within next couple of years: ultra Low Phase Noise PLL, Digital Step Attenuators, Phase shifters, and many other.

THANK YOU