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Embedded - System On Chip (SoC): The Heart of Modern Embedded Systems

Embedded - System On Chip (SoC) refers to an integrated circuit that consolidates all the essential components of a computer system into a single chip. This includes a microprocessor, memory, and other peripherals, all packed into one compact and efficient package. SoCs are designed to provide a complete computing solution, optimizing both space and power consumption, making them ideal for a wide range of embedded applications.

What are Embedded - System On Chip (SoC)?

System On Chip (SoC) integrates multiple functions of a computer or electronic system onto a single chip. Unlike traditional multi-chip solutions, SoCs combine a central

Details	
Product Status	Active
Architecture	MCU, FPGA
Core Processor	Quad ARM® Cortex®-A53 MPCore™ with CoreSight™
Flash Size	-
RAM Size	256KB
Peripherals	DMA, WDT
Connectivity	EBI/EMI, Ethernet, I²C, MMC/SD/SDIO, SPI, UART/USART, USB OTG
Speed	1.5GHz
Primary Attributes	FPGA - 2500K Logic Elements
Operating Temperature	0°C ~ 100°C (TJ)
Package / Case	2397-BBGA, FCBGA
Supplier Device Package	2397-FBGA, FC (50x50)
Purchase URL	https://www.e-xfl.com/product-detail/intel/1sx250lu2f50e2lg

Contents

1. Intel® Stratix® 10 GX/SX Device Overview

Intel's 14-nm Intel® Stratix® 10 GX FPGAs and SX SoCs deliver 2X the core performance and up to 70% lower power over previous generation high-performance FPGAs.

Featuring several groundbreaking innovations, including the all new HyperFlex™ core architecture, this device family enables you to meet the demand for ever-increasing bandwidth and processing performance in your most advanced applications, while meeting your power budget.

With an embedded hard processor system (HPS) based on a quad-core 64-bit ARM® Cortex®-A53, the Intel Stratix 10 SoC devices deliver power efficient, application-class processing and allow designers to extend hardware virtualization into the FPGA fabric. Intel Stratix 10 SoC devices demonstrate Intel's commitment to high-performance SoCs and extend Intel's leadership in programmable devices featuring an ARM-based processor system.

Important innovations in Intel Stratix 10 FPGAs and SoCs include:

- All new HyperFlex core architecture delivering 2X the core performance compared to previous generation high-performance FPGAs
- Industry leading Intel 14-nm Tri-Gate (FinFET) technology
- Heterogeneous 3D System-in-Package (SiP) technology
- Monolithic core fabric with up to 5.5 million logic elements (LEs)
- Up to 96 full duplex transceiver channels on heterogeneous 3D SiP transceiver tiles
- Transceiver data rates up to 28.3 Gbps chip-to-chip/module and backplane performance
- M20K (20 kbit) internal SRAM memory blocks
- Fractional synthesis and ultra-low jitter LC tank based transmit phase locked loops (PLLs)
- Hard PCI Express® Gen3 x16 intellectual property (IP) blocks
- Hard 10GBASE-KR/40GBASE-KR4 Forward Error Correction (FEC) in every transceiver channel
- Hard memory controllers and PHY supporting DDR4 rates up to 2666 Mbps per pin
- Hard fixed-point and IEEE 754 compliant hard floating-point variable precision digital signal processing (DSP) blocks with up to 10 TFLOPS compute performance with a power efficiency of 80 GFLOPS per Watt
- Quad-core 64-bit ARM Cortex-A53 embedded processor running up to 1.5 GHz in SoC family variants
- Programmable clock tree synthesis for flexible, low power, low skew clock trees

- Dedicated secure device manager (SDM) for:
  - Enhanced device configuration and security
  - AES-256, SHA-256/384 and ECDSA-256/384 encrypt/decrypt accelerators and authentication
  - Multi-factor authentication
  - Physically Unclonable Function (PUF) service and software programmable device configuration capability
- Comprehensive set of advanced power saving features delivering up to 70% lower power compared to previous generation high-performance FPGAs
- Non-destructive register state readback and writeback, to support ASIC prototyping and other applications

With these capabilities, Intel Stratix 10 FPGAs and SoCs are ideally suited for the most demanding applications in diverse markets such as:

- **Compute and Storage**—for custom servers, cloud computing and data center acceleration
- **Networking**—for Terabit, 400G and multi-100G bridging, aggregation, packet processing and traffic management
- **Optical Transport Networks**—for OTU4, 2xOTU4, 4xOTU4
- **Broadcast**—for high-end studio distribution, headend encoding/decoding, edge quadrature amplitude modulation (QAM)
- **Military**—for radar, electronic warfare, and secure communications
- **Medical**—for diagnostic scanners and diagnostic imaging
- **Test and Measurement**—for protocol and application testers
- **Wireless**—for next-generation 5G networks
- **ASIC Prototyping**—for designs that require the largest monolithic FPGA fabric with the highest I/O count

1.1. Intel Stratix 10 Family Variants

Intel Stratix 10 devices are available in FPGA (GX) and SoC (SX) variants.

- **Intel Stratix 10 GX** devices deliver up to 1 GHz core fabric performance and contain up to 5.5 million LEs in a monolithic fabric. They also feature up to 96 general purpose transceivers on separate transceiver tiles, and 2666 Mbps DDR4 external memory interface performance. The transceivers are capable of up to 28.3 Gbps short reach and across the backplane. These devices are optimized for FPGA applications that require the highest transceiver bandwidth and core fabric performance, with the power efficiency of Intel's industry-leading 14-nm Tri-Gate process technology.
- **Intel Stratix 10 SX** devices have a feature set that is identical to Intel Stratix 10 GX devices, with the addition of an embedded quad-core 64-bit ARM Cortex A53 hard processor system.

Common to all Intel Stratix 10 family variants is a high-performance fabric based on the new HyperFlex core architecture that includes additional Hyper-Registers throughout the interconnect routing and at the inputs of all functional blocks. The core fabric also contains an enhanced logic array utilizing Intel's adaptive logic module (ALM) and a rich set of high performance building blocks including:

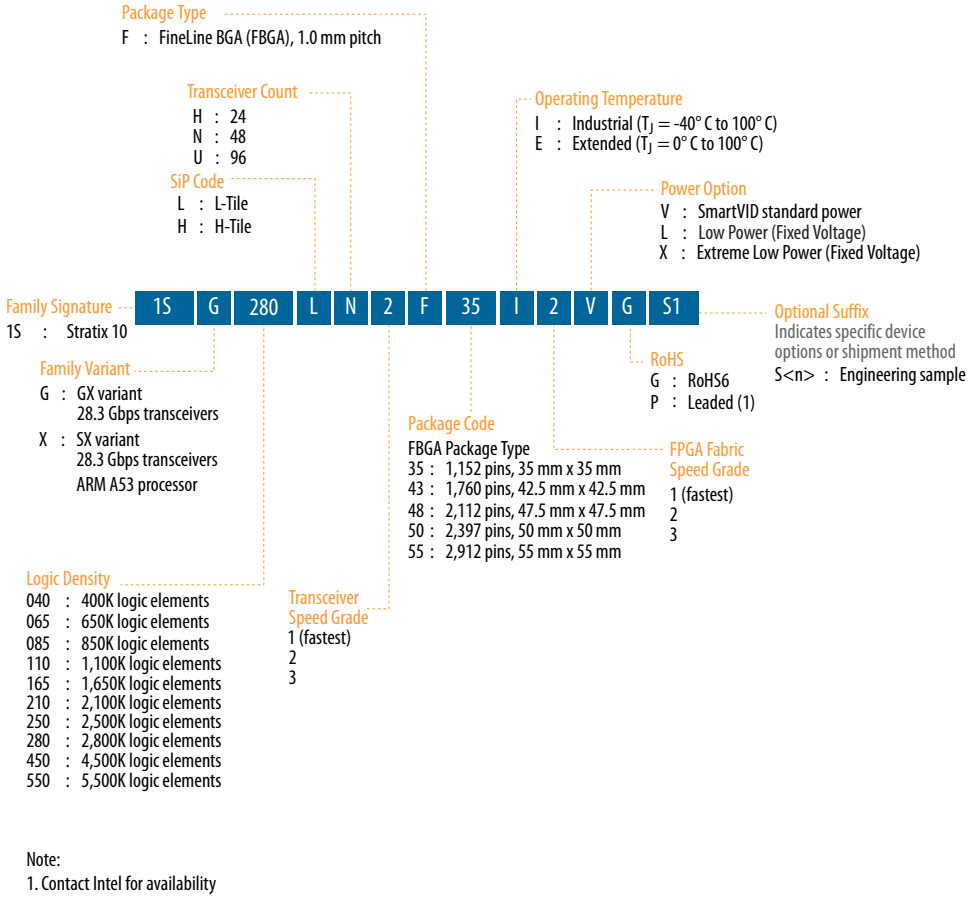
- M20K (20 kbit) embedded memory blocks
- Variable precision DSP blocks with hard IEEE 754 compliant floating-point units
- Fractional synthesis and integer PLLs
- Hard memory controllers and PHY for external memory interfaces
- General purpose IO cells

To clock these building blocks, Intel Stratix 10 devices use programmable clock tree synthesis, which uses dedicated clock tree routing to synthesize only those branches of the clock trees required for the application. All devices support in-system, fine-grained partial reconfiguration of the logic array, allowing logic to be added and subtracted from the system while it is operating.

All family variants also contain high speed serial transceivers, containing both the physical medium attachment (PMA) and the physical coding sublayer (PCS), which can be used to implement a variety of industry standard and proprietary protocols. In addition to the hard PCS, Intel Stratix 10 devices contain multiple instantiations of PCI Express hard IP that supports Gen1/Gen2/Gen3 rates in x1/x2/x4/x8/x16 lane configurations, and hard 10GBASE-KR/40GBASE-KR4 FEC for every transceiver. The hard PCS, FEC, and PCI Express IP free up valuable core logic resources, save power, and increase your productivity.

1.1.1. Available Options

Figure 1. Sample Ordering Code and Available Options for Intel Stratix 10 Devices



1.2. Innovations in Intel Stratix 10 FPGAs and SoCs

Intel Stratix 10 FPGAs and SoCs deliver many significant improvements over the previous generation high-performance Stratix V FPGAs.

Table 1. Key Features of Intel Stratix 10 Devices Compared to Stratix V Devices

Feature	Stratix V FPGAs	Intel Stratix 10 FPGAs and SoCs
Process technology	28-nm TSMC (planar transistor)	14 nm Intel Tri-Gate (FinFET)
Hard processor core	None	Quad-core 64-bit ARM Cortex-A53 (SoC only)
Core architecture	Conventional core architecture with conventional interconnect	HyperFlex core architecture with Hyper-Registers in the interconnect
Core performance	500 MHz	1 GHz
Power dissipation	1x	As low as 0.3x

continued...

Feature	Stratix V FPGAs	Intel Stratix 10 FPGAs and SoCs
Logic density	952 KLE (monolithic)	5,500 KLE (monolithic)
Embedded memory (M20K)	52 Mbits	229 Mbits
18x19 multipliers	3,926 *Note:* Multiplier is 18x18 in Stratix V devices.	11,520 *Note:* Multiplier is 18x19 in Intel Stratix 10 devices.
Floating point DSP capability	Up to 1 TFLOP, requires soft floating point adder and multiplier	Up to 10 TFLOPS, hard IEEE 754 compliant single precision floating point adder and multiplier
Maximum transceivers	66	96
Maximum transceiver data rate (chip-to-chip)	28.05 Gbps	28.3 Gbps L-Tile 28.3 Gbps H-Tile
Maximum transceiver data rate (backplane)	12.5 Gbps	12.5 Gbps L-Tile 28.3 Gbps H-Tile
Hard memory controller	None	DDR4 @ 1333 MHz/2666 Mbps DDR3 @ 1067 MHz/2133 Mbps
Hard protocol IP	PCIe Gen3 x8 (up to 4 instances)	PCIe Gen3 x16 (up to 4 instances) SR-IOV (4 physical functions / 2k virtual functions) on H-Tile devices 10GBASE-KR/40GBASE-KR4 FEC
Core clocking and PLLs	Global, quadrant and regional clocks supported by fractional-synthesis fPLLs	Programmable clock tree synthesis supported by fractional synthesis fPLLs and integer IO PLLs
Register state readback and writeback	Not available	Non-destructive register state readback and writeback for ASIC prototyping and other applications

These innovations result in the following improvements:

- **Improved Core Logic Performance**: The HyperFlex core architecture combined with Intel's 14-nm Tri-Gate technology allows Intel Stratix 10 devices to achieve 2X the core performance compared to the previous generation
- **Lower Power**: Intel Stratix 10 devices use up to 70% lower power compared to the previous generation, enabled by 14-nm Intel Tri-Gate technology, the HyperFlex core architecture, and optional power saving features built into the architecture
- **Higher Density**: Intel Stratix 10 devices offer over five times the level of integration, with up to 5,500K logic elements (LEs) in a monolithic fabric, over 229 Mbits of embedded memory blocks (M20K), and 11,520 18x19 multipliers
- **Embedded Processing**: Intel Stratix 10 SoCs feature a Quad-Core 64-bit ARM Cortex-A53 processor optimized for power efficiency and software compatible with previous generation Arria and Cyclone SoC devices
- **Improved Transceiver Performance**: With up to 96 transceiver channels implemented in heterogeneous 3D SiP transceiver tiles, Intel Stratix 10 GX and SX devices support data rates up to 28.3 Gbps chip-to-chip and 28.3 Gbps across the backplane with signal conditioning circuits capable of equalizing over 30 dB of system loss
- **Improved DSP Performance**: The variable precision DSP block in Intel Stratix 10 devices features hard fixed and floating point capability, with up to 10 TeraFLOPS IEEE754 single-precision floating point performance

Feature	Description
Configuration	• Dedicated Secure Device Manager • Software programmable device configuration • Serial and parallel flash interface • Configuration via protocol (CvP) using PCI Express Gen1/Gen2/Gen3 • Fine-grained partial reconfiguration of core fabric • Dynamic reconfiguration of transceivers and PLLs • Comprehensive set of security features including AES-256, SHA-256/384, and ECDSA-256/384 accelerators, and multi-factor authentication • Physically Unclonable Function (PUF) service
Packaging	• Intel Embedded Multi-die Interconnect Bridge (EMIB) packaging technology • Multiple devices with identical package footprints allows seamless migration across different device densities • 1.0 mm ball-pitch FBGA packaging • Lead and lead-free package options
Software and tools	• Intel Quartus Prime Pro Edition design suite with new compiler and Hyper-Aware design flow • Fast Forward compiler to allow HyperFlex architecture performance exploration • Transceiver toolkit • Platform designer integration tool • DSP Builder advanced blockset • OpenCL™ support • SoC Embedded Design Suite (EDS)

Table 3. Intel Stratix 10 SoC Specific Device Features

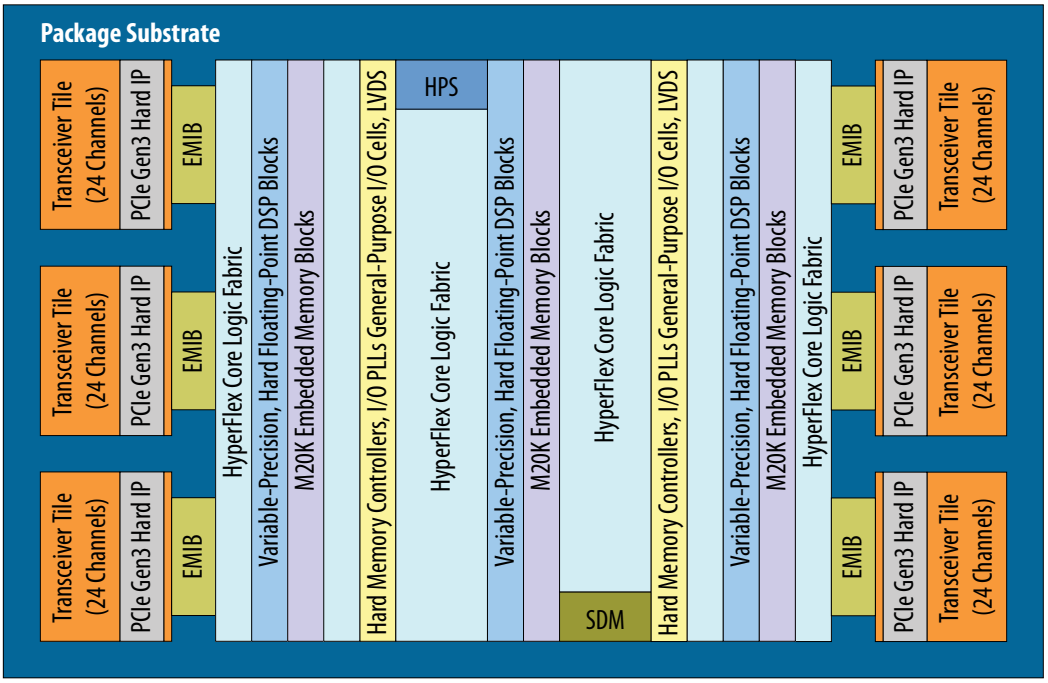
SoC Subsystem	Feature	Description
Hard Processor System	Multi-processor unit (MPU) core	• Quad-core ARM Cortex-A53 MPCore processor with ARM CoreSight debug and trace technology • Scalar floating-point unit supporting single and double precision • ARM NEON media processing engine for each processor
	System Controllers	• System Memory Management Unit (SMMU) • Cache Coherency Unit (CCU)
	Layer 1 Cache	• 32 KB L1 instruction cache with parity • 32 KB L1 data cache with ECC
	Layer 2 Cache	• 1 MB Shared L2 Cache with ECC
	On-Chip Memory	• 256 KB On-Chip RAM
	Direct memory access (DMA) controller	• 8-Channel DMA
	Ethernet media access controller (EMAC)	• Three 10/100/1000 EMAC with integrated DMA
	USB On-The-Go controller (OTG)	• 2 USB OTG with integrated DMA
	UART controller	• 2 UART 16550 compatible
	Serial Peripheral Interface (SPI) controller	• 4 SPI
	I^2C controller	• 5 I^2C controllers
	SD/SDIO/MMC controller	• 1 eMMC version 4.5 with DMA and CE-ATA support • SD, including eSD, version 3.0 • SDIO, including eSDIO, version 3.0 • CE-ATA - version 1.1

continued...

SoC Subsystem	Feature	Description
	NAND flash controller	• 1 ONFI 1.0, 8- and 16-bit support
	General-purpose I/O (GPIO)	• Maximum of 48 software programmable GPIO
	Timers	• 4 general-purpose timers • 4 watchdog timers
Secure Device Manager	Security	• Secure boot • Advanced Encryption Standard (AES) and authentication (SHA/ECDSA)
External Memory Interface	External Memory Interface	• Hard Memory Controller with DDR4 and DDR3, and LPDDR3

1.4. Intel Stratix 10 Block Diagram

Figure 2. Intel Stratix 10 FPGA and SoC Architecture Block Diagram



HPS: Quad ARM Cortex-A53 Hard Processor System
SDM: Secure Device Manager
EMIB: Embedded Multi-Die Interconnect Bridge

1.5. Intel Stratix 10 FPGA and SoC Family Plan

(1) The number of 27x27 multipliers is one-half the number of 18x19 multipliers.

Table 4. Intel Stratix 10 GX/SX FPGA and SoC Family Plan—FPGA Core (part 1)

Intel Stratix 10 GX/SX Device Name	Logic Elements (KLE)	M20K Blocks	M20K Mbits	MLAB Counts	MLAB Mbits	18x19 Multipliers (1)
GX 400/ SX 400	378	1,537	30	3,204	2	1,296
GX 650/ SX 650	612	2,489	49	5,184	3	2,304
GX 850/ SX 850	841	3,477	68	7,124	4	4,032
GX 1100/ SX 1100	1,092	4,401	86	9,540	6	5,040
GX 1650/ SX 1650	1,624	5,851	114	13,764	8	6,290
GX 2100/ SX 2100	2,005	6,501	127	17,316	11	7,488
GX 2500/ SX 2500	2,422	9,963	195	20,529	13	10,022
GX 2800/ SX 2800	2,753	11,721	229	23,796	15	11,520
GX 4500/ SX 4500	4,463	7,033	137	37,821	23	3,960
GX 5500/ SX 5500	5,510	7,033	137	47,700	29	3,960

Table 5. Intel Stratix 10 GX/SX FPGA and SoC Family Plan—Interconnects, PLLs and Hard IP (part 2)

Intel Stratix 10 GX/SX Device Name	Interconnects		PLLs		Hard IP
	Maximum GPIOs	Maximum XCVR	fPLLs	I/O PLLs	PCIe Hard IP Blocks
GX 400/ SX 400	392	24	8	8	1
GX 650/ SX 650	400	48	16	8	2
GX 850/ SX 850	736	48	16	15	2
GX 1100/ SX 1100	736	48	16	15	2
GX 1650/ SX 1650	704	96	32	14	4
GX 2100/ SX 2100	704	96	32	14	4
GX 2500/ SX 2500	1160	96	32	24	4

continued...

Within each transceiver tile, the transceivers are arranged in four banks of six PMA-PCS groups. A wide variety of bonded and non-bonded data rate configurations are possible within each bank, and within each tile, using a highly configurable clock distribution network.

1.8.1. PMA Features

PMA channels are comprised of transmitter (TX), receiver (RX), and high speed clocking resources.

Intel Stratix 10 device features provide exceptional signal integrity at data rates up to 28.3 Gbps. Clocking options include ultra-low jitter LC tank-based (ATX) PLLs with optional fractional synthesis capability, channel PLLs operating as clock multiplier units (CMUs), and fractional synthesis PLLs (fPLLs).

- **ATX PLL**—can be configured in integer mode, or optionally, in a new fractional synthesis mode. Each ATX PLL spans the full frequency range of the supported data rate range providing a stable, flexible clock source with the lowest jitter.
- **CMU PLL**—when not being used as a transceiver, select PMA channels can be configured as channel PLLs operating as CMUs to provide an additional master clock source within the transceiver bank.
- **fPLL**—In addition, dedicated fPLLs are available with precision frequency synthesis capabilities. fPLLs can be used to synthesize multiple clock frequencies from a single reference clock source and replace multiple reference oscillators for multi-protocol and multi-rate applications.

On the receiver side, each PMA has an independent channel PLL that allows analog tracking for clock-data recovery. Each PMA also has advanced equalization circuits that compensate for transmission losses across a wide frequency spectrum.

- **Variable Gain Amplifier (VGA)**—to optimize the receiver's dynamic range
- **Continuous Time Linear Equalizer (CTLE)**—to compensate for channel losses with lowest power dissipation
- **Decision Feedback Equalizer (DFE)**—to provide additional equalization capability on backplanes even in the presence of crosstalk and reflections
- **On-Die Instrumentation (ODI)**—to provide on-chip eye monitoring capabilities (Eye Viewer). This capability helps to optimize link equalization parameters during board bring-up and supports in-system link diagnostics and equalization margin testing

Feature	Capability
Digitally Assisted Analog CDR	Superior jitter tolerance with fast lock time
On-Die Instrumentation—Eye Viewer and Jitter Margin Tool	Simplify board bring-up, debug, and diagnostics with non-intrusive, high-resolution eye monitoring (Eye Viewer). Also inject jitter from transmitter to test link margin in system.
Dynamic Reconfiguration	Allows for independent control of each transceiver channel Avalon memory-mapped interface for the most transceiver flexibility.
Multiple PCS-PMA and PCS-Core to FPGA fabric interface widths	8-, 10-, 16-, 20-, 32-, 40-, or 64-bit interface widths for flexibility of deserialization width, encoding, and reduced latency

1.8.2. PCS Features

Intel Stratix 10 PMA channels interface with core logic through configurable and bypassable PCS interface layers.

The PCS contains multiple gearbox implementations to decouple the PMA and PCS interface widths. This feature provides the flexibility to implement a wide range of applications with 8, 10, 16, 20, 32, 40, or 64-bit interface width between each transceiver and the core logic.

The PCS also contains hard IP to support a variety of standard and proprietary protocols across a wide range of data rates and encoding schemes. The Standard PCS mode provides support for 8B/10B encoded applications up to 12.5 Gbps. The Enhanced PCS mode supports 64B/66B and 64B/67B encoded applications up to 17.4 Gbps. The enhanced PCS mode also includes an integrated 10GBASE-KR/40GBASE-KR4 Forward Error Correction (FEC) circuit. For highly customized implementations, a PCS Direct mode provides an interface up to 64 bits wide to allow for custom encoding and support for data rates up to 28.3 Gbps.

For more information about the PCS-Core interface or the double rate transfer mode, refer to the *Intel Stratix 10 L- and H-Tile Transceiver PHY User Guide*, and the *Intel Stratix 10 E-Tile Transceiver PHY User Guide*.

Table 9. Transceiver PCS Features

PCS Protocol Support	Data Rate (Gbps)	Transmitter Data Path	Receiver Data Path
Standard PCS	1 to 12.5	Phase compensation FIFO, byte serializer, 8B/10B encoder, bit-slipper, channel bonding	Rate match FIFO, word-aligner, 8B/10B decoder, byte deserializer, byte ordering
PCI Express Gen1/Gen2 x1, x2, x4, x8, x16	2.5 and 5.0	Same as Standard PCS plus PIPE 2.0 interface to core	Same as Standard PCS plus PIPE 2.0 interface to core
PCI Express Gen3 x1, x2, x4, x8, x16	8.0	Phase compensation FIFO, byte serializer, encoder, scrambler, bit-slipper, gear box, channel bonding, and PIPE 3.0 interface to core, auto speed negotiation	Rate match FIFO (0-600 ppm mode), word-aligner, decoder, descrambler, phase compensation FIFO, block sync, byte deserializer, byte ordering, PIPE 3.0 interface to core, auto speed negotiation
CPRI	0.6144 to 9.8	Same as Standard PCS plus deterministic latency serialization	Same as Standard PCS plus deterministic latency deserialization

continued...

1.11. 10G Ethernet Hard IP

Intel Stratix 10 devices include IEEE 802.3 10-Gbps Ethernet (10GbE) compliant 10GBASE-R PCS and PMA hard IP. The scalable 10GbE hard IP supports multiple independent 10GbE ports while using a single PLL for all the 10GBASE-R PCS instantiations, which saves on core logic resources and clock networks.

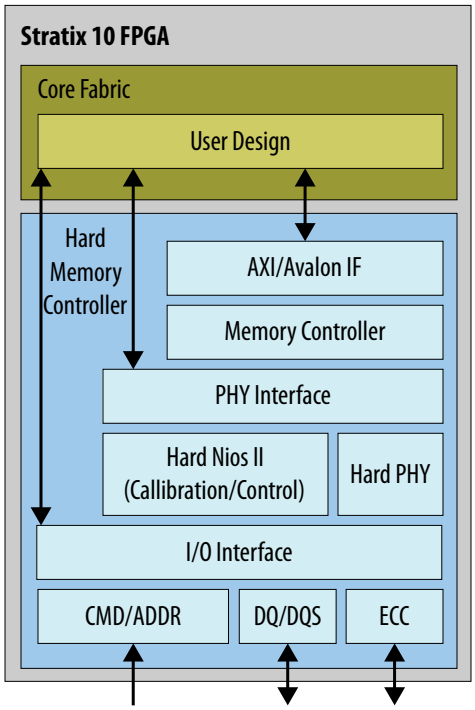
The integrated serial transceivers simplify multi-port 10GbE systems compared to 10 GbE Attachment Unit Interface (XAUI) interfaces that require an external XAUI-to-10G PHY. Furthermore, the integrated transceivers incorporate signal conditioning circuits, which enable direct connection to standard 10G XFP and SFP+ pluggable optical modules. The transceivers also support backplane Ethernet applications and include a hard 10GBASE-KR/40GBASE-KR4 Forward Error Correction (FEC) circuit that can be used for both 10G and 40G applications. The integrated 10G Ethernet hard IP and 10G transceivers save external PHY cost, board space and system power. The 10G Ethernet PCS hard IP and 10GBASE-KR FEC are present in every transceiver channel.

1.12. External Memory and General Purpose I/O

Intel Stratix 10 devices offer substantial external memory bandwidth, with up to ten 72-bit wide DDR4 memory interfaces running at up to 2666 Mbps.

This bandwidth is provided along with the ease of design, lower power, and resource efficiencies of hardened high-performance memory controllers. The external memory interfaces can be configured up to a maximum width of 144 bits when using either hard or soft memory controllers.

Figure 8. Hard Memory Controller



Each I/O bank contains 48 general purpose I/Os and a high-efficiency hard memory controller capable of supporting many different memory types, each with different performance capabilities. The hard memory controller is also capable of being bypassed and replaced by a soft controller implemented in the user logic. The I/Os each have a hardened double data rate (DDR) read/write path (PHY) capable of performing key memory interface functionality such as:

- Read/write leveling
- FIFO buffering to lower latency and improve margin
- Timing calibration
- On-chip termination

The timing calibration is aided by the inclusion of hard microcontrollers based on Intel's Nios® II technology, specifically tailored to control the calibration of multiple memory interfaces. This calibration allows the Intel Stratix 10 device to compensate for any changes in process, voltage, or temperature either within the Intel Stratix 10 device itself, or within the external memory device. The advanced calibration algorithms ensure maximum bandwidth and robust timing margin across all operating conditions.

Table 10. External Memory Interface Performance

The listed speeds are for the 1-rank case.

Interface	Controller Type	Performance
DDR4	Hard	2666 Mbps
DDR3	Hard	2133 Mbps
QDRII+	Soft	1,100 Mtps
QDRII+ Xtreme	Soft	1,266 Mtps
QDRIV	Soft	2,133 Mtps
RLDRAM III	Soft	2400 Mbps
RLDRAM II	Soft	533 Mbps

In addition to parallel memory interfaces, Intel Stratix 10 devices support serial memory technologies such as the Hybrid Memory Cube (HMC). The HMC is supported by the Intel Stratix 10 high-speed serial transceivers, which connect up to four HMC links, with each link running at data rates of 15 Gbps (HMC short reach specification).

Intel Stratix 10 devices also feature general purpose I/Os capable of supporting a wide range of single-ended and differential I/O interfaces. LVDS rates up to 1.6 Gbps are supported, with each pair of pins having both a differential driver and a differential input buffer. This enables configurable direction for each LVDS pair.

1.13. Adaptive Logic Module (ALM)

Intel Stratix 10 devices use a similar adaptive logic module (ALM) as the previous generation Arria 10 and Stratix V FPGAs, allowing for efficient implementation of logic functions and easy conversion of IP between the devices.

The ALM block diagram shown in the following figure has eight inputs with a fracturable look-up table (LUT), two dedicated embedded adders, and four dedicated registers.

The DSP blocks can be configured to support signal processing with precision ranging from 18x19 up to 54x54. A pipeline register has been added to increase the maximum operating frequency of the DSP block and reduce power consumption.

Figure 10. DSP Block: Standard Precision Fixed Point Mode

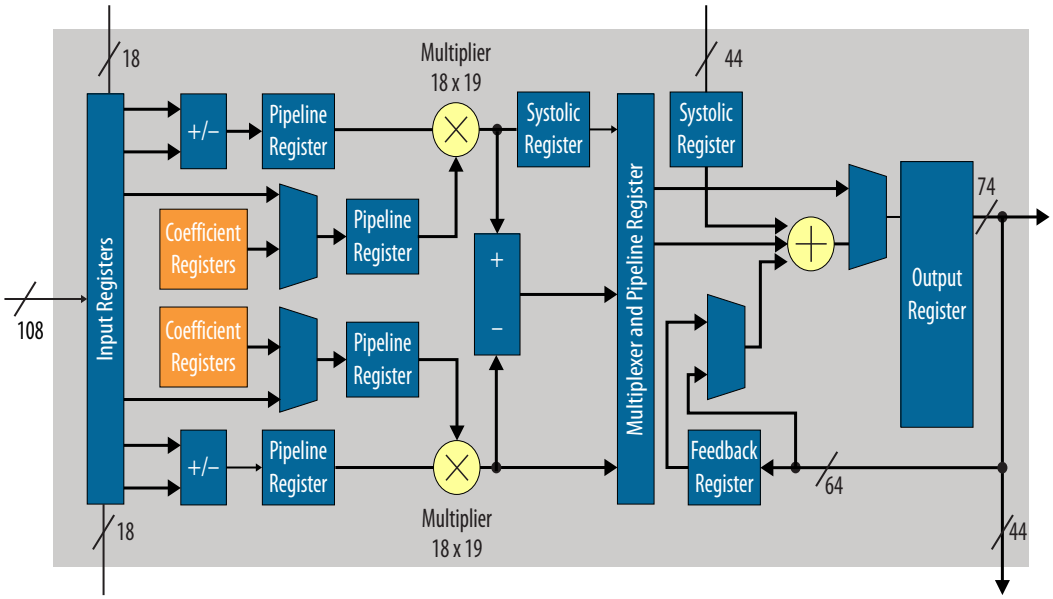


Figure 11. DSP Block: High Precision Fixed Point Mode

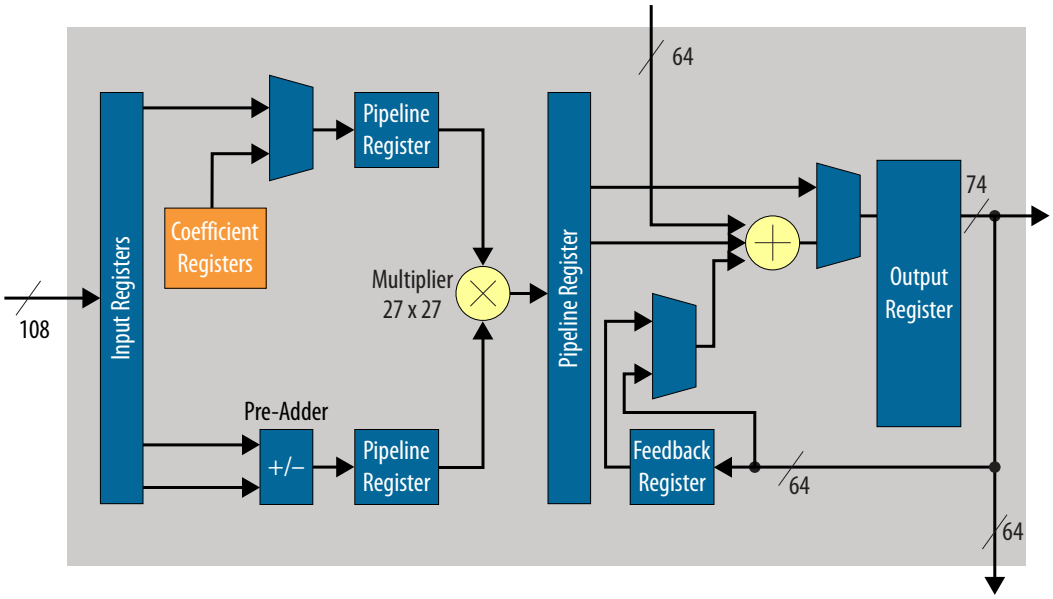
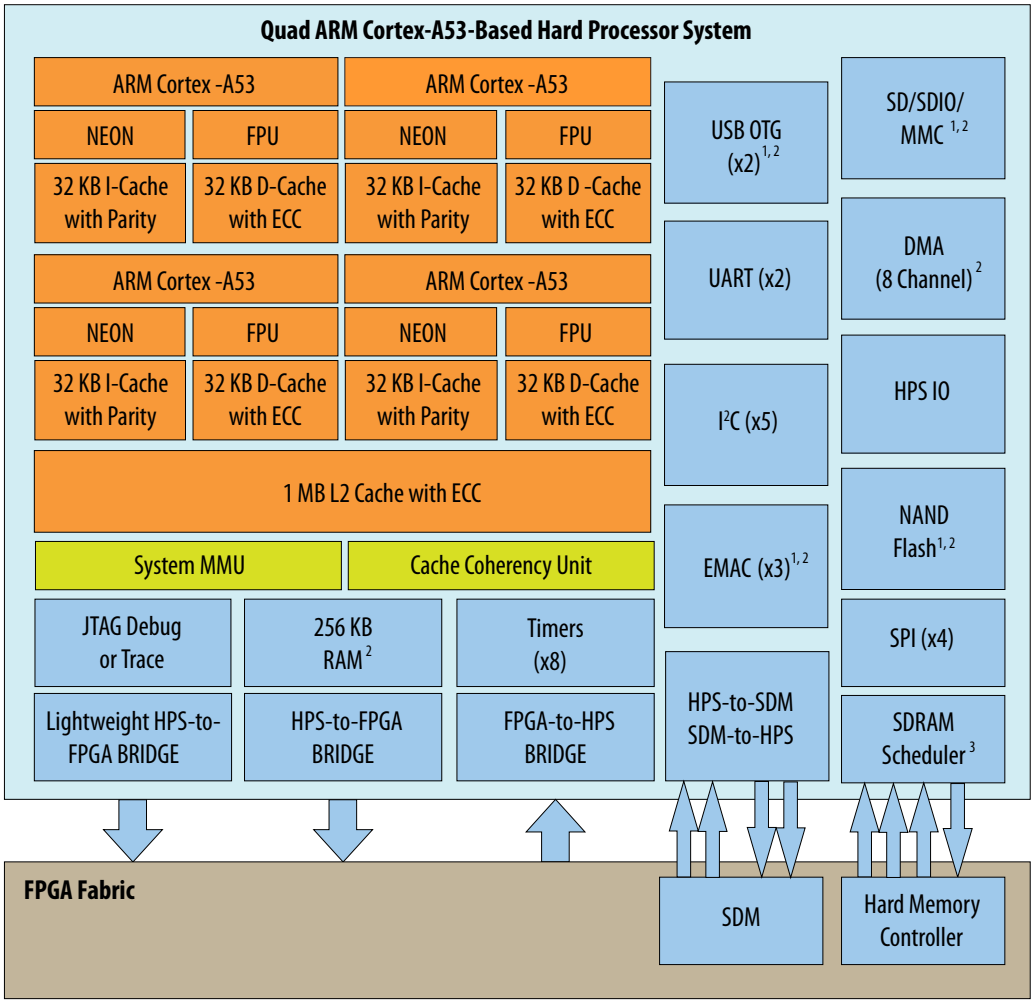


Figure 13. HPS Block Diagram



Notes:
1. Integrated direct memory access (DMA)
2. Integrated error correction code (ECC)
3. Multiport front-end interface to hard memory controller

1.18.1. Key Features of the Intel Stratix 10 HPS

Table 14. Key Features of the Intel Stratix 10 GX/SX HPS

Feature	Description
Quad-core ARM Cortex-A53 MPCore processor unit	• 2.3 MIPS/MHz instruction efficiency • CPU frequency up to 1.5 GHz • At 1.5 GHz total performance of 13,800 MIPS • ARMv8-A architecture • Runs 64-bit and 32-bit ARM instructions • 16-bit and 32-bit Thumb instructions for 30% reduction in memory footprint • Jazelle® RCT execution architecture with 8-bit Java bytecodes

continued...

Feature	Description
	• Superscalar, variable length, out-of-order pipeline with dynamic branch prediction • Improved ARM NEON™ media processing engine • Single- and double-precision floating-point unit • CoreSight™ debug and trace technology
System Memory Management Unit	• Enables a unified memory model and extends hardware virtualization into peripherals implemented in the FPGA fabric
Cache Coherency unit	• Changes in shared data stored in cache are propagated throughout the system providing bi-directional coherency for co-processing elements.
Cache	• L1 Cache — 32 KB of instruction cache w/ parity check — 32 KB of L1 data cache w /ECC — Parity checking • L2 Cache — 1MB shared — 8-way set associative — SEU Protection with parity on TAG ram and ECC on data RAM — Cache lockdown support
On-Chip Memory	• 256 KB of scratch on-chip RAM
External SDRAM and Flash Memory Interfaces for HPS	• Hard memory controller with support for DDR4, DDR3, LPDDR3 — 40-bit (32-bit + 8-bit ECC) with select packages supporting 72-bit (64-bit + 8-bit ECC) — Support for up to 2666 Mbps DDR4 and 2166 Mbps DDR3 frequencies — Error correction code (ECC) support including calculation, error correction, write-back correction, and error counters — Software Configurable Priority Scheduling on individual SDRAM bursts — Fully programmable timing parameter support for all JEDEC-specified timing parameters — Multiport front-end (MPFE) scheduler interface to the hard memory controller, which supports the AXI® Quality of Service (QoS) for interface to the FPGA fabric • NAND flash controller — ONFI 1.0 — Integrated descriptor based with DMA — Programmable hardware ECC support — Support for 8- and 16-bit Flash devices • Secure Digital SD/SDIO/MMC controller — eMMC 4.5 — Integrated descriptor based DMA — CE-ATA digital commands supported — 50 MHz operating frequency • Direct memory access (DMA) controller — 8-channel — Supports up to 32 peripheral handshake interface

continued...

Feature	Description
Communication Interface Controllers	• Three 10/100/1000 Ethernet media access controls (MAC) with integrated DMA — Supports RGMII and RMII external PHY Interfaces — Option to support other PHY interfaces through FPGA logic • GMII • MII • RMII (requires MII to RMII adapter) • RGMII (requires GMII to RGMII adapter) • SGMII (requires GMII to SGMII adapter) — Supports IEEE 1588-2002 and IEEE 1588-2008 standards for precision networked clock synchronization — Supports IEEE 802.1Q VLAN tag detection for reception frames — Supports Ethernet AVB standard • Two USB On-the-Go (OTG) controllers with DMA — Dual-Role Device (device and host functions) • High-speed (480 Mbps) • Full-speed (12 Mbps) • Low-speed (1.5 Mbps) • Supports USB 1.1 (full-speed and low-speed) — Integrated descriptor-based scatter-gather DMA — Support for external ULPI PHY — Up to 16 bidirectional endpoints, including control endpoint — Up to 16 host channels — Supports generic root hub — Configurable to OTG 1.3 and OTG 2.0 modes • Five I^2C controllers (three can be used by EMAC for MIO to external PHY) — Support both 100Kbps and 400Kbps modes — Support both 7-bit and 10-bit addressing modes — Support Master and Slave operating mode • Two UART 16550 compatible — Programmable baud rate up to 115.2Kbaud • Four serial peripheral interfaces (SPI) (2 Master, 2 Slaves) — Full and Half duplex
Timers and I/O	• Timers — 4 general-purpose timers — 4 watchdog timers • 48 HPS direct I/O allow HPS peripherals to connect directly to I/O • Up to three IO48 banks may be assigned to HPS for HPS DDR access
Interconnect to Logic Core	• FPGA-to-HPS Bridge — Allows IP bus masters in the FPGA fabric to access to HPS bus slaves — Configurable 32-, 64-, or 128-bit AMBA AXI interface • HPS-to-FPGA Bridge — Allows HPS bus masters to access bus slaves in FPGA fabric — Configurable 32-, 64-, or 128-bit AMBA AXI interface allows high-bandwidth HPS master transactions to FPGA fabric • HPS-to-SDM and SDM-to-HPS Bridges — Allows the HPS to reach the SDM block and the SDM to bootstrap the HPS • Light Weight HPS-to-FPGA Bridge — Light weight 32-bit AXI interface suitable for low-latency register accesses from HPS to soft peripherals in FPGA fabric • FPGA-to-HPS SDRAM Bridge — Up to three AMBA AXI interfaces supporting 32, 64, or 128-bit data paths

powered up and active within the 100 ms time allowed by the PCI Express specification. Intel Stratix 10 devices also support partial reconfiguration across the PCI Express bus which reduces system down time by keeping the PCI Express link active while the device is being reconfigured.

1.23. Partial and Dynamic Reconfiguration

Partial reconfiguration allows you to reconfigure part of the FPGA while other sections continue running. This capability is required in systems where uptime is critical, because it allows you to make updates or adjust functionality without disrupting services.

In addition to lowering power and cost, partial reconfiguration also increases the effective logic density by removing the necessity to place in the FPGA those functions that do not operate simultaneously. Instead, these functions can be stored in external memory and loaded as needed. This reduces the size of the required FPGA by allowing multiple applications on a single FPGA, saving board space and reducing power. The partial reconfiguration process is built on top of the proven incremental compile design flow in the Intel Quartus Prime design software

Dynamic reconfiguration in Intel Stratix 10 devices allows transceiver data rates, protocols and analog settings to be changed dynamically on a channel-by-channel basis while maintaining data transfer on adjacent transceiver channels. Dynamic reconfiguration is ideal for applications that require on-the-fly multiprotocol or multi-rate support. Both the PMA and PCS blocks within the transceiver can be reconfigured using this technique. Dynamic reconfiguration of the transceivers can be used in conjunction with partial reconfiguration of the FPGA to enable partial reconfiguration of both core and transceivers simultaneously.

1.24. Fast Forward Compile

The innovative Fast Forward Compile feature in the Intel Quartus Prime software identifies performance bottlenecks in your design and provides detailed, step-by-step performance improvement recommendations that you can then implement. The Compiler reports estimates of the maximum operating frequency that can be achieved by applying the recommendations. As part of the new Hyper-Aware design flow, Fast Forward Compile maximizes the performance of your Intel Stratix 10 design and achieves rapid timing closure.

Previously, this type of optimization required multiple time-consuming design iterations, including full design re-compilation to determine the effectiveness of the changes. Fast Forward Compile enables you to make better decisions about where to focus your optimization efforts, and how to increase your design performance and throughput. This technique removes much of the guesswork of performance exploration, resulting in fewer design iterations and as much as 2X core performance gains for Intel Stratix 10 designs.

1.25. Single Event Upset (SEU) Error Detection and Correction

Intel Stratix 10 FPGAs and SoCs offer robust SEU error detection and correction circuitry. The detection and correction circuitry includes protection for Configuration RAM (CRAM) programming bits and user memories. The CRAM is protected by a continuously running parity checker circuit with integrated ECC that automatically corrects one or two bit errors and detects higher order multibit errors.

The physical layout of the CRAM array is optimized to make the majority of multi-bit upsets appear as independent single-bit or double-bit errors which are automatically corrected by the integrated CRAM ECC circuitry. In addition to the CRAM protection, the user memories also include integrated ECC circuitry and are layout optimized for error detection and correction.

The SEU error detection and correction hardware is supported by both soft IP and the Intel Quartus Prime software to provide a complete SEU mitigation solution. The components of the complete solution include:

- Hard error detection and correction for CRAM and user M20K memory blocks
- Optimized physical layout of memory cells to minimize probability of SEU
- Sensitivity processing soft IP that reports if CRAM upset affects a used or unused bit
- Fault injection soft IP with the Intel Quartus Prime software support that changes state of CRAM bits for testing purposes
- Hierarchy tagging in the Intel Quartus Prime software
- Triple Mode Redundancy (TMR) used for the Secure Device Manager and critical on-chip state machines

In addition to the SEU mitigation features listed above, the Intel 14-nm Tri-Gate process technology used for Intel Stratix 10 devices is based on FinFET transistors which have reduced SEU susceptibility versus conventional planar transistors.

1.26. Document Revision History for the Intel Stratix 10 GX/SX Device Overview

Document Version	Changes
2018.08.08	Made the following changes: • Changed the specs for QDRII+ and QDRII+ Xtreme and added specs for QDRIV in the "External Memory Interface Performance" table. • Updated description of the power options in the "Sample Ordering COde and Available Options for Intel Stratix 10 Devices" figure. • Changed the description of the technology and power management features in the "Intel Stratix 10 FPGA and SoC Common Device Features" table. • Changed the description of SmartVID in the "Power Management" section. • Changed the direction arrow from the coefficient registers block in the "DSP Block: High Precision Fixed Point Mode" figure.
2017.10.30	Made the following changes: • Removed the embedded eSRAM feature globally. • Removed the Low Power (VID) and Military operating temperature options, and package code 53 from the "Sample Ordering Code and Available Options for Stratix 10 Devices" figure. • Changed the Maximum transceiver data rate (chip-to-chip) specification for L-Tile devices in the "Key Features of Intel Stratix 10 Devices Compared to Stratix V Devices" table.
2016.10.31	Made the following changes: • Changed the number of available transceivers to 96, globally. • Changed the single-precision floating point performance to 10 TeraFLOPS, globally. • Changed the maximum datarate to 28.3 Gbps, globally. • Changed some of the features listed in the "Stratix 10 GX/SX Device Overview" section. • Changed descriptions for the GX and SX devices in the "Stratix 10 Family Variants" section. • Changed the "Sample Ordering Code and Available Options for Stratix 10 Devices" figure.

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Document Version	Changes
	• Changed the features listed in the "Key Features of Stratix 10 Devices Compared to Stratix V Devices" table. • Changed the descriptions of the following areas of the "Stratix 10 FPGA and SoC Common Device Features" table: — Transceiver hard IP — Internal memory blocks — Core clock networks — Packaging • Reorganized and updated all tables in the "Stratix 10 FPGA and SoC Family Plan" section. • Removed the "Migration Between Arria 10 FPGAs and Stratix 10 FPGAs" section. • Removed footnotes from the "Transceiver PCS Features" table. • Changed the HMC description in the "External Memory and General Purpose I/O" section. • Changed the number of fPLLs in the "Fractional Synthesis PLLs and I/O PLLs" section. • Clarified HMC data width support in the "Key Features of the Stratix 10 HPS" table. • Changed the description in the "Internal Embedded Memory" section. • Changed the datarate for the Standard PCS and SDI PCS features in the "Transceiver PCS Features" table. • Added a note to the "PCI Express Gen1/Gen2/Gen3 Hard IP" section. • Updated the "Key Features of the Stratix 10 HPS" table. • Changed the description for the Cache coherency unit in the "Key Features of the Stratix 10 HPS" table. • Changed the description for the external SDRAM and Flash memory interfaces for HPS in the "Key Features of the Stratix 10 HPS" table.
2015.12.04	Initial release.