THE DATASHEET OF

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Versal Architecture and Product Data Sheet: Overview

DS950 (v1.17) November 18, 2022 **Advance Product Specification**

General Description

Versal® devices are the industry's first adaptive compute acceleration platform (ACAP), combining adaptable processing and acceleration engines with programmable logic and configurable connectivity to enable customized, heterogeneous hardware solutions for a wide variety of applications in Data Center, Automotive, 5G Wireless, Wired, and Defense. Versal ACAPs feature transformational features like an integrated silicon host interconnect shell and Intelligent Engines (AI and DSP), Adaptable Engines, and Scalar Engines, providing superior performance/watt over conventional FPGAs, CPUs, and GPUs.

AI Edge Series: Designed with safety in mind, this series delivers an adaptive technology platform that combines high AI inference performance, low latency, and power efficiency for edge applications.

AI Core Series: The high-compute series with medium density programmable logic and connectivity capability coupled with AI and DSP acceleration engines.

Prime Series: The mid-range series with medium density programmable logic, signal processing, and connectivity capability.

Premium Series: The high-end, high bandwidth series, rich in networking interfaces, security engines, and providing high compute density.

HBM Series: For memory-bound, compute-intensive applications, the series features heterogeneous integration of 3D IC memory, secure connectivity, and adaptive compute to eliminate performance bottlenecks.

Series Comparisons

Table 1: **Device Resources**

Resources and Capabilities	AI Edge Series	AI Core Series	Prime Series	Premium Series	HBM Series
Programmable Network on Chip (NoC)	✓	✓	✓	✓	✓
Aggregate INT8 TOPs	7–228	57–228	8–57	20–363	107–157
System Logic Cells (K)	44–1,139	540–1,968	329–2,233	833–7,352	3,837–5,631
Hierarchical Memory (Mb)	40–177	90–191	54–282	128–994	509–752
DSP Engines	90–1,312	928–1,968	464–3,984	1,140–14,352	7,392–10,848
AI Engines	8–304	128–400	–	0–472	–
Processing System	✓	✓	✓	✓	✓
Serial Transceivers	0–44	8–44	8–48	44–168	88–128
Max. Serial Bandwidth (full duplex) (Tb/s)	2.5	2.5	7.8	17.6	11.2
I/O	114–530	478–770	316–770	132–780	780
Memory Controllers	1–3	2–4	1–4	2–4	4
HBM (GB)	–	–	–	–	8–32

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Summary of Features

Architecture

Versal ACAPs are built around an integrated shell composed of a programmable network on chip (NoC), which enables seamless memory-mapped access to the full height and width of the device. ACAPs comprise: a multicore scalar processing system; an integrated block for PCIe® with DMA and Cache Coherent Interconnect Designs (CPM); SIMD VLIW AI Engine accelerators for artificial intelligence and complex signal processing; and Adaptable Engines in the programmable logic (PL). Together, these form a platform for fast time-to-market (TTM) compute acceleration for cloud, edge, and networking applications. The platform management controller, adjacent to the processing system, is responsible for booting and configuring the device. Versal devices typically have I/O and memory controllers on the north and south edges of the device and serial transceivers on the east and west edges. The NoC spans full height and width of the device.

Compute and Acceleration

Some Versal devices have an array of signal processing cores that are highly optimized for functions in machine learning, convolutional neural networks, wireless radio, backhaul, cable, and radar applications. The array consists of a number of AI Engines, each comprising a 32-bit scalar RISC processor, fixed and floating point vector units, data memory, and interconnect. AI Engines can be used as a single tile, as the complete array, or at any granularity in between. The creation of custom acceleration and compute engines in the AI Engine array is done at a high-level through C and C++.

Every Versal ACAP has Scalar Engines that comprise a dual-core Arm® Cortex®-A72 (APU) and a dual-core Arm Cortex-R5F (RPU) in the processing system. The processing system includes a number of peripherals for communication standards, including gigabit Ethernet and USB 2.0, and controllers for SPI, I2C, UART, and CAN-FD. The processing system accesses the DDR memory controllers on the top and bottom of the device through the NoC. In addition to interfacing to external memory, the APU includes: Level 2 (L2) cache; the RPU includes tightly coupled memory (TCM); and both APU and RPU have access to the on-chip memory (OCM).

The PL is made up of configurable logic blocks, containing 6-input look-up tables (LUTs) and flip-flops; different-sized memory blocks; 36Kb block RAM and 288Kb UltraRAM; digital signal processing (DSP) blocks; and a wealth of interconnect, switches, and muxes to connect blocks together. All resources are arranged in columns. The PL is divided into regions that are a fixed height. Each region has its own clocking capabilities and NoC access points.

Platform Management

The platform management controller (PMC)) resides adjacent to, but is independent from, the processing system. It is responsible for the boot and configuration of the device from the primary boot source. The PMC is also responsible for configuring the PL, which can be configured before or after the processing system. It also controls encryption, authentication, system monitoring, and device debug capabilities of the platform.

Connectivity

The south edge of the Versal devices typically contains a number of I/O banks and associated memory controllers to read from and write to DDR4 and LPDDR4 memory. I/O can be used independently from the dedicated memory controllers for many functions, including any with soft memory controllers created in the PL. The east and west edges of the device typically contain serial transceivers capable of communicating up to 112Gb/s. The PL can also contain integrated blocks for high-value functions, such as the integrated block for PCIe (PL PCIE), multirate Ethernet MAC, 600G Ethernet MAC, 600G Interlaken, and 400G High-Speed Crypto (HSC) Engine.

Feature Summary

Table 2: **Versal AI Edge Series**

	VE2002	VE2102	VE2202	VE2302	VE1752	VE2602	VE2802
AI Engines-ML	8	12	24	34	0	152	304
AI Engines	0	0	0	0	304	0	0
AIE/AIE-ML Data Memory (Mb)	4	6	12	17	76	76	152
AIE-ML Shared Memory (Mb)	48	48	68	68	0	304	304
AIE to NoC Interface Tiles	2	2	6	6	12	12	12
AIE to PL Interface Tiles	7	7	12	12	27	28	28
DSP Engines	90	176	324	464	1,312	984	1,312
System Logic Cells	43,750	80,080	229,688	328,720	981,120	820,313	1,139,040
CLB Flip-Flops	40,000	73,216	210,000	300,544	897,024	750,000	1,041,408
LUTs	20,000	36,608	105,000	150,272	448,512	375,000	520,704
Distributed RAM (Mb)	0.6	1.1	3.2	4.6	13.7	11.4	15.9
Block RAM Blocks	24	47	108	155	954	476	600
Block RAM (Mb)	0.8	1.7	3.8	5.4	33.5	16.7	21.1
UltraRAM Blocks	24	47	108	155	462	224	264
UltraRAM (Mb)	6.8	13.2	30.4	43.6	129.9	63.0	74.3
Accelerator RAM (Mb)	32	32	32	32	0	0	0
APU	Dual-core Arm® Cortex-A72, 48KB/32KB L1 Cache w/ parity & ECC; 1MB L2 Cache w/ ECC						
RPU	Dual-core Arm Cortex-R5F, 32KB/32KB L1 Cache, and 256KB TCM w/ECC						
Memory	256KB On-Chip Memory w/ECC						
Connectivity	Ethernet (x2); UART (x2); CAN-FD (x2); USB 2.0 (x1); SPI (x2); I2C (x2)						
NoC to PL Master/ Slave Ports	2	2	5	5	21	21	21
DDR Bus Width	64	64	64	64	192	192	192
DDR Memory Controllers (DDRMC)	1	1	1	1	3	3	3
PCIe w/DMA & CCIX (CPM4)	–	–	–	–	1 x Gen4x16, CCIX	–	–
PCIe w/DMA & CCIX (CPM5)	–	–	–	–	–	1 x Gen4x16, CCIX	1 x Gen4x16, CCIX
PCIe (PLPCIE4)	–	–	1 x Gen4x8	1 x Gen4x8	4 x Gen4x8	–	–
PCIe (PLPCIE5)	–	–	–	–		4 x Gen4x8	4 x Gen4x8
40G Multirate Ethernet MAC	0	0	1	1	2	2	2
XPIO	216	216	216	216	486	486	486
HDIO	0	0	22	22	44	44	44
GTY Transceivers(1)	0	0	0	0	44	0	0
GTYP Transceivers(1)	0	0	8	8	0	32(2)	32(2)
Video Decoder Engines (VDEs)	–	–	–	–	–	2	4

Notes:
1. Refer to DC and AC switching characteristics data sheet for performance per speed grade.
2. 16 GTYP transceivers are dedicated to CPM5 for PCI Express use.

Table 3: **Versal AI Edge Series: Device-Package Combinations and Maximum I/O**

	VE2002	VE2102	VE2202	VE2302	VE1752	VE2602	VE2802
	XPIO DDR Only, XPIO DDR+PL HDIO, MIO GTY, GTYP						
SBVA484	84,30 0, 78 0, 0	84, 30 0, 78 0, 0					
SBVA625	132, 84 0, 78 0, 0	132, 84 0, 78 0, 0					
SFVA784	132, 84 0, 78 0, 0	132, 84 0, 78 0, 0	132, 84 22, 78 0, 8	132, 84 22, 78 0, 8			
NSVG1369					132, 246 44, 78 24, 0		
NSVH1369						132, 192 44, 78 0, 32	132, 192 44, 78 0, 32
VSVA1596(1)					132, 246 44, 78 32, 0		
VSVH1760						186, 300 44, 78 0, 32	186, 300 44, 78 0, 32
VSVA2197					192, 294 44, 78 44, 0		

Notes:

1. VE1752 in the VSVA1596 package supports peak LPDDR4 data rates in 324 I/O only. The remaining 54 I/O support limited data rates. See the associated data sheet.

Table 4: **Versal AI Core Series**

	VC1352	VC1502	VC1702	VC1802	VC1902	VC2602	VC2802
AI Engines	128	198	304	300	400	0	0
AI Engines-ML	0	0	0	0	0	152	304
AIE/AIE-ML Data Memory (Mb)	32	50	76	75	100	76	152
AIE-ML Shared Memory (Mb)	0	0	0	0	0	304	304
AIE to NoC Interface Tiles	10	12	12	16	16	12	12
AIE to PL Interface Tiles	21	27	27	39	39	28	28
DSP Engines	928	1,032	1,312	1,600	1,968	984	1,312
System Logic Cells	539,840	814,520	981,120	1,585,938	1,968,400	820,313	1,139,040
CLB Flip-Flops	493,568	744,704	897,024	1,450,000	1,799,680	750,000	1,041,408
LUTs	246,784	372,352	448,512	725,000	899,840	375,000	520,704
Distributed RAM (Mb)	7.5	11.3	13.7	22.1	27.5	11.4	15.9
Block RAM Blocks	441	848	954	800	967	476	600
Block RAM (Mb)	15.5	29.8	33.5	28.1	34.0	16.7	21.1
UltraRAM Blocks	209	390	462	325	463	224	264
UltraRAM (Mb)	58.8	109.7	129.9	91.4	130.2	63.0	74.3
Accelerator RAM (Mb)	32	0	0	0	0	0	0
APU	Dual-core Arm Cortex-A72; 48KB/32KB L1 Cache w/ parity and ECC; 1MB L2 Cache w/ ECC						
RPU	Dual-core Arm Cortex-R5F; 32KB/32KB L1 Cache, and TCM w/ECC						
Memory	256KB On-Chip Memory w/ECC						
Connectivity	Ethernet (x2); UART (x2); CAN-FD (x2); USB 2.0 (x1); SPI (x2); I2C (x2)						
NoC to PL Master / Slave Ports	10	21	21	28	28	21	21
DDR Bus Width	128	192	192	256	256	192	192
DDR Memory Controllers (DDRMC)	2	3	3	4	4	3	3
PCIe w/DMA & CCIX (CPM4)	–	1 x Gen4x16, CCIX	1 x Gen4x16, CCIX	1 x Gen4x16, CCIX	1 x Gen4x16, CCIX	–	–
PCIe w/DMA & CCIX (CPM5)	–	–	–	–	–	2 x Gen5x8, CCIX	2 x Gen5x8, CCIX
PCIe (PLPCIE4)	1 x Gen4x8	4 x Gen4x8	4 x Gen4x8	4 x Gen4x8	4 x Gen4x8	–	–
PCIe (PLPCIE5)	–	–	–	–	–	4 x Gen5x4	4 x Gen5x4
100G Multirate Ethernet MAC	1	3	4	4	4	2	2
XPIO	378	486	486	648	648	486	486
HDIO	44	22	44	44	44	44	44
GTY Transceivers(1)	0	32	44	44	44	0	0
GTYP Transceivers(1)	8	0	0	0	0	32(2)	32(2)
Video Decoder Engines (VDEs)	–	–	–	–	–	2	4

Notes:
1. Refer to DC and AC switching characteristics data sheet for performance per speed grade.
2. 16 GTYP transceivers are dedicated to CPM5 for PCI Express use.

Table 5: **Versal AI Core Series: Device-Package Combinations and Maximum I/O**

	VC1352	VC1502	VC1702	VC1802	VC1902	VC2602	VC2802
	XPIO DDR Only, XPIO DDR+PL HDIO, MIO GTY, GTYP						
NBVA1024	168, 210 22, 78 0, 8						
NSVE1369	168, 210 44, 78 0, 8						
NSVG1369		132, 246 22, 78 24, 0	132, 246 44, 78 24, 0				
NSVH1369						132, 192 44, 78 0, 32	132, 192 44, 78 0, 32
VIVA1596(1)				132, 246 44, 78 32, 0	132, 246 44, 78 32, 0		
VSVA1596(1)		132, 246 22, 78 32, 0	132, 246 44, 78 32, 0				
VSVD1760				186, 462 0, 78 24, 0	186, 462 0, 78 24, 0		
VSVH1760						186, 300 44, 78 0, 32	186, 300 44, 78 0, 32
VSVA2197		192, 294 22, 78 32, 0	192, 294 44, 78 44, 0	186, 462 44, 78 44, 0	186, 462 44, 78 44, 0		

Notes:

1. Devices in VIVA1596 and VSVA1596 support peak LPDDR4 data rates in 324 I/O only. The remaining 54 I/O support limited data rates. See the associated data sheet.

Table 6: **Versal Prime Series**

	VM1102	VM1302	VM1402	VM1502	VM1802	VM2202	VM2302	VM2502	VM2902
System Logic Cells	328,720	693,280	1,237,600	981,120	1,968,400	1,139,040	1,574,720	1,969,240	2,233,280
CLB Flip-Flops	300,544	633,856	1,131,520	897,024	1,799,680	1,041,408	1,439,744	1,800,448	2,041,856
LUTs	150,272	316,928	565,760	448,512	899,840	520,704	719,872	900,224	1,020,928
Distributed RAM (Mb)	4.6	9.7	17.3	13.7	27.5	15.9	22.0	27.5	31.2
Block RAM Blocks	155	502	1,150	954	967	600	1,405	1,341	1,981
Block RAM (Mb)	5.4	17.6	40.4	33.5	34.0	21.1	49.4	47.1	69.6
UltraRAM Blocks	155	178	286	462	463	264	453	677	645
UltraRAM (Mb)	43.6	50.1	80.4	129.9	130.2	74.3	127.4	190.4	181.4
Accelerator RAM (Mb)	32	0	0	0	0	0	0	0	0
DSP Engines	464	832	1,696	1,312	1,968	1,312	1,904	3,984	2,672
APU	Dual-core Arm Cortex-A72; 48KB/32KB L1 Cache w/ parity and ECC; 1MB L2 Cache w/ ECC								
RPU	Dual-core Arm Cortex-R5F; 32KB/32KB L1 Cache, and TCM w/ECC								
Memory	256KB On-Chip Memory w/ECC								
Connectivity	Ethernet (x2); UART (x2); CAN-FD (x2); USB 2.0 (x1); SPI (x2); I2C (x2)								
NoC to PL Master / Slave Ports	5	9	18	21	28	21	30	28	42
DDR Bus Width	64	128	256	192	256	192	192	256	192
DDR Memory Controllers (DDRMC)	1	2	4	3	4	3	3	4	3
PCIe w/DMA & CCIX (CPM4)	–	1 x Gen4x16, CCIX	1 x Gen4x16, CCIX	1 x Gen4x16, CCIX	1 x Gen4x16, CCIX	–	–	–	–
PCIe w/DMA & CCIX (CPM5)	–	–	–	–	–	2 x Gen5x8, CCIX	–	2 x Gen5x8, CCIX	–
PCIe (PLPCIE4)	–	2 x Gen4x8	2 x Gen4x8	4 x Gen4x8	4 x Gen4x8	–	–	–	–
PCIe (PLPCIE5)	1 x Gen4x8	–	–	–	–	4 x Gen5x4	2 x Gen5x4	2 x Gen5x4	2 x Gen5x4
100G Multirate Ethernet MAC	1	2	2	4	4	2	6	2	6
XPIO	216	432	648	486	648	324	486	648	378
HDIO	22	22	22	44	44	44	44	0	44
GTY Transceivers(1)	0	24	24	44	44	0	0	0	0
GTYP Transceivers(1)	8	0	0	0	0	32(2)	8	16(2)	8
GTM Transceivers(1)	0	0	0	0	0	0	40	0	40

Notes:
1. Refer to DC and AC switching characteristics data sheet for performance per speed grade.
2. 16 GTYP transceivers are dedicated to CPM5 for PCI Express use.

Table 7: **Versal Prime Series: Device-Package Combinations and Maximum I/O**

	VM1102	VM1302	VM1402	VM1502	VM1802	VM2202	VM2302	VM2502	VM2902
	XPIO DDR Only, XPIO DDR+PL HDIO, MIO GTY, GTYP, GTM								
SFVA784	132, 84 22, 78 0, 8, 0								
NBVB1024		132, 84 22, 78 16, 0, 0	132, 192 22, 78 16, 0, 0						
NFVB1369				132, 246 22, 78 16, 0, 0					
NSVF1369		168, 156 22, 78 8, 0, 0	168, 480 22, 78 8, 0, 0						
NSVH1369						132, 192 44, 78 0, 32, 0			
VFVC1596		168, 264 22, 78 24, 0, 0	168, 480 22, 78 24, 0, 0						
VFVC1760(2)				132, 246 44, 78 44, 0, 0	132, 246 44, 78 44, 0, 0				
VSVI1760								132, 516 0, 78 0, 16, 0	
VSVD1760(3)(4)		168, 156 0, 78 16, 0, 0	168, 480 0, 78 16, 0, 0		186, 462 0, 78 24, 0, 0				
VFVF1760(1)							180, 306 22,78 0, 8, 40		180, 306 22,78 0, 8, 40
VSVA2197				192, 294 44, 78 44, 0, 0	186, 462 44, 78 44, 0, 0				

Notes:

1. Some packages are compatible with Versal Premium series devices.
2. Devices in VFVC1760 support peak LPDDR4 in 162 I/O only. The remaining 216 I/O support limited data rates. See the associated data sheet.
3. VM1302 in VSVD1760 supports peak LPDDR4 in 162 I/O only. The remaining 162 I/O support limited data rates. See the associated data sheet.
4. VM1402 in VSVD1760 supports peak LPDDR4 in 324 I/O only. The remaining 324 I/O support limited data rates. See the associated data sheet.

Table 8: **Versal Premium Series**

	VP1002	VP1052	VP1102	VP1202	VP1402	VP1502	VP2502	VP1552	VP1702	VP1802	VP2802
System Logic Cells	833,000	1,185,800	1,574,720	1,969,240	2,233,280	3,763,480	3,737,720	3,836,840	5,557,720	7,351,960	7,326,200
CLB Flip-Flops	761,600	1,084,160	1,439,744	1,800,448	2,041,856	3,440,896	3,417,344	3,507,968	5,081,344	6,721,792	6,698,240
LUTs	380,800	542,080	719,872	900,224	1,020,928	1,720,448	1,708,672	1,753,984	2,540,672	3,360,896	3,349,120
Distributed RAM (Mb)	12	17	22	27	31	53	52	54	78	103	102
Block RAM Blocks	535	751	1,405	1,341	1,981	2,541	2,541	2,541	3,741	4,941	4,941
Block RAM (Mb)	19	26	49	47	70	89	89	89	132	174	174
UltraRAM Blocks	345	489	453	677	645	1,301	1,301	1,301	1,925	2,549	2,549
UltraRAM (Mb)	97	138	127	190	181	366	366	366	541	717	717
DSP Engines	1,140	1,572	1,904	3,984	2,672	7,440	7,392	7,392	10,896	14,352	14,304
AI Engines	–	–	–	–	–	–	472	–	–	–	472
AIE Data Memory (Mb)	–	–	–	–	–	–	118	–	–	–	118
AIE to NoC Interface Tiles	–	–	–	–	–	–	20	–	–	–	20
AIE to PL Interface Tiles	–	–	–	–	–	–	47	–	–	–	47
APU	Dual-core Arm Cortex-A72; 48KB/32KB L1 Cache w/ parity and ECC; 1MB L2 Cache w/ ECC										
RPU	Dual-core Arm Cortex-R5F; 32KB/32KB L1 Cache, and TCM w/ECC										
Memory	256KB On-Chip Memory w/ECC										
Connectivity	Ethernet (x2); UART (x2); CAN-FD (x2); USB 2.0 (x1); SPI (x2); I2C (x2)										
NoC to PL Master / Slave Ports	22	22	30	28	42	52	52	52	76	100	100
DDR Bus Width	128	128	192	256	192	256	256	256	256	256	256
DDR Memory Controllers (DDRMC)	2	2	3	4	3	4	4	4	4	4	4
PCIe w/DMA & CCIX (CPM4)	2 x Gen4x4	2 x Gen4x4	–	–	–	–	–	–	–	–	–
PCIe w/DMA & CCIX (CPM5)	–	–	–	2 x Gen5x8	–	2 x Gen5x8	2 x Gen5x8	2 x Gen5x8	2 x Gen5x8	2 x Gen5x8	2 x Gen5x8
PCIe (PLPCIE4)	1 x Gen4x8	1 x Gen4x8	–	–	–	–	–	–	–	–	–
PCIe (PLPCIE5)	–	–	2 x Gen5x4	2 x Gen5x4	2 x Gen5x4	2 x Gen5x4	2 x Gen5x4	8 x Gen5x4	2 x Gen5x4	2 x Gen5x4	2 x Gen5x4
Multirate Ethernet MAC	3	5	6	2	6	4	4	4	6	8	8
600G Ethernet MAC	2	3	7	1	11	3	3	1	5	7	7
600G Interlaken	1	2	–	–	–	1	1	–	2	3	3
400G HSC Engine	1	1	3	1	4	2	2	2	3	4	4
XPIO	378	378	486	702	486	702	702	702	702	648	702
HDIO	–	–	–	–	44	–	–	–	–	–	–
GTY Transceivers(1)	20	20	–	–	–	–	–	–	–	–	–
GTYP Transceivers(1)	–	–	8	28(3)	8	28(3)	28(3)	68(3)	28(3)	28(3)	28(3)
GTM Transceivers(1) 58Gb/s (112Gb/s(2))	24 (12)	48 (24)	64 (32)	20 (10)	96 (64)(2)	60 (30)	60 (30)	20 (10)	100 (50)	140 (70)	140 (70)

Notes:
1. Refer to DC and AC switching characteristics data sheet for performance per speed grade.
2. GTM transceivers can operate at data rates up to 112Gb/s by combining two transceivers together. The VP1402 device in the VSVD2197 package can run 64 GTM transceivers at 112Gb/s.
3. 16 GTYP transceivers are dedicated to CPM5 for PCI Express use.

Table 9: **Versal Premium Series: Device-Package Combinations and Maximum I/O**

	VP1002	VP1052	VP1102	VP1202	VP1402	VP1502	VP2502	VP1552	VP1702	VP1802	VP2802
	XPIO DDR Only, XPIO DDR+PL HDIO, MIO GTY, GTM (112G)		XPIO DDR Only, XPIO DDR+PL HDIO, MIO GTYP, GTM (112G)								
NFVI1369	138, 24 0, 78 8, 24 (12)	138, 24 0, 78 8, 36 (18)									
VFVF1760[1]	192, 132 0, 78 8, 24 (12)	192, 132 0, 78 8, 36 (18)	132, 192 0, 78 8, 36 (18)		132, 192 22, 78 8, 36 (18)						
VSVC2021	192, 186 0, 78 20, 24 (12)	192, 186 0, 78 20, 48 (24)									
VSVD2197					0, 54 0, 78 8, 96, (64)[3]						
VSVA2785[2]			180, 306 0, 78 8, 64 (32)	132, 570 0, 78 28, 20 (10)	180, 306 44, 78 8, 80 (40)	132, 570 0, 78 28, 56 (28)		132, 570 0, 78 68, 16 (8)			
VSVA3340					180, 306 44, 78 8, 96 (48)	132, 354 0, 78 28, 60 (30)		132, 354 0, 78 68, 20 (10)	132, 354 0, 78 28, 88 (44)		
VSVB3340							132, 570 0, 78 28, 60 (30)				
LSVC4072										132, 570 0, 78 28, 140 (70)	
VSVA5601							132, 570 0, 78 28, 60 (30)		132, 570 0, 78 28, 100 (50)	132, 570 0, 78 28, 140 (70)	132, 570 0, 78 28, 140 (70)

Notes:
1. Some packages are compatible with Versal Prime series devices.
2. VP1202, VP1502, and VP1552 in VSVA2785 support peak LPDDR4 data rates in 486 I/O only. The remaining 216 I/O support limited data rates. See the associated data sheet.
3. GTM transceivers can operate at data rates up to 112Gb/s by combining two transceivers together. The VP1402 device in the VSVD2197 package can run 64 GTM transceivers at 112Gb/s.

Table 10: **Versal HBM Series**

	VH1522	VH1542	VH1582	VH1742	VH1782
System Logic Cells	3,836,840	3,836,840	3,836,840	5,631,080	5,631,080
CLB Flip-Flops	3,507,968	3,507,968	3,507,968	5,148,416	5,148,416
LUTs	1,753,984	1,753,984	1,753,984	2,574,208	2,574,208
Distributed RAM (Mb)	54	54	54	79	79
Block RAM Blocks	2,541	2,541	2,541	3,741	3,741
Block RAM (Mb)	89	89	89	132	132
UltraRAM Blocks	1,301	1,301	1,301	1,925	1,925
UltraRAM (Mb)	366	366	366	541	541
HBM (GB)	8	16	32	16	32
DSP Engines	7,392	7,392	7,392	10,848	10,848
APU	Dual-core Arm Cortex-A72; 48KB/32KB L1 Cache w/ parity and ECC; 1MB L2 Cache w/ ECC				
RPU	Dual-core Arm Cortex-R5F; 32KB/32KB L1 Cache, and TCM w/ECC				
Memory	256KB On-Chip Memory w/ECC				
Connectivity	Ethernet (x2); UART (x2); CAN-FD (x2); USB 2.0 (x1); SPI (x2); I2C (x2)				
NoC to PL Master / Slave Ports	52	52	52	76	76
DDR Bus Width	256	256	256	256	256
DDR Memory Controllers (DDRMC)	4	4	4	4	4
PCIe w/DMA & CCIX (CPM5)	2 x Gen5x8, CCIX	2 x Gen5x8, CCIX	2 x Gen5x8, CCIX	2 x Gen5x8, CCIX	2 x Gen5x8, CCIX
PCIe (PLPCIE5)	8 x Gen5x4	8 x Gen5x4	8 x Gen5x4	8 x Gen5x4	8 x Gen5x4
Multirate Ethernet MAC	4	4	4	6	6
600G Ethernet MAC	1	1	1	3	3
600G Interlaken	–	–	–	1	1
400G HSC Engine	2	2	2	3	3
XPIO	702	702	702	702	702
HDIO	–	–	–	–	–
GTYP Transceivers(1)	68(3)	68(3)	68(3)	68(3)	68(3)
GTM Transceivers(2) 58Gb/s (112Gb/s)	20 (10)	20 (10)	20 (10)	60 (30)	60 (30)

Notes:
1. Refer to DC and AC switching characteristics data sheet for performance per speed grade.
2. GTM transceivers can operate at data rates up to 112Gb/s by combining two transceivers together.
3. 16 GTYP transceivers are dedicated to CPM5 for PCI Express use.

Table 11: **Versal HBM Series: Device-Package Combinations and Maximum I/O**

	VH1522	VH1542	VH1582	VH1742	VH1782
	XPIO DDR Only, XPIO DDR+PL HDIO, MIO GTYP, GTM (112G)				
VSVA3697	132, 570 0, 78 68, 20 (10)	132, 570 0, 78 68, 20 (10)	132, 570 0, 78 68, 20 (10)		
LSVA4737		132, 570 0, 78 68, 20 (10)	132, 570 0, 78 68, 20 (10)	132, 570 0, 78 68, 60 (30)	132, 570 0, 78 68, 60 (30)

Device Layout (Architecture and Interconnect)

Versal devices are built from a library of building blocks dedicated to processing, compute, acceleration, and connectivity. Figure 1 shows the layout of an ACAP with the NoC connecting to an external host processor via the CPM and the various heterogeneous processing elements: PL, vector-based accelerators (AI Engines), and scalar processing accelerators.

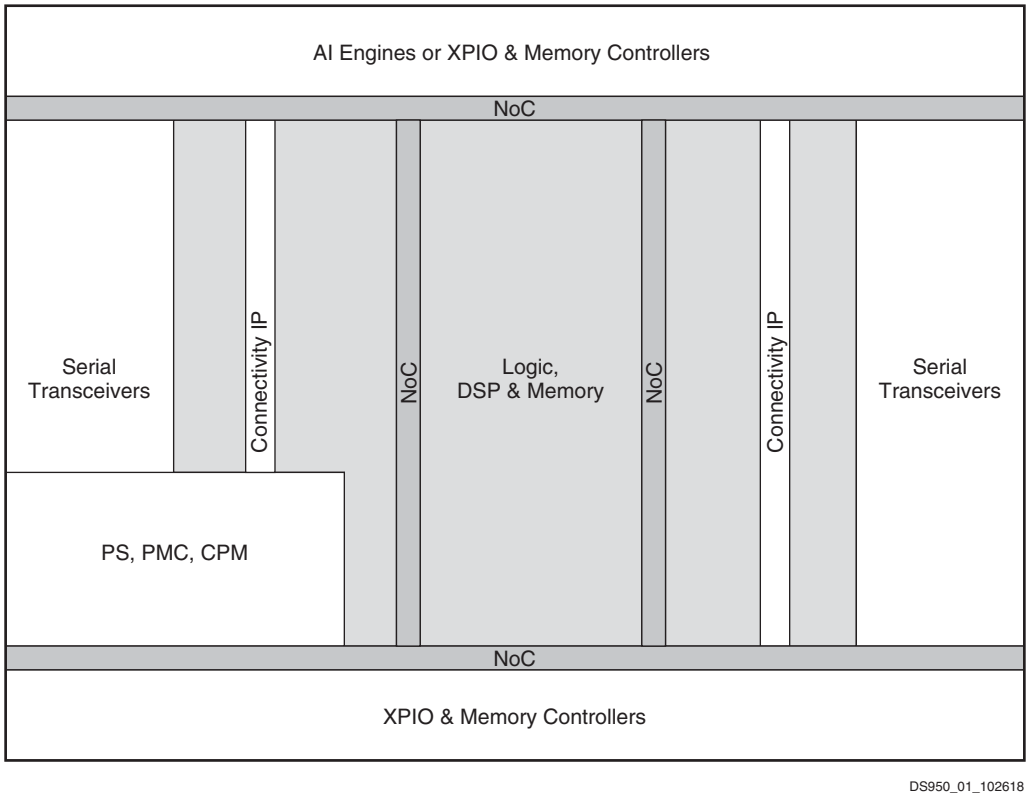

Figure 1: **Versal ACAP Device Layout**

Serial transceivers are located on the east and west edges of the device with XPIO and memory controllers on the south and north of the device. In Versal devices with AI Engines, there is an acceleration array on the north edge of the device in place of the XPIO and memory controllers. Connectivity IP is located in columns close to the serial transceivers. Resources are connected together through a matrix of programmable interconnect routes for local and regional signal connectivity as well as the NoC for high bandwidth and long distance communication around the device.

NoC

The programmable NoC is an AXI-4 based network of interconnect within the Versal ACAP architecture that easily enables high-bandwidth connections to be routed around the device. The NoC extends in both horizontal and vertical directions to the edges of the device. It exists to connect together areas of the device that demand and use large quantities of data alleviating any resource burden on the local and regional device interconnect. The NoC is a full blocking crossbar between memory controllers, programmable logic, processing system, AI Engines, and platform management controller. Examples of NoC connections include:

- Sharing device access to DRAM (DDR memory)
- PL to PL connections
- Memory mapped access to the AI Engine array
- Connecting between processing system and PL
- Connecting between the processing system and DDR memory

In devices built using stacked silicon interconnect (SSI) technology, the vertical NoC columns connect between adjacent super logic regions (SLRs), which allows device configuration data to travel between primary and secondary SLRs.

Platform Management Controller

The platform management controller is responsible for managing the Versal ACAP with the following main categories of responsibility: securely booting and configuring the platform; and life-cycle management, which includes device integrity and debug, and system monitoring.

Boot and Configuration

The platform management controller is responsible for booting the Versal ACAP from the primary boot source in a multi-stage boot process that supports both a non-secure and a secure boot. For a secure boot, the AES-GCM, SHA3-384 decryption/authentication, and ECDSA/RSA blocks decrypt and authenticate the image. Upon reset, the mode pins are read to determine the primary boot device, such as quad SPI, octal SPI, SD, or eMMC. The platform management controller then proceeds to execute the code out of on-chip BootROM and copies the platform loader and manager (PLM) from the boot device to the on-chip memory while undergoing authentication and decryption. The configuration of the PL is also undertaken by the PLM. The device image is loaded from its storage medium, and after authentication and decryption, is sent to the PL configuration interface.

It is also possible to reconfigure portions of the PL using Dynamic Function eXchange (DFX). A new device image for a portion of the PL can be loaded from the processing system, through the primary or secondary boot interfaces, e.g., PCIe or Ethernet. Upon reconfiguration, a portion of the PL provides the new functionality determined by the new device image, enabling users to quickly adapt the functionality of their design to changing system requirements.

System Monitoring

The platform management controller contains system monitoring capability for monitoring voltage and temperature in the processing system and PL to enhance the overall safety, security, and reliability of the system. The core of the system monitor is a 10-bit 200kSPS ADC, which can be accessed via JTAG, PMBus, or I2C interfaces, via the processing system directly, and via the PL through the NoC.

Device Integrity and Debug

JTAG is the primary interface for Versal ACAP debug features. The JTAG architecture has two IEEE Std 1149.1 compliant TAP controllers that are connected in series: the Arm DAP controller and the platform management controller TAP controller. The Arm DAP controller is the main controller for debug functions supporting: processing system CoreSight debug architecture, debug of the PL, programming of supported external flash memory, and eFUSE/BBRAM programming. The TAP controller supports: reading the device IDCODE, programming of the PL, and boundary scan.

The platform management controller also contains a high-speed debug port (HSDP) that can be used as a faster debug method than the primary JTAG interface. The HSDP interface is a high-throughput interface consisting of separate ingress and egress simplex Aurora 64B/66B channels that leverage the transceivers to the north of the processing system. The HSDP allows daisy-chaining of channels from different devices. The HSDP can also be accessed by the serial transceivers in the PL via an Aurora bridge also in the PL.

External Flash Memory Interfaces

The SD/eMMC controller supports 1- and 4-bit data interfaces at low, default, high-speed, and ultra-high-speed (UHS) clock rates. This controller also supports 1-, 4-, or 8-bit-wide eMMC interfaces that are compliant to the eMMC 4.51 specification. eMMC is one of the primary boot modes and supports boot from managed NAND devices. The controller has a built-in DMA for enhanced performance.

The quad SPI controller is one of the primary boot devices. It supports 4-byte and 3-byte addressing modes. In both addressing modes, single, dual-stacked, and dual-parallel configurations are supported. Single mode supports a quad serial NOR flash memory, while in double stacked and double parallel modes, it supports two quad serial NOR flash memories.

The octal SPI controller is one of the primary boot and configuration devices. It has an 8-pin interface and provides up to 400MB/s of bandwidth in double data rate mode and up to 166MB/s in single data rate mode. It has two chip-selects to support deeper memory and a built-in DMA for enhanced performance.

Slave Boot Modes

In addition to JTAG, SelectMAP is also an available slave boot mode. SelectMAP is a high bandwidth, stream oriented, parallel interface that can be configured as 8-, 16- or 32-bit wide. It runs up to 200MHz.

Compute and Acceleration Engines

AI Engine Array

Some Versal devices contain an array of AI Engine tiles or AI Engine-ML (AIE-ML) tiles on the north edge of the device. The AI Engine array is a two dimensional array of AI Engine tiles that each contain: an AI Engine, a high-performance VLIW vector (SIMD) processor; integrated data memory; and interconnects for streaming, configuration, and debug. Alongside the AI Engine tiles is the AI Engine array interface that provides the necessary logic to connect the AI Engine array to the other resources in the PL, processing system, and the NoC. Devices with an AI Engine-ML array include additional rows of 512KB memory tiles.

AI Engine

The AI Engine contains a scalar unit, a vector unit, load units, and a memory interface. The scalar unit contains: a 32-bit scalar RISC processor with register files for general-purpose, pointer, configuration, and backup registers; and a 32x32-bit scalar multiplier. The AI Engine also supports non-linear functions including sine/cosine, squareroot, and inverse-squareroot.

Three address generator units (AGUs) are available: two dedicated as load units, and one dedicated as a store unit. The vector unit contains: 512-bit vector fixed-point / integer unit. Devices with AI Engines contain a single-precision floating point vector unit. Devices with an AIE-ML contain a fixed-point vector unit also used for Bfloat16 and FP32 support. The vector units in both AI Engine and AIE-ML support concurrent operation on multiple vector lanes.

Within each AI Engine is a dedicated, single-port, 16KB program memory 128-bit wide and 1k deep. The program memory supports instruction compression and has ECC protection and reporting.

AI Engine Data Memory

Separate from the AI Engine, each AI Engine tile contains 32KB of data memory for AI Engine and 64KB of data memory for AIE-ML, divided into eight single-port banks. This structure allows up to eight parallel memory access transactions every clock cycle, with five cycle access latency. Stall signals identify memory access conflicts during which time any outstanding memory operations are buffered. Each data memory module supports memory error detection (parity) and reporting.

The data memory also contains DMA logic that supports incoming stream to local memory, outgoing stream from local memory, and buffered streams in local memory. Support for two-dimensional stride access enables any AI Engine to access data memories in adjacent AI Engine tiles in the north, south, east, and west directions, allowing a single AI Engine to access up to 128KB of data memory and a single AIE-ML to access up to 256KB of data memory.

Processing System

All Versal devices contain a processing system consisting of Scalar Engines (APU and RPU) and peripherals. The processing system is part of a group of architectural elements that include the platform management controller, CPM block, NoC, and integrated memory controllers that are tightly coupled, but are also capable of operating independently from each other. The simplified layout is shown in Figure 2.

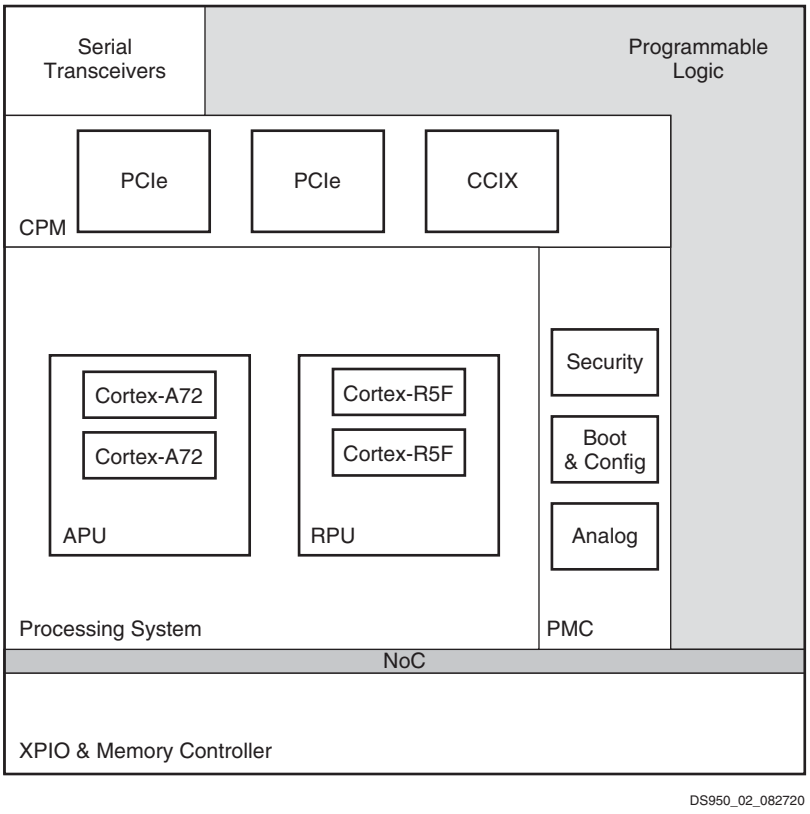

Figure 2: **Processing System and Surrounding Blocks**

The platform management controller is responsible for booting the processing system from one of its primary boot sources. The processing system also has direct access to the features inside the CPM, which talks to the serial transceivers directly to the north for implementation of high-performance interconnect based on PCI-SIG technologies. Programmable logic can be configured at any stage of the process and can be performed before or after the processing system is booted.

Processing System

Application Processing Unit (APU)

The APU has a feature-rich dual-core Arm Cortex-A72 processor. Cortex-A72 cores are 64-bit-wide application processors based on the Arm-v8A architecture, which supports hardware virtualization. Each of the Cortex-A72 cores has: 48KB of instruction L1 cache and 32KB of data L1 cache, with parity and ECC protection respectively; a NEON SIMD engine; and a single and double precision floating point unit. In addition to these blocks, the APU consists of a snoop control unit and a 1MB L2 cache with ECC protection to enhance system-level performance. The snoop control unit keeps the L1 caches coherent thus eliminating the need of spending software bandwidth for coherency. The APU also has a built-in interrupt controller supporting virtual interrupts.

The APU communicates to the rest of the processing system through the 128-bit AXI coherent extension (ACE) port via Cache Coherent Interconnect (CCI) block, using the system memory management unit (SMMU). The APU is also connected to the PL through the 128-bit accelerator coherency port (ACP), providing a low latency coherent port for accelerators in the PL. To support real-time debug and trace, each core also has an Embedded Trace Macrocell (ETM) that communicates with the Arm CoreSight™ Debug System.

Real-Time Processing Unit (RPU)

The RPU in the processing system contains a dual-core Arm Cortex-R5F processor. Cortex-R5F cores are 32-bit real-time processor cores based on the Arm-v7R architecture. Each of the Cortex-R5F cores has 32KB of Level 1 (L1) instruction and data cache with ECC protection. In addition to the L1 caches, each of the Cortex-R5F cores also has a 128KB tightly coupled memory (TCM) interface for real-time single cycle access. The RPU also has a dedicated interrupt controller and floating point unit. The RPU can operate in either split or lock-step mode. In split mode, both processors run independently of each other. In lock-step mode, they run in parallel with each other, with integrated comparator logic, and the TCMs are used as a 256KB unified memory.

The RPU communicates with the rest of the processing system via the 128-bit AXI-4 ports connected to the low power domain switch. It also communicates directly with the PL through 128-bit low latency AXI-4 ports. To support real-time debug and trace, each core also has an embedded trace macrocell (ETM) that communicates with the Arm CoreSight Debug System.

Connectivity Peripherals

In the processing system, many peripherals are used to connect to external devices over industry-standard protocols, including CAN-FD, SPI, USB, Ethernet, I2C, and UART. Many of the peripherals support clock gating and power gating modes to reduce dynamic and static power consumption. These peripherals either use multiplexed I/O (MIO) to connect to the external components, or if required, they can also be routed into and through the PL using the extended multiplexed I/O (EMIO).

With the adjacent CPM and platform management controller providing access to the high-speed and boot configuration interfaces respectively, the number of peripherals required directly in the I/O unit is relatively small, containing:

- 2 gigabit Ethernet controllers
- 2 SPI controllers
- 2 I2C controllers
- 2 CAN/CAN-FD controllers
- 2 UARTs
- GPIO
- 1 USB 2.0 (device and host) controller

The following functions are included in the I/O unit so they can share MIO:

- 4 triple-timer counters
- 1 watchdog timer

All peripherals within the I/O unit have Trustzone support through system control registers. The I/O unit has master and slave AXI interface ports to the LPD interconnect. One APB bus at top level is used to control AXI bridges within the I/O unit.

USB 2.0

The USB controller can be configured as host or device. The controller is compliant to the USB 2.0 specification and supports high, full, and low-speed modes in all configurations. In host mode, the USB controller is compliant with the Intel XHCI specification. In device mode, it supports up to the 12 endpoints. The Universal Low Peripheral Interface (ULPI) is used to connect the controller to an external PHY operating up to 480Mb/s.

Ethernet MAC

The pair of tri-speed Ethernet MACs support 10Mb/s, 100Mb/s, and 1Gb/s operations. They also support jumbo frames and timestamping through the interfaces based on IEEE Std 1588 v2. Time Sensitive Network (TSN), which either uses IEEE Std 1588 or 802.1AS-REV, is also supported. The Ethernet MACs can be connected through the MIO (RGMII), or through EMIO (GMII). The GMII interface can be converted to a different interface within the PL.

Configurable Logic Block (CLB)

Every configurable logic block (CLB) contains 32 look-up tables (LUTs) and 64 flip-flops. The LUTs can be configured as either one 6-input LUT with one output, or as two 5-input LUTs with separate outputs but common inputs. Each LUT can optionally be registered in a flip-flop. In addition to the LUTs and flip-flops, the CLB contains arithmetic carry logic and multiplexers to create wider logic functions. Within each CLB, 16 LUTs can be configured as a 64-bit RAM, as a 32-bit shift register (SRL32), or as two 16-bit shift registers (SRL16s). For every group of 64 flip-flops, there are four clocks signals, four set/reset signals, and 16 clock enables. Within every CLB are dedicated interconnect paths for connecting LUTs together without having to exit and re-enter a CLB and cascade muxes. This enables a flexible carry logic structure that allows a carry chain to start at any bit in the chain.

Internal Memory

Each Versal ACAP contains several programmable, internal storage capabilities. In addition to the distributed RAM capability in the CLB, there are dedicated blocks for building various size storage elements.

On-Chip Memory (OCM)

In addition to the 32KB of L1 data cache, the RPU contains 256KB OCM with ECC. The OCM is accessed through two 128-bit AXI interfaces with one AXI interface dedicated to the two Cortex-R5F processors and the other AXI interface available to the APU and other masters. Memory accesses from the RPU are treated with higher priority than memory accesses through the general 128-bit AXI interface.

Some Versal ACAPs include accelerator RAM, an additional 4MB of on-chip memory with ECC located outside of the processing system. This memory provides direct access from the RPU via a 128-bit AXI interface and can also be accessed from the PL through two 256-bit AXI interfaces. The memory is divided into three banks supporting concurrent read or write accesses from the PL and RPU to different banks.

Block RAM

True dual-port block RAMs, each having 36Kb of storage capacity, can be configured as either one 36Kb RAM, or two completely independent 18Kb RAMs. Each port can be configured as 4K × 9, 2K × 18, 1K × 36, or 512 x 72 in simple dual-port mode. The two ports can have different aspect ratios. Also, the read port width can be different from the write port width for each port.

Synchronous operation: Each memory access, read, and write is controlled by the clock. All inputs, data, address, clock enable, and write enable are registered. The data output is always latched, retaining data until the next operation. An optional output data pipeline register allows higher clock rates at the cost of an extra cycle of latency. During a write operation, the data output can be made to reflect the previously stored data, the newly written data, or remain unchanged. There is independent reset control of output latches and registers.

Asynchronous operation: The data outputs can also be set/reset asynchronously. The sleep input, which places the array in a low-power state, can be optionally asynchronous.

True dual-port operation: The block RAM has two completely independent ports that share nothing but the stored data.

Simple dual-port operation: One port is dedicated as a write port and the other as a read port. The data width can thus be extended to 72 bits for the 36Kb full block RAM or 36 bits for the "split" 18Kb block RAM.

Cascade mode supports all configurations available in 36Kb RAM or 18Kb RAM. Cascading refers to combining multiple block RAMs to build larger ones, without using additional logic resources.

Each 64-bit-wide block RAM can generate, store, and use eight additional bits to perform single-bit error correction and double-bit error detection (ECC) during the read process. The ECC logic can also be used without the memory array to support the implementation of ECC on user designed internal datapaths or memory controllers. Block RAM contents can be initialized or cleared by the configuration device image.

UltraRAM

Dual-port UltraRAMs, each having 288K bits of storage capacity, can be configured as one 288Kb RAM. Each port can be configured as 32K x 9, 16K x 18, 8K x 36, or 4K x 72. The two ports can have different aspect ratios.

Synchronous operation only: Each memory access, read, and write is controlled by the clock. All inputs, data, address, clock enable, and write enable are registered. The data output is always latched, retaining data until the next operation. An optional output data pipeline register allows higher clock rates at the cost of an extra cycle of latency.

Asynchronous control: The data outputs can also be set/reset asynchronously. The sleep input, which places the array in a low power state, can be optionally asynchronous.

Pseudo dual-port operation: There are two ports on the memory. Each is capable of reading or writing in a single cycle. The ports are sequenced in a fixed order, allowing up to two transactions per cycle. (Both ports write, both ports read, or one port reads while the other writes.) This necessitates that the two ports share a common clock. During a write operation, the data output remains unchanged on a given port. There is independent reset control of output latches and registers.

ECC logic in the UltraRAM supports error checking and correction. Both ports have dedicated ECC for either read or write. The ECC logic is organized for 64-bit-wide data, which can generate, store, and use eight additional bits to perform single-bit error correction and double-bit error detection (ECC) during the read process.

It is possible to cascade the address and data of adjacent blocks to build deeper memories. Optional pipelining is also available to maintain the clock rate through tall cascades of UltraRAM.

Digital Signal Processing (DSP)

DSP applications use many binary multipliers and accumulators, best implemented in dedicated DSP Engines. Versal devices have many dedicated, low-power DSP Engines, combining high speed with small size while retaining system design flexibility.

Each DSP Engine fundamentally consists of a dedicated 27 × 24 bit twos complement multiplier and a 58-bit accumulator. The multiplier can be dynamically bypassed, and two 58-bit inputs can feed a single-instruction-multiple-data (SIMD) arithmetic unit (dual 24-bit add/subtract/accumulate or quad 12-bit add/subtract/accumulate), or a logic unit that can generate any one of ten different logic functions of the two operands.

The DSP Engine includes an additional pre-adder, typically used in symmetrical filters. This pre-adder improves performance in densely packed designs and reduces the DSP Engine count by up to 50%. The 116-bit-wide XOR function, programmable to 12, 22, 24, 34, 58, or 116-bit widths, enables performance improvements when implementing forward error correction and cyclic redundancy checking algorithms.

The DSP Engine also includes a 58-bit-wide pattern detector that can be used for convergent or symmetric rounding. The pattern detector is also capable of implementing 116-bit-wide logic functions when used in conjunction with the logic unit.

The DSP Engine provides extensive pipelining and extension capabilities that enhance the speed and efficiency of many applications beyond digital signal processing, such as wide dynamic bus shifters, memory address generators, wide bus multiplexers, and memory-mapped I/O register files. The accumulator can also be used as a synchronous up/down counter.

The DSP Engine layout enables new modes of operation in addition to the conventional fixed-point operation.

Three element vector / INT8 dot product: The DSP Engine can be used in vector fixed-point ALU mode in which the 27 x 24 bit multiplier is replaced by a three-dimensional vector dot-product unit. The dot-product unit supports element-wise product negation with negate pins.

Complex 18b x 18b: Using two back to back DSP Engines, the Versal architecture enables creation of an 18 x 18 + 58 twos complement complex multiply accumulator in which each of the two complex inputs can be optionally conjugated.

Single precision floating point: The DSP Engine contains a floating-point multiplier and a floating-point adder with separate outputs in binary32 format. Each floating-point multiplier input can be in either binary32 (single-precision or FP32) or binary16 (half-precision or FP16) format.

Soft-Decision Forward Error Correction (SD-FEC)

The soft-decision forward error correction (SD-FEC) integrated IP block provides high throughput LDPC and polar code implementations. The LDPC decode and encode functionality is capable of covering a range of customer specified quasi-cyclic (QC) codes. The SD-FEC offers significant power and area savings versus implementations done in the programmable logic.

The SD-FEC block is integrated within the Versal ACAP as part of the connectivity IP column and interfaces to other blocks using interconnect and global clock resources. The memory requirements of the block are handled within the block itself and do not use block RAM or UltraRAM resources.

Connectivity

Transceivers

GTY/GTYP transceivers support data rates up to 32.75Gb/s. GTM transceivers support data rates up to 112Gb/s depending on the Versal ACAP series. Minimum data rate for all transceivers is 1.2Gb/s but lower data rates can be achieved by utilizing oversampling in the programmable logic.

GTY/GTYP Transceivers

The serial transmitter and receiver are independent circuits that use an advanced phase-locked loop (PLL) architecture to multiply the reference frequency input by certain programmable numbers between 4 and 25 to become the bit-serial data clock. Each transceiver has a large number of user-definable features and parameters. All of these can be defined during device configuration, and many can also be modified during operation.

Transmitter (GTY/GTYP)

The transmitter is fundamentally a parallel-to-serial converter with a conversion ratio of 16, 20, 32, 40, 64, 80, 128, or 160. This allows the designer to trade off datapath width against timing margin in high-performance designs. These transmitter outputs drive the PC board with a single-channel differential output signal. TXOUTCLK is the appropriately divided serial data clock and can be used directly to register the parallel data coming from the internal logic. The incoming parallel data is fed through an optional FIFO and has additional hardware support for the 8B/10B, 64B/66B, or 64B/67B encoding schemes to provide a sufficient number of transitions. The bit-serial output signal drives two package pins with differential signals. This output signal pair has programmable signal swing as well as programmable pre- and post-emphasis to compensate for PC board losses and other interconnect characteristics. For shorter channels, the swing can be reduced to reduce power consumption.

Receiver (GTY/GTYP)

The receiver is fundamentally a serial-to-parallel converter, changing the incoming bit-serial differential signal into a parallel stream of words, each 16, 20, 32, 40, 64, 80, 128, or 160. This allows the designer to trade off internal datapath width against logic timing margin. The receiver takes the incoming differential data stream, feeds it through programmable DC automatic gain control, linear and decision feedback equalizers (to compensate for PC board, cable, optical and other interconnect characteristics), and uses

the reference clock input to initiate clock recognition. There is no need for a separate clock line. The data pattern uses non-return-to-zero (NRZ) encoding and optionally ensures sufficient data transitions by using the selected encoding scheme. Parallel data is then transferred into the device logic using the RXUSRCLK clock. For short channels, the transceivers offer a special low-power mode (LPM) to reduce power consumption by approximately 30%.

The receiver DC automatic gain control and linear and decision feedback equalizers can optionally "auto-adapt" to automatically learn and compensate for different interconnect characteristics. This enables even more margin for 10G+ and 25G+ backplanes.

Out-of-Band Signaling

The transceivers provide out-of-band (OOB) signaling, often used to send low-speed signals from the transmitter to the receiver while high-speed serial data transmission is not active. This is typically done when the link is in a powered-down state or has not yet been initialized. This benefits PCIe and SATA/SAS applications.

GTM Transceivers

The serial transmitter and receiver are independent circuits that use an advanced phase-locked loop (PLL) architecture to multiply the reference frequency input by certain programmable numbers between 16 and 160 to become the bit-serial data clock. Each transceiver has a large number of user-definable features and parameters. All of these can be defined during device configuration, and many can also be modified during operation. The GTM transceiver in the Versal Prime series supports a PAM4 data rate up to 58Gb/s. In the Versal Premium series, two GTM transceivers can be combined to provide support up to 112Gb/s.

Transmitter (GTM)

The transmitter is fundamentally a parallel-to-serial converter. These transmitter outputs drive pulse amplitude modulated signals with either four levels (PAM4) or two levels (NRZ) to the PC board with a single-channel differential output signal. TXOUTCLK is the appropriately divided serial data clock and can be used directly to register the parallel data coming from the internal logic. The incoming parallel data can optionally leverage a Reed-Solomon, RS(544,514) Forward Error Correction encoder and/or 64b66b data encoder. The bit-serial output signal drives two package pins with PAM4 differential signals. This output signal pair has programmable signal swing as well as programmable pre- and post-emphasis to compensate for PC board losses and other interconnect characteristics. For shorter channels, the swing can be reduced to reduce power consumption.

Receiver (GTM)

The receiver is fundamentally a serial-to-parallel converter, changing the incoming PAM4 differential signal into a parallel stream of words. The receiver takes the incoming differential data stream, feeds it through automatic gain compensation (AGC) and a continuous time linear equalizer (CTLE), after which it is sampled with a high-speed analog to digital converter. Further equalization is completed digitally via a decision feedback equalizer (DFE) and feed forward equalizer (FFE) implemented in DSP logic before the recovered bits are parallelized and provided to the PCS. This equalization provides the flexibility to receive data over channels ranging from very short chip-to-chip to high loss backplane applications across all supported rates. Clock recovery circuitry generates a clock derived from the high-speed PLL to clock in serial data and provides an appropriately divided and phase-aligned clock, RXOUTCLK, to internal logic.

Parallel data can optionally be transferred into an RS-FEC and/or 64b/66b decoder before being presented to the programmable logic interface.

Integrated Block for PCI Express

The Versal architecture uses two different types of integrated blocks to enable PCIe designs. Versal devices can contain one or more instances of a programmable logic integrated block for PCIe designs (PL PCIE), which reside in the PL as illustrated in Figure 1. Versal devices can also contain one CPM, which resides adjacent to the processing system as illustrated in Figure 2. Multiple versions of both these integrated blocks exist in the Versal architecture, with details shown in Table 12.

PL PCIE

PL PCIE communicates with the adjacent serial transceivers and supports the protocols, data rates, and link widths shown in Table 12. Each PL PCIE can be configured as an Endpoint or Root Port. The Root Port configuration can be used to build the basis for a compatible Root Complex, to allow custom chip-to-chip communication via the PCI Express protocol, and to attach endpoint devices, such as Ethernet controllers or Fibre Channel HBAs, to the ACAP. For high-performance applications, advanced buffering techniques of the PL PCIE offer a flexible maximum payload size. The PL PCIE interfaces to the integrated high-speed transceivers for serial connectivity and to PL memory resources for data buffering. Combined, these elements implement the Physical Layer, Data Link Layer, and Transaction Layer of the PCI Express protocol.

CPM

The CPM has dedicated connects to a set of 16 adjacent serial transceivers and supports the protocols, data rates, and link widths shown in Table 12. The CPM contains sub-blocks for two PCIe functions, one or two optional DMA controllers, plus an optional coherent cache function. Both sub-blocks for PCIe can be configured as an Endpoint, and depending on the CPM version, either one or both of these sub-blocks has access to the available DMA controllers and can also be configured as a Root Port. The DMA controllers provide dedicated connections to the NoC.

The CPM also incorporates cache coherent interconnect functionality to allow construction of accelerator designs with CCIX interfaces. The CPM is configured separately from the PL, enabling the CPM to become operational early in the Versal ACAP boot sequence.

Table 12: **Supported Protocols, Data Rates, and Link Widths**

	PLPCIE4	CPM4	PLPCIE5	CPM5
Governing Specifications	PCI Express Base Specification Rev 4.0	PCI Express Base Specification Rev 4.0 CCIX Base Specification Rev 1.0	PCI Express Base Specification Rev 5.0 CCIX Base Specification Rev 1.1	PCI Express Base Specification Rev 5.0 CCIX Base Specification Rev 1.1
Max. PCIe Link Configurations	Gen4x8 Gen3x16	Gen4x16 2 x Gen4x8	Gen5x4 Gen4x8 Gen3x16	2 x Gen5x8 Gen4x16 2 x Gen4x8
Key PCIe Features	SRIOV 4PF / 252VF	SRIOV 4PF / 252VF	SRIOV 8PF / 2KVF	SRIOV 16PF / 4KVF
Optional Integrated DMAs	–	Choice of one: QDMA (2K queues) or XDMA	–	2 x QDMA (4K queues)
CCIX Data Rates and Features	–	16GT/s, 20GT/s, 25GT/s Integrated Cache	16GT/s, 20GT/s, 25GT/s, 32GT/s	16GT/s, 20GT/s, 25GT/s, 32GT/s Integrated Cache

Ethernet

The Versal architecture contains integrated blocks for Ethernet functionality capable of operating at different data rates.

600G Channelized Multirate Ethernet Subsystem (DCMAC)

The 600G channelized multirate Ethernet subsystem provides up to 600G of Ethernet bandwidth that can be configured for various rates including 1x400GE, 3x200GE, and 6x100GE. The DCMAC handles all protocol-related functions of an Ethernet MAC, PCS, and FEC, including handshaking, synchronizing, and error checking. It also provides a segmented AXI4-Stream interface for packet data and an AXI4-Lite interface for statistics and management.

The DCMAC can be configured to include forward error correction (FEC) capability, supporting: Clause 91 RS(528, 514) KR4 FEC; Clause 91 RS(544, 514) KP4 FEC; Clause 119 RS(544, 514) KP4 FEC and Clause 134 RS(544, 514) FEC.

The DCMAC flexible interface (FLEXIF) supports several operating modes including OTN mode, FlexE mode and PCS mode.

Multirate Ethernet MAC (MRMAC)

The multirate Ethernet MAC (MRMAC) provides high-performance, low latency Ethernet ports supporting a wide range of customization and statistics gathering. Supported configurations are: 1 x 100GE; 2 x 50GE; 1 x 40GE; 4 x 25GE; and 4 x 10GE.

The MRMAC supports the following FECs defined and required by IEEE standards: Clause 91 RS(528, 514) KR4 FEC, for 25/50/100GE NRZ support; Clause 91 RS(544, 514) KP4 FEC for 50/100GE PAM4 support; and Clause 74 FEC, for 10/25/40/50GE low-latency support. The MRMAC has a rich set of bypass modes to enable access to FEC-only mode (for custom protocols) and FEC+PCS (for protocol testers).

The MRMAC also supports a new high-precision timestamping feature to enable sub-nanosecond accuracy on IEEE Std 1588 timestamps. This provides hardware support for new IEEE Std 1588-based time-sensitive networks (TSN) as well as the next generation Ethernet-based wireless fronthaul protocol (eCPRI).

600G Interlaken with FEC

The integrated 600G Interlaken block with FEC supports channelized interfaces operating up to 600Gb/s with built-in flow control. Each 600G Interlaken block can be configured as 12x56.42G, 24x28.21G, or 24x12.5G. The flexible AXI-Stream user interface is configurable in width from 2048b to 512b. Pairs of lanes share 100G RS(544, 514) FEC and can support FEC-only mode.

400G High-Speed Crypto (HSC) Engine

The 400G High-Speed Crypto (HSC) Engine implements an AES-GCM-256/128 engine that provides up to 400Gb/s of bulk encryption capability on up to 40 channels that can be connected to the DCMAC. Each HSC Engine supports both MACSec and IPSec at up to 400Gb/s configurable as 1x400G, 2x200G, or 4x100G channels with up to 128 Source Addresses (SA) per 100G.

I/O

Three types of programmable I/Os exist in the programmable logic with additional I/Os available in the processing system. See Table 13.

Table 13: **Programmable I/O**

I/O Type	XPIO	HDIO	MIO
Voltage	1.0V–1.5V	1.8V–3.3V	1.8V–3.3V
Purpose	High performance, DDR4/LPDDR4	Lower performance, wider voltage range	Support processing system peripherals

XPIO

XPIO are optimized for high-performance communication including, but not limited to, interfacing to DDR4 memory through the integrated memory controller blocks. XPIO are arranged in banks of 54 I/O and organized as nine 6-bit nibbles. XPIO support standards with maximum supply voltage of 1.5V. Every XPIO bank includes a physical layer interface (PHY) that can operate in 4:1 mode for use with the integrated memory controllers or 8:1 mode for use with custom circuitry.

HDIO

High-density I/O (HDIO) banks are designed to be a cost-effective method for supporting lower speed, higher voltage range I/O standards. Arranged in banks of 22, the number of HDIO varies depending on Versal device and package. HDIOs offer single-ended I/O including 3.3V and 2.5V LVTTL and LVCMOS. HDIOs also offer differential receivers for low-speed clock inputs and pseudo-differential transmitters. There is Internal V_{REF} support. The system designer can specify the slew rate and the output strength. The input is always active but is usually ignored while the output is active. Each pin can optionally have a weak pull-up resistor, a weak pull-down resistor, or weak keeper.

MIO

Multiple banks of general-purpose I/O are implemented within the processing system and PMC, each with a dedicated power supply. The main category of I/O are the three banks of multiplexed I/O (MIO), which can be accessed by the processing system, the PMC, and the PL. Fixed-function I/O are also available for control and configuration functions.

Clocking

Multiple clock generation blocks are used to synthesize clock frequencies. Clock buffers and routing connect the signals to their destinations.

Processing System Clocking

All clocks in the processing system belong to one of three groups: the main PLL clocks; the internal ring oscillator clock and interface clocks.

Main PLL Clocks

The majority of the logic in the processing system is clocked from the three PLLs in the processing system and one PLL in the PMC through user configurable clock divider circuits. These divider circuits generate clocks to all CPUs, main interconnects, the PMC, and all peripherals. The clocks and their associated PLLs are spread across three power domains: the PMC domain, containing the PMC; the low-power domain, containing the RPU and all peripheral clocks; and the full-power domain, containing all other clocks and their PLLs.

Internal Ring Oscillator

The PMC operates as the security manager for the device and uses a clock provided by an internal ring oscillator.

Interface Clocks

This category includes clocks that are directly supplied from outside the processing system and includes clocks for the external interfaces, including Ethernet, USB, SWDT and CAN-FD.

PL Clocking

Clock signals travel around the Versal ACAPs on a network of bidirectional, horizontal, and vertical routing tracks that support many independent clock networks. The vertical tracks reside adjacent to the NoC columns. The programmable logic is divided into clock regions that each have a horizontal clock spine through the middle that can carry 24 clock signals. Clock signals travel along these horizontal clock spines and are then driven into the individual clocked elements within the PL such as flip-flops, DSP Engines, block RAM, and UltraRAM. Clock buffers and clock management components reside adjacent to the XPIO rows on south and (sometimes) north edges of the device.

Clock Management

To generate multiple clock frequencies and phases from an input clock source, Versal devices contain mixed-mode clock managers (MMCMs) and phase-locked loops (PLLs). MMCMs reside adjacent to the horizontal NoC row adjacent to the XPIO and PLLs reside in the XPIO banks. The MMCM and PLL share many characteristics. Both can serve as a frequency synthesizer for a wide range of frequencies and as a jitter filter for incoming clocks. At the center of both components is a voltage-controlled oscillator (VCO), which speeds up and slows down depending on the input voltage it receives from the phase frequency detector (PFD).

There are three sets of programmable frequency dividers: D, M, and O. The predivider D, programmable by configuration and afterwards via the dynamic reconfiguration port (DRP), reduces the input frequency and feeds one input of the traditional PLL phase/frequency comparator. The feedback divider M (programmable by configuration and afterwards via DRP) acts as a multiplier because it divides the VCO output frequency before feeding the other input of the phase comparator. D and M must be chosen appropriately to keep the VCO within its specified frequency range. The VCO has eight equally spaced output phases (0°, 45°, 90°, 135°, 180°, 225°, 270°, and 315°). Each can be selected to drive one of the output dividers (six for the PLL, O0 to O5, and seven for the MMCM, O0 to O6), each programmable by configuration to divide by any integer from 1 to 128.

MMCM additional programmable features: The MMCM has a fractional counter in either the feedback path (acting as a multiplier) or in one output path. Fractional counters allow non-integer increments of 1/8 and can thus increase frequency synthesis capabilities by a factor of 8. The MMCM can also provide fixed or dynamic phase shift in small increments that depend on the VCO frequency.

Memory Controllers

Versal architecture contains dedicated memory controllers (DDRMC), supporting DDR4 and LPDDR4. Each memory controller has four bidirectional 128-bit system ports and contains a scheduler with transaction reordering capability to improve memory access efficiency. The memory controller operates at half the DRAM clock rate. For example, if the DRAM data rate per bit is 3200Mb/s, then the DRAM clock rate is 1600MHz, and the memory controller clock rate is 800MHz. The memory controllers talk to the dedicated memory PHY (XPHY) in the XPIO banks which, in turn, interface with the I/O pins.

Stacked Silicon Interconnect (SSI) Technology

The Versal architecture uses the established SSI technology to build 3D ICs that exceed what can be achieved using monolithic die. SSI technology enables multiple super-logic regions (SLRs) to be combined on a passive interposer layer, using proven manufacturing and assembly techniques from industry leaders. Signals travel between adjacent SLRs through many distributed, low-latency connections.

Table 14 shows the number of SLRs in devices that use SSI technology and their dimensions.

Table 14: **SLR Count and Dimensions**

		Versal Premium Series						Versal HBM Series(1)				
Device		VP1502	VP1552	VP1702	VP1802	VP2502	VP2802	VH1522	VH1542	VH1582	VH1742	VH1782
# SLRs		2	2	3	4	2	4	2	2	2	3	3
SLR Width (in Regions)		10	10	10	10	10	10	10	10	10	10	10
Height (in Regions)	SLR3	–	–	–	6	–	6	–	–	–	–	–
	SLR2	–	–	6	6	–	6	–	–	–	6	6
	SLR1	6	6	6	6	6	6	6	6	6	6	6
	SLR0	7	7	7	7	7	7	7	7	7	7	7

Notes:
1. Versal HBM series information refers to logic SLRs only.

High Bandwidth Memory (HBM)

Versal HBM series devices, built on SSI technology, include high bandwidth memory (HBM) DRAM integrated on the same silicon interposer as the SLRs. One or two, 4-high or 8-high stacks of memory are available, delivering a maximum capacity of 32GB. The HBM interfaces with the SLRs through the silicon interposer with 16 channels of 64 bidirectional data signals per memory stack.

Video Decoder Unit (VDU)

The video decoder unit (VDU) comprises two or four video decoder engines (VDEs) containing a decode or decompress function supporting H.264 and H.265 standards. Each VDE can be used stand-alone, or they can be combined to achieve higher throughput. Maximum throughput is shown in Table 15.

Table 15: **VDE Supported Modes**

One VDE	Two VDEs	Four VDEs
1 x 4Kp60	2 x 4Kp60	4 x 4Kp60
2 x 4Kp30	4 x 4Kp30	8 x 4Kp30
8 x 1080p30	16 x 1080p30	32 x 1080p30
16 x 720p30	32 x 720p30	64 x 720p30
32 x 720p15	64 x 720p15	128 x 720p15

The VDU interfaces to the PL via two 128-bit master AXI ports for decoder access to memory, one 32-bit AXI master port for MCU access to memory, and one 32-bit APB or AXI-Lite slave port for register programming.

Ordering Information

Table 16 shows the speed and temperature grades available in the different device series. V_{CCINT} supply voltage is listed in parentheses.

Table 16: **Speed Grade and Temperature Grade**

Series	XC Devices	Speed, Voltage, Static Power, Voltage Information		
		Extended		Industrial
		0° to +100°C	0° to +110°C[1]	–40° to +110°C[1]
AI Edge	VE2002 VE2102 VE2202 VE2302 VE1752	-1MSE (0.80V)	-2MSE (0.80V)	-2HSI (0.88V)
		-1LSE (0.70V)	-2MLE (0.80V)	-2MSI (0.80V)
			-2LSE (0.70V)	-2MLI (0.80V)
			-2LLE (0.70V)	-1MSI (0.80V)
				-1MLI (0.80V)
				-2LLI (0.70V)
				-1LSI (0.70V)
				-1LLI (0.70V)
	VE2602 VE2802	-3HSE (0.88V)	-2MSE (0.80V)	-2MSI (0.80V)
		-1MSE (0.80V)	-2MLE (0.80V)	-2MLI (0.80V)
		-1LSE (0.70V)	-2LSE (0.70V)	-1MSI (0.80V)
			-2LLE (0.70V)	-1MLI (0.80V)
				-1LSI (0.70V)
				-1LLI (0.70V)
AI Core	VC1352 VC1502 VC1702 VC1802 VC1902	-1MSE (0.80V)	-2MSE (0.80V)	-2HSI (0.88V)
		-1LSE (0.70V)	-2MLE (0.80V)	-2MSI (0.80V)
			-2LSE (0.70V)	-2MLI (0.80V)
			-2LLE (0.70V)	-1MSI (0.80V)
				-1MLI (0.80V)
				-2LLI (0.70V)
				-1LSI (0.70V)
				-1LLI (0.70V)
	VC2602 VC2802	-3HSE (0.88V)	-2MSE (0.80V)	-2MSI (0.80V)
		-1MSE (0.80V)	-2MLE (0.80V)	-2MLI (0.80V)
		-1LSE (0.70V)	-2LSE (0.70V)	-1MSI (0.80V)
			-2LLE (0.70V)	-1MLI (0.80V)
				-1LSI (0.70V)
				-1LLI (0.70V)

Table 16: **Speed Grade and Temperature Grade *(Cont'd)***

Series	XC Devices	Speed, Voltage, Static Power, Voltage Information		
		Extended		Industrial
		0° to +100°C	0° to +110°C[1]	–40° to +110°C[1]
Prime	VM1102 VM1302 VM1402 VM1502 VM1802	-1MSE (0.80V)	-2MSE (0.80V)	-2HSI (0.88V)
		-1LSE (0.70V)	-2MLE (0.80V)	-2MSI (0.80V)
			-2LSE (0.70V)	-2MLI (0.80V)
			-2LLE (0.70V)	-1MSI (0.80V)
				-1MLI (0.80V)
				-2LLI (0.70V)
				-1LSI (0.70V)
				-1LLI (0.70V)
	VM2102 VM2202 VM2302 VM2502 VM2902	-3HSE (0.88V)	-2MSE (0.80V)	-2MSI (0.80V)
		-1MSE (0.80V)	-2MLE (0.80V)	-2MLI (0.80V)
		-1LSE (0.70V)	-2LSE (0.70V)	-1MSI (0.80V)
			-2LLE (0.70V)	-1MLI (0.80V)
				-1LSI (0.70V)
				-1LLI (0.70V)
Premium	VP1002 VP1052	-1MSE (0.80V)	-2MSE (0.80V)	-2HSI (0.88V)
		-1LSE (0.70V)	-2MLE (0.80V)	-2MSI (0.80V)
			-2LSE (0.70V)	-2MLI (0.80V)
			-2LLE (0.70V)	-1MSI (0.80V)
				-1MLI (0.80V)
				-2LLI (0.70V)
				-1LSI (0.70V)
				-1LLI (0.70V)
	VP1102 VP1202 VP1402 VP1502 VP2502 VP1552 VP1702 VP1802 VP2802	-3HSE (0.88V)	-2MSE (0.80V)	-2MSI (0.80V)
		-1MSE (0.80V)	-2MLE (0.80V)	-2MLI (0.80V)
		-1LSE (0.70V)	-2LSE (0.70V)	-1MSI (0.80V)
			-2LLE (0.70V)	-1MLI (0.80V)
				-1LSI (0.70V)
				-1LLI (0.70V)
HBM	All	-3HSE (0.88V)	-2MSE (0.80V)	
		-1MSE (0.80V)	-2MLE (0.80V)	
		-1LSE (0.70V)	-2LSE (0.70V)	
			-2LLE (0.70V)	

Notes:

1. In extended and industrial temperature grades, some ordering combinations can operate for a limited time with a junction temperature of 110°C. Timing parameters adhere to the same speed file at 110°C as they do below 110°C, regardless of operating voltage. Operation at 110°C Tj is limited to 3% of the device lifetime and can occur sequentially or at regular intervals as long as the total time does not exceed 3% of device lifetime.

The ordering information shown in Figure 3 applies to Versal devices.

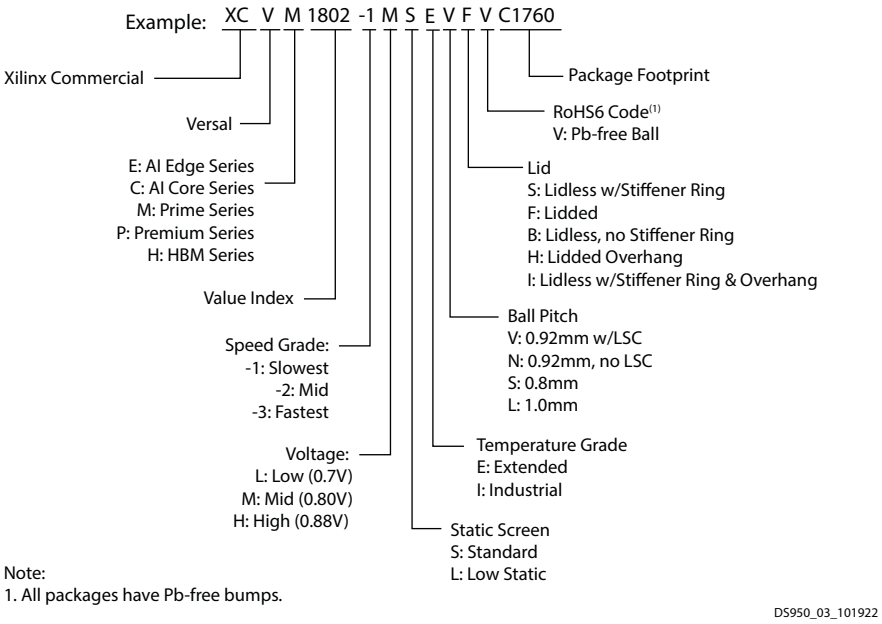

Figure 3: **Versal ACAP Ordering Information**

Revision History

The following table shows the revision history for this document:

Date	Version	Description of Revisions
11/18/2022	1.17	Updated AI Edge series information in Table 2 and Table 3. Updated AI Core series information in Table 4 and Table 5. Added NSVH1369 package to VM2202 and VSVI1760 package to VM2502 and removed VSVC2197 in Table 7. Removed VSVC2197 from Table 9 and updated HDIO counts.
04/20/2022	1.16	Added four Premium devices to Table 8, Table 9, and Table 16: VP1002, VP1052, VP2502, and VP2802.
02/28/2022	1.15	Updated Table 1, Table 7, Table 8, and Table 9.
12/09/2021	1.14	Updated Table 1 and Table 16. Added table note to Table 2, Table 4, Table 6, Table 8, Table 9, and Table 10.
10/19/2021	1.13	Updated Table 1, Table 2, Table 3, Table 4, Table 5, Table 7, Table 9, Table 14, and Table 16.
07/14/2021	1.12	Added HBM series throughout document. Added Video Decoder Unit (VDU). Updated Table 1. Updated I/O information in Table 3, Table 5, Table 7, and Table 9. Updated package information in Table 7. Updated Table 16.
06/29/2021	1.11	Added VDU information to product tables. Updated package information in Table 3. Updated VC1502 in Table 4 and Table 5. Added note to Table 6. Made typographical edit to Table 7.
06/09/2021	1.10	Added AI Edge series throughout document. Added two AI Core devices to Table 4: VC2602 and VC2802. Updated Compute and Acceleration Engines.
04/26/2021	1.9	Added VM2202. Updated Table 4, Table 5, Table 6, Table 7, and Table 16.
02/26/2021	1.8	Updated Table 1, Table 5, Table 7, Table 9, and Figure 3. Added Table 16.
08/27/2020	1.7	Updated Table 1, Table 6, Table 7, and added Stacked Silicon Interconnect (SSI) Technology.
05/11/2020	1.6	Updated Table 6, Table 7, and Table 8.
03/10/2020	1.5.1	Typographical edits.
03/10/2020	1.5	Updated Table 1 and added Versal Premium series information throughout document.
01/16/2020	1.4	Updated Figure 3. Corrected revision history date of v1.3.
12/16/2019	1.3	Added Ordering Information. Updated Table 1, Table 4, Table 5, Table 6, Table 7, and Boot and Configuration.
07/03/2019	1.2	Updated External Flash Memory Interfaces and HDIO.
05/16/2019	1.1	Updated Table 1, Table 5, Table 6, Table 7, NoC, and Connectivity Peripherals.
10/02/2018	1.0	Initial Xilinx release.

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