SmartFusion2 System-on-Chip FPGAs

Microsemi's SmartFusion®2 SoC FPGAs integrate fourth generation flash-based FPGA fabric, an ARM® Cortex™-M3 processor, and high performance communications interfaces on a single chip. The SmartFusion2 family is the industry's lowest power, most reliable and highest security programmable logic solution. This next generation SmartFusion2 architecture offers up to 3.6X gate count implemented with 4-input look-up table (LUT) fabric with carry chains, giving 2X performance, and includes multiple embedded memory options and math blocks for digital signal processing (DSP). The 166 MHz ARM Cortex-M3 processor is enhanced with an embedded trace macrocell (ETM), memory protection unit (MPU), 8 Kbyte instruction cache, and additional peripherals, including controller area network (CAN), Gigabit Ethernet, and high speed universal serial bus (USB). High speed serial interfaces include PCI EXPRESS® (PCIe®), 10 Gbps attachment unit interface (XAUI) / XGMII extended sublayer (XGXS) plus native serialization/deserialization (SERDES) communication, while double data rate 2 (DDR2)/DDR3 memory controllers provide high speed memory interfaces.

SmartFusion2 Family

Reliability

- Single Event Upset (SEU) Immune
  - Zero FIT FPGA Configuration Cells
- Junction Temperature: 125°C – Military Temperature, 100°C – Industrial Temperature, 85°C – Commercial Temperature
- Single Error Correct Double Error Detect (SECDED) Protection on the Following:
  - Ethernet Buffers
  - CAN Message Buffers
  - Cortex-M3 Embedded Scratch Pad Memory (eSRAMs)
  - USB Buffers
  - PCIe Buffer
  - DDR Memory Controllers with Optional SECDED Modes
- Buffers Implemented with SEU Resistant Latches on the Following:
  - DDR Bridges (MSS, MDDR, FDDR)
  - Instruction Cache
  - MMUART FIFOs
  - SPI FIFOs
- NVM Integrity Check at Power-Up and On-Demand
- No External Configuration Memory Required—Instant-On, Retains Configuration When Powered Off

Security

- Design Security Features (available on all devices)
  - Intellectual Property (IP) Protection via Unique Security Features and Use Models New to the PLD Industry
  - Encrypted User Key and Bitstream Loading, Enabling Programming in Less-Trusted Locations
  - Supply-Chain Assurance Device Certificate
  - Enhanced Anti-Tamper Features
  - Zeroization
- Data Security Features (available on premium devices)
  - Non-Deterministic Random Bit Generator (NRBG)
  - User Cryptographic Services (AES-256, SHA-256, Elliptical Curve Cryptographic (ECC) Engine)
  - User Physically Unclonable Function (PUF) Key Enrollment and Regeneration
  - CRI Pass-Through DPA Patent Portfolio License
  - Hardware Firewalls Protecting Microcontroller Subsystem (MSS) Memories

Low Power

- Low Static and Dynamic Power
  - Flash*Freeze Mode for Fabric
- For the M2S050 Device:
  - < 1 mW in Flash*Freeze Mode
  - 10 mW in Standby Mode
- Based on 65 nm Nonvolatile Flash Process

High-Performance FPGA

- Efficient 4-Input LUTs with Carry Chains for High Performance and Low Power
- Up to 236 Blocks of Dual-Port 18 Kbit SRAM (Large SRAM) with 400 MHz Synchronous Performance (x18, x9, x4, x2, x1)
- Up to 240 Blocks of Three-Port 1 Kbit SRAM with 2 Read Ports and 1 Write Port (micro SRAM)
- High Performance DSP Signal Processing
  - Up to 240 Fast Math Blocks with 18 x 18 Signed Multiplication, 17 x 17 Unsigned Multiplication and 44-Bit Accumulator

Microcontroller Subsystem (MSS)

- Hard 166 MHz 32-Bit ARM Cortex-M3 Processor
  - 1.25 DMIPS/MHz
  - 8 Kbyte Instruction Cache
  - Embedded Trace Macrocell (ETM)
  - Memory Protection Unit (MPU)
  - Single Cycle Multiplication, Hardware Divide
  - JTAG Debug (4 wires), Serial Wire Debug (SWD, 2 Wires), and Serial Wire Viewer (SWV) Interfaces
- 64 KB Embedded SRAM (eSRAM)
- Up to 512 KB Embedded Nonvolatile Memory (eNVM)
- Triple Speed Ethernet (TSE) 10/100/1000 Mbps MAC
- USB 2.0 High Speed On-The-Go (OTG) Controller with ULPI Interface
- CAN Controller, 2.0B Compliant, Conforms to ISO11898-1, 32 Transmit and 32 Receive Buffers
- Two Each: SPI, I^2C, Multi-Mode UARTs (MMUART) Peripherals
- Hardware Based Watchdog Timer
- 1 General Purpose 64-Bit (or two 32-bit) Timer(s)
- Real-Time Calendar/Counter (RTC)
- DDR Bridge (4 Port Data R/W Buffering Bridge to DDR Memory) with 64-Bit AXI Interface
- Non-Blocking, Multi-Layer AHB Bus Matrix Allowing Multi-Master Scheme Supporting 10 Masters and 7 Slaves
- Two AHB/APB Interfaces to FPGA Fabric (Master/Slave Capable)
- Two DMA Controllers to Offload Data Transactions from the Cortex-M3 Processor
  - 8-Channel Peripheral DMA (PDMA) for Data Transfer Between MSS Peripherals and Memory
  - High Performance DMA (HPDMA) for Data Transfer Between eSRAM and DDR Memories

Clocking Resources

- Clock Sources
  - Up to Two High Precision 32 KHz to 20 MHz Main Crystal Oscillator
  - 1 MHz Embedded RC Oscillator
  - 50 MHz Embedded RC Oscillator
- Up to 8 Clock Conditioning Circuits (CCCs) with Up to 8 Integrated Analog PLLs
  - Output Clock with 8 Output Phases and 45° Phase Difference (Multiply/Divide, and Delay Capabilities)
  - Frequency: Input 1 to 200 MHz, Output 20 to 400 MHz

High Speed Serial Interfaces

- Up to 16 SERDES Lanes, Each Supporting:
  - XGXS/XAUI Extension (To Implement a 10 Gbps (XGMII) Ethernet PHY Interface)
  - Native SERDES Interface Facilitates Implementation of Serial RapidIO in Fabric or an SGMII Interface to the Ethernet MAC in MSS
  - PCI Express (PCIe) Endpoint Controller

    x1, x2, x4 Lane PCI Express Core

    Up to 2 Kbytes Maximum Payload Size

    64-/32-Bit AXI/AHB Master and Slave Interfaces to the Application Layer

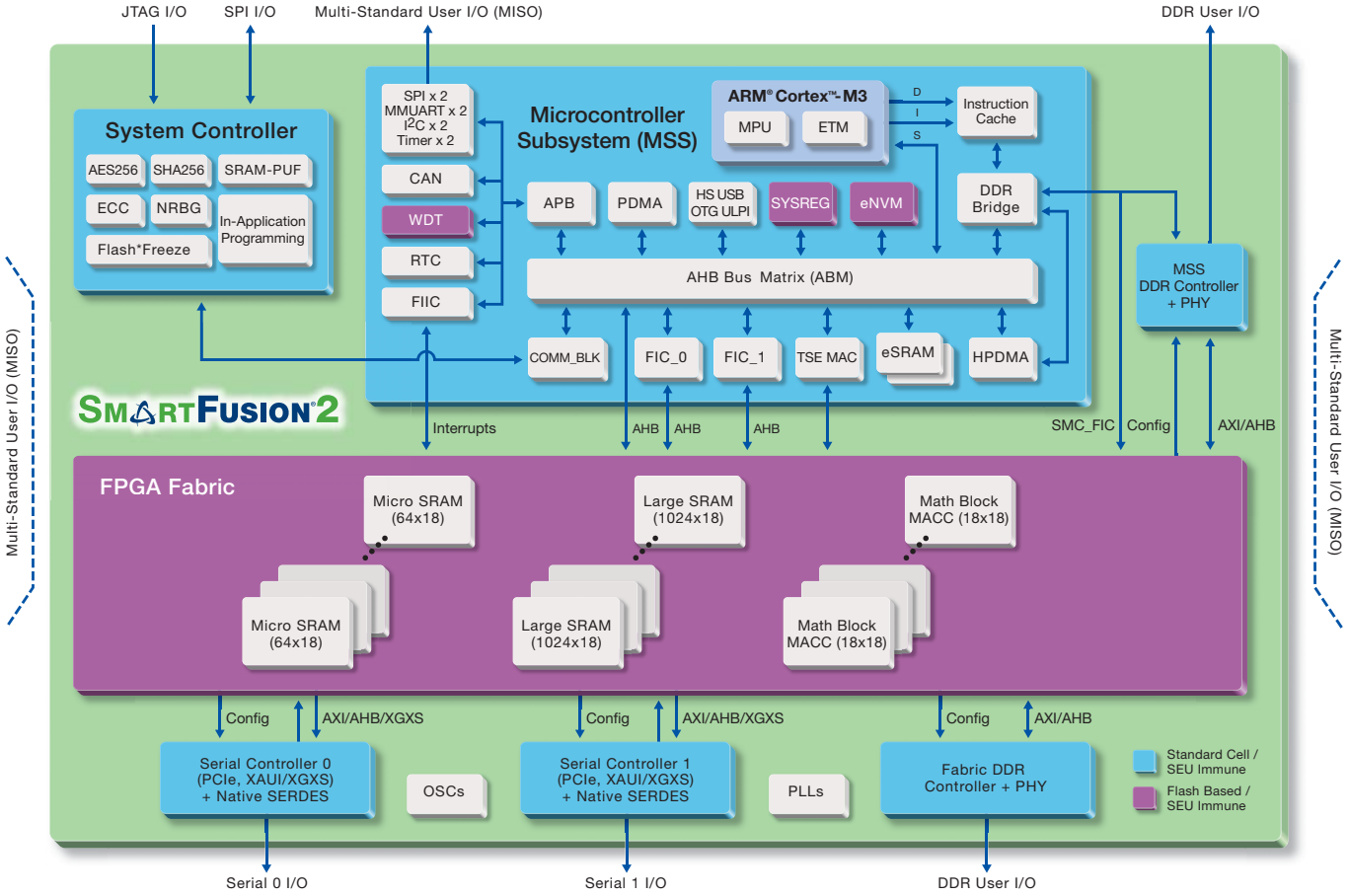
High Speed Memory Interfaces

- Up to 2 High Speed DDRx Memory Controllers
  - MSS DDR (MDDR) and Fabric DDR (FDDR) Controllers
  - Supports LPDDR/DDR2/DDR3
  - Maximum 333 MHz Clock Rate
  - SECDED Enable/Disable Feature
  - Supports Various DRAM Bus Width Modes, x16, x18, x32, x36
  - Supports Command Reordering to Optimize Memory Efficiency
  - Supports Data Reordering, Returning Critical Word First for Each Command
- SDRAM Support through the SMC_FIC and Additional Soft SDRAM Memory Controller

Operating Voltage and I/Os

- 1.2 V Core Voltage
- Multi-Standard User I/Os (MSIO/MSIOD)
  - LVTTL/LVCMOS 3.3 V
  - LVCMOS 1.2 V, 1.5 V, 1.8 V, 2.5 V
  - DDR (SSTL2_1, SSTL2_2)
  - DDR2 (SSTL18_1, SSTL18_2)
  - LVDS, MLVDS, Mini-LVDS, RSDS Differential Standards
  - PCI
  - LVPECL (receiver only)
- DDR I/Os (DDRIO)
  - DDR, DDR2, DDR3, LPDDR, SSTL2, SSTL18, HSTL
  - LVCMOS 1.2 V, 1.5 V, 1.8 V, 2.5 V
- Market Leading Number of User I/Os with 5G SERDES

SmartFusion2 SoC FPGA Block Diagram



Acronyms

AES	Advanced Encryption Standard
AHB	Advanced High-Performance Bus
APB	Advanced Peripheral Bus
AXI	Advanced eXtensible Interface
COMM_BLK	Communication Block
DDR	Double Data Rate
DPA	Differential Power Analysis
ECC	Elliptical Curve Cryptography
EDAC	Error Detection And Correction
ETM	Embedded Trace Macrocell
FDDR	DDR2/3 controller in FPGA fabric
FIC	Fabric Interface Controller
FIIC	Fabric Interface Interrupt Controller
HS USB OTG	High Speed USB 2.0 On-The-Go
IAP	In-Application Programming
MACC	Multiply-Accumulate
MDDR	DDR2/3 Controller in MSS
MMUART	Multi-Mode UART
MPU	Memory Protection Unit
MSS	Microcontroller Subsystem
SECDED	Single Error Correct Double Error Detect
SEU	Single Event Upset
SHA	Secure Hashing Algorithm
SMC_FIC	Soft Memory Controller
TSE	Triple Speed Ethernet (10/100/1000 Mbps)
ULPI	UTMI + Low Pin Interface
UTMI	USB 2.0 Transceiver Macrocell Interface
WDT	Watchdog Timer
XAUI	10 Gbps Attachment Unit Interface
XGMII	10 Gigabit Media Independent Interface
XGXS	XGMII Extended Sublayer

Table 1 • SmartFusion2 SoC FPGA Product Family

	Features	M2S005	M2S010	M2S025	M2S050	M2S080	M2S120
FPGA	Logic Modules (4-Input LUT)	4,956	9,744	23,988	48,672	82,232	120,348
	LSRAM 18K Blocks	10	21	31	69	160	236
	uSRAM 1K Blocks	11	22	34	72	160	240
	Total RAM (Bits)	191K	400K	592K	1,314K	3,040K	4,500K
	Math Blocks	11	22	34	72	160	240
	PLLs and CCCs	2	2	4	6	8	8
MSS	Cortex-M3 Processor + Instruction Cache	Yes	Yes	Yes	Yes	Yes	Yes
	eNVM (Bytes)	128K	256K	256K	256K	512K	512K
	eSRAM (Bytes)	64K	64K	64K	64K	64K	64K
	eSRAM (Bytes non-SECDED)	80K	80K	80K	80K	80K	80K
	CAN 2.0 A and B	1	1	1	1	1	1
	Triple speed Ethernet 10/100/1000	1	1	1	1	1	1
	USB 2.0 High Speed On-The-Go	1	1	1	1	1	1
	Multi-Mode UART	2	2	2	2	2	2
	SPI	2	2	2	2	2	2
	I2C	2	2	2	2	2	2
	Timer	2	2	2	2	2	2
Memory, Serial I/F	DDR Controllers	1x18	1x18	1x18	2x36	2x36	2x36
	SERDES Channels	0	4	4	8	8	16
	PCIe Endpoint x1, x2, x4	0	1	1	2	2	4
User I/O	3.3 V Multi-Standard User I/Os (MSIOs)	115[1]	123	157	139	292	292
	MSIOD I/Os	28[1]	40	40	62	106	106
	DDRIO I/Os	66[1]	70	70	176	176	176
	Total User I/Os	209[1]	233	267	377	574	574

Notes:
1. *Preliminary I/O count*

I/Os Per Package

Table 2 • I/Os per Package and Package Options

Package Options	VF400		FG484		FG896		FC1152	
Pin Count	400		484		896		1,152	
Ball Pitch (mm)	0.8		1.0		1.0		1.0	
Length × Width (mm\mm)	17 × 17		23 × 23		31 × 31		35 × 35	
	I/Os	XCVRs	I/Os	XCVRs	I/Os	XCVRs	I/Os	XCVRs
M2S005	169[1]	–	209[1]	–	–	–	–	–
M2S010	189[1]	4	233	4	–	–	–	–
M2S025	201[1]	4	267	4	–	–	–	–
M2S050	201[1]	4	267	4	377	8	–	–
M2S080	–	–	–	–	–	–	574	8
M2S120	–	–	–	–	–	–	574	16

Notes:
1. *Preliminary I/O count*
2. *User I/Os do not include the SERDES and JTAG pins.*

Features per Device/Package Combination

Table 3 • Features per Package/Device Combination (Preliminary)

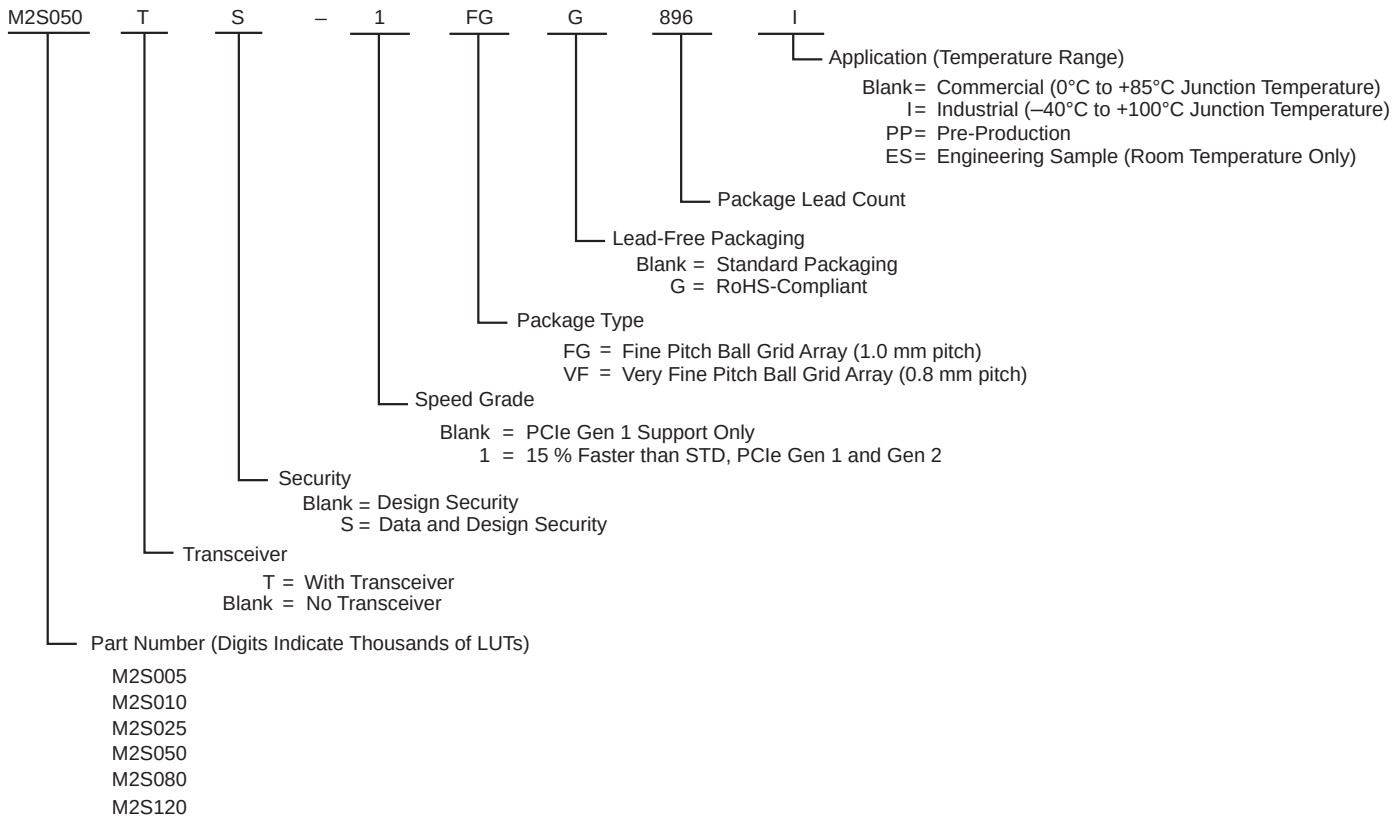
Feature	VF400				FG484				FG896	FC1152	
	M2S005	M2S010	M2S025	M2S050	M2S005	M2S010	M2S025	M2S050	M2S050	M2S080	M2S120
FDDR	–	–	–	–	–	–	–	–	x36[3]	x36[4]	x36[4]
MDDR	x18[1]	x18[1]	x18[1]	x18[2]	x18[1]	x18[1]	x18[1]	x18[2]	x36[3]	x36[4]	x36[4]
FICs	1	1	1	2	1	1	1	2	2	2	2
Crystal oscillators	2	2	2	1	2	2	2	1	1	2	2
MSIO	77[5]	97[5]	109[5]	109[5]	115[5]	123	157	105	139	292[5]	292[5]
MSIOD	28[5]	28[5]	28[5]	28[5]	28[5]	40	40	40	62	106[5]	106[5]
DDRIO	64[5]	64[5]	64[5]	64[5]	66[5]	70	70	122	176	176[5]	176[5]
Total user I/Os	169[5]	189[5]	201[5]	201[5]	209[5]	233	267	267	377	574[5]	574[5]

Feature	VF400			FG484			FG896	FC1152	
	M2S010T	M2S025T	M2S050T	M2S010T	M2S025T	M2S050T	M2S050T	M2S080T	M2S120T
FDDR	–	–	–	–	–	–	x36[3]	x36[4]	x36[4]
MDDR	x18[1]	x18[1]	x18[2]	x18[1]	x18[1]	x18[2]	x36[3]	x36[4]	x36[4]
FICs	1	1	2	1	1	2	2	2	2
Crystal oscillators	2	2	1	2	2	1	1	2	2
5G SERDES lanes	4	4	4	4	4	4	8	16	16
MSIO	97[5]	109[5]	109[5]	123	157	105	139	292[5]	292[5]
MSIOD	28[5]	28[5]	28[5]	40	40	40	62	106[5]	106[5]
DDRIO	64[5]	64[5]	64[5]	70	70	122	176	176[5]	176[5]
Total user I/Os	189[5]	201[5]	201[5]	233	267	267	377	574[5]	574[5]

Notes:

1. *x18 DDR supports x16, x9, and x8 modes.*
2. *x18 DDR supports x16 modes.*
3. *x36 DDR supports x32, x18, and x16 modes.*
4. *x36 DDR supports x32, x18, x16, x9, and x8 modes.*
5. *Preliminary I/O counts*

SmartFusion2 Ordering Information



SmartFusion2 Valid Part Numbers

Table 4 • SmartFusion2 Valid Part Numbers for Devices with Design Security

Commercial		Industrial	
Std. Speed Grade	**–1 Speed Grade**	**–1 Speed Grade**	**–1 Speed Grade, Data Security**
M2S005-VF400	M2S005-1VF400	M2S005-1VF400I	M2S005S-1VF400I
M2S010-VF400	M2S010-1VF400	M2S010-1VF400I	M2S010S-1VF400I
M2S025-VF400	M2S025-1VF400	M2S025-1VF400I	M2S025S-1VF400I
M2S050-VF400	M2S050-1VF400	M2S050-1VF400I	M2S050S-1VF400I
M2S005-FG484	M2S005-1FG484	M2S005-1FG484I	M2S005S-1FG484I
M2S010-FG484	M2S010-1FG484	M2S010-1FG484I	M2S010S-1FG484I
M2S025-FG484	M2S025-1FG484	M2S025-1FG484I	M2S025S-1FG484I
M2S050-FG484	M2S050-1FG484	M2S050-1FG484I	M2S050S-1FG484I
M2S050-FG896	M2S050-1FG896	M2S050-1FG896I	M2S050S-1FG896I
M2S080-FC1152	M2S080-1FC1152	M2S080-1FC1152I	M2S080S-1FC1152I
M2S120-FC1152	M2S120-1FC1152	M2S120-1FC1152I	M2S120S-1FC1152I

Table 4 • SmartFusion2 Valid Part Numbers for Devices with Design Security (continued)

Commercial		Industrial	
Std. Speed Grade	**–1 Speed Grade**	**–1 Speed Grade**	**–1 Speed Grade, Data Security**
Transceivers	**Transceivers**	**Transceivers**	**Transceivers**
M2S010T-VF400	M2S010T-1VF400	M2S010T-1VF400I	M2S010TS-1VF400I
M2S025T-VF400	M2S025T-1VF400	M2S025T-1VF400I	M2S025TS-1VF400I
M2S050T-VF400	M2S050T-1VF400	M2S050T-1VF400I	M2S050TS-1VF400I
M2S010T-FG484	M2S010T-1FG484	M2S010T-1FG484I	M2S010TS-1FG484I
M2S025T-FG484	M2S025T-1FG484	M2S025T-1FG484I	M2S025TS-1FG484I
M2S050T-FG484	M2S050T-1FG484	M2S050T-1FG484I	M2S050TS-1FG484I
M2S050T-FG896	M2S050T-1FG896	M2S050T-1FG896I	M2S050TS-1FG896I
M2S080T-FC1152	M2S080T-1FC1152	M2S080T-1FC1152I	M2S080TS-1FC1152I
M2S120T-FC1152	M2S120T-1FC1152	M2S120T-1FC1152I	M2S120TS-1FC1152I

Table 5 • SmartFusion2 Valid Lead-Free Part Numbers for Devices with Design Security

Commercial		Industrial	
Std. Speed Grade	**–1 Speed Grade**	**–1 Speed Grade**	**–1 Speed Grade, Data Security**
M2S005-VFG400	M2S005-1VFG400	M2S005-1VFG400I	M2S005S-1VFG400I
M2S010-VFG400	M2S010-1VFG400	M2S010-1VFG400I	M2S010S-1VFG400I
M2S025-VFG400	M2S025-1VFG400	M2S025-1VFG400I	M2S025S-1VFG400I
M2S050-VFG400	M2S050-1VFG400	M2S050-1VFG400I	M2S050S-1VFG400I
M2S005-FGG484	M2S005-1FGG484	M2S005-1FGG484I	M2S005S-1FGG484I
M2S010-FGG484	M2S010-1FGG484	M2S010-1FGG484I	M2S010S-1FGG484I
M2S025-FGG484	M2S025-1FGG484	M2S025-1FGG484I	M2S025S-1FGG484I
M2S050-FGG484	M2S050-1FGG484	M2S050-1FGG484I	M2S050S-1FGG484I
M2S050-FGG896	M2S050-1FGG896	M2S050-1FGG896I	M2S050S-1FGG896I
M2S080-FCG1152	M2S080-1FCG1152	M2S080-1FCG1152I	M2S080S-1FCG1152I
M2S120-FCG1152	M2S120-1FCG1152	M2S120-1FCG1152I	M2S120S-1FCG1152I
Transceivers	**Transceivers**	**Transceivers**	**Transceivers**
M2S010T-VFG400	M2S010T-1VFG400	M2S010T-1VFG400I	M2S010TS-1VFG400I
M2S025T-VFG400	M2S025T-1VFG400	M2S025T-1VFG400I	M2S025TS-1VFG400I
M2S050T-VFG400	M2S050T-1VFG400	M2S050T-1VFG400I	M2S050TS-1VFG400I
M2S010T-FGG484	M2S010T-1FGG484	M2S010T-1FGG484I	M2S010TS-1FGG484I
M2S025T-FGG484	M2S025T-1FGG484	M2S025T-1FGG484I	M2S025TS-1FGG484I
M2S050T-FGG484	M2S050T-1FGG484	M2S050T-1FGG484I	M2S050TS-1FGG484I
M2S050T-FGG896	M2S050T-1FGG896	M2S050T-1FGG896I	M2S050TS-1FGG896I
M2S080T-FCG1152	M2S080T-1FCG1152	M2S080T-1FCG1152I	M2S080TS-1FCG1152I
M2S120T-FCG1152	M2S120T-1FCG1152	M2S120T-1FCG1152I	M2S120TS-1FCG1152I

SmartFusion2 Device Status

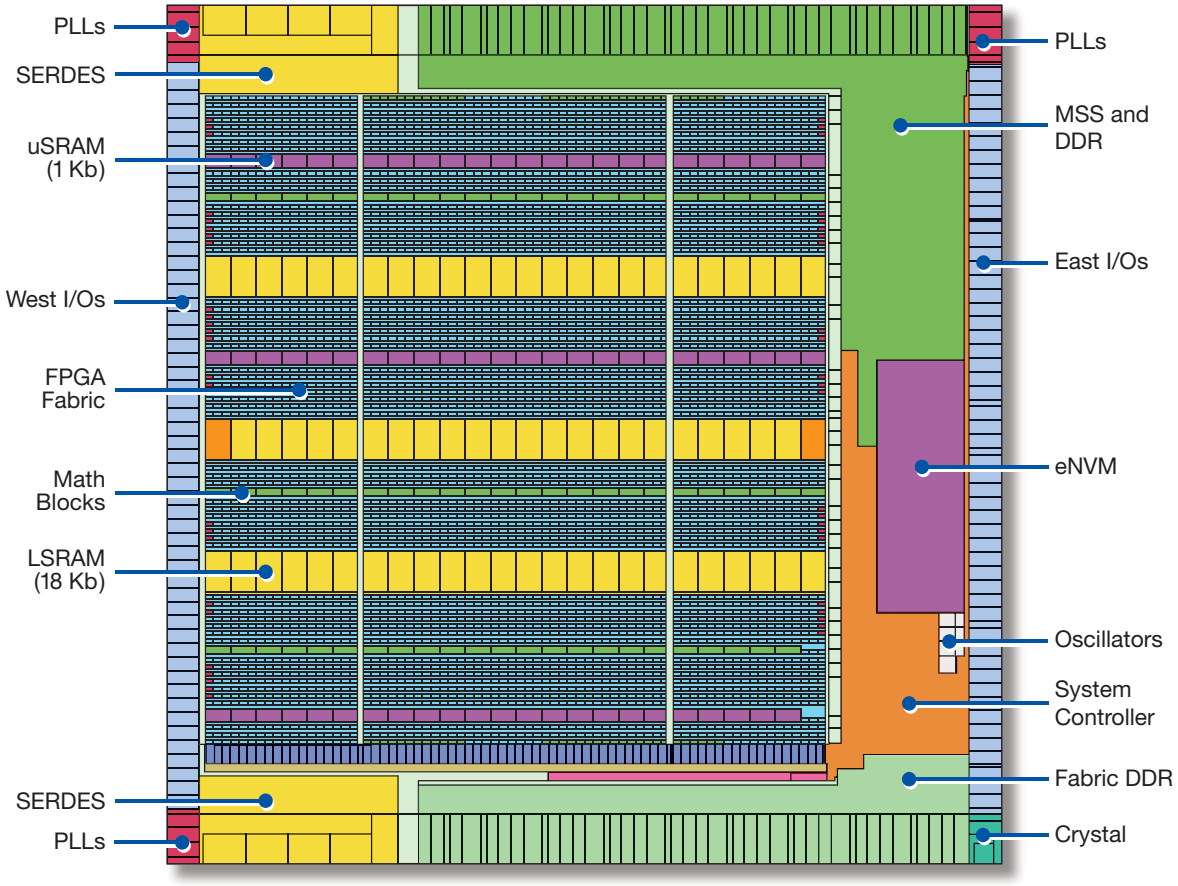
Family Devices	Status
M2S050T	Advance

Contact your local Microsemi SoC Products Group representative for device availability:
http://www.microsemi.com/soc/contact/default.aspx.

1 – SmartFusion2 Device Family Overview

Microsemi's SmartFusion2 SoC FPGAs integrate fourth generation flash-based FPGA fabric, an ARM Cortex-M3 processor, and high performance communications interfaces on a single chip. The SmartFusion2 family is the industry's lowest power, highest reliability and most secure programmable logic solution. This next generation SmartFusion2 architecture offers up to 3.6X gate count, implemented with 4-input look-up table (LUT) fabric with carry chains, giving 2X performance, and includes multiple embedded memory options and math blocks for DSP. The 166 MHz ARM Cortex-M3 processor is enhanced with ETM and 8 Kbyte instruction cache, and additional peripherals including CAN, Gigabit Ethernet, and high speed USB. High speed serial interfaces enable PCIe, XAUI / XGXS plus native SERDES communication while DDR2/DDR3 memory controllers provide high speed memory interfaces.

SmartFusion2 Chip Layout



Reliability

SmartFusion2 flash-based fabric has zero FIT configuration rate due to its single event upset (SEU) immunity, which is critical in reliability applications. The flash fabric also has the advantage that no external configuration memory is required, making the device instant-on; it retains configuration when powered off. To complement this unique FPGA capability, SmartFusion2 devices add reliability to many other aspects of the device. Single Error Correct Double Error Detect (SECDED) protection is implemented on the Cortex-M3 embedded scratch pad memory, Ethernet, CAN and USB buffers, and is optional on the DDR memory controllers. This means that if a one-bit error is detected, it will be corrected. Errors of more than one bit are detected only and not corrected. SECDED error signals are brought to the FPGA fabric to allow the user to monitor the status of these protected internal memories. Other areas of the architecture are implemented with latches, which are not subject to SEUs. Therefore, no correction is needed in these locations: DDR bridges (MSS, MDDR, FDDR), instruction cache and MMUART, SPI, and PCIe FIFOs.

Highest Security Devices

Building further on the intrinsic security benefits of flash nonvolatile memory technology, the SmartFusion2 family incorporates essentially all the legacy security features that made the original SmartFusion, Fusion®, IGLOO®, and ProASIC®3 third-generation flash FPGAs and cSoCs the gold standard for secure devices in the PLD industry. In addition, the fourth-generation flash-based SmartFusion2 SoC FPGAs add many unique design and data security features and use models new to the PLD industry.

Design Security vs. Data Security

When classifying security attributes of programmable logic devices (PLDs), a useful distinction is made between design security and data security.

Design Security

Design security is protecting the intent of the owner of the design, such as keeping the design and associated bitstream keys confidential, preventing design changes (insertion of Trojan Horses, for example), and controlling the number of copies made throughout the device life cycle. Design security may also be known as intellectual property (IP) protection. It is one aspect of anti-tamper (AT) protection. Design security applies to the device from initial production, includes any updates such as in-the-field upgrades, and can include decommissioning of the device at the end of its life, if desired. Good design security is a prerequisite for good data security.

The following are the main design security features supported:

- User key and bitstream loading in less-trusted locations
  - Encrypted key loading using device-unique built-in factory key
- Methods to verify devices are programmed correctly, even if done in less-trusted locations
- Supply-chain assurances to eliminate counterfeiting
- Differential power analysis (DPA) and enhanced anti-tamper features to address non-invasive, semi-invasive, and invasive attacks
- Ability to zeroize (destroy) all sensitive stored data in the event of tampering
- The M2S080 and M2S120 also have the following features:
  - Elliptic Curve Cryptography (ECC) for securely loading user keys
  - An SRAM-type physically unclonable function (SRAM-PUF) for device authentication

Data Security

Data security is protecting the information the FPGA is storing, processing, or communicating in its role in the end application. If, for example, the configured design is implementing the key management and encryption portion of a secure military radio, data security could entail encrypting and authenticating the radio traffic, and protecting the associated application-level cryptographic keys. Data security is closely related to the terms information assurance (IA) and information security.

All SmartFusion2 devices incorporate enhanced design security, making them the most secure programmable logic devices ever made. Select SmartFusion2 models also include an advanced set of on-chip data security features that make designing secure information assurance applications easier and better than ever before.

The following are the main data security features supported:

- Non-deterministic random bit generator (NRBG) service
- User cryptographic services (e.g., AES-128/-256, SHA-256, and HMAC)
- Hardware firewalls protecting MSS memories
- Cryptography Research Inc. (CRI) pass-through Differential Power Analysis (DPA) Patent Portfolio license
- The M2S080 and M2S120 also have the following features:
  - Elliptic Curve Cryptography (ECC) cryptographic computation services
  - User PUF key enrollment and regeneration for advanced design and data security applications

Low Power

Microsemi's flash-based FPGA fabric results in extremely low power design implementation with static power on the M2S050 device as low as 10 mW. Flash*Freeze (F*F) technology provides an ultra-low power static mode (Flash*Freeze mode) for SmartFusion2 devices, with power less than 1 mW. F*F mode entry retains all the SRAM and register information and the exit from F*F mode achieves rapid recovery to active mode.

High Performance FPGA Fabric

Built on 65 nm process technology, the SmartFusion2 FPGA fabric is composed of 4 building blocks: the logic module, the large SRAM, the micro SRAM and the mathblock. The logic module is the basic logic element and has advanced features:

- A fully permutable 4-input LUT (look-up table) optimized for lowest power
- A dedicated carry chain based on carry look-ahead technique
- A separate flip-flop which can be used independently from the LUT

The 4-input look-up table can be configured either to implement any 4-input combinatorial function or to implement an arithmetic function where the LUT output is XORed with carry input to generate the sum output.

Dual-Port Large SRAM (LSRAM)

Large SRAM (RAM1Kx18) is targeted for storing large memory for use with various operations. Each LSRAM block can store up to 18,432 bits. Each RAM1Kx18 block contains two independent data ports: Port A and Port B. The LSRAM is synchronous for both Read and Write operations. Operations are triggered on the rising edge of the clock. The data output ports of the LSRAM have pipeline registers which have control signals that are independent of the SRAM's control signals.

Three-Port Micro SRAM (uSRAM)

Micro SRAM (RAM64x18) is the second type of SRAM which is embedded in the fabric of SmartFusion2 devices. RAM64x18 uSRAM is a 3-port SRAM; it has two read ports (Port A and Port B) and one write port (Port C). The two read ports are independent of each other and can perform Read operations in both synchronous and asynchronous modes. The write port is always synchronous. The uSRAM block is approximately 1 Kb (1,152 bits) in size. These uSRAM blocks are primarily targeted for building embedded FIFOs to be used by any embedded fabric masters.

Math Blocks for DSP Applications

The fundamental building block in any digital signal processing algorithm is the multiply-accumulate function. SmartFusion2 implements a custom 18x18 Multiply-Accumulate (18x18 MACC) block for efficient implementation of complex DSP algorithms such as finite impulse response (FIR) filters, infinite impulse response (IIR) filters, and fast Fourier transform (FFT) for filtering and image processing applications.

Each mathblock has the following capabilities:

- Supports 18x18 signed multiplications natively (a[17:0] x b[17:0])
- Supports dot product; the multiplier computes:

  $(A[8:0] \times B[17:9] + A[17:9] \times B[8:0]) \times 2^9$
- Built-in addition, subtraction, and accumulation units to combine multiplication results efficiently

In addition to the basic MACC function, DSP algorithms typically need small amounts of RAM for coefficients and larger RAMs for data storage. SmartFusion2 micro RAMs are ideally suited to serve the needs of coefficient storage while the large RAMs are used for data storage.

Microcontroller Subsystem (MSS)

The microcontroller subsystem (MSS) contains a high-performance integrated Cortex-M3 processor, running at up to 166 MHz. The MSS contains an 8 Kbyte instruction cache to provide low latency access to internal eNVM and external DDR memory. The MSS provides multiple interfacing options to the FPGA fabric in order to facilitate tight integration between the MSS and user logic in the fabric.

ARM Cortex-M3 Processor

The MSS uses the latest revision (r2p1) of the ARM Cortex-M3 processor. Microsemi's implementation includes the optional embedded trace macrocell (ETM) features for easier development and debug and the memory protection unit (MPU) for real-time operating system support.

Cache Controller

In order to minimize latency for instruction fetches when executing firmware out of off-chip DDR or on-chip eNVM, an 8 kbyte, 4-way set associative instruction cache is implemented. This provides zero wait state access for cache hits and is shared by both I and D code buses of the Cortex-M3 processor. In the event of cache misses, cache lines are filled, replacing existing cache entries based on a least recently used (LRU) algorithm.

There is a configurable option available to operate the cache in a locked mode, whereby a fixed segment of code from either the DDR or eNVM is copied into the cache and locked there, so that it is not replaced when cache misses occur. This would be used for performance-critical code.

It is also possible to disable the cache altogether, which is desirable in systems requiring very deterministic execution times.

The cache is implemented with SEU tolerant latches.

DDR Bridge

The DDR bridge is a data bridge between four AHB bus masters and a single AXI bus slave. The DDR bridge accumulates AHB writes into write combining buffers prior to bursting out to external DDR memory. The DDR bridge also includes read combining buffers, allowing AHB masters to efficiently read data from the external DDR memory from a local buffer. The DDR bridge optimizes reads and writes from multiple masters to a single external DDR memory. Data coherency rules between the four masters and the external DDR memory are implemented in hardware. The DDR bridge contains three write combining / read buffers and one read buffer. All buffers within the DDR bridge are implemented with SEU tolerant latches and are not subject to the single event upsets (SEUs) that SRAM exhibits. SmartFusion2 devices implement three DDR bridges in the MSS, FDDR, and MDDR subsystems.

AHB Bus Matrix (ABM)

The AHB bus matrix (ABM) is a non-blocking, AHB-Lite multi-layer switch, supporting 10 master interfaces and 7 slave interfaces. The switch decodes access attempts by masters to various slaves, according to the memory map and security configurations. When multiple masters are attempting to access a particular slave simultaneously, an arbiter associated with that slave decides which master gains access, according to a configurable set of arbitration rules. These rules can be configured by the user to provide different usage patterns to each slave. For example, a number of consecutive access opportunities to the slave can be allocated to one particular master, to increase the likelihood of same type accesses (all reads or all writes), which makes more efficient usage of the bandwidth to the slave.

System Registers

The MSS System registers are implemented as an AHB slave on the AHB bus matrix. This means the Cortex-M3 processor or a soft master in the FPGA fabric may access the registers and therefore control the MSS. The System registers can be initialized by user-defined flash configuration bits on power-up. Each register also has a flash bit to enable write protecting the contents of the registers. This allows the MSS system configuration to be reliably fixed for a given application.

Fabric Interface Controller (FIC)

The FIC block provides two separate interfaces between the MSS and the FPGA fabric: the MSS master (MM) and fabric master (FM). Each of these interfaces can be configured to operate as AHB-Lite or APB3. Depending on device density, there are up to two FIC blocks present in the MSS (FIC_0 and FIC_1).

Embedded SRAM (eSRAM)

The MSS contains two blocks of 32 KB eSRAM, giving a total of 64 KB. Having the eSRAM arranged as two separate blocks allows the user to take advantage of the Harvard architecture of the Cortex-M3 processor. For example, code could be located in one eSRAM, while data, such as the stack, could be located in the other.

The eSRAM is designed for Single Error Correct Double Error Detect (SECDED) protection. When SECDED is disabled, the SRAM usually used to store SECDED data may be reused as an extra 16 KB of eSRAM.

Embedded NVM (eNVM)

The MSS contains up to 512 KB of eNVM (64 bits wide). Accesses to the eNVM from the Cortex-M3 processor are cacheable.

DMA Engines

Two DMA engines are present in the MSS: high performance DMA and peripheral DMA.

High Performance DMA (HPDMA)

The high-performance DMA (HPDMA) engine provides efficient memory to memory data transfers between an external DDR memory and internal eSRAM. This engine has two separate AHB-Lite interfaces—one to the MDDR bridge and the other to the AHB bus matrix. All transfers by the HPDMA are full word transfers.

Peripheral DMA (PDMA)

The peripheral DMA engine (PDMA) is tuned for offloading byte-intensive operations, involving MSS peripherals, to and from the internal eSRAMs. Data transfers can also be targeted to user logic/RAM in the FPGA fabric.

APB Configuration Bus

On every SmartFusion2 device memory, an APB configuration bus is present to allow the user to initialize the SERDES ASIC blocks, the fabric DDR memory controller, and user instantiated peripherals in the FPGA fabric.

Peripherals

A large number of communications and general purpose peripherals are implemented in the MSS.

USB Controller

The MSS contains a high speed USB 2.0 On-The-Go (OTG) controller with the following features:

- Operates either as the function controller of a high-speed / full-speed USB peripheral or as the host/peripheral in point-to-point or multi-point communications with other USB functions.
- Complies with the USB 2.0 standard for high-speed functions and with the *On-The-Go* supplement to the USB 2.0 specification.
- Supports OTG communications with one or more high-speed, full-speed, or low-speed devices.

TSE Ethernet MAC

The triple speed Ethernet (TSE) MAC supports IEEE 802.3 10/100/1000Mbps Ethernet operation. The following PHY interfaces are directly supported by the MAC:

- RMII
- GMII
- MII
- TBI

The Ethernet MAC hardware implements the following functions:

- 4 KB internal transmit FIFO and 8 KB internal receive FIFO
- IEEE 802.3X full-duplex flow control
- DMA of Ethernet frames between internal FIFOs and system memory (such as eSRAM or DDR)
- Cut-through operation
- SECDED protection on internal FIFOs

SGMII PHY Interface

SGMII mode is implemented by means of configuring the MAC for 10-bit interface (TBI) operation, allocating one of the high-speed serial channels to SGMII, and by implementing custom logic in the fabric.

10 Gbps Ethernet

Support for 10 Gbps Ethernet is achieved by programming the SERDES interface to XAUI mode. In this mode, a soft 10G EMAC with XGMII interface can be directly connected to the SERDES interface.

Communication Block (COMM_BLK)

The COMM block provides a UART-like communications channel between the MSS and the system controller. System services are initiated through the COMM block. System services such as *Enter Flash*Freeze Mode* are initiated though this block.

SPI

The serial peripheral interface controller is compliant with the Motorola SPI, Texas Instruments synchronous serial, and National Semiconductor MICROWIRE™ formats. In addition, the SPI supports interfacing to large SPI flash and EEPROM devices by way of the slave protocol engine. The SPI controller supports both Master and Slave modes of operation.

The SPI controller embeds two 4×32 (depth × width) FIFOs for receive and transmit. These FIFOs are accessible through RX data and TX data registers. Writing to the TX data register causes the data to be written to the transmit FIFO. This is emptied by transmit logic. Similarly, reading from the RX data register causes data to be read from the receive FIFO.

Multi-Mode UART (MMUART)

SmartFusion2 devices contain two identical multi-mode universal asynchronous/synchronous receiver/transmitter (MMUART) peripherals that provide software compatibility with the popular 16550 device. They perform serial-to-parallel conversion on data originating from modems or other serial devices, and perform parallel-to-serial conversion on data from the Cortex-M3 processor to these devices.

The following are the main features supported:

- Fractional baud rate capability
- Asynchronous and synchronous operation
- Full programmable serial interface characteristics
  - Data width is programmable to 5, 6, 7, or 8 bits
  - Even, odd, or no-parity bit generation/detection
  - 1,1½, and 2 stop bit generation
- 9-bit address flag capability used for multidrop addressing topologies

I^2C

SmartFusion2 devices contain two identical master/slave I^2C peripherals that perform serial to-parallel conversion on data originating from serial devices, and perform parallel-to-serial conversion on data from the ARM Cortex-M3 processor, or any other bus master, to these devices. The following are the main features supported:

- I^2C v2.1
  - 100 Kbps
  - 400 Kbps
- Dual-slave addressing
- SMBus v2.0
- PMBus v1.1

Clock Sources: On-Chip Oscillators, PLLs, and CCCs

SmartFusion2 devices have two on-chip RC oscillators—a 1 MHz RC oscillator and a 50 MHz RC oscillator—and up to two main crystal oscillators (32 KHz–20 MHz). These are available to the user for generating clocks to the on-chip resources and the logic built on the FPGA fabric array. The second crystal oscillator available on the SmartFusion2 devices is dedicated for RTC clocking. These oscillators (except the RTC crystal oscillator) can be used in conjunction with the integrated user phase-locked loops (PLLs) and FAB_CCCs to generate clocks of varying frequency and phase. In addition to being available to the user, these oscillators are also used by the system controller, power-on reset circuitry, MSS during Flash*Freeze mode, and the RTC.

SmartFusion2 devices have up to eight fabric CCC (FAB_CCC) blocks and a dedicated PLL associated with each CCC to provide flexible clocking to the FPGA fabric portion of the device. The user has the freedom to use any of the eight PLLs and CCCs to generate the fabric clocks and the internal MSS clock from the base fabric clock (CLK_BASE). There is also a dedicated CCC block for the MSS (MSS_CCC) and an associated PLL (MPLL) for MSS clocking and de-skewing the CLK_BASE clock. The fabric alignment clock controller (FACC), part of the MSS CCC, is responsible for generating various aligned clocks required by the MSS for correct operation of the MSS blocks and synchronous communication with the user logic in the FPGA fabric.

High Speed Serial Interfaces

SERDES Interface

SmartFusion2 has up to four 5 Gbps SERDES transceivers, each supporting the following:

- 4 SERDES/PCS lanes
- The native SERDES interface facilitates implementation of Serial RapidIO (SRIO) in fabric or an SGMII interface for the Ethernet MAC in MSS

PCI Express (PCIe)

PCIe is a high speed, packet-based, point-to-point, low pin count, serial interconnect bus. The SmartFusion2 family has two hard high-speed serial interface blocks. Each SERDES block contains a PCIe system block. The PCIe system is connected to the SERDES block and following are the main features supported:

- Supports x1, x2, and x4 lane configuration
- Endpoint configuration only
- PCI Express Base Specification Revision 2.0
- 2.5 and 5.0 Gbps compliant
- Embedded receive (2 KB), transmit (1 KB) and retry (1 KB) buffer dual-port RAM implementation
- Up to 2 Kbytes maximum payload size
- 64-bit AXI or 32-bit/64-bit AHBL Master and Slave interface to the application layer
- 32-bit APB interface to access configuration and status registers of PCIe system
- Up to 3 x 64 bit base address registers
- 1 virtual channel (VC)

XAUI/XGXS Extension

The XAUI/XGXS extension allows the user to implement a 10 Gbps (XGMII) Ethernet PHY interface by connecting the Ethernet MAC fabric interface through an appropriate soft IP block in the fabric.

High Speed Memory Interfaces: DDRx Memory Controllers

There are up to three DDR subsystems, MDDR (MSS DDR) and FDDR (fabric DDR) present in SmartFusion2 devices. Each subsystem consists of a DDR controller, PHY, and a wrapper. The MDDR has an interface from the MSS and fabric, and FDDR provides an interface from the fabric.

The following are the main features supported by the FDDR and MDDR:

- Support for LPDDR, DDR2, and DDR3 memories
- Simplified DDR command interface to standard AMBA AXI/AHB interface
- Up to 667 Mbps (333 MHz double data rate) performance
- Supports 1, 2, or 4 ranks of memory
- Supports different DRAM bus width modes: x16, x18, x32, and x36
- Supports DRAM burst length of 2, 4, or 8 in full bus-width mode; supports DRAM burst length of 2, 4, 8, or 16 in half bus-width mode
- Supports memory densities up to 4 GB
- Supports a maximum of 8 memory banks
- SECDED enable/disable feature
- Embedded physical interface (PHY)
- Read and Write buffers in fully associative CAMs, configurable in powers of 2, up to 64 Reads plus 64 Writes
- Support for dynamically changing clock frequency while in self-refresh
- Supports command reordering to optimize memory efficiency
- Supports data reordering, returning critical word first for each command

MDDR Subsystem

The MDDR subsystem has two interfaces to the DDR. One is an AXI 64-bit bus from the DDR bridge within the MSS. The other is a multiplexed interface from the FPGA fabric, which can be configured as either a single AXI 64-bit bus or two 32-bit AHB-Lite buses. There is also a 16-bit APB configuration bus, which is used to initialize the majority of the internal registers within the MDDR subsystem after reset. This APB configuration bus can be mastered by the MSS directly or by a master in the FPGA fabric. Support for 3.3 V Single Data Rate DRAMs (SDRAM) can be obtained by using the SMC_FIC interface in the MDDR subsystem. Users would then instantiate a soft AHB or AXI SDRAM memory controller in the FPGA fabric and connect I/O ports to 3.3 V MSIO.

FDDR Subsystem

The FDDR subsystem has one interface to the DDR. This is a multiplexed interface from the FPGA fabric, which can be configured as either a single AXI 64-bit bus or two 32-bit AHB-Lite buses. There is also a 16-bit APB configuration bus, which is used to initialize the majority of the internal registers within the FDDR subsystem after reset. This APB configuration bus can be mastered by a master in the FPGA fabric.

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