**Bandwidth Engine (BE) Overview**

The **BLAZAR Family of Accelerator Engines** are high capacity, high-speed memories that support high bandwidth, fast random memory access rates and includes optional **embedded In-Memory Functions (IMF)** that solve critical memory access challenges for memory bottlenecked applications like network search, statistics, buffering, security, firewall, 8k video, anomaly detect, genomics, ML random forest of trees, graph walking, traffic monitoring, AI and IoT.

All Accelerator Engines have two ways to be uses in a system:
1. As a standard parallel like QDR, SyncSRAM or RLDRAM
2. As a high density, high bandwidth memory with Optional In-Memory Acceleration Functions

Both modes are independent. You do not have to use the In-Memory functions if they are not useful in your application. In that case, you would use the Accelerator Engine like any other memory.

### Base Features: The Bandwidth Engine 2 RMW (BE2-RMW)

- **576 Mb** of tRC of 3.2 ns memory
  - Replaces 4 QDR type memories
- **In-Memory BURST functions**
- **In-Memory RMW functions**
- **RTL Memory Controller**

### Key Features - Memory

- **576 SRAM (8M x 72b)**
  - User defined WORD width
  - Typical 8x, 16x, 32x, 36x, ... 72x
- **High Bandwidth, low pin count serial interface**
  - Highly efficient reliable transport command and data protocol optimized for 90% efficiency
  - Eases board layout and signal integrity, minimal trace length matching required, operates over connectors
  - Reduction of I/O pins from 5x to 45x depending on equivalent memory density and type
- **High access rate SRAM class memory**
  - Up to 3.3 Billion transactions/sec
  - 2.7 ns tRC
- **Highest Single Chip Bandwidth** – up to 320 Gb/s throughput (160 full duplex)

### Applications Focus

- Slower speed applications needing high capacity
- SRAM with high capacity and high speed
- High bandwidth data access application where low latency and movement of data is a critical
- Applications that use base level compute or decisions functions
- FPGA Acceleration for Xilinx and Intel

### Key Features – In-Memory Functions

- The Acceleration function is optional and does not impact the device used as a memory only

**BURST In-Memory Function**

- For sequential Read or Write functions for data movement
- Burst length: 1, 2, 4 or 8 words
- Can double or triple QDR bandwidth

**RMW In-Memory Function**

- RMW are Read/Modify/Write functions
- Includes may functions for compute and decision
- Examples: ADD, SUB, Compare, INC plus 15 other functions
- Increases execution speed and bandwidth

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MoSys Accelerator Engine Elements of BE2-RMW

MoSys Engines have a Unique Memory Architecture that can replace SyncRAM/RLDRAM memories and **Embeds In Memory Functions (IMF)** that execute many times faster. A single function replaces many traditional memory accesses.
**Common Key Features for Bandwidth Engines (BE2 & BE3)**

- **High capacity High-Speed Memory on a single device**
  - BE2 576Mb
  - BE3 1Gb

- **High speed tRC access**
  - BE2 with 3.2ns
  - BE3 with 2.7ns

- **Achieve the highest bandwidth possible**
  - Use of serial interface with high efficiency GCI protocol
  - BE2 with 3.3B access per sec
  - BE3 with 6.5B accesses per sec

- **Reduce number of interface pins compared to other memories**
  - Typical system uses 8 lanes or 32 pins
  - Highest bandwidth uses 16 lanes or 64 pins
  - Minimum use of 4 lanes on one port or 16 pins

- **Eliminate external components required for signal integrity**
  - On device Auto-Adaption to eliminate external signal conditioning board components
  - Signals will work over a backplane

- **Make the interface like a parallel QDR**
  - MoSys supplies an RTL memory controller that handles the memory and serial interface
  - Serial device interface is transparent to user
  - Provides a parallel QDR like Read/Write RTL interface

- **Make interface easily adapted to an AXI or Avalon bus**
  - Minimal RTL logic required
Benefits of BE2 vs QDR

**SUMMARY OF BENEFITS**

- **Capacity**: 576Mb memory replaces 4 QDR/SyncSRAM devices.
- **Cost**: One BE-2 with 4x the capacity is approximately the price of 2 QDR memories.
- **Pins**: Typical application uses only 16 signals (32 pins) with signal Auto-Adaptation.

**More High-Speed memory generally allows acceleration options for software and hardware architects/designers.**

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**Overview Comparison BE vs. QDR**

- **Memory size**
  - BE2 with 576Mb equivalent to 4 QDRs with 144Mb per device.
- **Device PCB board Space Saving**
  - 1 BE2 device vs 4 QDR devices.
- **Signal Pin Reductions**
  - 4 QDR...576Mb requires 500-720 pins.
  - 1 BE2...576Mb...BE2 typical system uses 8 lanes or 32 pins.
  - All BE devices have Auto-Adaptation which handles on-board signal tuning, eliminating the need for any external components to insure clean, reliable signals.
- **Cost**
  - One BE-2 with 4x the memory capacity is approximately the price of two QDR memories.
- **Application Benefits**
  - Larger Buffers, High Bandwidth.
  - Allows Realtime operations and analysis at Line rate.
  - Eliminates need for complex parallel operations using RLDARAM, HBM, or slow DRAM.
In-Memory Functions

Example of BURST Function (BE2/BE3/PHE)

Example In-Memory BURST time saving
- tRC 3ns
- QDR 144b read
- QPR 576b read
- QPR 4x of a QDR
- There are more than 12 different commands

Focused on DATA COMPUTING AND DECISION where there is need for memory location modification involving RMW in applications such as metering, as well a single or dual counter update for statistics. There are over 27 operations available such as add, subtract, compare, increment, etc.

Example In-Memory RMW time saving
Add a Number to a Location (RMW)
QDR Traditional Memory System
- 3 operations Time Analysis
- Total Time = 6ns + FPGA ADD TIME

MoSys In Memory Function
- 1 operations Time Analysis
- Total Time = 3ns

Compatibility Quazar - Blazar Family of Accelerator Engines
- MSP220 (QPR4) pin compatible MSR622/MSR820 (BE2)
- MSP230 (QPR8) pin compatible MSR630/MSR830 (BE3)
Simplifying User Interface to BE2/3 w/MoSys RTL Controller

**Interface Ports**

- Device has two, 8 lane independent ports
- Typical system uses one port (shown), 8 lanes or 32 pins
- Can use as few as 4 lanes on one port or 16 pins
- High bandwidth systems use both ports, 16 lanes, 64 pins
- Independent ports can operate as a dual port with simultaneous access between two FPGAs

**Serial Interface**

- Benefits of a serial interface allows high bandwidth over very few pins
- Key to bandwidth is the MoSys GCI interface that is transparent to the user with the MoSys-supplied FPGA RTL Memory controller

**MOSYS FPGA Parallel RTL Interface**

MoSys-Supplied RTL Controller Simplifies The User Interface with the BE

MoSys-supplied FPGA RTL Memory Controller interfaces with the MoSys Bandwidth Engine. This controller is between the User Application RTL logic and the BE device.

MoSys-Supplied RTL Controller Simplifies the User Interface with the BE

- It handles all the logic for the Serial GigaChip Interface (GCI) in the FPGA
- Eliminates the user having to design a serial interface by making it transparent and providing a QDR parallel-like interface
- Memory WORD width is user definable in RTL
  - Typical word widths are 8, 16, 32, 36, 64 ...
- While the memory on the BE2 is organized as 8Mx72b and the BE3 is 16Mx72b, the address conversion mapping from the selected WORD width to the BE memory is handled by the RTL
  - Address translation to BE memory organization is transparent to the application
- All memory addressing and commands are presented to the QDR like parallel interface
- If the optional In-Memory functions are used, the RTL controller will manage their execution

The signal interface at the User Application is a simple SRAM memory Address, Data, Control structure. This simple interface shields the users from the BE commands, serial interface and the scheduling logic and memory partition timing.
### High Speed GCI Serial Interface

#### Read Interface

<table>
<thead>
<tr>
<th>SIGNAL NAME</th>
<th>WIDTH</th>
<th>DIR</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>rd_p</td>
<td>1</td>
<td>In</td>
<td>Assertion of this signal indicates that this is a read transaction.</td>
</tr>
<tr>
<td>rd_addr_p</td>
<td>32</td>
<td>In</td>
<td>Read address. Please refer to the Address section of this specification to see the detail of this address field.</td>
</tr>
<tr>
<td>rd_partsel_p</td>
<td>1</td>
<td>In</td>
<td>Indicates the BE-2 partition that this read command will be operated upon: 0 = Partition 0 for GCI port A, Partition 1 for GCI port B 1 = Partition 2 for GCI port A, Partition 3 for GCI port B</td>
</tr>
<tr>
<td>rd_data_p0</td>
<td>*</td>
<td>Out</td>
<td>Returned data from BE-2 memory. This data is qualified by the &quot;rd_datav_p0&quot; signal</td>
</tr>
<tr>
<td>rd_data_p1</td>
<td>*</td>
<td>Out</td>
<td>Returned data from BE-2 memory. This data is qualified by the &quot;rd_datav_p1&quot; signal. Note that rd_data_p1 will only have valid data if rd_data_p0 is valid as well.</td>
</tr>
<tr>
<td>rd_datav_p0</td>
<td>1</td>
<td>Out</td>
<td>The Memory Controller asserts this signal to indicate the current data in the &quot;rd_data_p0&quot; bus is valid</td>
</tr>
<tr>
<td>rd_datav_p1</td>
<td>1</td>
<td>Out</td>
<td>The Memory Controller asserts this signal to indicate the current data in the &quot;rd_data_p1&quot; bus is valid. Note that rd_data_p1 will only have valid data if rd_data_p0 is valid as well</td>
</tr>
<tr>
<td>rd_wait_rq_p</td>
<td>1</td>
<td>Out</td>
<td>The Memory controller asserts &quot;rd_wait_rq_p&quot; to indicate that it cannot accept the current read request from user. The User Application should hold all the request signals (rd_p, rd_addr_p ...) until the de-assertion of this signal.</td>
</tr>
</tbody>
</table>

#### Write Interface

<table>
<thead>
<tr>
<th>SIGNAL NAME</th>
<th>WIDTH</th>
<th>DIR</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>wr_p</td>
<td>1</td>
<td>In</td>
<td>Assertion of this signal indicates that this is a write transaction.</td>
</tr>
<tr>
<td>wr_addr_p</td>
<td>32</td>
<td>In</td>
<td>Write address of the memory for this transaction. Please refer to the Address section of this specification to see the detail of this address field.</td>
</tr>
<tr>
<td>wr_partsel_p</td>
<td>1</td>
<td>In</td>
<td>Indicates the BE-2 partition that this write command will be operated upon: 0=Partition 0 for GCI port A, Partition 1 for GCI port B 1=Partition 2 for GCI port A, Partition 3 for GCI port B</td>
</tr>
<tr>
<td>wr_data_p</td>
<td>*</td>
<td>In</td>
<td>Write data from the User Application logic.</td>
</tr>
<tr>
<td>wr_wait_rq_p</td>
<td>1</td>
<td>Out</td>
<td>The Memory controller asserts &quot;wr_wait_rq_p&quot; to indicate that it cannot accept the current write request. The User Application should hold all the request signals (wr_p, wr_addr_p ...) until the de-assertion of this signal.</td>
</tr>
</tbody>
</table>
## Accelerator Engine Family Overview
### Software Defined - Hardware Accelerated

<table>
<thead>
<tr>
<th>In-Memory</th>
<th>Part Number</th>
<th>Description</th>
<th>Package</th>
<th>Interface</th>
<th>Memory</th>
<th>Access Rate</th>
<th>In-Memory Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pkg Size</td>
<td>Lanes</td>
<td>Rate per Lane Gb/s</td>
<td>BW MAX.</td>
<td>tRC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>mm</td>
<td>Tx/Rx</td>
<td>10.3</td>
<td>12.5</td>
<td>15.6</td>
</tr>
<tr>
<td>QPR4</td>
<td>MSQ220</td>
<td>QPR4 (Quad Partition Rate) 0.5 Gb</td>
<td>FCBGA</td>
<td>19x19</td>
<td>16</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>QPR8</td>
<td>MSQ230</td>
<td>QPR8 (Quad Partition Rate) 10G</td>
<td>FCBGA</td>
<td>27x27</td>
<td>16</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>BURST</td>
<td>MSR622</td>
<td>Bandwidth Engine 2 Burst Serial 0.5G High Access Memory</td>
<td>FCBGA</td>
<td>19x19</td>
<td>16</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>MSR620</td>
<td>Bandwidth Engine 3 Burst Serial 10G High Access Memory</td>
<td>FCBGA</td>
<td>27x27</td>
<td>16</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>RMW</td>
<td>MSR820</td>
<td>Bandwidth Engine 2 RMW Serial 0.5G High Access Memory with ALU for RMW functions</td>
<td>FCBGA</td>
<td>19x19</td>
<td>16</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>MSR830</td>
<td>Bandwidth Engine 3 RMW Serial 10G High Access Memory with ALU for RMW functions</td>
<td>FCBGA</td>
<td>27x27</td>
<td>16</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Program</td>
<td>MSP530</td>
<td>Programmable HyperSpeed Engine Serial Interface, 10G Memory, 32 RISC Processor cores for custom algorithms, compute, functions</td>
<td>FCBGA</td>
<td>27x27</td>
<td>16</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>RTL-AE</td>
<td>RTL Memory Controller for Bandwidth Engine and Programmable HyperSpeed Engine. Manages memory and the serial interface signals. Presents a QDR like parallel RTL interface to the user,</td>
<td>FPGA RTL Code</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

*BW MAX. = Aggregate of all SerDes lanes at the highest serial interface speed*

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### In-Memory Acceleration Functions

**THE MEMORY**
- Perfect SRAM replacement for QDR/RLDRAM devices
- High Speed Serial with GCI
- High Efficiency Serial Protocol
- High Speed Random-access SRAM
  - 1Gb memory
  - tRC 2.7ns

**OPTIONAL USE IN-MEMORY FUNCTIONS**
- Software/Hardware Accelerator Options from In Memory Functions (IMF)
- Burst IMF
  - High speed DATA MOVEMENT for sequential read and write
- RMW IMF
  - Multiple ALUs for Read/Modify/Write operations for COMPUTE and DECISION
- User Programmable IMF
  - Uses 32 RISC processors
  - Added levels of memory architecture
  - Parallel/Multi-thread Options

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### Optional Function Will Not Impact the Device When Used as Memory Only

**BURST In-Memory Function**
- For sequential Read or Write functions for data movement
- Burst length: 1, 2, 4, or 8 words
- Can double or triple QDR bandwidth
- Simultaneous execution of read and writes

**RMW In-Memory Function**
- RMW are Read/Modify/Write functions
- Includes many functions for compute and decision
- Examples: ADD, SUB, Compare, INC plus 15 other functions
- Increases execution, speed and bandwidth

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### Flexible Configuration Uses

**CONTACT MOSYS TO LEARN ABOUT THESE ADVANCED FEATURES**

- DUAL PORT
- PIPELINE
- HIGH BANDWIDTH

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