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## Embedded Processing and Control Solutions for Spartan-3 FPGAs

### Introduction

In a variety of applications, an embedded processor or controller is key to system flexibility, maintainability, and low cost. Spartan-3™ FPGAs support two powerful yet flexible Field Programmable Controller (FPC) solutions, shown in [Table 1](#). The PicoBlaze™ FPC is a simple, highly efficient 8-bit RISC controller optimized for the Spartan-3 FPGA architecture. The MicroBlaze™ FPC is a powerful, full-featured, high-performance 32-bit RISC processor offering high-level language and real-time operating system (RTOS) support.

**Table 1: Embedded Processing/Control Solutions for Spartan-3 FPGAs**

Function/Feature	PicoBlaze FPC	MicroBlaze FPC
Processor Architecture	8-bit RISC controller	32-bit RISC CPU
Typical Applications	Embedded control, state machines, I/O processing	Embedded computation and control
Memory Architecture	Harvard (separate data/code data paths)	Harvard (separate data/code data paths)
ALU/register width	8 bits (byte)	32 bits (word)
Registers	16 byte-wide	32 word-wide
Pipeline Stages	0	3
Code Address Space	512 or 1K instructions	512 to 4G bytes
Code Storage	Block RAM (internal)	Block RAM (internal) External memory
Data Address Space	64 bytes (internal)	0 to 4G bytes
Data Storage	Distributed RAM (internal)	Block RAM (internal) External memory
I/O Address Space	256 locations	N/A
Processor Instructions	57	106
Operands per Instruction	2	3
Clocks per Instruction	2	1 to 3, 34 for integer divide
Call/Return/Interrupt Stack	31 locations (internal)	Variable size, in data memory
Interrupts	1, Expandable	1, Expandable
Maximum Interrupt Latency	4 clock cycles (46 ns at maximum clock rate)	7 to 40 clock cycles (application dependent)
Instruction Cache	N/A	0, 2K, 4K, 8K, 16K, 32, or 64K

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Table 1: Embedded Processing/Control Solutions for Spartan-3 FPGAs (Continued)

Function/Feature	PicoBlaze FPC	MicroBlaze FPC
Data Cache	N/A	0, 2K, 4K, 8K, 16K, 32, or 64K
Hardware Multiplier	N/A	32x32 = 32 in 3 cycles
Hardware Divider	N/A	Optional, up to 20% performance improvement
Hardware Barrel Shifter	N/A	Optional, up to 15X performance improvement
Hardware Debugger Support	N/A	✓
LocalLink Direct Processor Interface	N/A	200 MB/sec communication

The PicoBlaze FPC is always fully embedded within a Spartan-3 FPGA using on-chip block RAM and distributed RAM for code and data storage. The MicroBlaze FPC optionally uses internal FPGA memory resources or interfaces to external memory to support larger code or data storage requirements. The Embedded Development Kit (EDK) for the MicroBlaze FPC includes hardware IP cores to support external Flash, SRAM, SDRAM, DDR DRAM, and ZBT SRAM memory. Similarly, the MicroBlaze FPC supports both instruction and data caches, each up to 64K bytes, to increase performance when connected to external memory.

Table 2: PicoBlaze and MicroBlaze Resource Requirements and Performance

Function/Feature	PicoBlaze FPC	MicroBlaze FPC
<b>Resource Requirements</b>		
Slices (4 slices = 1 CLB)	96	525
Block RAMs	0.5 or 1	2+
Effective cost in high-volume applications (250Ku, 2004)	From US\$0.40	From US\$1.40
Percent of XC3S50	13% – 25%	68%+
Percent of XC3S200	4% – 8%	27%+
Percent of XC3S400	3% – 6%	15%+
Percent of XC3S1000	2% – 4%	7%+
Percent of XC3S1500	2% – 3%	4%+
Percent of XC3S2000	1.3% – 3%	3%+
Percent of XC3S4000	0.5% – 1%	2%+
Percent of XC3S5000	0.5% – 1%	1.6%+
<b>Performance (Spartan-3 –4 speed grade)</b>		
Maximum clock frequency	87 MHz	85 MHz
Instructions per second	43.5M	85M
Dhrystone MIPS (D-MIPS)	N/A	68

Using Spartan-3 FPGAs, both MicroBlaze and PicoBlaze FPCs consume minimal FPGA resources and are highly cost effective, as shown in [Table 2](#). Complete PicoBlaze solutions

cost as little as \$0.40 in high-volume applications. MicroBlaze solutions start from \$1.40 in volume.

Both the MicroBlaze and PicoBlaze FPCs provide significant numbers of flexible I/O at much lower cost than off-the-shelf controllers. Similarly, the peripheral set for both FPCs can be customized to meet the specific feature, function, and cost requirements of the target application. Because both FPCs are delivered in synthesizable HDL, both cores are future-proof, safe from any possible product obsolescence. Being integrated into the FPGA, both FPCs reduce board space, design cost, and inventory.

## PicoBlaze Application Development Support

The PicoBlaze FPC solution is a simple 8-bit RISC controller with an easy-to-use assembler. The PicoBlaze core has no direct support for in-system debugging although it can be debugged using the standard Xilinx JTAG-based interface. A simple instruction-set simulator is available.

The PicoBlaze reference design also includes UART transmitter and receiver macros with integrated 16-byte FIFOs. The UART supports 8-bit data, no parity, with one stop bit.

## MicroBlaze Application Development Support

The MicroBlaze FPC offers complete application development support, including a full suite of software development tools, an IP library of processor hardware peripheral functions, plus in-circuit hardware debugger/emulation support.

### Embedded Development Kit (EDK)

The Embedded Development Kit (EDK) is an all-encompassing solution for creating embedded programmable systems design. The EDK includes and supports the MicroBlaze soft processor core. The EDK also includes support for the PowerPC™ hard processor core, which is only available within the Xilinx Virtex-II Pro and Virtex-II Pro X FPGA families.

#### Xilinx Platform Studio (XPS)

- Tools for editing software; creating hardware and software platforms
- Runs library generation, and compiler tool chains; generates implementation and simulation netlists for use with ISE Logic Design Tools

#### GNU Software Development Tools

- C/C++ compiler for MicroBlaze and PowerPC cores (GNU gcc)
- Debugger for MicroBlaze and PowerPC cores (GNU gdb)
- Other GNU utilities

#### Hardware/Software Development Tools

- XMD - Xilinx Microprocessor Debug engine for MicroBlaze and PowerPC cores
- SystemACE tools
- Data2BRAM – Updates internal block RAM contents without recompiling the FPGA design

#### Board Support Packages (BSPs)

- Stand Alone BSP - For non-RTOS systems (MicroBlaze and PowerPC cores)

### Operating Systems

Many embedded processing applications require operating system capabilities. The following operating systems and real-time operating systems (RTOS) have ports to the MicroBlaze FPC.

- Micrium μC/OS-II Real-Time Operating System  
<http://ucos-ii.com/>

- $\mu$ Clinux Operating System  
<http://www.uclinux.org>  
<http://www.uclinux.org/pub/uClinux/ports/microblaze/>
- ATI Nucleus Real-Time Operating System  
<http://www.mentor.com/nucleus>  
[http://www.mentor.com/nucleus/nucleus\\_cpu\\_support.html#xilinx](http://www.mentor.com/nucleus/nucleus_cpu_support.html#xilinx)
- Xilinx Microkernel (XMK) Libraries
  - ◆ Highly modular scheduler, network stack, and file system
  - ◆ Minimal resource requirements and footprint size
  - ◆ Royalty-free license included with EDK purchase
  - ◆ Fully supported by Xilinx

## Processor Peripheral IP Functions

The EDK includes the following processor IP cores that support the MicroBlaze FPC. The IP cores also include device drivers and RTOS adaptation layers. Add one or more IP cores to create a custom processor to meet specific application requirements.

### Processor Peripherals

- Timer/Counter
- Timebase/Watchdog Timer
- UART-Lite
- Interrupt Controller
- General-Purpose I/O port (GPIO)

### Serial I/O

- SPI Master and Slave
- JTAG UART
- 16450 UART\*
- 16550 UART\*
- I<sup>2</sup>C two-wire serial Master and Slave\*

### Memory Interfaces

- SDRAM controller and interface
- DDR SDRAM controller and interface
- Flash memory interface
- SRAM memory interface
- Block RAM interface

### Networking Interfaces

- Single-channel HDLC controller\*
- ATM Utopia L2 master and slave controller\*
- 10/100 Ethernet Media Access Controller (MAC)\* (Full and Lite versions)

\* IP core available as a separate product. Plugs into EDK. Evaluation versions available.

## In-Circuit Hardware Debugger Support

- EDK Software Debugger
  - ◆ Requires MicroBlaze Hardware Debug Module
  - ◆ Connects via FPGA JTAG port using Xilinx Parallel Cable IV
- Nohau In-Circuit Hardware Debugger for MicroBlaze FPC  
<http://www.nohau.com/emul-microblaze-pc.html>

## Related Materials and References

- MicroBlaze 32-bit RISC Processor  
[http://www.xilinx.com/ipcenter/processor\\_central/microblaze](http://www.xilinx.com/ipcenter/processor_central/microblaze)
- PicoBlaze 8-bit RISC Controller  
[http://www.xilinx.com/ipcenter/processor\\_central/picoblaze](http://www.xilinx.com/ipcenter/processor_central/picoblaze)
- Embedded Development Kit (EDK)  
<http://www.xilinx.com/ise/embedded/edk.htm>
- Embedded Systems Development Training Course  
<http://www.xilinx.com/support/training/abstracts/embedded-systems.htm>
- MicroBlaze Recorded Lectures  
<http://www.xilinx.com/support/training/mb.htm>

## Revision History

The following table shows the revision history for this document.

Date	Version	Revision
07/11/03	1.0	Initial Xilinx release.
08/11/03	1.0.1	Clarified RTOS ports to MicroBlaze in “Operating Systems” section.

