White Paper:  
FPGAs for Speed and Flexibility

Benefits of FPGA Modules derived from their Speed and Flexibility - You Can’t Do More for Less

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High Speed Control
Let's look at High Speed Control:

If traditional bus-interfaced I/O is used, you will find in an ideal situation a control loop execution time of approximately 1 µS. An example would be a CPU executing a real time OS and talking over the PCI Bus to an I/O module which is connected to the external interface world.

This execution time includes:

1. input to the I/O module across some transceiver,
2. transmission of the input over the PCI bus to the CPU,
3. application software execution layered on the RTOS,
4. an output command response generated by the application software,
5. transmission across the PCI bus to the I/O module,
6. and finally output through the I/O transceiver.

This same I/O control loop, when formulated around an FPGA module, has:

1. the input to the FPGA across some transceiver,
2. control loop execution in the FPGA,
3. and finally command output through the I/O transceiver.

This control loop is roughly 1000x faster. The control loop is executed in the FPGA just the other side of the I/O transceivers.
FPGA I/O Flexibility

The external world has a wide mix of I/O interfaces. Any FPGA module to be used must meet that interface. Acromag started with and developed a large family of FPGA modules. The IP-EP20x family of FPGA modules has a fixed I/O interface with several options including CMOS/TTL, RS422/485, mixtures of these, and LVDS.

The larger FPGA modules in the Virtex-4 and Virtex-5 family (PMC and XMC) offer rear I/O configurable within the FPGA via the constraints file to accommodate LVCMOS, LVTTL, and LVDS for 64 total connection points. Realizing that the need for I/O flexibility is paramount to a successful FPGA application, Acromag proceeded by providing additional I/O flexibility at the front I/O using the AXM mezzanine module concept. These AXM modules provide for wide flexibility with standard offerings of: TTL, RS422/485, LVDS, and 105MHz A/D. Custom modules for an open specification can also be designed by you or by Acromag to meet your specification.

Processing Power

So how fast can an FPGA module process data?

Speed is very important. You can see that the IP-EP20x family executes logic at 125Mhz. The Virtex-4 FPGA modules (PMC-LX/SX) perform at 500MHz. And the Virtex-5 family (PMC/XMC-VLX/VSX) processes data at the amazing rate of 550MHz.

But that’s not the whole story. FPGA devices on Acromag’s modules can execute state logic in several simultaneous parallel execution streams.

A digital clock manager is used to define the clock rate of a particular execution stream. Notice that the IP-EP20x family can only execute one state logic stream. However, the PMC-LX/SX family can operate up to 8 DCMs and the Virtex-5 (PMC/XMC-VLX/VSX) family up to 12. The Virtex-4 FPGA, running 8 DCMs at 500MHz, provides the horsepower of a 4GHz CPU. The Virtex-5 FPGA running 12 DCMs at 550MHz is pushing the horsepower of a 6.5GHz CPU.
FPGA I/O Overview

What we’ve learned thus far is that FPGAs are FAST and powerful. Let’s see pictorially what we’ve discussed so far.

Both the PMC and XMC modules make the FPGA device available to the customer for programming. Along with the FPGA device is both front and rear I/O plus a bus interface. The interface to the front and rear I/O is via FPGA lines coming directly from the customer programmed FPGA device. The rear I/O exits the module directly from the FPGA device.

The front I/O connector provides a mating location for the AXM mezzanine module which will support TTL, LVDS, RS422/485, and more as may be custom designed and implemented either by the customer, Acromag, or any 3rd party to an open specification.
**Communications, Logic, & Enablers**

Communications to/from the FPGA device is determined by the logic and any enablers loaded into the FPGA device. Logic consists of VHDL combining that which Acromag provides in the engineering design kit along with the applications logic devised by the customer.

Although all logic can and is often implemented in VHDL, some customers find it convenient to use as enablers:

1. soft core CPUs (i.e. Xilinx MicroBlaze or PicoBlaze),
2. an operating system on the soft core CPU (LINUX, Windows, VxWorks, or home-grown),
3. and logic coded in the customer’s preference of high level languages.

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**FPGA PMC/XMC-Module**
Putting it all Together

Now if we look at an application employing all the rich FPGA features together, we might have an application requiring six processes running at different digital clock manager clock rates such as:

1. DDR controller at 200MHz
2. SERDES running at 400MHz
3. A logic sequencer and FIFO manager running at 200MHz
4. FFT image processing screaming at 500MHz
5. A slow apparatus control interface at 1MHz
6. A bus interface & SDRAM controller running at 100MHz

Of course, as you can see, this implementation will use:

1. Front I/O coming through the AXM-D0x module
2. DDR RAM for intermediate high speed bit stream recording
3. The SDRAM as the DMA interface buffer to the host CPU
4. The bus interface, which can be PCI, PCI-X, or PCIe.

The serial bit stream enters through the AXM mezzanine module, is converted from serial to parallel data and stored into the DDR. Upon demand of the logic sequence and FIFO manager, data is pulled from the DDR, filtered and processed by the FFT image processor. Data then moves to the SDRAM in preparation for DMA to the host CPU across the bus interface.
**Sophisticated Tools**

What we just saw was a very sophisticated set of integrated processes. They are successful because of the rich development and debug tools available from the FPGA manufacturer along with the engineering design kit available from Acromag.

The Xilinx ISE foundation provides the FPGA developer with the tools to create logic, structure logic, place logic into the FPGA for execution, and debug logic using ChipScope for the Xilinx parts.

Modeling and process simulation is often accomplished at a higher level of abstraction through tools such as SIMULINK and MathLab.

**You Can’t Do More for Less**

To conclude, FPGA’s provide a very unique set of high performance features ready for deployment in challenging applications.

- Faster logic processing than any real-time system
- Soft-cores provide for powerful customization and re-use of developed logic
- The Acromag FPGA platforms offer significant off-the-shelf customization
- Acromag offers a family of FPGAs which permits selection of the right level of performance and memory capacities limiting excessive costs
- Acromag’s FPGA modules work to support distributed computation and application customization.
- The applications: control, digital signal processing, communications, simulation, etc.

With an FPGA, You can’t do more for less!

**About Acromag**

Acromag has designed and manufactured measurement and control products for more than 50 years. They are an AS9100 and ISO 9001-certified international corporation with a world headquarters near Detroit, Michigan and a global network of sales representatives and distributors. Acromag offers a complete line of embedded I/O products including bus boards, mezzanine modules, wiring accessories, and software. Industries served include military, aerospace, manufacturing, transportation, utilities, and scientific research laboratories.

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