Introduction to LEON3, GRLIB

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Few words about KAL:

- KAL provides professional ASIC consultancy for Digital/Analog ASIC Projects
- Silicon IP services
- Projects
- More info at our web site

www.KALtech.co.il
• Located in Gothenburg, Sweden

• Private Company

• Management team with 40 years combined experience in the space sector:
  – Per Danielsson: CEO
  – Jiri Gaisler: Founder and CTO
  – Sandi Habinc: System Design

• 14 engineers with expertise within electronics, ASIC and software design
GAISLER PRODUCT PORTFOLIO

- LEON3 processor, STD/FT
- LEON compatible IP-blocks:
  - GRFPU, Floating Point Unit
  - Memory controllers
  - PCI, CAN, USB, I2C, SPI
  - 10/100/1000 Mbit Ethernet MAC
  - SpaceWire, 1553

- LEON development boards
- Test Systems
- Technical support and adaptations
- Full software development environment based on open source tools

- TSIM, ERC32 and LEON simulator
- GRMON, LEON Debug monitor
- RTOS ports for VxWorks & ThreadX

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LEON3 FEATURES

High Performance
- 400 MHz on 0.13 µm ASIC (std-cell)
- 125 MHz on FPGA

Open Source Standard SW Environment
- GNU C/C++ compiler
- RTEMS real-time kernel
- eCos real-time kernel
- SnapGear Linux

Low Gate Count
- 25 k gates for ASIC
- 3,500 LUT
- 4,000 Cells

Full Simulator and Debug Monitor
- Simulator for developing and debugging SW
- Monitor for HW and SW validation

Customer Approval and Validation
- LEON is the standard processor of ESA
- Numerous commercial customers are using LEON

IP-Library of Cores for SOC Design
- Portable and Vendor independent
- Connection through standard AMBA bus

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LEON3 SPARC V8 PROCESSOR

- 7-stage pipeline, multi-processor support
- Separate multi-set caches with LRU/LRR/RND
- On-chip debug support unit with trace buffer
- 250/400 MHz on 0.18/0.13 um, 250/400 MIPS, 25 Kgates
- 125 MHz on FPGA, 3500 LUT
- Highly configurable:
  - Cache size 1-256 Kbyte, sets 1-4, LRU/LRR Random
  - Mul/div options, FPU, MMU
  - Pipeline optimisation for specific target technologies
- SEU tolerance by design for space applications, FT version

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GRLIB is a complete design environment:
- LEON3 / LEON3-FT
- Floating Point Unit, Mul/Div
- Timers, Interrupt Controller
- Memory controllers (SRAM, SDRAM, DDR)
- SpaceWire, CAN, Ethernet, PS2, UART, PCI, MIL-STD-1553B, USB 2.0
- CCSDS Telemetry/Telecommand
- AMBA on-chip bus with Plug & Play support
- Support for many tools and prototyping boards
- Support for portability between technologies
GRLIB PLUG & PLAY

- Fully compliant with AMBA 2.0 AHB/APB buses, with additional sideband signals
- Plug&Play information allows for distributed address decoding, interrupt steering, cachability information, etc.
- No modification of centralized resources, e.g. address decoder, arbiter or interrupt controller.
- Automatic generation of table including vendor and device identifier for each attached core, including version and interrupt information.
- Software can scan table and install the corresponding drivers etc.
- Hardware debuggers can use table for initializing the various IP cores etc.

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TSIM SIMULATOR

- Emulates LEON3 system including memory
  - Configurable cache size/size, PROM/SRAM size/width
  - Break/watchpoints, trace buffer, stack backtrace
  - Code coverage, check-pointing, profiling, GDB I/F
  - Loadable modules (I/O and AHB) for extension, library version
  - 20 MIPS, accuracy better than 5% (1% typical)
  - Memory EDAC emulation
  - SDRAM support up to 512 Mbyte
  - GRFPU timing
  - MMU emulation

- Used in many projects (space and consumer)
VHDL Simulation

VHDL Simulation

VSIM 3> run 4000
# LEON-1 VHDL model and generic testbench, copyright ESA/ESTEC 1999
# Comments and bug reports to Jiri Gaisler, jgais@ws.estec.esa.nl
#
# Testbench configuration:
# 8 kbyte 32-bit rom, 0-ws
# 2x128 kbyte 32-bit ram, 0-ws
#
# 0x00000000 flush 0
# 0x00000004 ssethi %hi(0x1000), %g1
# 0x00000000 or %g1, 0x00, %g1
# 0x00000000 mov %g1, %psr
# 0x00000010 mov 0, %swm
# 0x00000014 mov 0, %tbr

VSIM 10>

wave -default
GRGMON

- Debug monitor for LEON2 systems providing non-intrusive debug environment on real target hardware
  - Read/write access to all LEON registers and memories
  - Download and execution of applications
  - Built-in disassembler and trace buffer
  - Breakpoint and watchpoint management
  - Command-line mode or graphical user interface
  - Remote connection to GNU debugger (GDB)
  - Supported debug interfaces: PCI, USB, Ethernet, JTAG, UART and SpaceWire
- Used in many projects (space and consumer)
Eclipse
```
int i;
fixed = 0.0; floated = 0.0;
printf("Starting \n");
    /* rewrite (output); */
    printf("Perm\n");
    timer = GetClock(); Perm(); xtTimes[1] = GetClock() - timer;
    printf("fixed + permbase \times xtTimes[1]\n");
    fixed = fixed + permbase * xtTimes[1];
    printf("Towers\n");
    timer = GetClock(); Towers(); xtTimes[2] = GetClock() - timer;
    printf("fixed + towersbase \times xtTimes[2]\n");
    fixed = fixed + towersbase * xtTimes[2];
    printf("Queen\n");
    timer = GetClock(); Queen(); xtTimes[3] = GetClock() - timer;
    printf("fixed + queenbase \times xtTimes[3]\n");
    fixed = fixed + queenbase * xtTimes[3];
    printf("Int\n");
    timer = GetClock(); Int(); xtTimes[4] = GetClock() - timer;
    printf("fixed + IntBase \times xtTimes[4]\n");
    fixed = fixed + IntBase * xtTimes[4];
    printf("Mm\n");
    timer = GetClock(); Mm(); xtTimes[5] = GetClock() - timer;
    printf("fixed + mmbase \times xtTimes[5]\n");
    fixed = fixed + mmbase * xtTimes[5];
    printf("Puzzle\n");
    printf("fixed + puzzlebase \times xtTimes[6]\n");
    fixed = fixed + puzzlebase * xtTimes[6];
    printf("Quick\n");
    timer = GetClock(); Quick();
```

Dump of assembler code from 0x2000000 to 0x2000900:
[Output of assembler code]

Reading symbols from stanford.exe... done.
(gdb) exit extended remote localhost:1234
Remote debugging using localhost:1234
0x2000000 in test_start (gdb)
```

Disassembling location 0x2000000 to 0x2000300 done.
```

Nonfloating point composite is 318
Floating point composite is 472

Program exited normally, task per
```
Available today
- RTEMS-4.6.5+
- VxWorks 5.4, 6.3, 6.4
- ThreadX
- eCos
- Linux-2.6.21, uClinux-2.0.x

Under development
- Nucleus
- LynxOS
RTEMS FOR LEON

- RCC tool-chain, based on RTEMS-4.6.5 with extensions
- Initially ported from ERC32 BSP, maintained by GR
- Updates are being merged with RTEMS CVS (4.8)
- Supports AT697 with standard peripherals and any LEON3FT configuration with plug&play
- GRLIB drivers: GRPCI, GRSPW, CANOC, 1553, GRETH
- New drivers added for RASTA and GR701
  - InSilicon-PCI, GRSPW, HCAN, PCI-F
  - LAN91C111 Ethernet MAC
Port and BSP available for VxWorks 5.4, 6.3 and 6.4
Full source code for BSP and port (6.x) provided
Compiled with DIAB or GCC (VxWorks-5.4)
LEON2 Drivers:
- standard peripherals, LAN91C111
- Supports MMU in COLE
- GR701 support in development (PCI, SPW, 1553, CAN)
LEON3 Drivers:
- GRLIB: standard peri. + GRETH, GRSPW, CAN, 1553BRM
- LEON3FT MMU support, LAN91C111
Workbench support on Linux and Windows hosts
THREADEX FOR LEON

- Popular RTOS for deeply embedded systems
- LEON Port and BSP available for ThreadX-5.0
- Full source code for Kernel, BSP and port provided
- Small foot-print, GCC tool-chain
- Network stack (NetX) under testing
- USB stack (USBX) to be ported Q4-2007
- Has been used by NASA with ERC32 and Mongoose
  - NASA Deep Impact Sensor
- Device driver development done by end-user

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Gaisler Research uses an open source business model based on Dual Licensing. Dual licensing allows to provide commercial licenses for a fee, while at the same time offering the source code under open source licenses.

- Free access for the academic research community
- Free evaluation possibilities for companies
- Large user base gives sizable and quick feedback
- Commercial licenses for IP cores to companies not willing to comply with the GPL license
- Commercial licenses for the LEON3 FT IP core library
- Provide technical support and development tools
The Fault Tolerant (FT) version is used for critical, military and aerospace applications.

The Standard version (Non-FT) is used for commercial applications.
CUSTOMERS AND APPLICATION

- **Commercial examples**
  - GPS receiver
  - Set top boxes
  - Sensors
  - RF-ID
  - Printers
  - Wireless
  - Power transmission
  - Video games

- **Space**
  - All European space companies
  - US, China, Canada, Korea, Israel, India, Taiwan

- **Research and Universities**
  - Used by hundreds of universities and research centres around the world
## Other processors vs. Leon

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>ARM 9</th>
<th>ARM 11</th>
<th>ARC 700</th>
<th>Xtensa LX</th>
<th>LEON3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clock frequency (MHz)</td>
<td>250</td>
<td>400</td>
<td>400</td>
<td>350</td>
<td>400</td>
</tr>
<tr>
<td>Pipe-line stages</td>
<td>5</td>
<td>8</td>
<td>7</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Gate count</td>
<td>000’100 &lt;</td>
<td>000’100 &lt;</td>
<td>000’100</td>
<td>000’28</td>
<td>000’25</td>
</tr>
<tr>
<td>Synthesizable to FPGA</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Third party SW development tools</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Open Source VHDL</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>License Cost</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
<td>Low</td>
</tr>
</tbody>
</table>

**Clock frequency:** Depends on process and technology, figures are approximate for 0.13 µm process

**Gate count:** Depends on processor configuration, figures are for bare processor
- LEON3 independently certified by Sparc International
- Verified for space use according to the stringent requirements of the European Space Agency
- Used as reference design in the low power design package
- Used as reference design by major tool vendors: (Synopsis, Synplify, Mentor, Spirit)
- Promoted by Cadence through the open choice programme
- Partnership for military and space FPGA applications
Example on the NX750LP