

GRETA

Technical description

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January 6, 2014

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Chapter 1

Introduction

This document is a technical description of the GRETA expansion board for Amiga 500. The intended audience is any person who wants to learn more about how to develop hardware for the Amiga computer in general, and especially the one who wants to develop the GRETA expansion further.

All schematics, PCB layout and VHDL code described in this document are released under the GNU General Public License, version 3. Gerber files are readily available and can be sent to a PCB manufacturer for production. Refer to the schematic files for bill of materials (BOM).

As of January 2014, some features are still to be implemented in VHDL as well as corresponding software device drivers on the Amiga.

Be free to contact the original author at martin@fripost.org. Also feel free and welcome to develop this project further under the current license and report your progress to the author. Cheerful support and cooperation will be given. :-)

1.1 Background

The Amiga 500 computer, based on the Amiga platform, became popular in the late eighties for combining low-cost, a powerful CPU (Motorola MC68000), advanced multimedia functionality and a well-designed operating system. The Amiga platform was designed to be a basis for business, creative computing, video production, as well as pure game machines of its times. Hardware expandability and modularity was designed into the architecture from start. The auto-configuration protocol AUTOCONFIG is an example of this (more on this later).

A set of on-board custom hardware chips were responsible for DMA-powered multimedia functionality including graphics, hardware sprites, memory copying, four channels of digital audio, and more.

Amiga 500 came as standard with memory configurations of 512KiB or 1024KiB. This memory resides on a memory bus which is shared between the main CPU and the Amiga custom chips. When the custom chips are heavily utilized, only a fraction of the memory bus time is available for the CPU to use.

For more information on the Amiga architecture, see [1].

1.2 GRETA Features

GRETA expansion board is a hardware expansion which connects to the expansion bus on the Amiga 500 computer and adds the following features to the system¹.

8 MiB Fast RAM

The RAM is always available to the main CPU. There are no wait states involved so throughput is 3.4 MiB/s for a PAL Amiga 500. This also holds when the on-board peripherals described below are used. It is installed automatically in the system at boot by using the AUTOCONFIG protocol.

micro SD

A uSD flash memory controller is used for non-volatile storage. All accesses are performed by DMA to the 8 MiB Fast RAM. AUTOCONFIG together with custom device drivers loaded from the GRETA board is responsible for allowing booting from uSD memory.

Ethernet controller

A custom network controller that allows for 10/100MBit Ethernet networking. The network controller performs DMA to the 8 MiB Fast RAM.

External I/O

An external I/O pin header allows for use for diverse use. For example a fast UART can be implemented. Another option is to use it as a debug port implementing the GDB Remote Serial protocol [2].

1.3 Expandability of GRETA

The GRETA expansion board can in principle be the basis of any peripheral suitable for the expansion bus of Amiga 500. For example a graphics or SATA adapter could be implemented by fitting the appropriate controller chip which is directed by the FPGA chip.

Also, with minor modification, the board can be made to fit the Zorro 2 bus in Amiga 2000/3000/4000. It could in principle be achieved by modifying the physical connection and rerouting the AUTOCONFIG signals as appropriate.

1.4 Hardware overview

Figure 1.1 illustrates the hardware components constituting the GRETA expansion board. For more details, appendix A contains the electronic schematics the GRETA expansion board. The schematic files are also the hardware documentation. Everything needed to reproduce the hardware is included.

The PCB itself is routed on four layers with the following stack-up from top to bottom: Signal, ground, 3.3V, signal. Great care has been taken to achieve good signal integrity properties. For example, no bus signals or fast switching

¹As of January 2014, only Fast RAM with AUTOCONFIG is implemented in HDL. Preparation for the other peripherals is done in terms of AUTOCONFIG and DMA access to the SDRAM. All the necessary hardware components are there aswell.

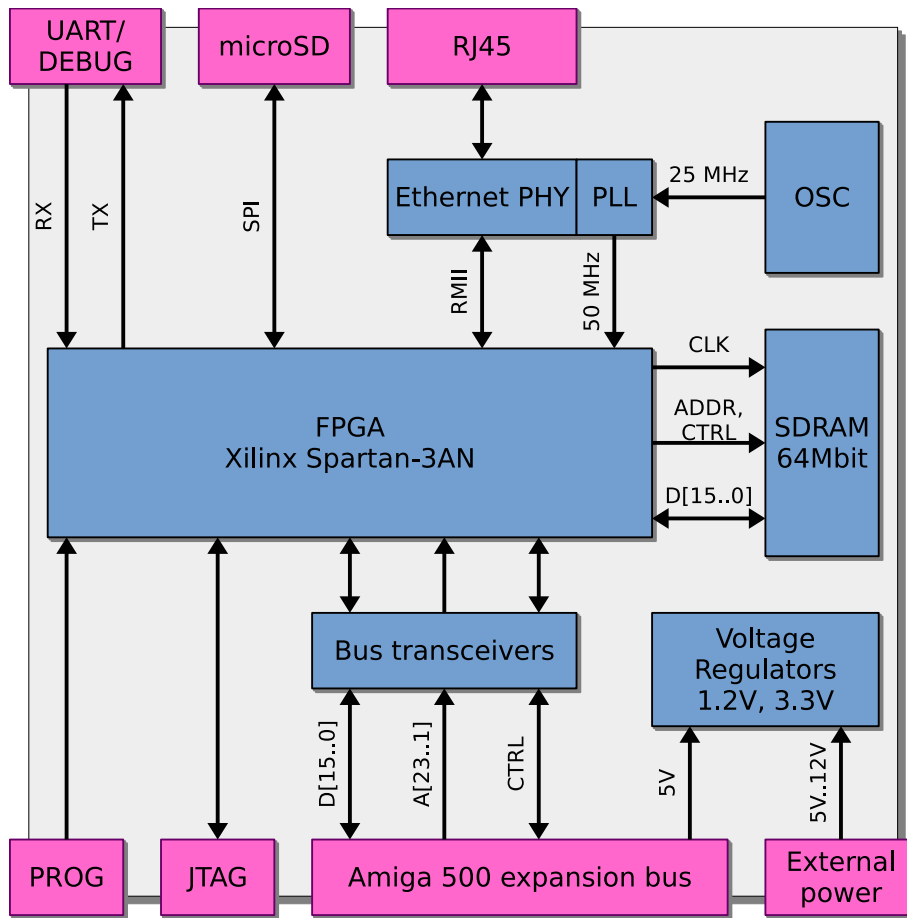


Figure 1.1: Hardware block diagram of the GRETA expansion board. Blue boxes indicate on-board devices. Pink boxes are external connectors.

signals are routed through vias. Routing is tight; only two pins on the FPGA are unconnected.

All components, except for external connectors, are surface mounted. 0603 package is chosen for all resistors and most capacitors.

Figure 1.2 shows the PCB with components mounted and figure 1.3 the expansion board connected to the host computer. In figures 1.4 1.5 are images rendered from the Gerber files supplied to the PCB manufacturer.

1.4.1 Notes on the hardware design

The Amiga computer uses 5V TTL signals throughout while the FPGA and the other GRETA components are rated at 3.3V and thus some signal level conversion is needed. The solution is to use 5V tolerant drivers for bidirectional signals and unidirectional signals from the computer to the expansion board. A 16-bit bidirectional transceiver, NXP 74LVCH162245A, a component with built-in 30 ohm series termination resistors, solves this. For signals going from the FPGA back to the computer, the device SN74LVC07A is used. It has TTL level tolerant open-drain outputs which fits well with the open collector inputs on the Amiga.

RMII is chosen over MII as Media Independent Interface for the Ethernet PHY. This reduces pin-count. As a bonus, the selected chip has a PLL that can feed the FPGA with a clock signal.

1.5 Tools

The following software tools have been used in the development of the GRETA hardware and HDL.

Arch Linux

Operating system, tools and infrastructure.

KiCad, build (2013-may-18)-stable

Schematic capture and PCB layout.

GNU Make

Dependency tracking for compiling documentation and HDL code.

GHDL 0.30dev (20100112)

Functional simulation of HDL code.

Xilinx ISE 14.6

Development environment for Xilinx FPGA.

ASM-One V1.20

Macro-assembler and development environment for the Amiga computer.

Git

Revision control.

LibreOffice Draw

Vector graphics.

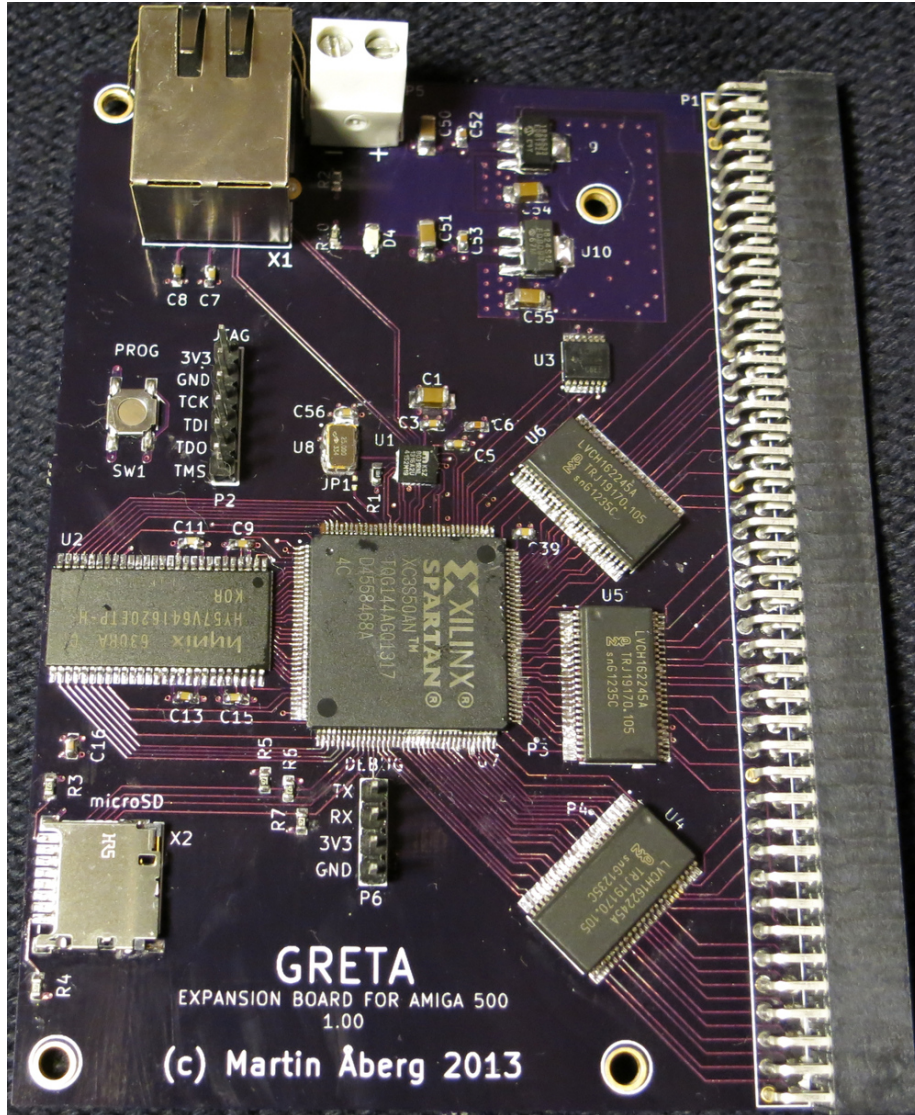


Figure 1.2: Top side of GRETA expansion board. On the right edge is the connector to the Amiga computer expansion bus. The expansion connector has all its signals connected to three 16-bit transceivers and a 6-bit open drain driver.

Down to the left is the microSD card slot and above it the SDRAM. At top left is the RJ45 Ethernet connector and next to it the connector for external power. The large chip in the middle is the Xilinx FPGA. Above it are clock oscillator and Ethernet PHY.

Between the expansion connector and external power are two voltage regulators which generate 1.2V and 3.3V.



Figure 1.3: The expansion board connects on the left side of the computer. The big chip closest to the expansion is the Motorola MC68000 CPU.

VIM

Text editing.

L^AT_EX

Typesetting text documents.

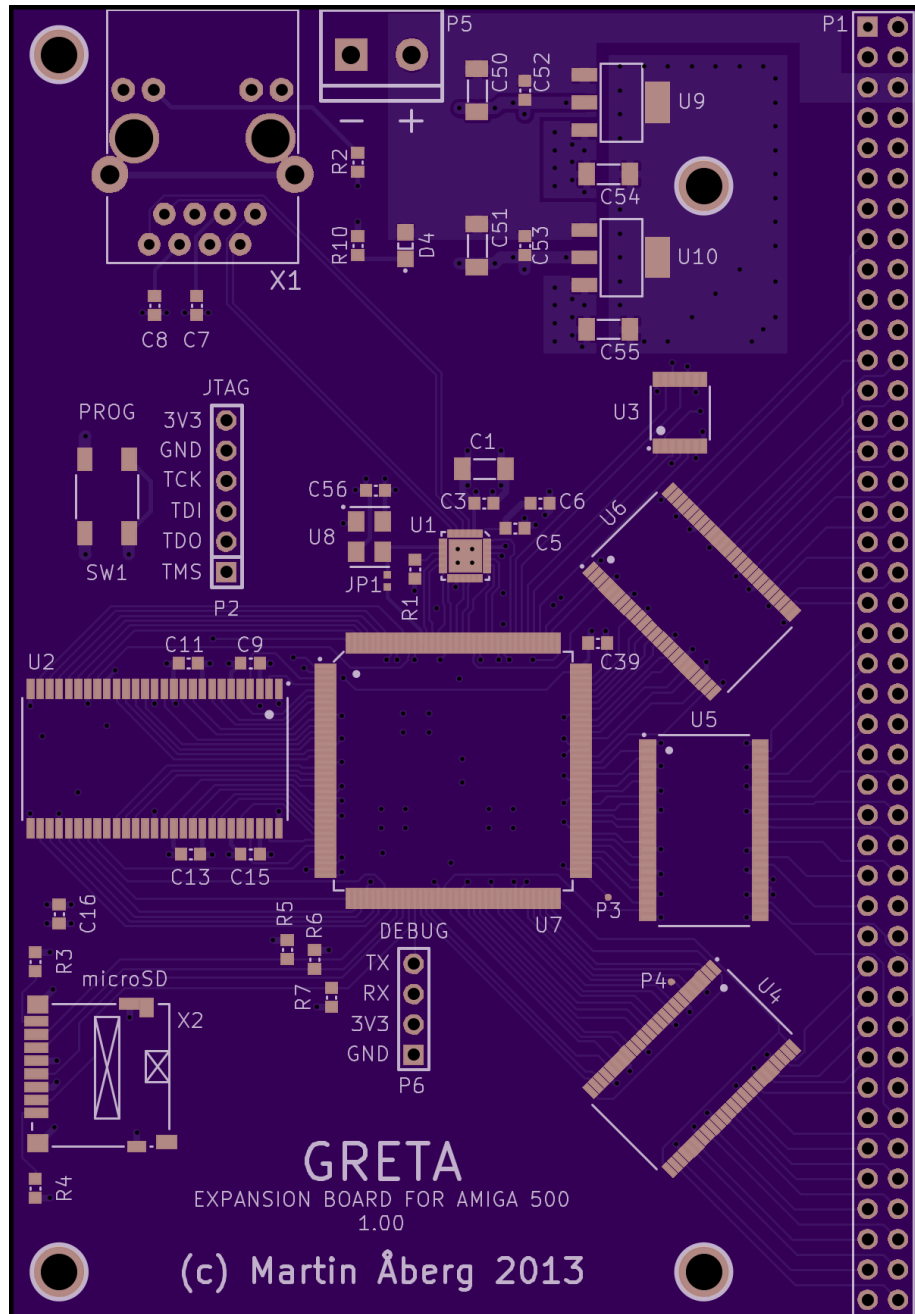


Figure 1.4: PCB top.

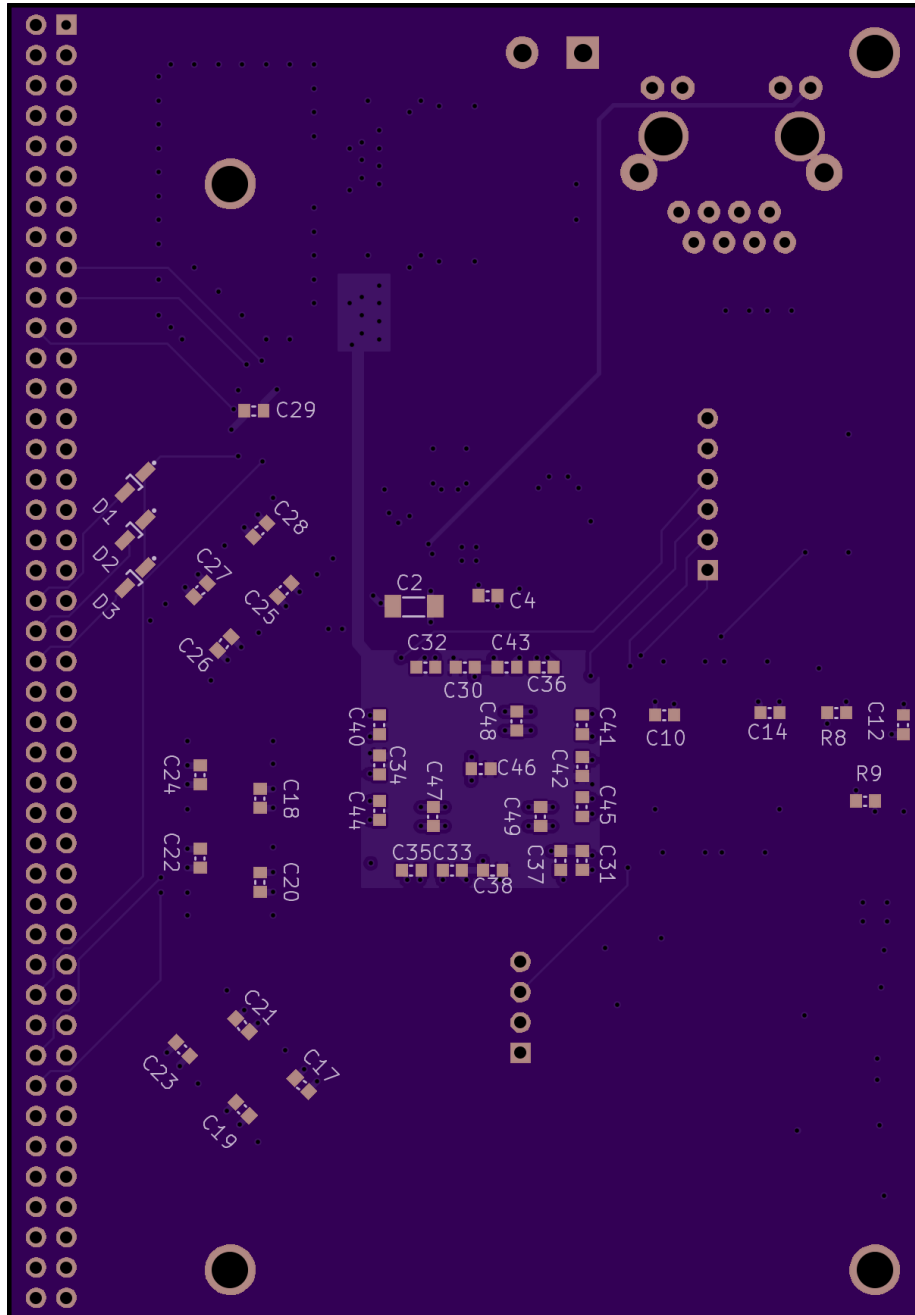


Figure 1.5: PCB bottom.

Chapter 2

HDL Overview

This chapter gives an overview of the HDL architecture for GRETA. All VHDL source files are presented in appendix B. During the development of the HDL components, a set of testbenches were developed. These are not included in the listings in this document. They are however provided in the GRETA file distribution.

The top-level module is contained in `greta.vhdl` with the port definition described in table 2.1. The VHDL package in file `greta_pkg.vhdl` contains type definitions, address definitions and bit definitions and helper functions for the other HDL modules. Even though several custom types are used in the design, the top level ports only use types defined in `IEEE.STD_LOGIC_1164`.

Figure 2.1 illustrates how the HDL components are related to each other.

A clock synthesizer unit (DCM) in the FPGA is used to generate the 133 MHz clock which is used in the internal logic. It is commonly referred to as the `clk` signal.

2.1 AUTOCONFIG

According to the AUTOCONFIG protocol of the Amiga computer ZORRO II specification [1], a peripheral device can be in one of the states `UNCONFIGURED`, `CONFIGURED` or `SHUT_UP`. After reset, every device is `UNCONFIGURED` and responds to bus accesses in the address space `$E80000-$E8FFFF` if its `nCONFIG_IN` signal is asserted. The system software reads certain registers from the device in this area and eventually issues a write to relocate the device to another address space, typically somewhere inside `$E90000-$EFFFFFF` or `$200000-$9FFFFFF` depending on size requirements. The device is now `CONFIGURED` and passes its `nCONFIG_OUT` signal to the next device's `nCONFIG_IN`.

If the system for some reason chooses not to configure the device, the device is forced into the `SHUT_UP` state by writing a certain register. In this state the device must never respond again until the next reset.

The AUTOCONFIG space area is the address area from `$E80000-$EFFFFFF`. Inside this area there are eight equally sized slots.

`autoconfig_pkg` has definitions and helper functions for the AUTOCONFIG protocol.

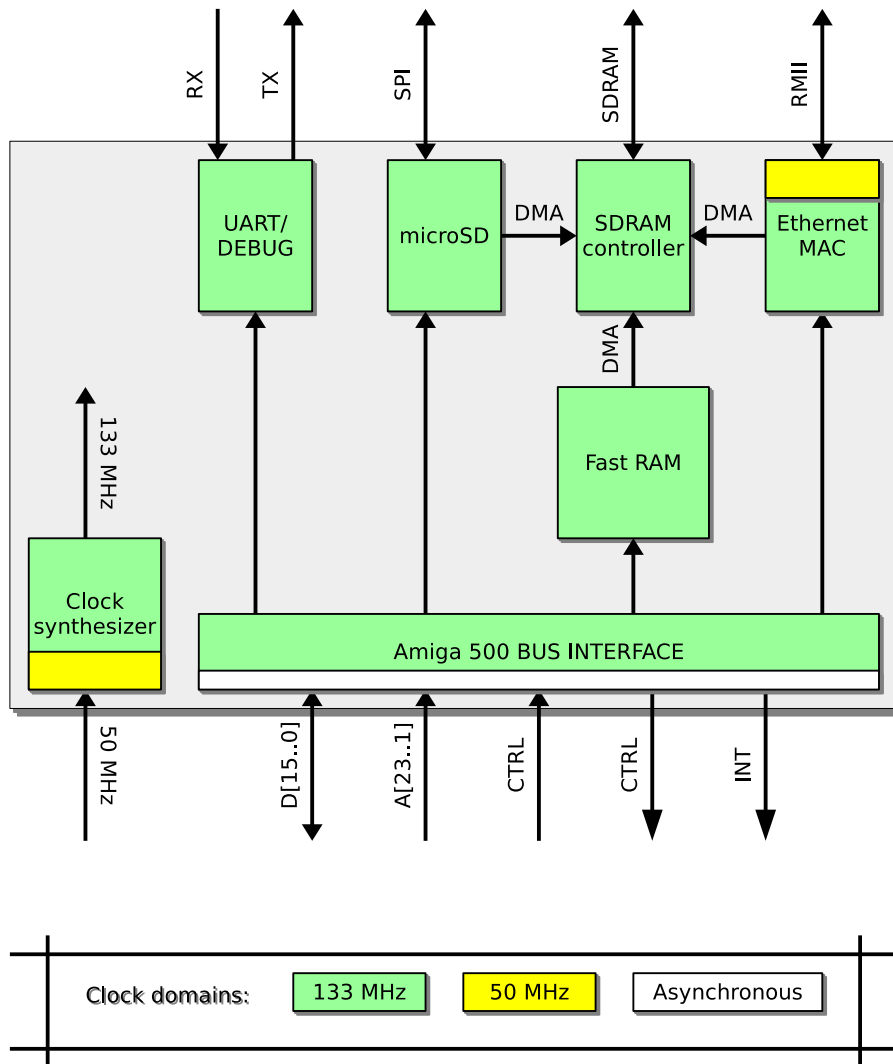


Figure 2.1: HDL block diagram of GRETA. Each box represents one HDL component. All components are implemented using VHDL and are realised in FPGA.

<i>Port</i>	<i>Direction</i>	<i>Description</i>
CLK25MHZ	in	JP1 open: undefined.
Amiga 500 (Rock Lobster) expansion bus		
RL_nRST	in	Reset
RL_nAS	in	Address Strobe
RL_nUDS	in	Data Upper Strobe
RL_nLDS	in	Data Lower Strobe
RL_RnW	in	Read/Write
RL_CDAC	in	Amiga system clock with 90° phase.
RL_nOVR	out	Override internal nDTAC generation
RL_nINT2	out	Amiga interrupt level 2
RL_nINT6	out	Amiga interrupt level 2
RL_nINT7	out	Non-maskable interrupt
RL_nDTACK	out	Data Acknowledge
RL_A[23:1]	in	Address bus
RL_D[15:0]	inout	Data bus
RL_D_nOE	out	Output enable for data bus transceiver.
RL_D_TO_GRETA	out	Direction of data bus transceiver.
SDRAM interface		
SDRAM_CLK	out	Clock
SDRAM_CKE	out	Clock Enable
SDRAM_nRAS	out	Row Address Strobe
SDRAM_nCAS	out	Column Address Strobe
SDRAM_nWE	out	Write Enable
SDRAM_UDQM	out	Upper Data Input/Output Mask
SDRAM_LDQM	out	Lower Data Input/Output Mask
SDRAM_BA[1:0]	out	Bank Address
SDRAM_A[11:0]	out	Address
SDRAM_DQ[15:0]	inout	Data bus
microSD interface (SPI)		
SPI_CLK	out	Clock (SCLK)
SPI_nCS	out	Chip Select (SS)
SPI_DO	out	Data Output (MOSI)
SPI_DI	in	Data Input (MISO)
Ethernet PHY (RMII)		
PHY_nRST	out	Reset
PHY_MDC	out	MDIO Clock
PHY_MDIO	inout	MDIO Data I/O
RMII_REF_CLK	in	RMII Clock (50 MHz)
RMII CRS_DV	in	RMII Carrier Sense/Data Valid
RMII_RXD[1:0]	in	RMII Receive Data
RMII_TXD[1:0]	out	RMII Transmit Data
RMII_TX_EN	out	RMII Transmit Data Enable
UART/DEBUG interface		
DEBUG_RX	in	
DEBUG_TX	out	

Table 2.1: GRETA top level ports.

Chapter 3

Bus interface

The bus decoder is responsible for decoding the asynchronous 68000 bus signals and exporting a synchronous read/write protocol to the GRETA peripherals.

3.1 Specification

The internal bus protocol is presented in table 3.1.

A pulse on **req** means that **nwe**, **addr** and **wdata** are valid and will remain so for at least 34 **clk** periods¹.

Each GRETA peripheral device holds its **rdata** output valid as long as the peripheral is addressed, and zero otherwise. This allows for all GRETA peripherals to have their **rdata** outputs OR-wired to the the bus interface **rdata** input. An addressed GRETA peripheral must respond to a read request in 34 **clk** periods² by asserting its **dev_select** signal. The individual **dev_select** signals are OR:ed together at the top level. The bus interface **dev_selected** is used to determine if the bus transceivers shall drive data towards the Amiga.

The Amiga ZORRO II bus interface also defines the **XRDY** signal that can be used to delay bus accesses. This signal is not used in the GRETA design and is not even connected to the GRETA hardware.

3.2 Implementation

All input Rock Lobster signals are synchronized before use in the GRETA clock domain. Control signals have two synchronizer stages while the data and address bus have one each. Also all inputs and outputs have their registers in the FPGA IO pads.

¹To be decided. This is a safe minimum.

²To be decided. This is a safe minimum.

<i>Port</i>	<i>Type</i>	<i>Direction</i>	<i>Description</i>
clk	std_logic	in	GRETA clock
cpu_reset	std_logic	out	Synchronous reset, activated by Amiga.
Internal bus interface			
req	std_logic	out	Pulsed once for each 68000 read/write
nwe	bus_nwe	out	Upper and lower byte select for write. "11" means read.
addr	bus_addr	out	Word destination for read and write transfers
wdata	bus_data	out	WRITE data
rdata	bus_data	in	READ data

Table 3.1: Bus interface, internal interface ports.

Chapter 4

SDRAM Controller

The SDRAM controller offers a user interface to a physical SDRAM chip. Design goals are to provide determinism and an easy to use control interface. Performance demands are set by client access requirements.

All timings in this chapter refers to a *Hynix* SDRAM chip clocked at 133 MHz and CAS latency of three.

4.1 Time resource estimations for SDRAM clients

The access time requirements for each SDRAM client presented in the previous chapter are presented in this section and summarised in Table 4.1.

4.1.1 Fast RAM Controller

For the Rock Lobster bus interface on an NTSC Amiga 500, accesses can be performed at most once every fourth 7.16MHz clock cycle [3]. The bus read period and deadlines are derived from [3] and actual signal measurements.

Deadline for a bus read is limited by the time at which Motorola 68000 bus samples read data (falling edge leading to bus cycle state S7). For bus write, the deadline is effectively the time at which a following of bus read may occur. Requests from bus read and bus write can never be active at the same time

<i>Client</i>	<i>Period</i>	<i>Execution time</i>	<i>Deadline</i>
Fast RAM	55	8	34
Disk	85	8	85
MAC TX	213	8	213
MAC RX	213	8	213
Auto refresh	2083	9	2083

Table 4.1: Real time requirements for clients issuing DMA operations on SDRAM. All time values are in units of 133 MHz clock periods, 7.5ns. Read and write execution times are based on single 16 bit word access with CAS latency of 3 cycles. Auto refresh is 9 cycles for this configuration.

so they are combined to one task in Table 4.1 to simplify calculations. As a consequence of this, timing budget for the bus interface is a bit pessimistic.

4.1.2 Disk Controller

A bitrate of 25Mbit/s for Secure Digital over SPI gives a maximum throughput of 2.98MiB/s. The number of 7.5ns periods per 16bit SDRAM access is $85 \leq \frac{16bit}{25Mbit/s} \cdot \frac{1}{7.5ns}$.

4.1.3 Ethernet MAC

Periods and deadlines for MAC RX and MAC TX are based on 10Mbit Ethernet in full-duplex mode. With the presented timing guarantees, only a very narrow FIFO buffer is required to transfer data between the Ethernet PHY clock domain and SDRAM.

The SDRAM access period time for a sustained transfer in each direction, expressed as 7.5ns periods, is $213 \leq \frac{16bit}{10Mbit/s} \cdot \frac{1}{7.5ns}$.

If support for two word bursts is added to the SDRAM controller, then 100Mbit full-duplex can be supported without affecting the real time properties of the other RAM clients. (Though this is possible in theory, the Amiga 500 running a TCP/IP stack with SANA-II driver interface would never handle rates above 10Mbit anyway.)

4.1.4 Auto refresh

The SDRAM requires 64 refresh operation every 4096 ms. In terms of 7.5ns periods, this is $2083 \leq \frac{64ms}{4096} \cdot \frac{1}{7.5ns}$.

4.2 SDRAM Scheduling

To solve the SDRAM scheduling problem, a static off-line approach is taken. A time table in which clients get their dedicated time slots is pre-calculated. An offset pointer iterates over the calendar slots and loops when it reaches the end of the table.

This satisfies the goal of determinism and simplicity. Of course, it must be assured that each client will meet its deadline.

To simplify matters, the accessed bank is always always precharged after an access. Furthermore, if a client does not issue a request in its designated time slot, the SDRAM will carry out an unused read operation anyway. Note that self refreshes are scheduled just as an ordinary client.

Also note that scheduling of requests to the SDRAM resource as presented in this section, will result in accesses not being served in the same time order as they were requested. Because of this, any of the peripherals must send its interrupt back to the computer only after an access has been acknowledged by the RAM arbiter. Anyhow, requests made by the same client will always be served in the same order as they were issued.

Table 4.2 illustrates the client calendar. The tightest timing budget is for a *Disk* request arriving at time 10 and finishes at time 89, resulting in a response time of 79 time units.

<i>Offset</i>	<i>Time</i>	<i>Client</i>
0	0 - 8	Fast RAM
1	9 - 17	Disk
2	18 - 26	Fast RAM
3	27 - 35	MAC TX
4	36 - 44	Fast RAM
5	45 - 53	MAC RX
6	54 - 62	Fast RAM
7	63 - 71	Auto refresh
0	72 - 80	Fast RAM
1	81 - 89	Disk
⋮	⋮	⋮

Table 4.2: Calendar for static scheduling of the SDRAM resource. The unit of time offset is one period of a 133 MHz clock (7.5ns). Calendar has eight positions and repeats after offset 7.

<i>Member</i>	<i>Type</i>	<i>Description</i>
req	std_logic	Assert high to issue an SDRAM request.
nwe	bus_nwe	Upper and lower byte select for write. "11" means read.
addr	bus_addr	Target address for request.
wdata	bus_data	Write data.

Table 4.3: Record type definition for **ram.bus**. The type is used by SDRAM clients.

4.3 Specification

Each client communicates with the SDRAM controller using an in/out signal pair with types **ram.bus** and **std_logic** respectively. An example is the **fast/fast_ack** pair. All clients share the read data bus **rdata**. See table 4.3 for a description of the **ram.bus** record type.

Transfers are 16 bit wide but for write accesses, it is possible to select target bytes individually with the mask signal **nwe**.

To do an SDRAM request, the client sets its **req** signal high and holds it high until the corresponding **ack** signal goes high (pulse). The record members **nwe**, **addr** and **wdata** must be constant for the duration of asserted **req**. If it was a read request, then **rdata** is valid only in the same clock cycle as **ack** is pulsed.

Table 4.4 illustrates the internal HDL interface to the SDRAM controller.

<i>Port</i>	<i>Type</i>	<i>Direction</i>	<i>Description</i>
clk	std_logic	in	GRETA clock
reset	std_logic	in	Synchronous reset
ready	std_logic	out	Controller is ready for requests
Fast RAM client			
fast	ram_bus	in	Control structure for accesses by Disk
fast_ack	std_logic	out	Acknowledge signal for Disk
microSD client			
disk	ram_bus	in	Control structure for accesses by Disk
disk_ack	std_logic	out	Acknowledge signal for Disk
Ethernet MAC client			
mactx	ram_bus	in	Control structure for accesses by MAC TX
mactx_ack	std_logic	out	Acknowledge signal for MAC TX
macrx	ram_bus	in	Control structure for accesses by MAC RX
macrx_ack	std_logic	out	Acknowledge signal for MAC RX
Common read data bus			
rdata	bus_data	out	Read data, only valid at the corresponding _ack=1

Table 4.4: SDRAM component, interface for internal ports.

Chapter 5

Fast RAM Controller

The Fast RAM controller is responsible for implementing the AUTOCONFIG protol for configuring RAM at system start and then responds to Fast RAM accesses in the Amiga address range \$200000-\$9FFFFFF.

This Amiga address range needs 23 bits to describe 16-bit word locations. This is a 16MiB range but only 8MiB in this range is used for accessing actual RAM. An important observation is that bit 23 is not significant for addressing to the SDRAM.

In fact, bit 23 can be ignored. This can be seen by splitting the Fast RAM address range into three parts and observe the mappings on SDRAM (table 5.1.

5.1 Specification

The HDL port interface of the Fast RAM component consists of the bus interface and the SDRAM interface as described above.

<i>Amiga address</i>	<i>SDRAM address</i>	<i>Size</i>
\$200000-\$3FFFFFF (bit 23=0)	\$200000-\$9FFFFFF	2MiB
\$400000-\$7FFFFFF (bit 23=0)	\$400000-\$7FFFFFF	4MiB
\$800000-\$9FFFFFF (bit 23=1)	\$000000-\$1FFFFFF	2MiB

Table 5.1: Mapping of the external RAM in the Amiga address space to SDRAM address space.

Chapter 6

Disk Controller

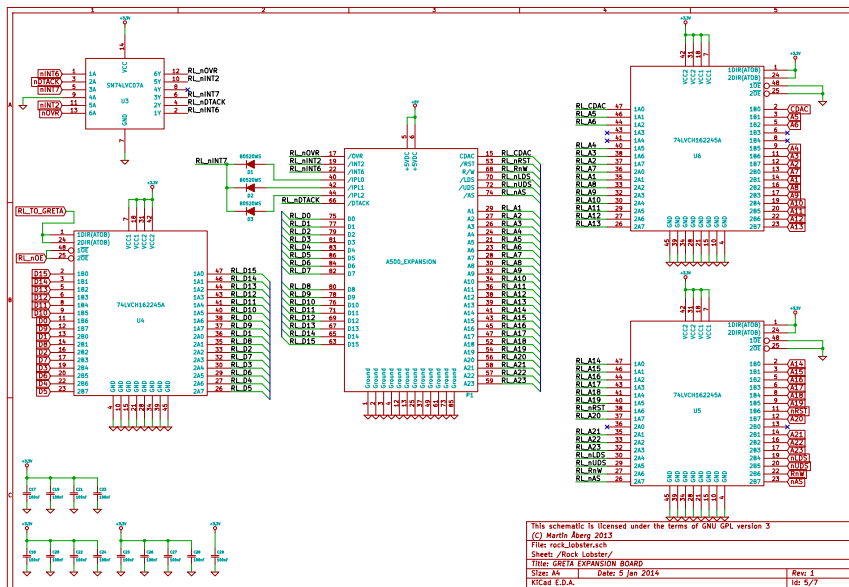
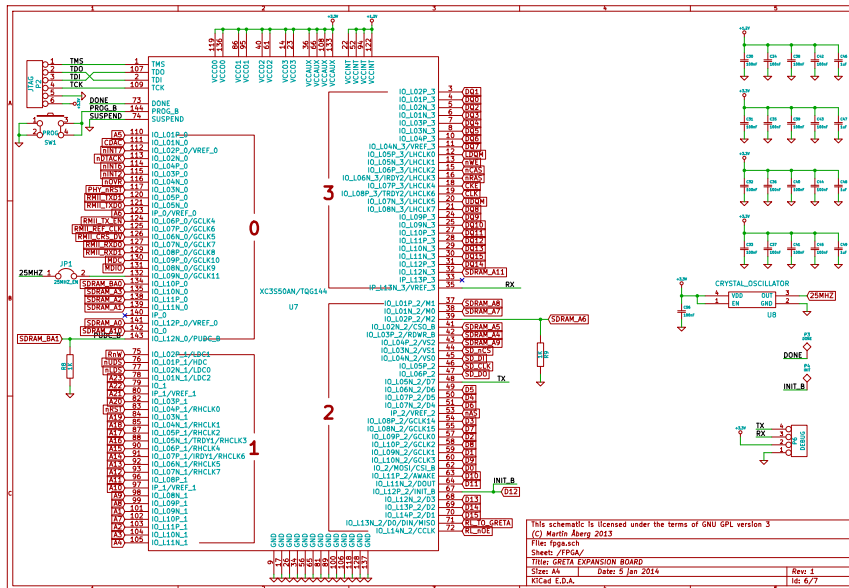
6.1 Specification

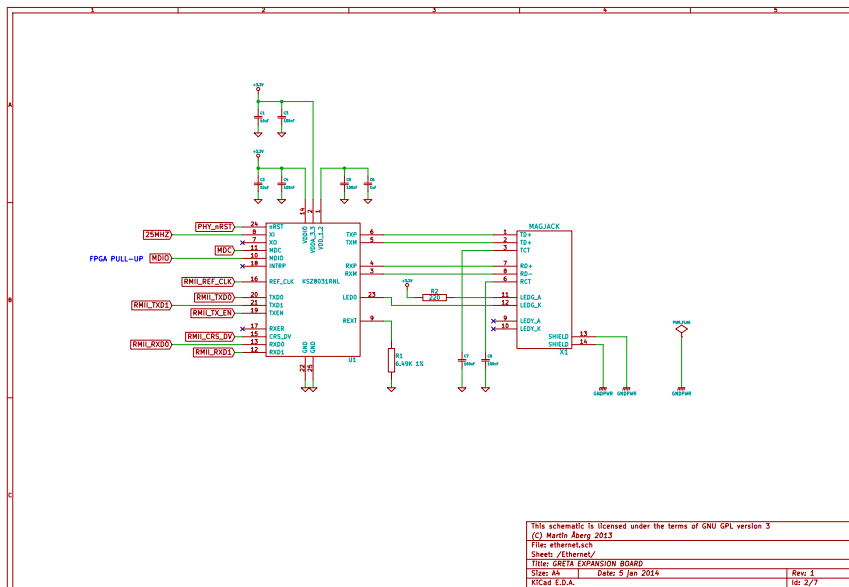
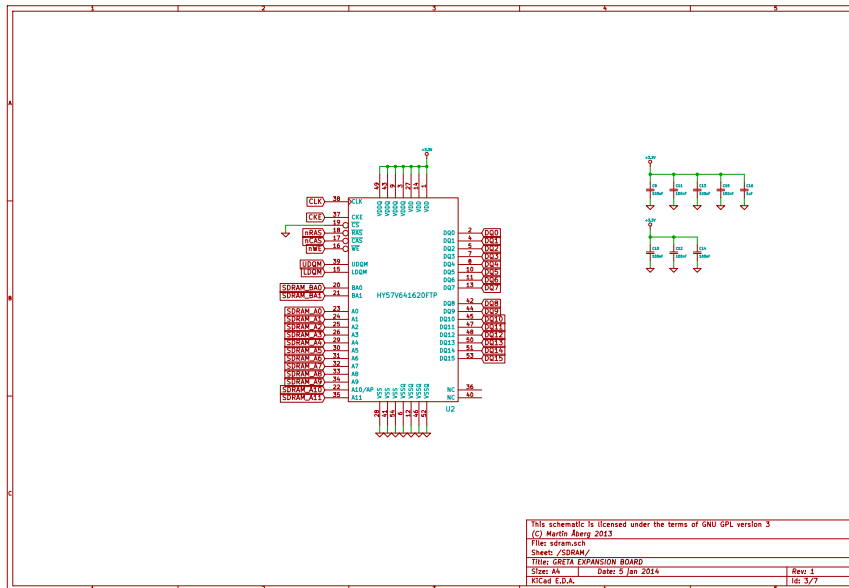
6.1.1 User registers

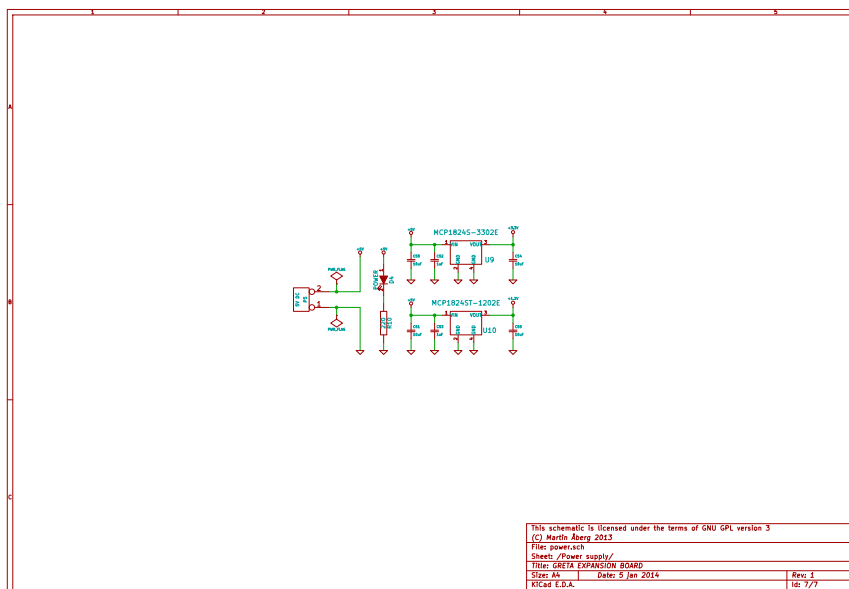
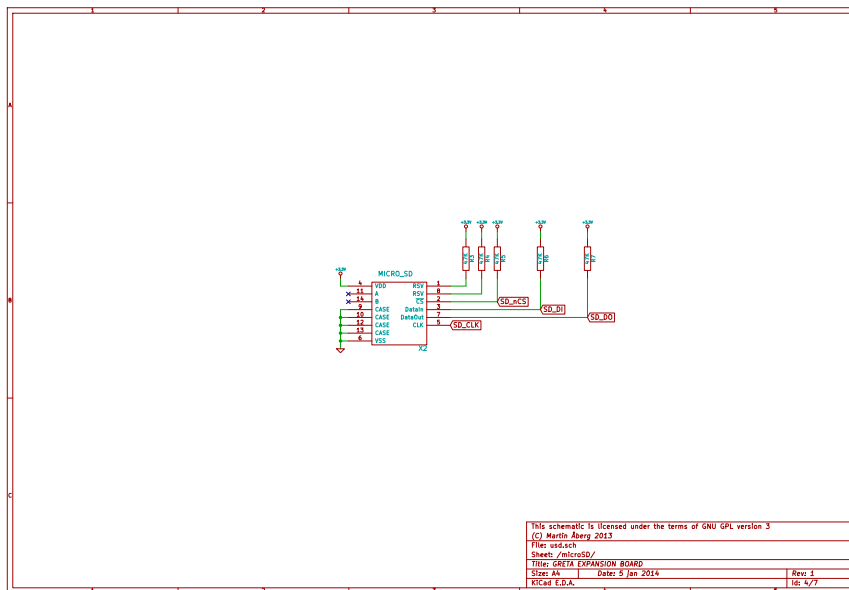
6.2 Implementation

Electronic schematics









Appendix B

HDL code

B.1 GRETA types, constants and functions

```
--
-- Copyright (C) 2013 Martin Aberg
--
-- This program is free software: you can redistribute it
-- and/or modify it under the terms of the GNU General Public
-- License as published by the Free Software Foundation,
-- either version 3 of the License, or (at your option)
-- any later version.
--
-- This program is distributed in the hope that it will
-- be useful, but WITHOUT ANY WARRANTY; without even the
-- implied warranty of MERCHANTABILITY or FITNESS FOR A
-- PARTICULAR PURPOSE. See the GNU General Public License
-- for more details.
--
-- You should have received a copy of the GNU General
-- Public License along with this program. If not, see
-- <http://www.gnu.org/licenses/>.
--
library ieee;
use ieee.std_logic_1164.all;
use ieee.numeric_std.all;

package greta_pkg is
    subtype bus_addr      is std_logic_vector(23 downto 1);
    subtype bus_addr24    is std_logic_vector(23 downto 0);
    subtype autoconfig_slot is std_logic_vector(18 downto 16);
    subtype bus_data      is std_logic_vector(15 downto 0);
    subtype bus_data8     is std_logic_vector( 7 downto 0);
    subtype nibble        is std_logic_vector( 3 downto 0);

    -- Auto-config space. Boards appear here before the system
    -- relocates them to their final address.
    constant AUTOCONFIG_BASE : bus_addr := x"E8_000" & o"0";
    constant AUTOCONFIG_MASK : bus_addr := x"F8_000" & o"0";
    constant AUTOCONFIG_SLOT0 : autoconfig_slot := o"0";

    -- Because the Fast RAM area overlaps bit 23, we split it
    -- into three separate areas.
    constant FAST_RAM_BASE2 : bus_addr := x"20_000" & o"0";
    constant FAST_RAM_BASE4 : bus_addr := x"40_000" & o"0";
```

```

constant FAST_RAM_BASE8 : bus_addr := x"80_000" & o"0";
constant FAST_RAM_MASK2 : bus_addr := x"E0_000" & o"0";
constant FAST_RAM_MASK4 : bus_addr := x"C0_000" & o"0";
constant FAST_RAM_MASK8 : bus_addr := x"E0_000" & o"0";

constant UPPER : natural := 1;
constant LOWER : natural := 0;

subtype bus_nwe is std_logic_vector(UPPER downto LOWER);

constant WRITE_UPPER : bus_nwe := (UPPER => '0', LOWER => '1');
constant WRITE_LOWER : bus_nwe := (UPPER => '1', LOWER => '0');
constant WRITE_WORD : bus_nwe := (UPPER => '0', LOWER => '0');
constant READ_WORD : bus_nwe := (UPPER => '1', LOWER => '1');

type ram_bus is
record
    req : std_logic;
    nwe : bus_nwe;
    addr : bus_addr;
    wdata : bus_data;
end record;

-- Note that use of the ec_BaseAddress register is
-- tricky. The system will actually write twice. First
-- the low order nybble is written to the ec_BaseAddress
-- register+2 (D15-D12). Then the entire byte is written
-- to ec_BaseAddress (D15-D8). This allows writing of a
-- byte-wide address to nybble size registers.
constant ec_BaseAddress : natural := 16#48#;
constant ec_ShutUp : natural := 16#4C#;

constant FAST_PRODUCT_NUMBER : std_logic_vector := x"1";
constant DISK_PRODUCT_NUMBER : std_logic_vector := x"2";
constant ERT_ZORROII : nibble := "1100";
constant ERT_MEMLIST : nibble := "0010";
constant ERT_DIAGVALID : nibble := "0001";

constant ERT_CHAINEDCONFIG : nibble := "1000";
constant ERT_MEMSIZE_8MB : nibble := "0000";
constant ERT_MEMSIZE_64K : nibble := "0001";

constant ERF_MEMSPACE : nibble := "1000";
constant ERF_NOSHUTUP : nibble := "0100";

-- A special "hacker" Manufacturer ID number is reserved
-- for test use: 2011 ($7DB). When inverted this will look
-- like $F824.
constant HACKER_MANUFACTURER :
    std_logic_vector(15 downto 0) := x"07DB";

function is_autoconfig_reg(n : natural; a : bus_addr)
    return boolean;

function is_autoconfig(a : bus_addr)
    return boolean;

function get_autoconfig_slot(a : bus_addr)
    return autoconfig_slot;

function is_fast_ram(a : bus_addr)
    return boolean;

```

```

end;

package body greta_pkg is

    function is_autoconfig_reg(n : natural; a : bus_addr)
        return boolean is
        variable reg_addr : std_logic_vector(6 downto 0);
    begin
        reg_addr := std_logic_vector(to_unsigned(n, reg_addr'length));
        return reg_addr(6 downto 1) = a(6 downto 1);
    end;

    function is_autoconfig(a : bus_addr)
        return boolean is
    begin
        return (a and AUTOCONFIG_MASK) = AUTOCONFIG_BASE;
    end;

    function get_autoconfig_slot(a : bus_addr)
        return autoconfig_slot is
    begin
        return a(autoconfig_slot'range);
    end;

    function is_fast_ram(a : bus_addr)
        return boolean is
    begin
        return (
            ((a and FAST_RAM_MASK2) = FAST_RAM_BASE2) or
            ((a and FAST_RAM_MASK4) = FAST_RAM_BASE4) or
            ((a and FAST_RAM_MASK8) = FAST_RAM_BASE8)
        );
    end;

end;

```

B.2 GRETA

```
--
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--
library ieee;
use ieee.std_logic_1164.all;
use work.greta_pkg.all;

entity greta is
  port(
    --- EXTERNAL CLOCK
    CLK25MHZ      : in      std_logic;

    --- ROCK LOBSTER
    RL_nRST       : in      std_logic;
    RL_nAS        : in      std_logic;
    RL_nUDS       : in      std_logic;
    RL_nLDS       : in      std_logic;
    RL_RnW        : in      std_logic;
    RL_CDAC       : in      std_logic;
    RL_nOVR       : out     std_logic;
    RL_nINT2      : out     std_logic;
    RL_nINT6      : out     std_logic;
    RL_nINT7      : out     std_logic;
    RL_nDTACK     : out     std_logic;
    RL_A          : in      std_logic_vector(23 downto 1);
    RL_D          : inout   std_logic_vector(15 downto 0);
    RL_D_nOE      : out     std_logic;
    RL_D_TO_GRETA : out     std_logic;

    --- SDRAM
    SDRAM_CLK     : out     std_logic;
    SDRAM_CKE     : out     std_logic;
    SDRAM_nRAS    : out     std_logic;
    SDRAM_nCAS    : out     std_logic;
    SDRAM_nWE     : out     std_logic;
    SDRAM_UDQM    : out     std_logic;
    SDRAM_LDQM    : out     std_logic;
    SDRAM_BA      : out     std_logic_vector(1 downto 0);
    SDRAM_A       : out     std_logic_vector(11 downto 0);
    SDRAM_DQ      : inout   std_logic_vector(15 downto 0);

    --- SECURE DIGITAL (SPI)
    SPI_CLK       : out     std_logic;
    SPI_nCS       : out     std_logic;
```

```

    SPI_DO          : out    std_logic;
    SPI_DI          : in     std_logic;

    --- ETHERNET PHY (RMII)
    PHY_nRST        : out    std_logic;
    PHY_MDC          : out    std_logic;
    PHY_MDIO         : inout  std_logic;
    RMII_REF_CLK     : in     std_logic;
    RMII_CRS_DV      : in     std_logic;
    RMII_RXD         : in     std_logic_vector(1 downto 0);
    RMII_TXD         : in     std_logic_vector(1 downto 0);
    RMII_TX_EN       : out    std_logic;

    --- UART/DEBUG
    DEBUG_RX         : in     std_logic;
    DEBUG_TX         : out    std_logic
);
end;

architecture structural of greta is
    signal clk        : std_logic;
    signal clk180      : std_logic;
    signal cpu_reset   : std_logic;
    signal dcm_locked  : std_logic;
    signal req         : std_logic;
    signal nwe         : bus_nwe;
    signal addr        : bus_addr;
    signal wdata       : bus_data;
    signal rdata       : bus_data;

    signal fast_select : std_logic;
    signal fast_rdata  : bus_data;
    signal fast_config_in : std_logic;
    signal fast_config_out : std_logic;

    signal sdram_rdata : bus_data;

    signal sdram_fast : ram_bus := (
        req => '0',
        nwe => READ_WORD,
        addr => (others => '0'),
        wdata => (others => '0')
    );
    signal sdram_fast_ack : std_logic := '0';

    signal disk_select : std_logic;
    signal disk_rdata  : bus_data;
    signal disk_config_in : std_logic;
    signal disk_config_out : std_logic;

    signal sdram_disk : ram_bus := (
        req => '0',
        nwe => READ_WORD,
        addr => (others => '0'),
        wdata => (others => '0')
    );
    signal sdram_disk_ack : std_logic := '0';

    signal dev_select : std_logic;

begin

```



```

-- debug outputs
DEBUG_TX <= disk_config_out;

dev_select <= fast_select or disk_select;
fast_config_in <= '1';
disk_config_in <= fast_config_out;
rdata <= fast_rdata or disk_rdata;

-- Enable PLL.
PHY_nRST <= '1';
PHY_MDC <= 'Z';
RMII_TX_EN <= '0';

-- Generate 133.3 MHz clock from 50 MHz PHY clock.
dcm_0 : entity work.dcm_greta
port map(
    CLKIN_IN      => RMII_REF_CLK,
    CLKFX_OUT     => clk,
    CLKFX180_OUT  => clk180,
    CLKIN_IBUFG_OUT => open,
    LOCKED_OUT    => dcm_locked
);

-- SDRAM clock output uses a DDR output buffer. See Xilinx
-- documentation for generic and port descriptions.
ODDR2_inst : ODDR2
generic map(
    DDR_ALIGNMENT => "NONE",
    INIT => '0',
    SRTYPE => "SYNC")
port map (
    Q  => SDRAM_CLK,
    C0 => clk,
    C1 => clk180,
    CE => '1',
    D0 => '0',
    D1 => '1',
    R  => '0',
    S  => '0'
);

bus_interface_0 : entity work.bus_interface
port map(
    clk          => clk,
    cpu_reset    => cpu_reset,
    dcm_locked   => dcm_locked,

    dev_select   => dev_select,
    req          => req,
    nwe          => nwe,
    addr         => addr,
    wdata        => wdata,
    rdata        => rdata,

    --- ROCK LOBSTER
    nRST         => RL_nRST,
    nAS          => RL_nAS,
    nUDS         => RL_nUDS,
    nLDS         => RL_nLDS,
    RnW          => RL_RnW,
    CDAC         => RL_CDAC,
    nOVR         => RL_nOVR,

```

```

nINT2      => RL_nINT2,
nINT6      => RL_nINT6,
nINT7      => RL_nINT7,
nDTACK     => RL_nDTACK,
A          => RL_A,
D          => RL_D,
D_nOE      => RL_D_nOE,
D_TO_GRETA => RL_D_TO_GRETA
);

```

```

sdram_0 : entity work.sdram
port map(
    clk          => clk,
    reset        => cpu_reset,
    ready        => open,

    --- CLIENTS
    disk         => sdram_disk,
    disk_ack     => sdram_disk_ack,
    fast         => sdram_fast,
    fast_ack     => sdram_fast_ack,
    rdata        => sdram_rdata,

    --- SDRAM
    SDRAM_CKE    => SDRAM_CKE,
    SDRAM_nRAS   => SDRAM_nRAS,
    SDRAM_nCAS   => SDRAM_nCAS,
    SDRAM_nWE    => SDRAM_nWE,
    SDRAM_UDQM   => SDRAM_UDQM,
    SDRAM_LDQM   => SDRAM_LDQM,
    SDRAM_BA     => SDRAM_BA,
    SDRAM_A      => SDRAM_A,
    SDRAM_DQ     => SDRAM_DQ
);

```

```

fast_0 : entity work.fast
port map(
    clk          => clk,
    reset        => cpu_reset,

    req          => req,
    nwe          => nwe,
    dev_select   => fast_select,
    addr         => addr,
    wdata        => wdata,
    rdata        => fast_rdata,
    config_in    => fast_config_in,
    config_out   => fast_config_out,

    ram          => sdram_fast,
    ram_ack      => sdram_fast_ack,
    ram_rdata    => sdram_rdata
);

```

```

disk_0 : entity work.disk
port map(
    clk          => clk,
    reset        => cpu_reset,

    req          => req,
    nwe          => nwe,
    dev_select   => disk_select,

```

```
    addr      => addr ,
    wdata     => wdata ,
    rdata     => disk_rdata ,
    config_in => disk_config_in ,
    config_out => disk_config_out ,

    ram       => sdram_disk ,
    ram_ack   => sdram_disk_ack ,
    ram_rdata => sdram_rdata ,

    SPI_CLK   => SPI_CLK ,
    SPI_nCS   => SPI_nCS ,
    SPI_D0    => SPI_D0 ,
    SPI_DI    => SPI_DI
);
end;
```

B.3 Bus Interface

```
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--

-- This component is responsible for translating asynchronous
-- MC68000 bus accesses to a protocol suitable for the
-- AUTOCONFIG component and the other upstream components.
library ieee;
use ieee.std_logic_1164.all;
use work.greta_pkg.all;

entity bus_interface is
  port(
    --- GRETA
    clk          : in    std_logic;
    cpu_reset    : out   std_logic;
    dcm_locked   : in    std_logic;
    req          : out   std_logic;
    nwe          : out   bus_nwe;
    addr         : out   bus_addr;
    wdata        : out   bus_data;
    rdata        : in    bus_data;
    dev_select   : in    std_logic;
    --- ROCK LOBSTER
    nRST         : in    std_logic;
    nAS          : in    std_logic;
    nUDS         : in    std_logic;
    nLDS         : in    std_logic;
    RnW          : in    std_logic;
    CDAC         : in    std_logic;
    nOVR         : out   std_logic;
    nINT2        : out   std_logic;
    nINT6        : out   std_logic;
    nINT7        : out   std_logic;
    nDTACK       : out   std_logic;
    A            : in    bus_addr;
    D            : inout bus_data;
    D_nOE        : out   std_logic := '1';
    D_TO_GRETA   : out   std_logic := '1'
  );
end;

architecture rtl of bus_interface is
  signal nRST_sync      : std_logic_vector(1 downto 0) := "00";
```

```

signal nAS_sync      : std_logic_vector(1 downto 0) := "11";
signal nUDS_sync     : std_logic_vector(2 downto 0);
signal nLDS_sync     : std_logic_vector(2 downto 0);
signal RnW_sync      : std_logic_vector(1 downto 0);

signal cpu_reset_int : std_logic := '1';

type bus_state is (S1, W1, W2, R1);
signal state : bus_state := S1;

begin

synchronizers : process(clk)
begin
    if rising_edge(clk) then
        nRST_sync <= nRST_sync(0) & nRST;
        nAS_sync  <= nAS_sync(0) & nAS;
        RnW_sync  <= RnW_sync(0) & RnW;
        nUDS_sync <= nUDS_sync(1 downto 0) & nUDS;
        nLDS_sync <= nLDS_sync(1 downto 0) & nLDS;

        wdata <= D;
        addr  <= A;

        -- NOTE: clk may be in any state, so the following logic
        -- may get trashed...
        if (dcm_locked = '1') and (nRST_sync(1) = '1') then
            cpu_reset_int <= '0';
        else
            cpu_reset_int <= '1';
        end if;
    end if;
end process;

process(clk)
begin
    if rising_edge(clk) then
        if cpu_reset_int = '1' then
            D_nOE      <= '1';
            D_TO_GRETA <= '1';
            req <= '0';
            state <= S1;
        else
            D_nOE      <= '1';
            D_TO_GRETA <= '1';
            req <= '0';
            D <= "ZZZZZZZZZZZZZZZZ";

            case state is
            when S1 =>
                if nAS_sync(1) = '0' then
                    -- Transfer
                    if (RnW_sync(1) = '0') then
                        -- Write
                        state <= W1;
                    else
                        -- Read, wait for nUDS and nLDS to become stable.
                        if (nUDS_sync(1) = '0') or (nLDS_sync(1) = '0') then
                            req <= '1';
                            nwe <= READ_WORD;
                            D_TO_GRETA <= '0';
                            state <= R1;
                        end if;
                    end if;
                end if;
            end case;
        end if;
    end if;
end process;

```

```

        end if;
    end if;
end if;

when R1 =>
    D_TO_GRETA <= '0';
    D_nOE <= not dev_select;
    D <= rdata;
    if (nUDS_sync(1) = '1') and (nLDS_sync(1) = '1') then
        state <= S1;
        D_nOE <= '1';
        D <= "ZZZZZZZZZZZZZZZZ";
    end if;

when W1 =>
    D_nOE <= '0';
    -- Wait for nUDS and nLDS to become stable.
    if ((nUDS_sync(2) = nUDS_sync(1))) and
        ((nLDS_sync(2) = nLDS_sync(1))) and
        ((nUDS_sync(2) = '0') or (nLDS_sync(2) = '0')) then
        nwe <= nUDS_sync(1) & nLDS_sync(1);
        req <= '1';
        -- wdata and addr is driven elsewhere.
        state <= W2;
    end if;

when W2 =>
    D_nOE <= '0';
    if nAS_sync(1) = '1' then
        D_nOE <= '1';
        state <= S1;
    end if;

end case;

end if;
end if;
end process;

cpu_reset <= cpu_reset_int;

nOVR        <= '1';
nINT2       <= '1';
nINT6       <= '1';
nINT7       <= '1';
nDTACK      <= '1';

end;
```

B.4 SDRAM Controller

```
--
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--

-- RAM arbiter and controller
library ieee;
use ieee.std_logic_1164.all;
use ieee.numeric_std.all;
use work.greta_pkg.all;

entity sdram is
  port(
    clk          : in    std_logic;
    reset        : in    std_logic;
    ready        : out   std_logic := '0';

    --- CLIENTS
    fast         : in    ram_bus;
    fast_ack     : out   std_logic;
    disk         : in    ram_bus;
    disk_ack     : out   std_logic;
    rdata        : out   bus_data;

    --- SDRAM
    SDRAM_CKE    : out   std_logic;
    SDRAM_nRAS   : out   std_logic;
    SDRAM_nCAS   : out   std_logic;
    SDRAM_nWE    : out   std_logic;
    SDRAM_UDQM   : out   std_logic;
    SDRAM_LDQM   : out   std_logic;
    SDRAM_BA     : out   std_logic_vector( 1 downto 0);
    SDRAM_A      : out   std_logic_vector(11 downto 0);
    SDRAM_DQ     : inout  std_logic_vector(15 downto 0) :=
      (others => 'Z')
  );
end;

architecture rtl of sdram is
  constant NCLIENTS : integer := 2;
  constant AP : integer := 10;

  subtype init_counter_t is unsigned(14 downto 0);
  signal init_counter : init_counter_t := (others => '0');
```

```

subtype tick_t is unsigned(3 downto 0);
signal tick : tick_t := (others => '0');

subtype offset_t is unsigned(1 downto 0);
signal offset : offset_t := (others => '0');

type state_t is (INIT_NOP, INIT_PRE, INIT_AR, INIT_MRS,
  INIT_DONE);
signal state : state_t := INIT_NOP;

-- nRAS, nCAS, nWE
subtype cmd_t is std_logic_vector(2 downto 0);
constant CMD_MRS : cmd_t := "000";
constant CMD_AR : cmd_t := "001";
constant CMD_PRE : cmd_t := "010";
constant CMD_ACT : cmd_t := "011";
constant CMD_WRITE : cmd_t := "100";
constant CMD_READ : cmd_t := "101";
constant CMD_NOP : cmd_t := "111";
signal cmd : cmd_t := CMD_NOP;

signal addr : bus_addr := (others => '0');
signal nwe : bus_nwe := READ_WORD;
signal refresh : std_logic := '0';
signal acks : std_logic_vector(NCLIENTS - 1 downto 0) :=
  (others => '0');
signal acks_pend : std_logic_vector(NCLIENTS - 1 downto 0) :=
  (others => '0');
signal wdata : bus_data;

begin
-- psl default clock is rising_edge(clk);
-- psl assert
--   always({state = INIT_DONE and fast.req='1' and acks(0) = '0'} | =>
--     {[*0 to 26]; acks(0)='1'});
-- psl assert
--   always({state = INIT_DONE and disk.req='1' and acks(1) = '0'} | =>
--     {[*0 to 44]; acks(1)='1'});
SDRAM_nRAS <= cmd(2);
SDRAM_nCAS <= cmd(1);
SDRAM_nWE <= cmd(0);
SDRAM_CKE <= '1';

fast_ack <= acks(0);
disk_ack <= acks(1);

counters: process(clk)
begin
  if rising_edge(clk) then
    -- Manage counters.
    if tick(tick'high) = '1' then
      tick <= (others => '0');
      offset <= offset + 1;
    else
      tick <= tick + 1;
    end if;
  end if;
end process;

state_machine: process(clk)
begin
  if rising_edge(clk) then

```



```

cmd <= CMD_NOP;
acks <= (others => '0');
-- Sample read data. Only use together with the
-- distributed ack.
rdata <= SDRAM_DQ;
SDRAM_DQ <= (others => 'Z');

if reset = '1' then
    ready <= '0';
    init_counter <= (others => '0');
    -- NOP
    SDRAM_A <= (others => '0');
    SDRAM_A(AP) <= '1';
    SDRAM_BA <= (others => '0');
    SDRAM_UDQM <= '1';
    SDRAM_LDQM <= '1';
    state <= INIT_NOP;
else
    init_counter <= init_counter + 1;

    case state is
    when INIT_NOP =>
        if init_counter(14 downto 12) = "111" then
            -- Anything greater than 200 us * 133.333 MHz
            cmd <= CMD_PRE;
            state <= INIT_PRE;
        end if;

    when INIT_PRE =>
        SDRAM_A(AP) <= '0';
        if init_counter(1) = '1' then
            -- "111000000000010"
            -- Pre lasts for 3 cycles.
            state <= INIT_AR;
        end if;

    when INIT_AR =>
        if init_counter(3 downto 0) = "0011" then
            -- "111000000000011"
            -- "1110000000010011"
            -- "111000000100011"
            -- "111000000110011"
            -- "111000001000011"
            -- "111000001010011"
            -- "111000001100011"
            -- "111000001110011"
            cmd <= CMD_AR;
        end if;
        if init_counter(7) = '1' then
            cmd <= CMD_MRS;
            -- SDRAM_A is zero. Set bits according to MRS.
            -- CAS Latency 3.
            -- A(6) <= '0';
            SDRAM_A(5) <= '1';
            SDRAM_A(4) <= '1';
            -- Burst length 1.
            -- SDRAM_A(2) <= '0';
            -- SDRAM_A(1) <= '0';
            -- SDRAM_A(0) <= '0';
            state <= INIT_MRS;
        end if;
    end case;
end if;

```

```

when INIT_MRS =>
  if init_counter(0) = '1' then
    state <= INIT_DONE;
  end if;

when INIT_DONE =>
  ready <= '1';
  if nwe = WRITE_UPPER then
    SDRAM_UDQM <= '0';
    SDRAM_LDQM <= '1';
  elsif nwe = WRITE_LOWER then
    SDRAM_UDQM <= '1';
    SDRAM_LDQM <= '0';
  else
    SDRAM_UDQM <= '0';
    SDRAM_LDQM <= '0';
  end if;

  -- Registered outputs
  case tick is
    when x"0" =>
      -- Transfer offset, tick, req => acks_pend.
      null;
    when x"1" =>
      -- ACT
      SDRAM_BA <= addr(22 downto 21);
      SDRAM_A <= addr(20 downto 9);
      if refresh = '0' then
        cmd <= CMD_ACT;
      else
        cmd <= CMD_AR;
      end if;
    when x"2" =>
      -- NOP
    when x"3" =>
      -- NOP
    when x"4" =>
      -- Auto Precharge
      SDRAM_A(AP) <= '1';
      SDRAM_A(7 downto 0) <= addr(8 downto 1);
      if refresh = '1' then
        -- NOP
      elsif nwe = READ_WORD then
        cmd <= CMD_READ;
        -- READ + AP
      else
        SDRAM_DQ <= wdata;
        cmd <= CMD_WRITE;
      end if;
    when x"5" =>
      -- NOP
    when x"6" =>
      -- NOP
    when x"7" =>
      -- NOP
    when others =>
      -- NOP
      acks <= acks_pend;
      nwe <= READ_WORD;
  end case;
end case;

```

```

case offset is
when "00" | "10" =>
    refresh <= '0';
    addr <= fast.addr;
    wdata <= fast.wdata;
    if tick = 0 then
        acks_pend(0) <= fast.req;
        acks_pend(1) <= '0';
    end if;
    if tick = 1 and fast.req = '1' then
        nwe <= fast.nwe;
    end if;

when "01" =>
    refresh <= '0';
    addr <= disk.addr;
    wdata <= disk.wdata;
    if tick = 0 then
        acks_pend(0) <= '0';
        acks_pend(1) <= disk.req;
    end if;
    if tick = 1 and disk.req = '1' then
        nwe <= disk.nwe;
    end if;

when others =>
    refresh <= '1';
    addr <= disk.addr;
    wdata <= disk.wdata;
    acks_pend <= "00";
end case;
end if;
end if;
end process;
end;

```

B.5 Fast RAM Controller

```
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--

-- Amiga Fast RAM
library ieee;
use ieee.std_logic_1164.all;
use work.greta_pkg.all;

entity fast is
  port(
    clk          : in    std_logic;
    reset        : in    std_logic;

    req          : in    std_logic;
    nwe          : in    bus_nwe;
    dev_select   : out   std_logic;
    addr         : in    bus_addr;
    wdata        : in    bus_data;
    rdata        : out   bus_data;
    config_in    : in    std_logic;
    config_out   : out   std_logic;

    ram          : out   ram_bus;
    ram_ack      : in    std_logic;
    ram_rdata    : in    bus_data
  );
end;

architecture rtl of fast is
  type fast_state is (
    UNCONFIGURED, SHUT_UP_FOREVER, CONFIGURED, RAM_ACCESS
  );

  signal state : fast_state := UNCONFIGURED;
  signal addr_autoconfig0 : boolean := false;
  signal addr_fast_ram : boolean := false;
  signal dev_select_reg : std_logic := '0';
  signal rom_rdata : std_logic_vector(15 downto 12);
  signal rdata_reg : bus_data := (others => '0');
  signal addr_low7 : std_logic_vector(7 downto 0);

begin
```

```

process (clk)
begin
    if rising_edge(clk) then
        if reset = '1' then
            state <= UNCONFIGURED;
            ram.req <= '0';
        else
            case state is
                when UNCONFIGURED =>
                    if (
                        req = '1' and nwe(UPPER) = '0' and
                        addr_autoconfig0 and config_in = '1'
                    ) then
                        if is_autoconfig_reg(ec_ShutUp, addr) then
                            state <= SHUT_UP_FOREVER;
                        elsif is_autoconfig_reg(ec_BaseAddress, addr) then
                            state <= CONFIGURED;
                        end if;
                    end if;

                when SHUT_UP_FOREVER =>
                    null;

                when CONFIGURED =>
                    if req = '1' and addr_fast_ram then
                        ram.req <= '1';
                        state <= RAM_ACCESS;
                    end if;

                when RAM_ACCESS =>
                    if ram_ack = '1' then
                        ram.req <= '0';
                        state <= CONFIGURED;
                    end if;
            end case;
        end if;
    end if;
end process;

-- Address comparator for the unconfigured device.
addr_autoconfig0 <= is_autoconfig(addr) and
    get_autoconfig_slot(addr) = "000";
-- Address comparator for the configured device.
addr_fast_ram <= is_fast_ram(addr);

-- Register for rdata back to bus_interface.
process (clk)
begin
    if rising_edge(clk) then
        -- Create register stage for dev_select and rdata. This
        -- improves performance as the signals are heavy on logic
        -- and are used as output.
        if (addr_autoconfig0 and state = UNCONFIGURED and
            config_in = '1')
        or (addr_fast_ram and state /= UNCONFIGURED and
            state /= SHUT_UP_FOREVER)
        then
            -- Selected for AUTOCONFIG or Fast RAM
            dev_select_reg <= '1';
            if state = UNCONFIGURED then
                -- Output AUTOCONFIG ROM data

```

```

        rdata_reg(15 downto 12) <= rom_rdata;
    elsif ram_ack = '1' then
        -- Reload rdata when SDRAM has given us a read word.
        rdata_reg <= ram_rdata;
    end if;
else
    -- We must give zeroes out when not selected.
    dev_select_reg <= '0';
    rdata_reg <= x"0000";
end if;
end if;
end process;

-- AUTOCONFIG ROM
addr_low7 <= '0' & addr(6 downto 1) & '0';
with addr_low7 select
    rom_rdata <=
        -- ERT_MEMLIST links memory into memory free list.
        (ERT_ZORROII or ERT_MEMLIST)           when x"00",
        (ERT_CHAINEDCONFIG or ERT_MEMSIZE_8MB)  when x"02",
        not (FAST_PRODUCT_NUMBER)              when x"06",
        not (HACKER_MANUFACTURER(15 downto 12)) when x"10",
        not (HACKER_MANUFACTURER(11 downto 8))  when x"12",
        not (HACKER_MANUFACTURER(7 downto 4))   when x"14",
        not (HACKER_MANUFACTURER(3 downto 0))   when x"16",
        "0000"                                  when x"40",
        "0000"                                  when x"42",
        "1111" when others;

dev_select <= dev_select_reg;
rdata <= rdata_reg;
config_out <= '0' when state = UNCONFIGURED else
    '1';
ram.nwe <= nwe;
ram.addr <= addr;
ram.wdata <= wdata;
end;
```

B.6 Disk Controller

```
--
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library ieee;
use ieee.std_logic_1164.all;
use work.greta_pkg.all;

entity disk is
  port(
    clk      : in    std_logic;
    reset     : in    std_logic;

    req       : in    std_logic;
    nwe       : in    bus_nwe;
    dev_select : out   std_logic;
    addr      : in    bus_addr;
    wdata     : in    bus_data;
    rdata     : out   bus_data;
    config_in  : in    std_logic;
    config_out : out   std_logic;

    ram       : out   ram_bus;
    ram_ack   : in    std_logic;
    ram_rdata : in    bus_data;

    --- SECURE DIGITAL (SPI)
    SPI_CLK   : out   std_logic;
    SPI_nCS   : out   std_logic;
    SPI_DO    : out   std_logic;
    SPI_DI    : in    std_logic
  );
end;

architecture rtl of disk is
  type disk_state is (
    UNCONFIGURED, SHUT_UP_FOREVER, CONFIGURED
  );

  signal state : disk_state := UNCONFIGURED;
  signal addr_autoconfig_disk : boolean := false;
  signal dev_select_reg : std_logic := '0';
  signal rom_rdata : std_logic_vector(15 downto 12);
  signal disk_rdata : bus_data := x"c0de";
  signal rdata_reg : bus_data := (others => '0');
```

```

    signal addr_low7 : std_logic_vector(7 downto 0);
    signal slot : std_logic_vector(2 downto 0) := "000";

begin

    SPI_CLK <= 'Z';
    SPI_nCS <= 'Z';
    SPI_D0 <= 'Z';

    process(clk)
    begin
        if rising_edge(clk) then
            if reset = '1' then
                state <= UNCONFIGURED;
                ram.req <= '0';
                slot <= "000";
            else
                case state is
                    when UNCONFIGURED =>
                        if (
                            req = '1' and nwe(UPPER) = '0' and
                            addr_autoconfig_disk and config_in = '1'
                        ) then
                            if is_autoconfig_reg(ec_ShutUp, addr) then
                                state <= SHUT_UP_FOREVER;
                            elsif is_autoconfig_reg(ec_BaseAddress, addr) then
                                state <= CONFIGURED;
                                slot <= wdata(10 downto 8);
                            end if;
                        end if;

                        when SHUT_UP_FOREVER =>
                            null;

                        when CONFIGURED =>
                            null;

                        end case;
                    end if;
                end if;
            end process;

            -- Address comparator for the unconfigured or configured
            -- device.
            addr_autoconfig_disk <= is_autoconfig(addr) and
                                   get_autoconfig_slot(addr) = slot;

            -- Register for rdata back to bus_interface.
            process(clk)
            begin
                if rising_edge(clk) then
                    -- Create register stage for dev_select and rdata. This
                    -- improves performance as the signals are heavy on logic
                    -- and are used as output.
                    if (addr_autoconfig_disk and config_in = '1' and
                        state /= SHUT_UP_FOREVER) then
                        -- We are selected.
                        dev_select_reg <= '1';
                        if state = UNCONFIGURED then
                            -- Output AUTOCONFIG ROM data
                            rdata_reg(15 downto 12) <= rom_rdata;
                        else

```



```

        -- Reload rdata with disk register data.
        rdata_reg <= disk_rdata;
    end if;
else
    -- We must give zeroes out when not selected.
    dev_select_reg <= '0';
    rdata_reg <= x"0000";
end if;
end if;
end process;

-- AUTOCONFIG ROM
addr_low7 <= '0' & addr(6 downto 1) & '0';
with addr_low7 select
    rom_rdata <=
        -- ERT_MEMLIST links memory into memory free list.
        (ERT_ZORROII) when x"00",
        (ERT_CHAINEDCONFIG or ERT_MEMSIZE_64K) when x"02",
        not (DISK_PRODUCT_NUMBER) when x"06",
        not (HACKER_MANUFACTURER(15 downto 12)) when x"10",
        not (HACKER_MANUFACTURER(11 downto 8)) when x"12",
        not (HACKER_MANUFACTURER( 7 downto 4)) when x"14",
        not (HACKER_MANUFACTURER( 3 downto 0)) when x"16",
        "0000" when x"40",
        "0000" when x"42",
        "1111" when others;

dev_select <= dev_select_reg;
rdata <= rdata_reg;
config_out <= '0' when state = UNCONFIGURED else
    '1';
ram.nwe <= nwe;
ram.addr <= addr;
ram.wdata <= wdata;
end;
```

Appendix C

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