RISC-V UART Debugger Implementation

for CPE-233

Contents

1 Introduction

The debugger client and modules allow for instant programming of your Otter without Vivado and powerful debugging features such as pausing execution, breakpoints, register access, and memory access.

To use the debugger, the first step is to get a hold of the modules and the debugging client. Everything is included in a GitHub repository. Clone the repository to download all the necessary files:

```
git clone git@github.com:trmckay/universal-otter-debugger.git
```

The debugger currently only supports Linux and macOS, though it can be used in Windows via WSL.

2 Integrating the debugger with your Otter

2.1 Adding the files

From the repository, include all the SystemVerilog files in *uart-db/module/design* as well as *otter-adapter/multicycle/db_adapter.sv* in your Vivado project. Or, add them from wherever you downloaded them. You will add a total of seven files.

2.2 Adding UART connections to the Otter

In your wrapper, add a one bit output *stx* and a one bit input *srx*.

File: *otter_wrapper.sv*

```
module OTTER_Wrapper (
    // other I/O...
    input srx,
    output stx
);
```

Do the same in the MCU.

File: *otter_mcu.sv*

```
module OTTER_MCU (
    // other I/O...
    input srx,
    output stx
);
```

Where the MCU is instantiated in the wrapper, connect the new signals.

File: *otter_wrapper.sv*

```
OTTER_MCU MCU(
    // other I/O...
    .srx(srx),
    .stx(stx)
);
```

You will need to modify the constraints to connect *srx* and *stx* to the micro-USB port on the Basys3. Paste the following into your constraints:

```
##USB-RS232 Interface
set_property PACKAGE_PIN B18 [get_ports srx]
    set_property IOSTANDARD LVCMOS33 [get_ports srx]
set_property PACKAGE_PIN A18 [get_ports stx]
    set_property IOSTANDARD LVCMOS33 [get_ports stx]
```

2.3 Modifying the FSM

The FSM requires some very small modifications to accomodate the debugger. It needs the ability to pause as well as a new output for the present state.

Add a one bit input to your MCU called *pause* and a two bit output for the state.

```
module cu_fsm (
    // other I/O...
    input pause,
    output [1:0] state
);
```

The state output can simply be assigned to the present state variable.

```
assign state = ps;
```

The signal *pause* should prevent your FSM from changing states while high. This can be done by adding a conditional around the state transition.

Before:

```
always_ff @(posedge clk)
    ps <= ns;
```

After:

```
always_ff @(posedge clk) begin
    if (!pause)
        ps <= ns;
end
```

2.4 Instantiation and variable declaration

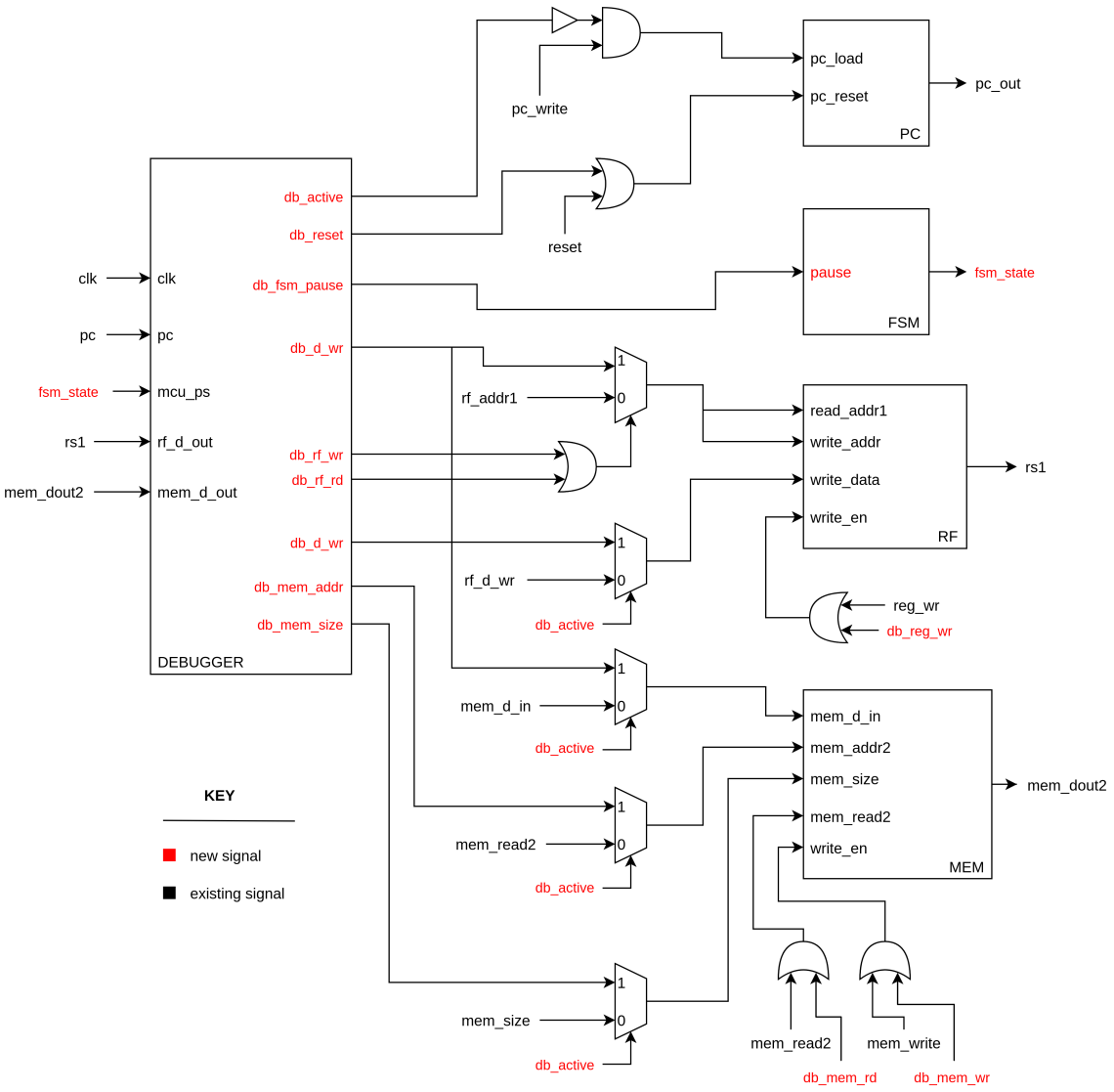
Add the module to your MCU and connect the relevent signals. Here is a template instantiation with the output variables declared.

```
wire db_active, db_fsm_pause, db_mem_rd, db_mem_wr, db_rf_rd, db_rf_wr, db_reset;
wire [1:0] db_mem_size;
wire [31:0] db_mem_addr, db_d_wr;
wire [4:0] db_rf_addr;

db_adapter_mc debugger(
    .srx(srx),                    // serial input
    .stx(stx),                    // serial output
    .clk(),                       // 50 MHz clock
    .pc(),                        // program count
    .mcu_ps(),                    // present state of FSMi
    .opcode(),                    // opcode of current instruction
    .mem_d_out(),                 // data out 2 from memory
    .rf_d_out(),                  // rs1 output from register file
    .db_active(db_active),        // debugger is active
    .db_fsm_pause(db_fsm_pause),  // fsm should remain paused
    .db_mem_addr(db_mem_addr),    // address for memory access
    .db_mem_size(db_mem_size),    // size of memory access
    .db_mem_wr(db_mem_wr),        // write enable for memory
    .db_mem_rd(db_mem_rd),        // read enable for memory
    .db_rf_addr(db_rf_addr),      // address for register access
    .db_rf_wr(db_rf_wr),          // write enable for register file
    .db_rf_rd(db_rf_rd),          // read enable for register file
    .db_d_wr(db_d_wr),            // write data for register file and memory
    .db_reset(db_reset)           // reset PC and FSM
);
```

2.5 Connections in the MCU

Below is a diagram of the necessary connections in the Otter.



Alternatively, the modifications are described textually below. Only the modified connections are listed and variable names may vary.

Program counter

```
program_counter PC(
    .load(pc_write && !db_active),
    .reset(reset || db_reset)
);
```

Register file

```
program_counter PC(
    .read_addr1((db_rf_rd) ? db_rf_addr : ir[19:15]),
    .write_addr((db_rf_rd) ? db_rf_addr : ir[11:7]),
    .write_data((db_rf_wr) ? db_d_wr : rf_data_in),
    .write_enable(rf_wr || db_rf_wr)
);
```

Memory

```
OTTER_mem_byte #(14) memory (
    .MEM_ADDR2((db_active) ? db_mem_addr : alu_result),
    .MEM_DIN2((db_active) ? db_d_wr : rs2),
    .MEM_WRITE2(memWrite || db_mem_wr),
    .MEM_READ1(memRead1 && !db_active),
    .MEM_READ2(memRead2 || db_mem_rd),
    .MEM_SIZE((db_active) ? db_mem_size : ir[13:12]),
);
```

FSM

```
otter_fsm FSM(
    .reset(mcu_reset || db_reset),
    .state(mcu_ps),
    .pause(db_fsm_pause)
);
```

3 Debugging client

3.1 Installation

Using and installing the debug client is very simple. To clone the source code, build, and install, run the install script in the *uart-db* folder in the repository. Follow the instructions in your terminal, and installation should be easy. Be sure to scan the output of the installer for any warnings.

3.2 Usage

When installation is complete, launch the debugger with the command *uart-db*. If you agree to autodetect, it will automatically connect to the Otter. If you already know the location of your serial port, you can launch the client with *uart-db [device path]*. Once in the debugging shell, enter *h* or *help* to output the help message.

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