

IOB-SoC

A RISC-V-based System on Chip

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Introduction

- Building processor-based systems from scratch is challenging
- The IOB-SoC template eases this task
- Provides a base Verilog SoC equipped with
 - a RISC-V CPU
 - a memory system including boot ROM, RAM and AXI4 interface to DDR
 - a UART communications module
- Users can add IP cores and software to build more complex SoCs
- Here, the addition of a timer IP and its software driver is exemplified



Project setup

- Use a Linux machine or VM
- Install the latest stable version of the open source Icarus Verilog simulator (iverilog.icarus.com)
- Make sure you can access github.com using an ssh key
- At github.com create your SoC repository using github.com/IObundle/iob-soc as a template
- Follow the instructions in the README file to clone the repository in your Linux machine



Create an IP core to instantiate in your SoC

- Create a timer IP core repository or, alternatively, use the one at [www.github.com/IObundle/iob-timer.git](https://github.com/IObundle/iob-timer.git)
- An IP core can be integrated in an IOB-SoC if it provides the following 2 files:
 - ① hardware/hardware.mk
 - ② software/embedded/embedded.mk
- Add the IP core repository as a git submodule of your IOB-SoC repository:

```
git submodule add  
https://github.com/IObundle/iob-timer.git  
submodules/TIMER
```
- To configure the system to host the IP core, edit the `./system.mk` file as in the next slide



Edit the ./system.mk configuration file to declare a new peripheral

```
#FIRMWARE
FIRM_ADDR.W:=13

#SRAM
SRAM_ADDR.W=13

#DDR
USE_DDR:=0
RUN_DDR:=0
DDR_ADDR.W:=30

#ROM
BOOTROM_ADDR.W:=12

#Init memory (only works in simulation or FPGA not running DDR)
INIT_MEM:=1

#Peripheral list (must match respective submodule name)
PERIPHERALS:=UART TIMER

...

N_SLAVES:=1
```



Instantiate the timer IP in file hardware/src/system.v

```
'timescale 1ns/1ps
'include "system.vh"

module system (

    ...

    //
    // TIMER
    //

    iob_timer timer (
        .clk (clk),
        .rst (reset),

        //cpu interface
        .valid(slaves_req['valid('TIMER)]),
        .address(slaves_req['address('TIMER, 'TIMER_ADDR.W+2,2)]),
        .wdata(slaves_req['wdata('TIMER)]),
        .rdata(slaves_resp['rdata('TIMER)]),
        .ready(slaves_resp['ready('TIMER)])
    );

    ...
endmodule
```



Edit the `firmware.c` file to drive the new peripheral

```
./software/firmware/firmware.c
```

```
#include "system.h"
#include "iob-uart.h"
#include "iob-timer.h"

int main()
{
    unsigned long long elapsed;
    unsigned int elapsedu;

    //read current timer count, compute elapsed time
    elapsed = timer_get_count(TIMER_BASE);
    elapsedu = timer_time_us(TIMER_BASE);

    //init uart
    uart_init(UART_BASE, FREQ/BAUD);

    uart_printf("\nHello world!\n");

    uart_txwait();

    uart_printf("\nExecution time: %d clocks in %dus @%dMHz (%d MBaud)\n\n",
        (unsigned int)elapsed, elapsedu, FREQ/1000000, BAUD/1000000);

    uart_txwait();
    return 0;
}
```



Run the firmware in internal SRAM

- ❶ Run the firmware in internal RAM and disable (re)programming
 - Assign `USE_DDR=0` and `USE_BOOT=0`
 - Loading programs after the FPGA is programmed is disabled: if the firmware is modified the FPGA must be recompiled
 - This option is only valid for FPGA which permits memory initialisation
- ❷ Run the firmware in internal RAM and enable (re)programming
 - Assign `USE_DDR=0` `USE_BOOT=1`
 - Loading programs after the FPGA is programmed is enabled
 - This option is valid for FPGA and ASIC
 - Firmware is (re)loaded via UART



Run the firmware in external DDR

- ❶ Run the firmware in external DDR and disable (re)programming
 - Assign `USE_DDR=1` and `USE_BOOT=0`
 - This option is only allowed in simulation which permits memory initialisation
 - An FPGA or ASIC implementation will not work
- ❷ Run the firmware in external DDR memory and enable (re)programming
 - Define `USE_DDR=1` `USE_BOOT=1`
 - This option is valid for FPGA and ASIC
 - Firmware is (re)loaded via UART
 - Third party DDR controller IP core is required



Simulate and implement the system

- To simulate the system just type `make`
- The firmware, bootloader and system verilog description are compiled as you can see from the printed messages
- The last prints should look like the following

```
IOB-SoC Bootloader:
```

```
Reboot CPU and run program...
```

```
Hello world!
```

```
Execution time: 6583 clocks in 66us @100MHz (30 MBaud)
```

- To implement in your chosen FPGA just type `make fpga`
- To implement in your chosen ASIC just type `make asic`
- To load the firmware in the hardware just type `make load-firmware`



Conclusions and future work

- Conclusions

- A tutorial on SoC creation using IOb-SoC is presented
- The addition of a peripheral IP core (timer) is illustrated
- A simple software driver for the IP core is exemplified
- How to compile and run the system is explained
- Options for implementing the main memory are presented

- Future work

- Non-volatile (flash) external memory support
- Real Time Operating System (RTOS)

