

# IOB-SoC

## Tutorial: Create a RISC-V-based System on Chip

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# Outline

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- Project setup
- Instantiate an IP core in your SoC
- Edit file `firmware.c` to drive the new peripheral
- Simulate IOb-SoC
- Run IOb-SoC in FPGA
- Conclusions and future work



# 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, cache system 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 core 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](http://iverilog.icarus.com))
- Make sure you have **ssh** push/pull access to [github.com](https://github.com) (https access is not enough) key
- Visit the repository at [github.com/IObundle/iob-soc](https://github.com/IObundle/iob-soc)
- Follow the instructions in its README file to clone the repository and install the tools
- Create the system configuration file `system.mk` as indicated



# Instantiate an IP core in your SoC

- The Timer IP core at [github.com/IObundle/iob-timer.git](https://github.com/IObundle/iob-timer.git) will be used as an example
- Add the Timer IP core repository as a git submodule of your IOB-SoC repository:

```
git submodule add git@github.com:IObundle/iob-timer.git submodules/TIMER
```

- Add the timer IP core to the list of peripherals in the `./system.mk` file:

```
PERIPHERALS:=UART TIMER
```

- An IP core can be integrated into IOB-SoC if it provides the following files:
  - `hardware/hardware.mk`
  - `software/embedded.mk`
- Study these files and its references in the Timer IP core repository.



# Edit the `firmware.c` file to look as follows and drive the new peripheral

`./software/firmware/firmware.c`

```
#include "system.h"
#include "periphs.h"
#include "iob_uart.h"
#include "iob_timer.h"

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

    //init timer and uart
    timer_init(TIMER_BASE);
    uart_init(UART_BASE, FREQ/BAUD);

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

    uart_txwait();

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

    uart_printf("\nExecution time: %d clock cycles\n", (unsigned int) elapsed);
    uart_printf("\nExecution time: %dus @%dMHz\n\n", elapsedu, FREQ/1000000);

    uart_txwait();
}
```



# Simulate IOb-SoC

- The following assumes the Icarus Verilog simulator is installed locally and that the SIMULATOR variable is set as SIMULATOR=icarus (see the README.md file)
- To run the simulation with the firmware pre-initialised in the memory:  
`make sim`
- The firmware and bootloader C files, and the system's Verilog files are compiled as you can see from the printed messages
- During the simulation itself, the following is printed:

```
IOb-Bootloader: USE_DDR=0 RUN_DDR=0
IOb-Bootloader: Restart CPU to run user program...
```

```
Hello world!
```

```
Execution time: 2190 clock cycles
```

```
Execution time: 23us @100MHz
```



# Run IOb-SoC in FPGA

- To compile and run your SoC in one of our FPGA boards, contacts us at [info @ iobundle . com](mailto:info@iobundle.com). The following assumes your are using our default Intel Cyclone V GT Development Kit
- To add your own FPGA board, add a directory into `./hardware/fpga`, using the existing board directories as examples
- To compile the FPGA design with the firmware pre-initialised in the memory:  

```
make fpga INIT_MEM=1
```
- To load the hardware design in the FPGA:  

```
make fpga-load
```
- To run your firmware in the FPGA:  

```
make run-hw INIT_MEM=1
```
- You may change the firmware afterwards and use the previous command to recompile and reload the firmware via UART





# Conclusions

- A tutorial on creating a simple SoC using IOb-SoC has been presented
- The addition of an example peripheral IP core has been illustrated
- A simple software driver for the IP core has been described
- Simulation of IOb-SoC has been explained
- Compiling and running IOb-SoC in FPGA has been explained

