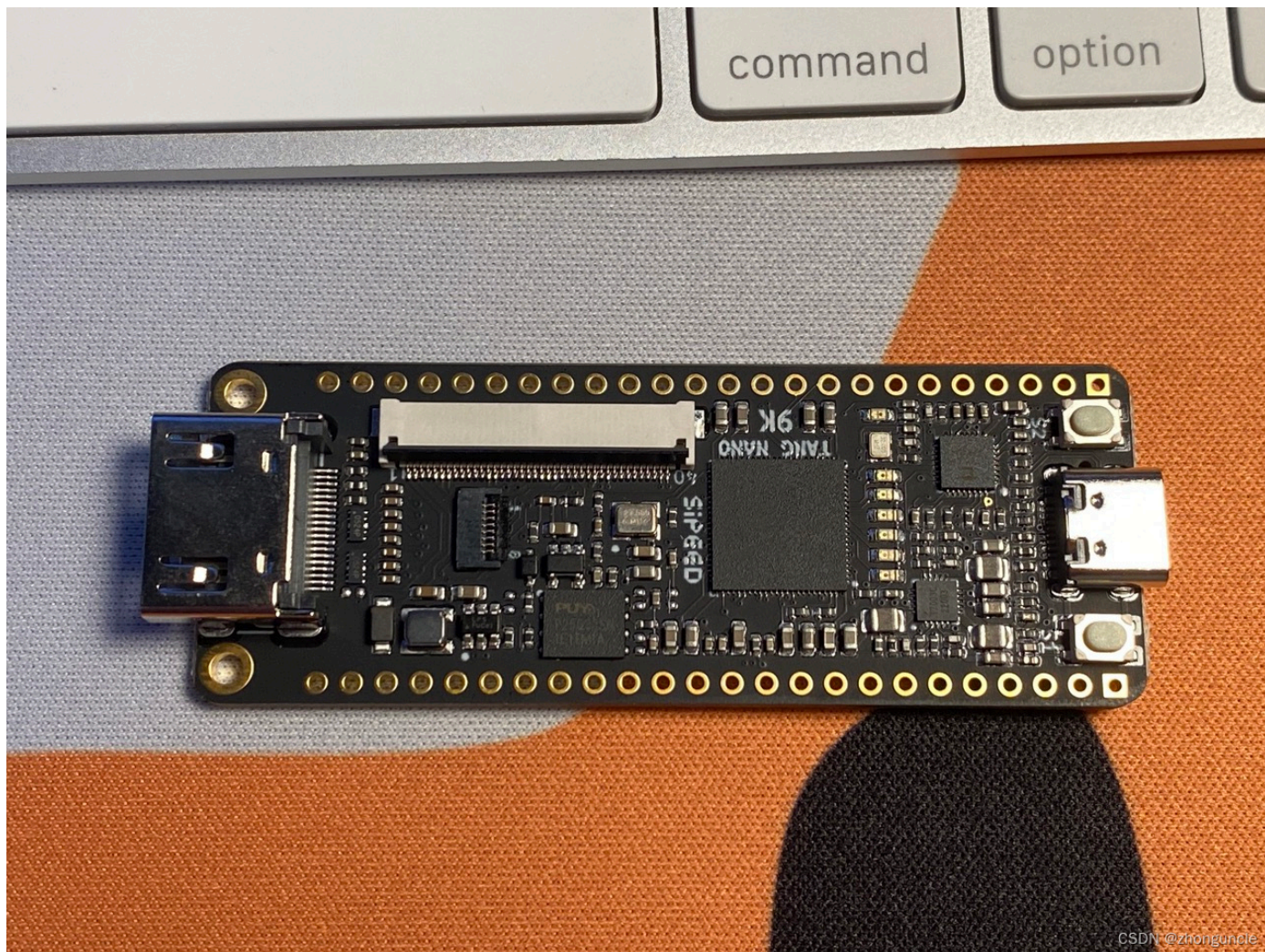


Recently I received a Tang nano 9K FPGA development board as gift, so I wanted to take this opportunity to study FPGA.

The official document recommend to use GOWIN IDE to develop GOWIN FPGA, but you need to apply for a license and submit a lot of information. Since it was a gift, So it is not convenient. In addition, IDE is actually not very suitable for learning and putting into production, because IDE hides many details. So I want to find other workflows, just like using any text editor and Clang/LLVM to compile C/C++ programs.



What is being developed in FPGA development?

First of all, you need to know what is being developed in FPGA development, and you can find the tools and software needed.

The essence of the computing machine executing various instructions is to energize the pins of series of logic units, and then output new circuit signals after passing through the logic circuit. From software perspective, the input of each pin is one bit of binary numbers (such as `01011101010`) (in positive logic used generally, `1` represents high level, `0` means low level), the early perforated boards were the physical version of this binary number. **At all, finally you need a file that stores binary instructions, which will be executed by the FPGA.**

There is another question: The instructions how to know which the interfaces and pins are? If they don't know, there is no way to get the correct binary instructions, because the operation objects of instructions will be wrong.

This kit contains many FPGA tools, those directory name or program name with `gowin` are what the Tang Nano series needs generally. So in fact, you can just install the tools for the Gowin FPGA chip. However, OSS CAD Suite can be used not only on the terminal, but also on VS Code. Therefore, using OSS CAD Suite is more convenient. If you use other FPGAs, you can reduce the installation effort.

The download link of OSS CAD Suite is: <https://github.com/YosysHQ/oss-cad-suite-build/releases/latest>

If you encounter the following error when building with the latest OSS CAD Suite, it is recommended to download any version in February or March 2023.

```
gowin_pack -d GW1N-9C -o rio.fs rio_pnr.json
Traceback (most recent call last):
File "/opt/oss-cad-suite/libexec/gowin_pack", line 33, in
sys.exit(load_entry_point('Apycula==0.8.2a1', 'console_scripts', 'gowin_pack')())
File "/opt/oss-cad-suite/lib/python3.8/site-packages/Apycula-0.8.2a1-py3.8.egg/apycula/gowin_pack.py", line 984, in main
AttributeError: module 'importlib.resources' has no attribute 'files'
make: *** [Makefile:16: rio.fs] Error 1
```

Then put the path to `bin` of OSS-CAD-Suite into the environment variable `PATH`. You can directly put it into your Shell configuration file (such as `.bashrc`). The statement is as follows:

```
export PATH="...../oss-cad-suite/bin:$PATH"
```

Then use `source` to activate the update or open a new terminal window.

Only install the tool chains required by Gowin FPGA

The Gowin FPGA chip used by Tang Nano, its bitstream and format tools are in the Apicula project, this is the address: <https://github.com/YosysHQ/apicula>. If you need to read the documentation, it's also in this project too.

The installation method is as follows:

```
$ pip3 install apycula
```

If you want a simple installation, you can use this method. The size of the package downloaded and installed in this way will be much smaller (4.1 MB vs. 1.35 GB), but if you need to use other tools during the development process, you will have to download these tools separately.

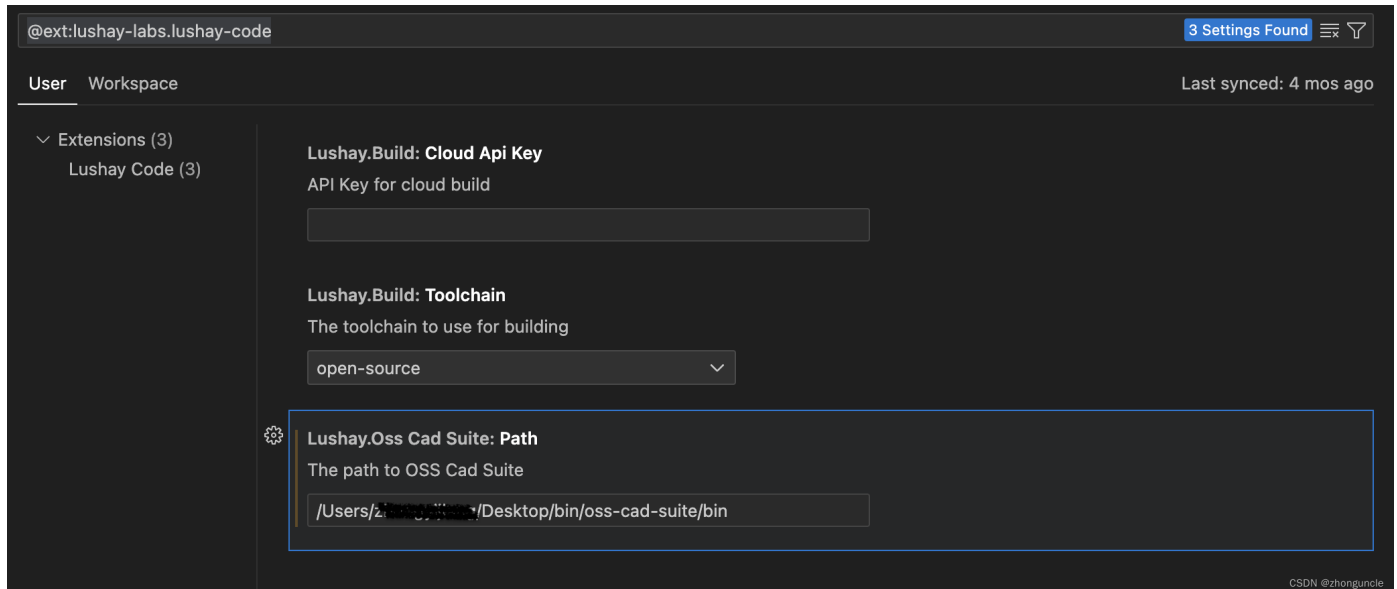
Text Editor: VS Code

We will use Visual Studio Code to write code. Of course you can use any text editor to write code, such as Vim, Emacs, etc. However, applications such as Word and Pages cannot be used, because such applications are text processors, rather than editors and don't use simple text at the bottom.

The main reason for using Visual Studio Code here is the extension will highlight the code, set pins easily and build automatically. The two extensions are `Lushay Code` and `Verilog-HDL/SystemVerilog/Bluespec SystemVerilo`.

- `Lushay Code` is for using OSS-CAD-Suite. If `Lushay Code` does not support your FPGA, please also find extension that supports your FPGA.
- `Verilog-HDL/SystemVerilog/Bluespec SystemVerilo` is for code highlighting and easy pin setting.

In addition, you need to configure the extension. In "Settings - Extensions", enter your OSS-CAD-Suite location into highlight area shown below, then VS Code can use OSS-CAD-Suite:



Sample: Make the onboard LEDs light up one by one

There are two files `top.v` and `tangnano9k.cst`, the contents as follows (Notice `top.v` must have a blank line at the end)

```
// top.v
module top
(
    input clk,
    output [5:0] led
);

localparam WAIT_TIME = 13500000;
reg [23:0] clockCounter = 0;
reg [5:0] cur_state = 6'b111111; // Each bit represent an onboard LED

always @(posedge clk) begin
    clockCounter <= clockCounter + 1;
    if (clockCounter == WAIT_TIME) begin
        clockCounter <= 0;
        cur_state <= cur_state << 1;
        if (cur_state == 6'b000000) begin
            cur_state <= 6'b111111;
        end
    end
end
end
```

```
assign led[5:0] = cur_state[5:0];

endmodule
```

```
// tangnano9k.cst
IO_LOC   "clk" 52;
IO_PORT  "clk" PULL_MODE=UP;

IO_LOC   "led[0]" 10;

IO_LOC   "led[1]" 11;

IO_LOC   "led[2]" 13;

IO_LOC   "led[3]" 14;

IO_LOC   "led[4]" 15;

IO_LOC   "led[5]" 16;
```

If use VS Code extension to set up `tangnano9k.cst`, it should be as follows:

The screenshot shows the 'Constraints Editor' for the 'Tang Nano 9K' device. The main table lists constraints with the following data:

PORT NAME	LOCATION	PORT OPTIONS
clk	52	Pull Up
led[0]	10	
led[1]	11	
led[2]	13	
led[3]	14	
led[4]	15	
led[5]	16	

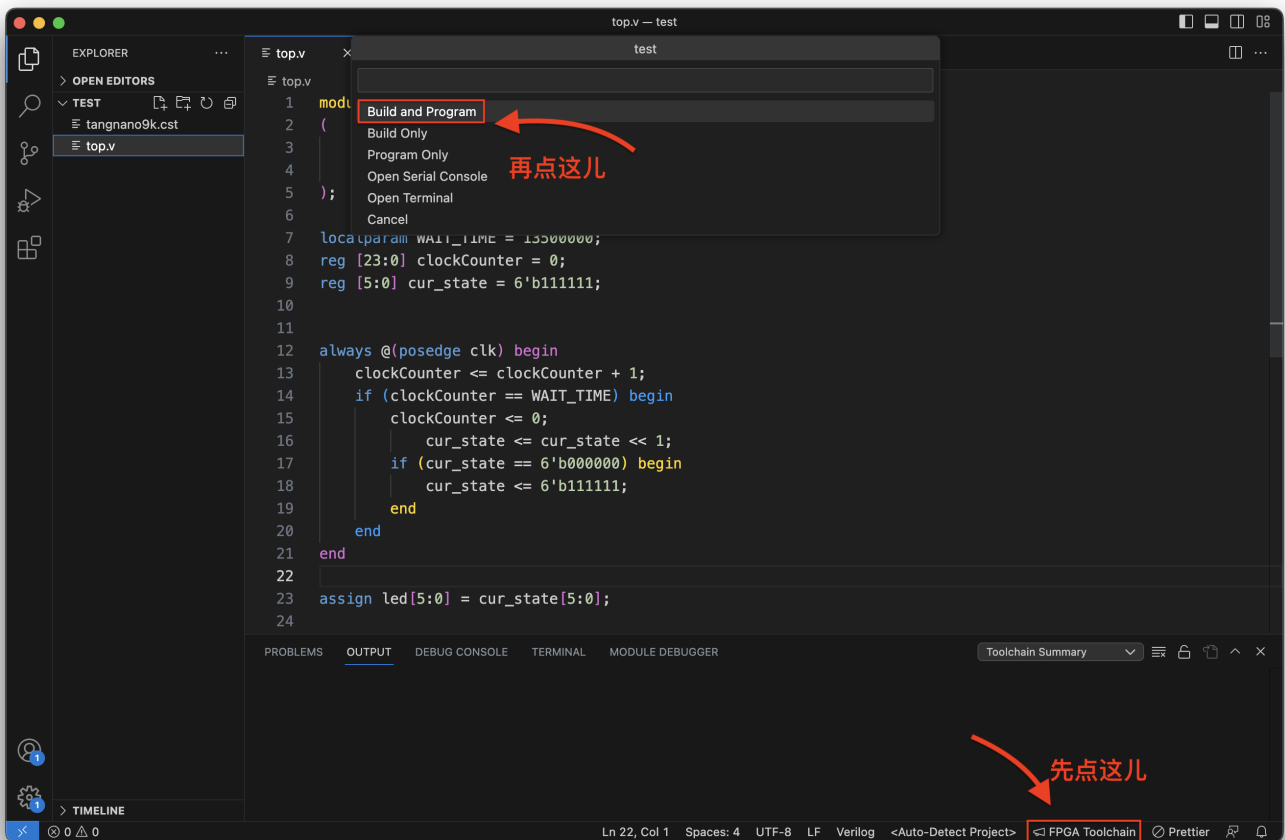
The right panel, titled 'Edit Constraint', shows the configuration for the selected 'led[0]' constraint:

- Port Name: led[0]
- Location: 10
- Pull Mode: None
- Drive Power: Unset
- IO Standard: Unset

Build

Use VS Code

This method is very simple. If you have configured VS Code and connected your FPGA to your Mac, just click in the order shown below (First bottom, Second top). Wait a while, the `fs` file will have been built and burned to FPGA:

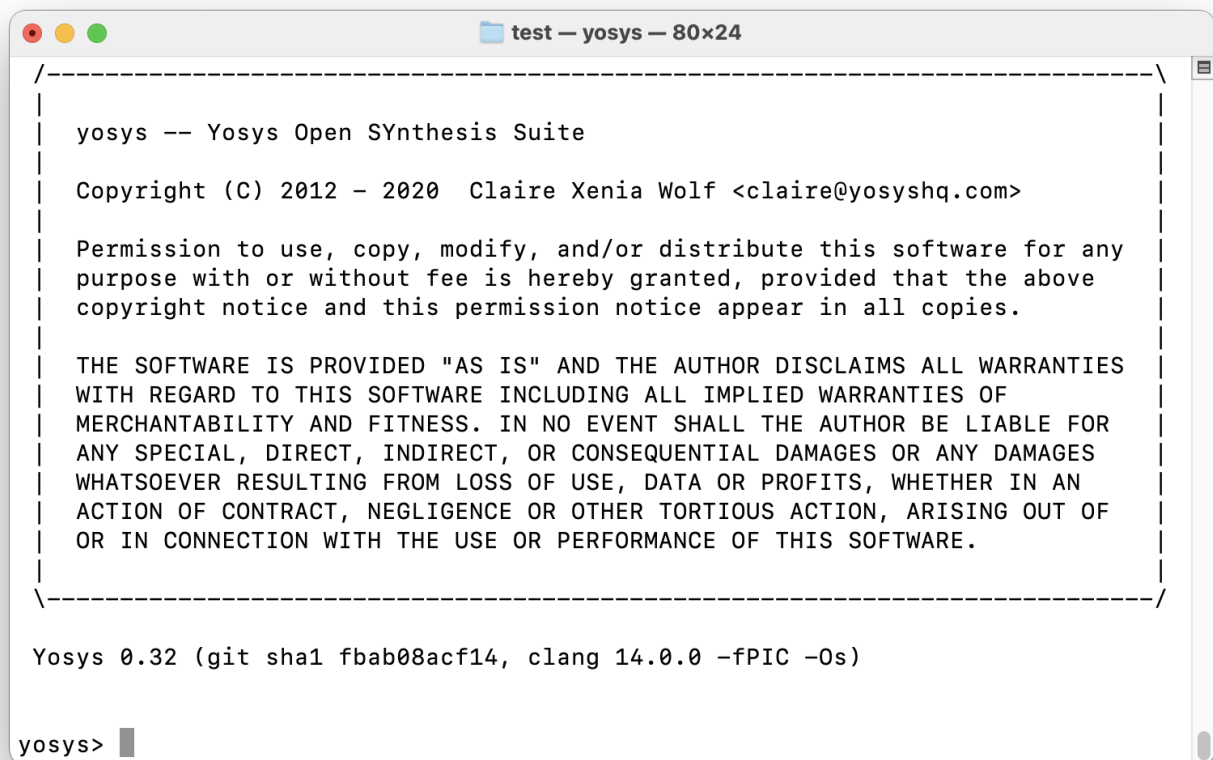


Build using terminal

This part is divided into two sections. The first section introduces the use and description of each step in detail. The second section organizes it into a script, which is much more convenient.

Step by step

First enter `yosys` (press and press Enter), the page is as follows:



```
test — yosys — 80x24

/-----\
|
|  yosys -- Yosys Open SYnthesis Suite
|
|  Copyright (C) 2012 - 2020  Claire Xenia Wolf <claire@yosyshq.com>
|
|  Permission to use, copy, modify, and/or distribute this software for any
|  purpose with or without fee is hereby granted, provided that the above
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|
|  THE SOFTWARE IS PROVIDED "AS IS" AND THE AUTHOR DISCLAIMS ALL WARRANTIES
|  WITH REGARD TO THIS SOFTWARE INCLUDING ALL IMPLIED WARRANTIES OF
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|  ANY SPECIAL, DIRECT, INDIRECT, OR CONSEQUENTIAL DAMAGES OR ANY DAMAGES
|  WHATSOEVER RESULTING FROM LOSS OF USE, DATA OR PROFITS, WHETHER IN AN
|  ACTION OF CONTRACT, NEGLIGENCE OR OTHER TORTIOUS ACTION, ARISING OUT OF
|  OR IN CONNECTION WITH THE USE OR PERFORMANCE OF THIS SOFTWARE.
|
|-----\

Yosys 0.32 (git sha1 fbab08acf14, clang 14.0.0 -fPIC -Os)

yosys> █
```

Then enter the following command:

```
# Read and analyze the contents of 'top.v'
> read -sv top.v
# Synthesize and convert the contents of 'top.v' into json format (since yosys has
already analyzed the file, so the file name 'top.v' will not be used. We will use the
module name 'top')
> synth_gowin -top top -json test.json
# exit yosys
> exit
```

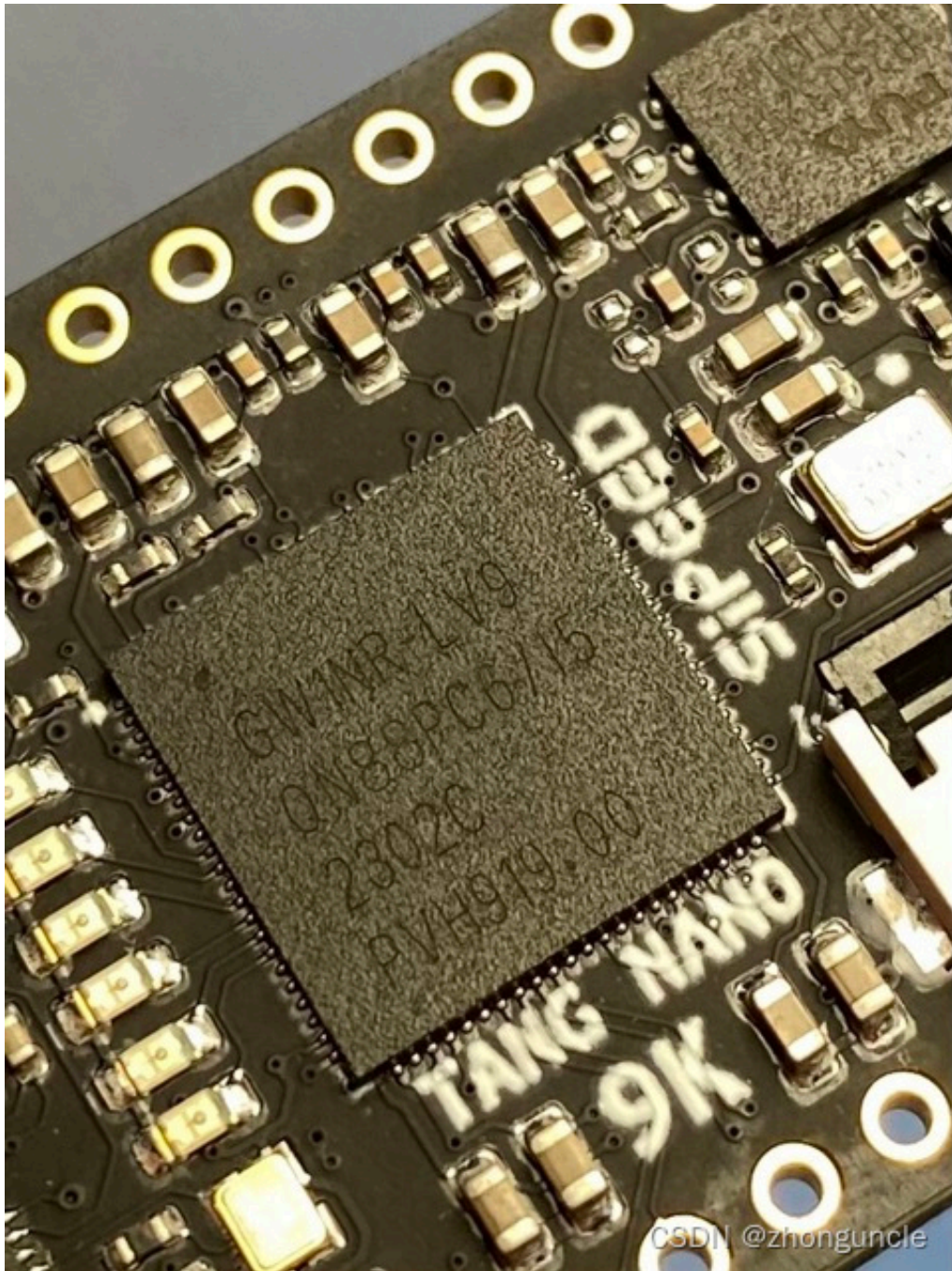
Of course, the above part can be simplified into one command in Shell:

```
$ yosys -p "read_verilog top.v; synth_gowin -json test.json"
```

Now use the following commands for further work:

```
# Generate FPGA layout and routing information by setting the device name, CST file and
JSON file just generated, and put these into test_pnr.json.
$ nextpnr-gowin --family GW1N-9C --device GW1NR-LV9QN88PC6/I5 --cst tangnano9k.cst --json
test.json --write test_pnr.json
```

The family name and device name need to be modified according to your FPGA (if it is not Tang nano 9K, you do not need to use the `--family` option). These names are not the short one on the official website. You can see it on your FPGA chip package. For example, the image below is the device name of Tang nano 9K GW1NR-LV9QN88PC6/I5:



You also can search it from the table below:

name	device	board
Trenz TEC0117	GW1NR-UV9QN881C6/I5	tec0117
Sipeed Tang Nano:	GW1N-LV1QN48C6/I5	tangnano
Sipeed Tang Nano 1K	GW1NZ-LV1QN48C6/I5	tangnano1k
Sipeed Tang Nano 4K	GW1NSR-LV4CQN48PC7/I6	tangnano4k
Sipeed Tang Nano 9K	GW1NR-LV9QN88PC6/I5	tangnano9k
Seeed RUNBER	GW1N-UV4LQ144C6/I5	runber
@Disasm honeycomb	GW1NS-UX2CQN48C5/I4	honeycomb

Next, if you have a Tang nano 9K like me, then use the following command (the device cannot write the long one in table):

```
$ gowin_pack -d GW1N-9C -o top.fs test_pnr.json
```

If other Gowin FPGA:

```
$ gowin_pack -d [device from above table] -o top.fs test_pnr.json
```

Then burn the bitstream file to FPGA:

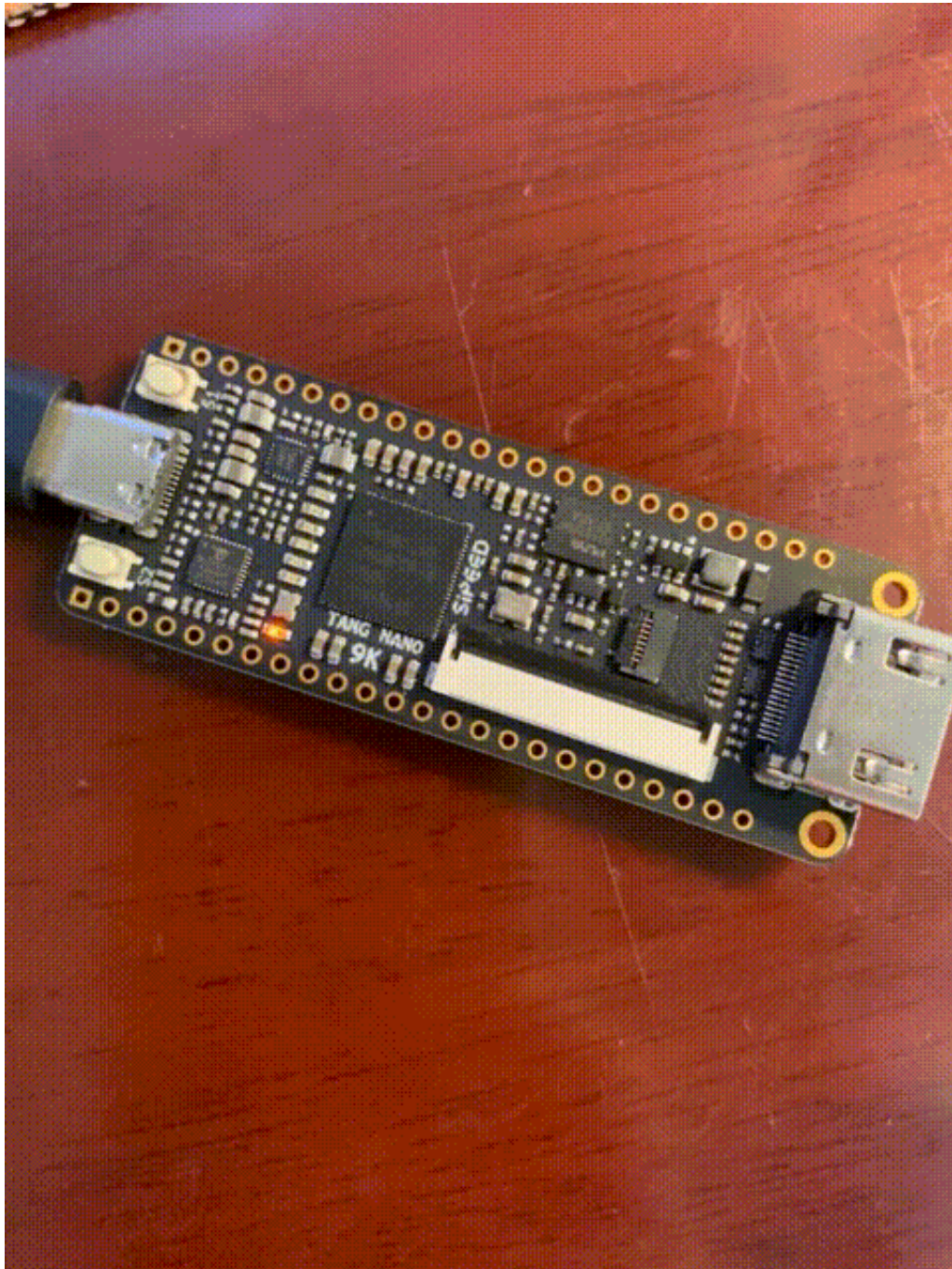
```
openFPGALoader -b [board from above table] pack.fs
```

The corresponding `board` can be seen in the table above. If you see something similar to the following, then the burning is successful:

```
Jtag frequency : requested 6.00MHz    -> real 6.00MHz
Parse file Parse top.fs:
Done
DONE
Jtag frequency : requested 2.50MHz    -> real 2.00MHz
erase SRAM Done
Flash SRAM: [=====] 100.00%
Done
CRC check: Success
```

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Then you can see FPGA board look like:



Write a script

To get some productivity, we will write it into a script to achieve "one-step generation and burning". You can modify it according to your own model.

Create a new blank text file `build.sh` and type:

```
#!/bin/bash
```

```
DEVICE='GW1NR-LV9QN88PC6/I5|tangnano9k'
```

```
BOARD='tangnano9k'
```

```
yosys -p "read_verilog top.v; synth_gowin -json temp.json"
```

```
nextpnr-gowin --family GW1N-9C --device GW1NR-LV9QN88PC6/I5 --cst tangnano9k.cst --json
```

```
temp.json --write test_pnr.json
```

```
gowin_pack -d GW1N-9C -o top.fs test_pnr.json
```

```
openFPGALoader -b $BOARD top.fs
```

Then use the following command to grant execute permission:

```
$ chmod +x build.sh
```

Now you can just use `./build.sh` to build and burn.

Further reading

FPGA is a branch of digital electronics. During the learning process of FPGA, you need to understand many digital electronics terms and concepts, so you can use professional books on digital electronics as start and will also be helpful for subsequent learning. I recommend materials from the University of Cambridge:

ELECTRICAL, ELECTRONIC AND INSTRUMENTATION

Resources

- * Electronics Textbook 'Lessons in electric Circuits' ([Website](#))
 - [DC Circuits](#)
 - [AC Circuits](#)
 - [Semiconductors](#)
 - [Digital Circuits](#)
 - [Reference Information](#)
 - [Experiments](#)
- US Dept of Energy Fundamentals Handbook - Electrical Science, [Vol. 1](#), [Vol. 2](#), [Vol. 3](#), [Vol. 4](#). ([website](#))
- [Op Amps For Everyone](#) and [Handbook of Operational Amplifier Applications](#), with the kind permission of Texas Instruments ([website](#))
- [Introduction to Microprocessors \(ARM based\)](#)
- [Fundamentals of Circuit Design](#) (Currently in draft form, an updated version will be made available from [www-mdp.eng.cam.ac.uk](#) and on future versions of the disk)
- [Practical Circuit Design](#) (Currently in draft form, an updated version will be made available from [www-mdp.eng.cam.ac.uk](#) and on future versions of the disk)
- [PCB Design Tutorial](#), with kind permission of Mr. David Jones ([website](#))

Instrumentation

- Transactions, instrumentation methods [Pressure/Strain/Force/Acceleration/Torque measurement](#), [Flow/Level measurement](#), [IR Temperature measurement](#), [Data Acquisition](#) With the kind permission of [Omega Engineering Inc.](#)
- US Dept of Energy Fundamentals Handbook - Instrumentation and Control, [Vol. 1](#), [Vol. 2](#),

CUED Databooks

- [Microprocessor](#)
- [Electrical](#)

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This information is good for people who are not majoring in digital electronics. Many knowledge are not difficult. You maybe have learned them in middle and high schools. For me, the main reason is that the Soviet-style symbols were used in middle schools, but most of the materials use American symbols or current national standard symbols.

If you're new to FPGAs like me, some FPGA terms may be confusing. For example, what is Verilog, what is a hard IP. For these FPGA terms and concepts, I recommend reading a book "FPGAs for Dummies" jointly published by Intel. The cover of "FPGAs for Dummies" As shown below:

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This book uses a very relaxed language to introduce the terminology, language, design ideas, development history, applications and other aspects of knowledge you need to prepare to enter the FPGA field. It also talks about the most basic question: why you should use FPGA.

"XXX FOR DUMMIES" is a series of books dedicated to introducing technology in humorous and simple language, similar to "Learning XXX in Ten Minutes", but some authors are very powerful in the industry. This series is not from Intel, but the FPGA is a collaboration with Intel.

About Tang Nano 9K, there are also very good blogs, which introduce many cases and usages. The Lushay Code plug-in mentioned above was made by them: <https://learn.lushaylabs.com/getting-setup-with-the-tang-nano-9k/>

There are some codes and documents of YosysHQ projects, such as those mentioned above:

- OSS CAD Suite: <https://github.com/YosysHQ/oss-cad-suite-build>
- Project Apicula: <https://github.com/YosysHQ/apicula>
- nextpnr: <https://github.com/YosysHQ/nextpnr>

I hope these will help someone in need~