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Democratizing IC Design in the Philippines – "From Concept to Tapeout" Using Open-source Tools and Tiny Tapeout

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Abstract: This paper discusses an overview of the different open-source Electronic Design Automation (EDA) tools and resources that may help democratize IC design in the Philippines. The discussion on the different open-source EDA tools, PDK, circuit designs, learning materials, and low-cost tapeout from Tiny Tapeout hopes to inspire others to learn and to teach IC design or microelectronics courses. There are live hyperlinks in the paper that will direct the reader to different online open-source resources. As a proof of concept, a simple circuit with a 7-segment display showing the text PILIPINASLASALLE was submitted to Tiny Tapeout for an actual chip fabrication using Sky130 Process Design Kit (PDK) to show that we can do tapeouts using open-source tools and PDK.

Key Words: open-source, IC design, EDA tool

1. INTRODUCTION

"PH to produce 128,000 semiconductor engineers by 2028—Marcos" is the headline of one of the leading news outlets in the Philippines (Unite, 2024), but there is an enrollment decline or "dwindling number of enrollees in the electronics engineering courses" in the Philippines (An Act Amending Section 16 of Republic Act No. 9292, Otherwise Known as the "Electronics Engineering Law of 2004," 2023; IECEP National, 2023; Joaquin et al., 2022). Microelectronics track is vital to produce a semiconductor engineer for Integrated Circuit (IC) design and manufacturing. Unfortunately, the microelectronics track is just an elective in the Electrical Engineering or Electronics and Communications Engineering (ECE) curriculum in the country. It might be possible to offer this track also to Computer Engineering. However, there are only a few colleges, and universities (less than ten) that offer microelectronics tracks.

If you ask different colleges and universities in the country why they are not offering microelectronics tracks, here are their reasons: 1) licensed Electronic Design Automation (EDA) tools such as Cadence and Synopsys used for IC design are expensive and cost millions of pesos, 2) Process Design Kits (PDK) of many foundries needs a lot of paper works and Non-Disclosure Agreements (NDA), 3) functional IC design simulations and layouts that reached tapeout or chip fabrication are not readily accessible in many books or papers, 4) workshops and lectures about IC designs are mostly given by vendors selling their expensive products, and 5) tapeout or chip fabrication costs millions of pesos which very expensive on the point of view of the academe.

This paper aims to give some information that may mitigate, if not solve, the negative impacts of the five issues stated. The first four issues might be solved using open-source EDA tools, PDKs, circuit designs, and learning materials and the last issue might be solved by the low-cost Tiny Tapeout (Tiny Tapeout, 2024b). Many top U.S. colleges and universities use or promote open-source materials for IC design in their microelectronics courses. Here are some examples: UC Berkeley (Reais-Parsi, 2024), UC San Diego (Jacobs School of Engineering, 2018), Stanford University (Raina, 2024), University of Michigan (June, 2023), University of Hawaii (UH News, 2024), Cornell University (Batten, 2023), Purdue University (Purdue SoCET, 2021), Oklahoma State University (Stine,

n.d.), and Carnegie Mellon University (Burns, 2023). Even the Institute of Electrical and Electronics Engineering Solid State Circuits Society (IEEE-SSCS) promotes open-source tools (IEEE Solid-State Circuits Society, 2023). There is also an open letter signed by different prominent European and UK professors promoting the use of open-source EDA tools: "Importance of Open-Source EDA Tools for Academia-Open Letter on European Strategic and Funding Directions".

The following sections of the paper are about open-source EDA tools in section 2, open-source PDKs in section 3, open-source circuit designs in section 4, open-source learning materials in section 5, low-cost tapeout from Tiny Tapeout (Tiny Tapeout, 2024b) in section 6, and conclusion and recommendation in section 7.

2. Open-source EDA tools

There are many open-source EDA tools right now that can be used to learn and teach the fundamentals of IC design in the microelectronics track. Most of them are FREE and can be installed locally on a computer. While most open-source tools run on the Linux Operating System (OS), Windows and Mac OS can use virtual machines to run Linux.

The website "Open Circuit Design" is the repository for the suite of open-source EDA tools including Magic, Qflow, Qrouter, Netgen, IRSIM, PCB, and XCircuit. These tools are all provided for free under the GNU Public License (GPL) or similar open-source license. Aside from the open-source EDA tools listed on the Open Circuit Design website, there are other tools such as Xschem, Ngspice, Klayout, Yosys, and Wokwi.

Open-source EDA tools can be installed individually but they can be grouped to form a complete IC design flow such as the OpenRoad Project (OpenROAD Project, 2024b) which is the leading open-source, foundational application for semiconductor digital design. The OpenROAD flow delivers an Autonomous, No-Human-In-Loop (NHIL) flow, with 24-hour turnaround from RTL-GDSII for rapid design exploration and physical design implementation. OpenROAD is used in research and commercial applications such as OpenROAD-flow-scripts from OpenROAD, OpenLane (OpenROAD Project, 2024a) from Efabless, Silicon Compiler from Zero ASIC, Hammer from UC Berkeley, and OpenFASoC from IDEA-FASoC for mixed-signal design flows.

Though RTL-GDSII automates digital designs to tapeout, the automation of analog designs to tapeout is very challenging. But there are some open-source EDA tools that are up to the challenge. Here are some of them: ALIGN: Analog Layout, Intelligently Generated from Netlists, and MAGICAL: Machine Generated Analog IC Layout.

Moreover, there is also a Docker-type compilation of open-source tools such as IIC-OSIC-TOOLS, an all-in-one Docker container for open-source-based integrated circuit designs for analog and digital circuit flows. The CPU architectures x86_64/amd64 and aarch64/arm64 are natively supported based on Ubuntu 22.04LTS (since release 2022.12). This collection of tools is curated by the Institute for Integrated Circuits (IIC), Johannes Kepler University (JKU).

3. Open-source PDKs

A factory's specific chip fabrication process is described in detail in a library called the Process Design Kit or PDK. This frequently consists of illustrations of the devices and design guidelines that are compatible with specific implementations and verification tools that have been examined and approved by the fabrication facility (https://www.zerotoasiccourse.com).

Unlike commercial PDK, an open-source PDK does not need a Non-Disclosure Agreement (NDA). Here are some examples of open-source PDK that reached tapeout or chip fabrication: Skywater PDK (Sky130) and GlobalFoundries GF180MCU Open Source PDK.

4. Open-source Circuit Designs

One of the best features of open-source IC designs is the sharing of ideas. Your design can be seen or used by others in the same way you can see and use other open-source IC designs. The SkyWater (SKY130) Open Source Program IP Catalog (Efabless ChipIgnite, 2022)is a collection of different open-source IC designs that use the open-source Skywater PDK. Moreover, the latest open-source IC designs can be found on the Tiny Tapeout 6 circuit designs compilation.

5. Open-source Learning Materials

There are so many open-source learning materials for IC designs. Here are some of them: the Facebook page IC Design LIBRE (Abad, 2024) is a publicly accessible social media page where open-

source tools and learning materials are posted; online simulators for learning and teaching demo: Siliwiz (Venn, n.d.), Electronics Demonstrations, and Awesome opensource ASIC resources; ebooks on designing analog chips and "Analysis and Design of Elementary MOS Amplifier Stages"; and YouTube channels: ENGR3426: MADVLSI Tutorials, efabless, and Zero to ASIC course.

6. Low-cost Tapeout from Tiny Tapeout

The ultimate goal of IC design is to create an actual chip. With the advent of Tiny Tapeout, the cost of tapeout or chip fabrication has become low-cost which is around $300 versus $10,000 from other tapeouts or chip fabrications. For a 160 x 100 um tile + ASIC + demonstration board: The standard price is $300 plus shipping. However, Efabless is sponsoring a special early bird offer of $150 (plus shipping), limited to one order per person. Each extra tile is $50, and extra analog pins start from $40 per pin (Tiny Tapeout, 2024b). The latest circuit design submissions can be accessed at https://tinytapeout.com/runs/tt06/ (Tiny Tapeout, 2024a).

There are three possible ways to submit your IC design to Tiny Tapeout: 1) schematic using their Wokwi template, 2) custom layout using their Magic template, and 3) Verilog using their HDL template. All the templates can be found at https://tinytapeout.com and all design entries are processed automatically through GitHub actions and OpenLane.

In this paper, we used the Wokwi (CodeMagic, 2024) template where we created the schematic of our design, as shown in Fig. 1. Our circuit is composed of a 4-bit counter, multiplexers, and combinations logic gates to produce letters "PILIPINASLASALLE" on a 7-segment display, as shown in Fig. 2. The letters are displayed individually using a clock input or can be inputted manually through push-button switches. The online circuit simulation can be accessed at https://wokwi.com/projects/392873974467527681. The 2D IC design layout of our project is shown in Fig. 3 while a 3D layout is shown in Fig. 4. We are the first one from the Philippines to submit a design to Tiny Tapeout and we got a 50% discount sponsored by Efabless, as shown in Fig. 5. Our design can be accessed through GitHub link: (https://github.com/alexandercoabad/PILIPINAS)

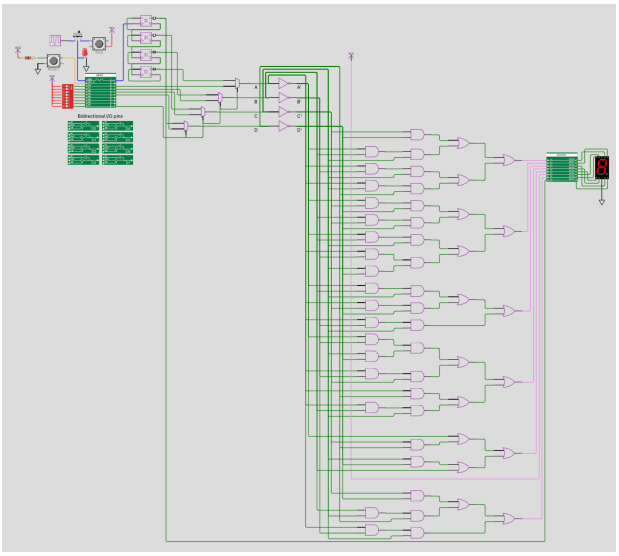

Fig. 1. System schematic using Wokwi.

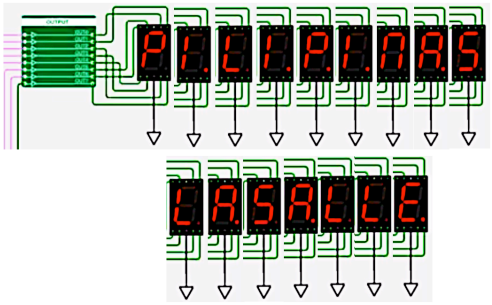

Fig. 2. A composite picture of "PILIPINASLASALLE" letters on a 7-segment display.

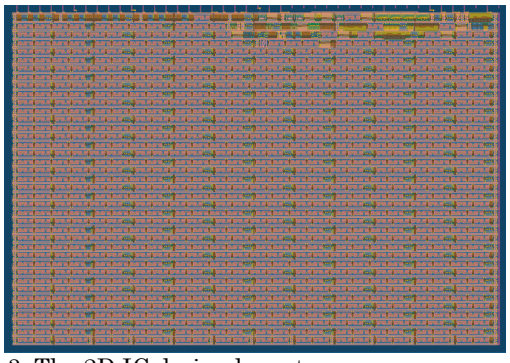

Fig. 3. The 2D IC design layout.

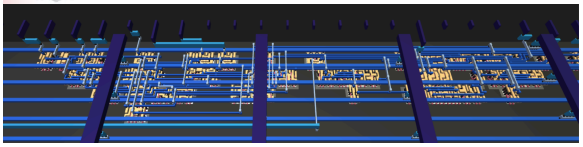

Fig. 4. The 3D IC design layout.

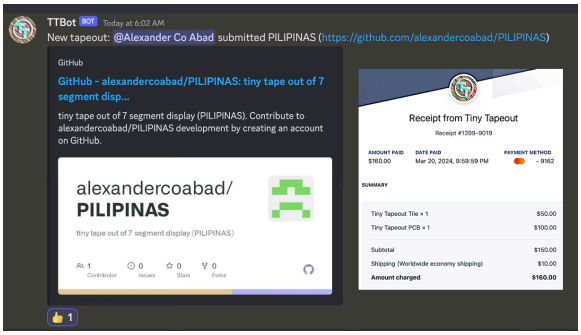

Fig. 5. GitHub repository and payment receipt from Tiny Tapeout.

7. CONCLUSION

We discussed in this paper the different open-source EDA tools, PDK, circuit designs, learning materials, and low-cost tapeout from Tiny Tapeout hoping to inspire others to learn and to teach IC design or microelectronics courses. We presented a simple circuit and submitted it for a low-cost tapeout to show that we can do tapeouts using open-source tools. This paper could be used as a reference by those who are interested in pursuing the microelectronics track and those who want to teach it.

Open-source tools and PDKs can complement the licensed tools in the training of personnel. The government can also promote the use of open-source IC design tools and might even mandate that the microelectronics track be put in the core curriculum of the ECE and CpE courses to meet the high demand for IC designers and semicon engineers.

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