Finite Impulse Response Filter (FIR) with Digital-to-Analog Converter (DAC) Application Specific Integrated Circuit (ASIC)

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Introduction

Motivation

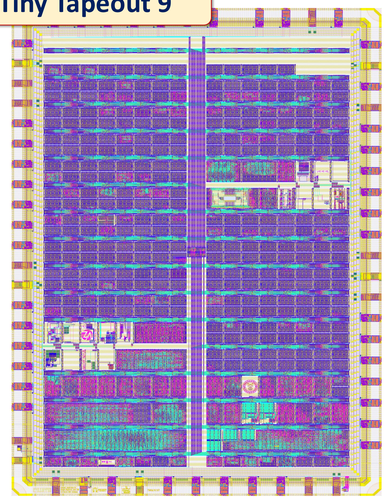
Due to the prohibitive costs of manufacturing integrated circuits, as well as the restrictive licensing associated with proprietary process design kits (PDKs) and tool vendors, many university programs are limited in their ability to tape out their application-specific integrated circuit (ASIC) designs. This prevents students from learning the important nuances of every step of the implementation process as well as testing process. As a result, we sought to establish a cost-friendly, open-source design process for mixed-signal circuits at Cal Poly Pomona. To accomplish this, we are collaborating with the Tiny Tapeout platform which reduces the cost of taping out a chip by 100x and uses open-source tools and PDK. To demonstrate this process, we seek to implement a 5-bit current switching DAC with a Finite Impulse Response filter on the upcoming Tiny Tapeout 11 shuttle.

Google + SkyWater — FOSS 130nm Production PDK

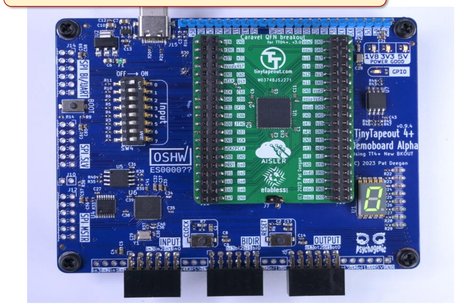
efabless.com

Tiny Tapeout

Tiny Tapeout 9



Tiny Tapeout Demo Board

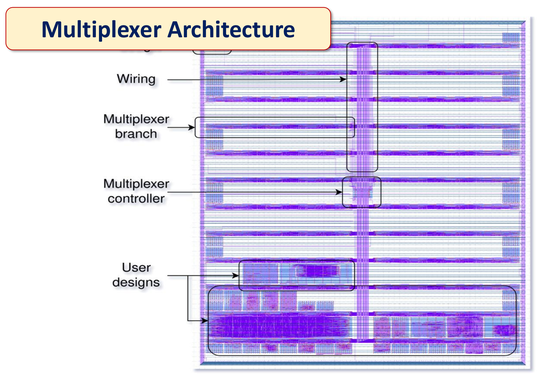


- Multi project chip platform makes it cheaper/easier to manufacture application specific integrated circuit (ASIC) designs
- Open-source tools and process design kits (PDKs) used to avoid restrictive licensing and NDAs
- Each Tiny Tapeout production run has around 400 open-source designs multiplexed to 24 general-purpose I/O (GPIO) pins

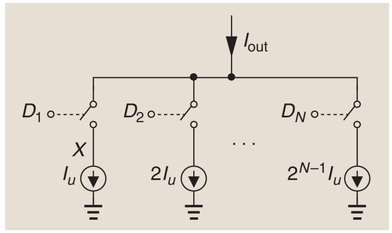
Multi Project Platform

- Each chip contains a copy of every design that can be selected and tested
- Multiplexer architecture enables up to 512 user designs (32 mux units – each with up to 16 designs)
- Basic unit is a 160x100 um tile where designs can occupy up to 16 tiles

Multiplexer Architecture

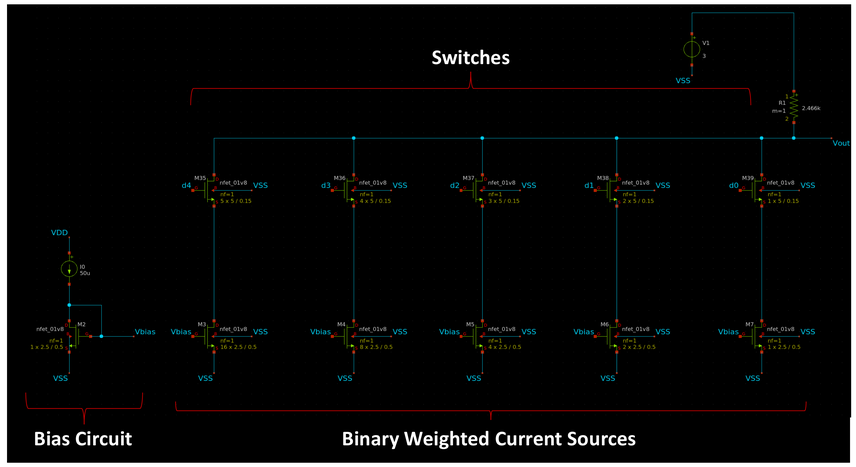


Digital-to-Analog Converter (DAC) Current Switching Architecture

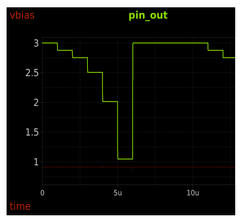


- Each input bit controls a current that is binarily weighted to a unit value I_U
- Current sources are scaled up by a factor of two for each successive bit
- Advantage: Can drive resistive loads with no need for a buffer – important in driving transmission lines, displays, and optical modulators

5-bit Current Switching DAC

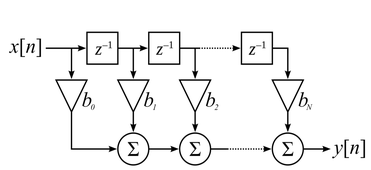


- Unit Value I_U=26.2µA
- Current scaling accomplished by doubling multiplier factor (puts transistors in parallel) for each increasing bit

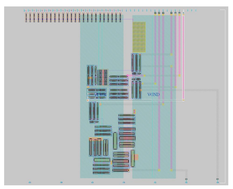


Future Work and Impact

With our current 5-bit DAC, we will undergo layout then layout vs schematic (LVS) to harden our analog design. Following this, we plan on using the digital portion of the course to create a finite impulse response filter (FIR) to feed into our digital-to-analog converter (DAC). Future senior design project teams will have access to these digital and analog tools and will be able to create their own Tiny Tapeout mixed-signal designs.



FIR Filter



Layout of a TT5 Design

Acknowledgements

We'd like to thank Matt Venn, an open-source contributor and lead of the Tiny Tapeout course for gifting us with the analog course at a discounted student ticket rate. Our project's analog capabilities would not be possible without his help. We'd also like to thank our advisor Dr. Brita Olson for her guidance and expertise through this senior design project.

References

B. Razavi, "The Current-Steering DAC [A Circuit for All Seasons]," in IEEE Solid-State Circuits Magazine, vol. 10, no. 1, pp. 11-15, Winter 2018
M. Venn, "Tiny Tapeout: A shared silicon tape out platform accessible to everyone," in IEEE Solid-State Circuits Magazine, vol. 16, no. 2, pp. 20-29, Spring 2024