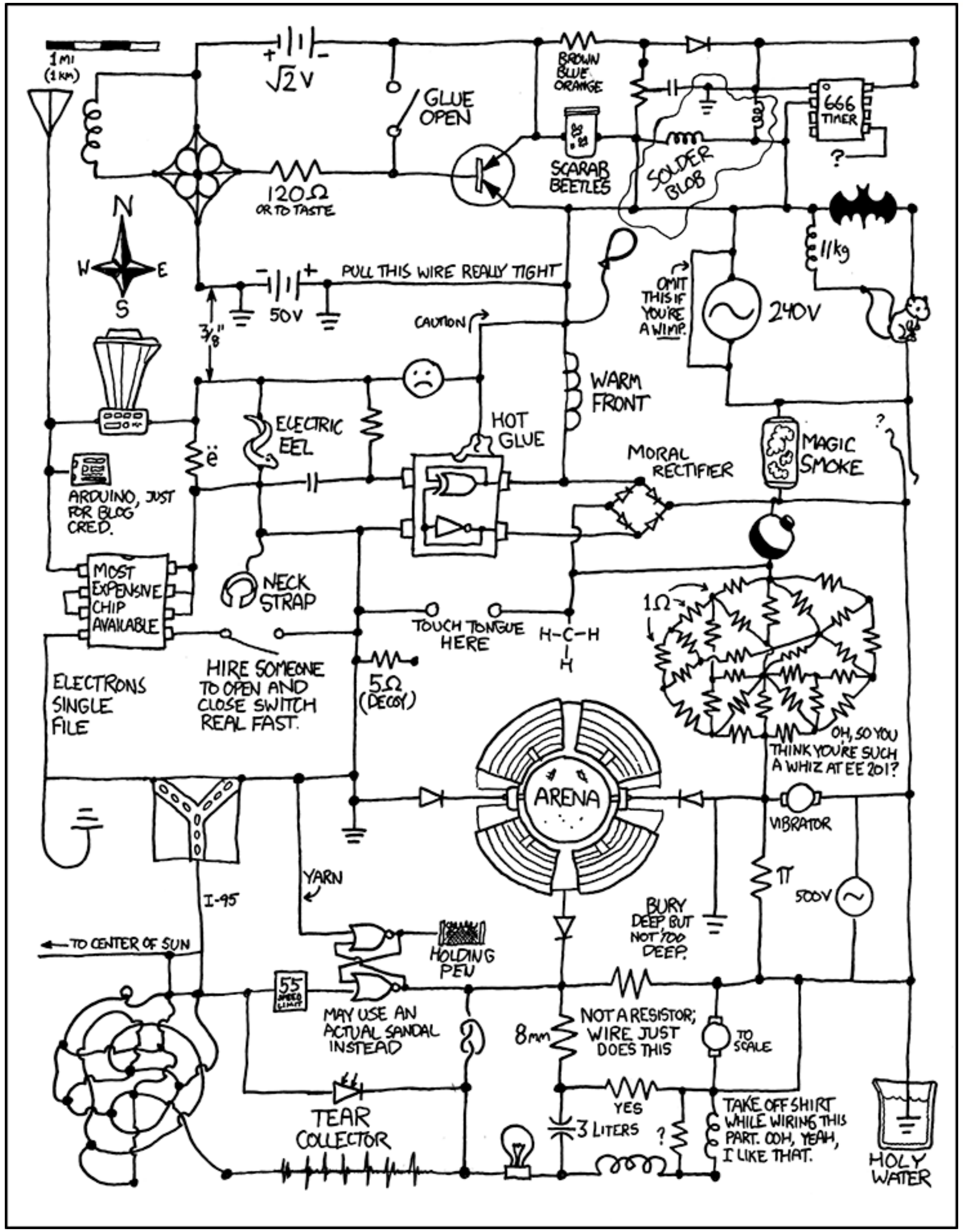


https://xkcd.com/730/

ENR-325/325L Principles of Digital Electronics and Laboratory

Xiang Li

Fall 2025

COE COLLEGE

Course Syllabus and Discussion

This introductory course provides a comprehensive foundation in Digital Electronics, starting with basic principles and progressing to digital design and system applications.

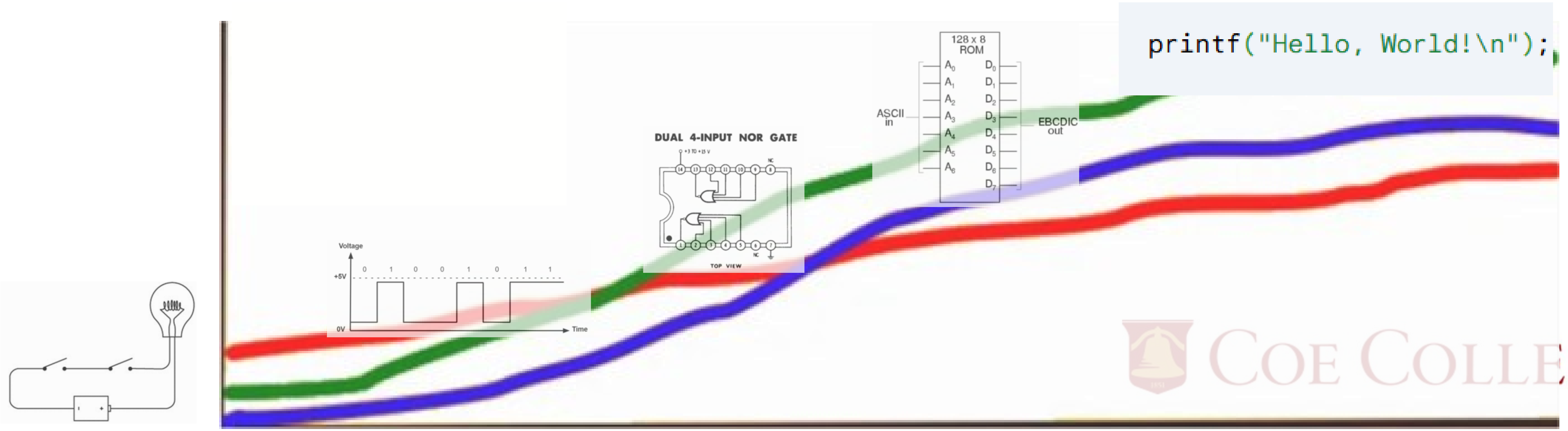
Through a combination of lectures, hands-on labs, and a final project, students will develop the skills to design, implement, and test basic digital systems and IoT prototypes. The course incorporates the use of digital logic simulation software and emphasizes the engineering design process and ethical considerations.

EP1: Digital and Information Systems

- The learning curve from EE to IC.
- Digital abstraction.
- Information theory and its application.

The learning curve from EE to IC

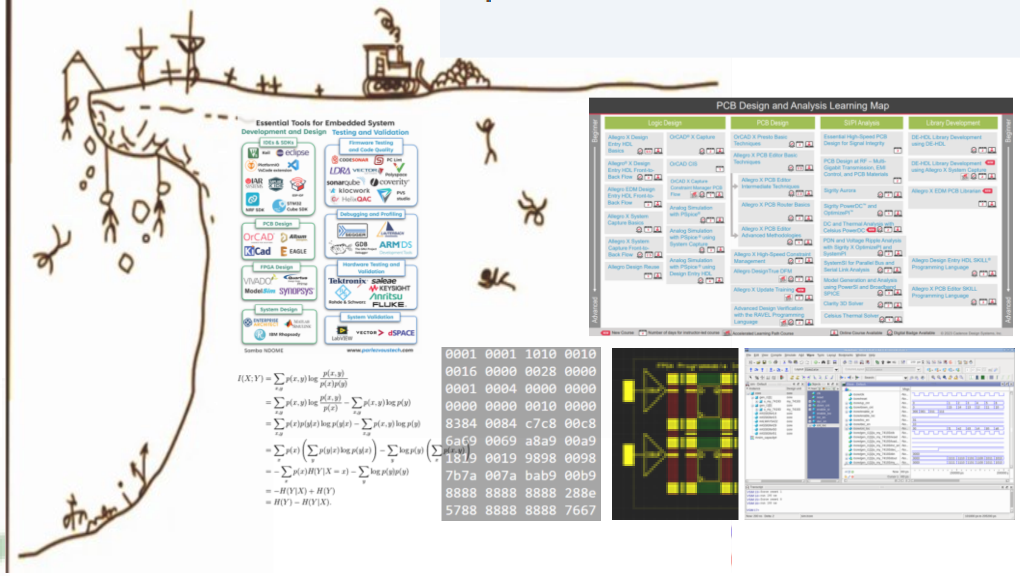
Presented learning curve from many EE/IC/CE courses.

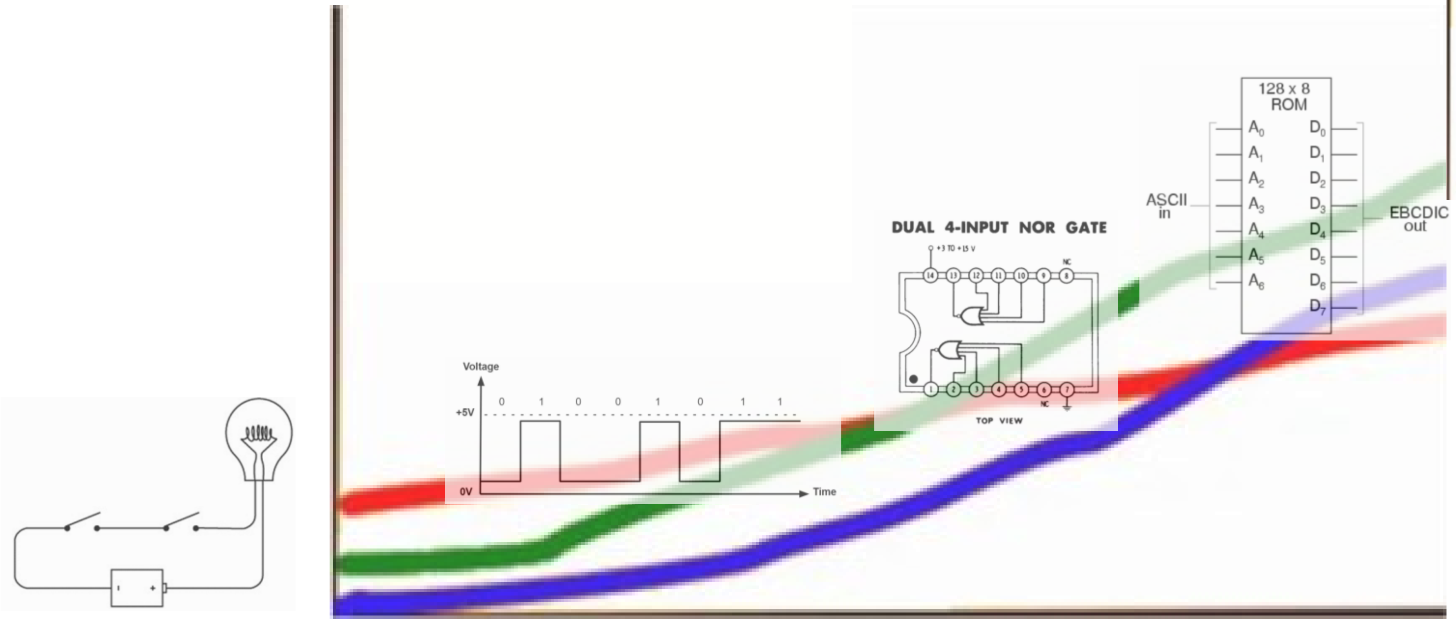


The learning curve from EE to IC

Actual learning curve to (part of the) industry.

```
printf("Hello, World!\n");
```





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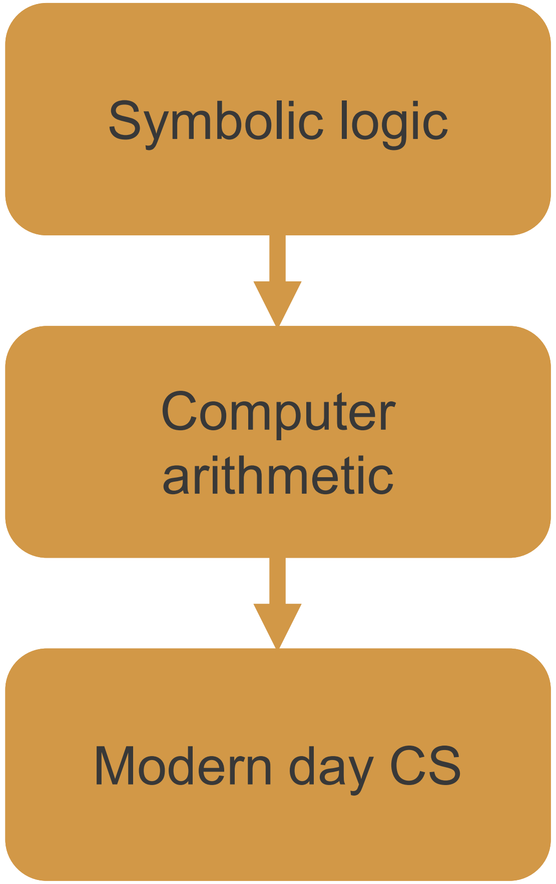
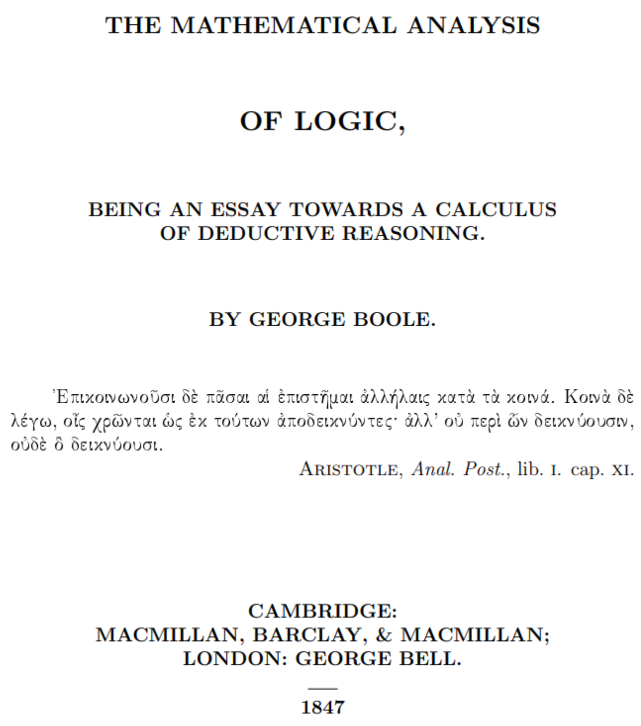
The learning curve from EE to IC

The goal of this course:

Theory Hardware Software System integration

Why go digital? – the MATH/CS version (theory)





THE MATHEMATICAL ANALYSIS

OF LOGIC,

BEING AN ESSAY TOWARDS A CALCULUS OF DEDUCTIVE REASONING.

BY GEORGE BOOLE.

Ἐπικοινωνοῦσι δὲ πᾶσαι αἱ ἐπιστῆμαι ἀλλήλαις κατὰ τὰ κοινά. Κοινὰ δὲ λέγω, οἷς χρῶνται ὡς ἐκ τούτων ἀποδεικνύντες· ἀλλ' οὐ περὶ ὧν δεικνύουσιν, οὐδὲ ὃ δεικνύουσι.

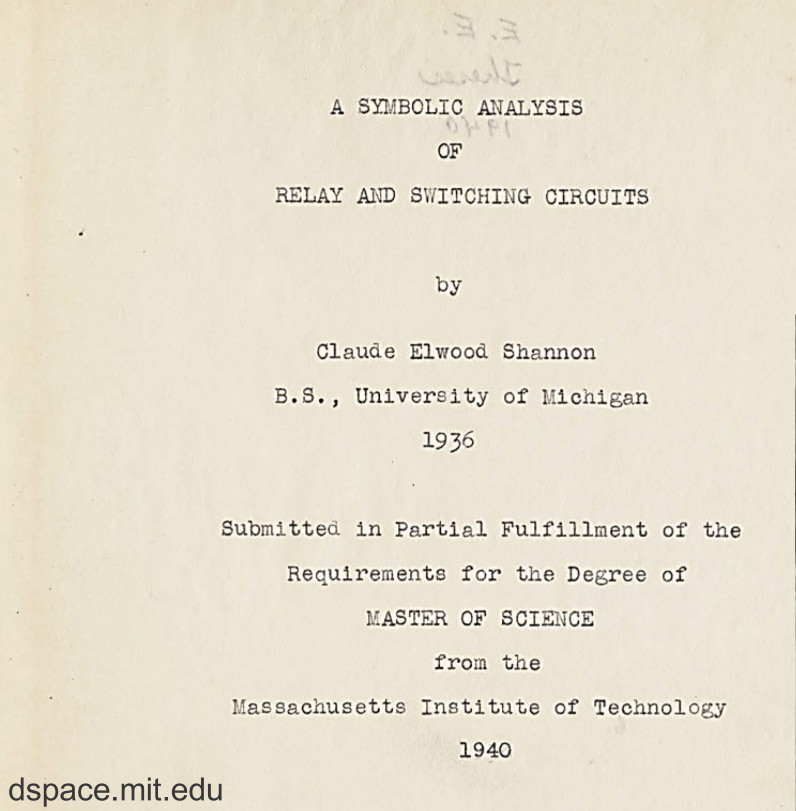
ARISTOTLE, *Anal. Post.*, lib. I. cap. XI.

CAMBRIDGE:
MACMILLAN, BARCLAY, & MACMILLAN;
LONDON: GEORGE BELL.

1847

gutenberg.org

“The starting point of digital circuit design.”



A SYMBOLIC ANALYSIS

OF

RELAY AND SWITCHING CIRCUITS

by

Claude Elwood Shannon

B.S., University of Michigan

1936

Submitted in Partial Fulfillment of the

Requirements for the Degree of

MASTER OF SCIENCE

from the

Massachusetts Institute of Technology

1940

dspace.mit.edu

https://www.juggle.org

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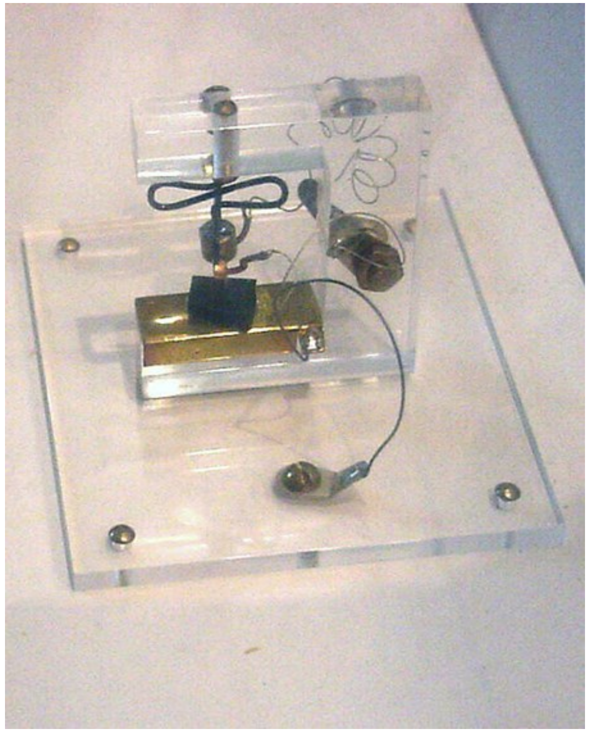
Shannon’s juggling bot: https://www.youtube.com/watch?v=tXU3EPg2cgA

Why go digital? – the Computational/IC version (hardware)

Charles Babbage's Difference Engine, 1820s

Science Museum
London, UK

A replica of the world's first transistor, 1947

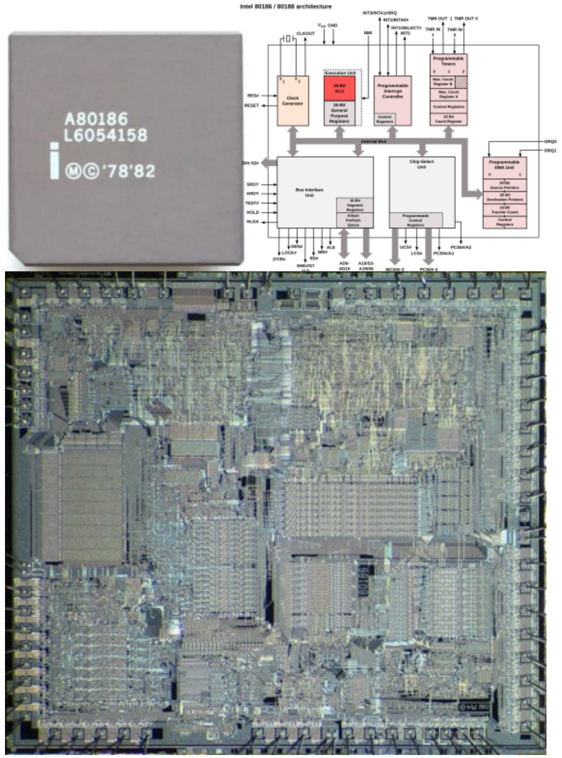


National Air and Space Museum
Washington, DC, USA

The IAS computer, 1952

www.computerhistory.org

Intel 80186, 1982



wikipedia.org/wiki/Intel_80186

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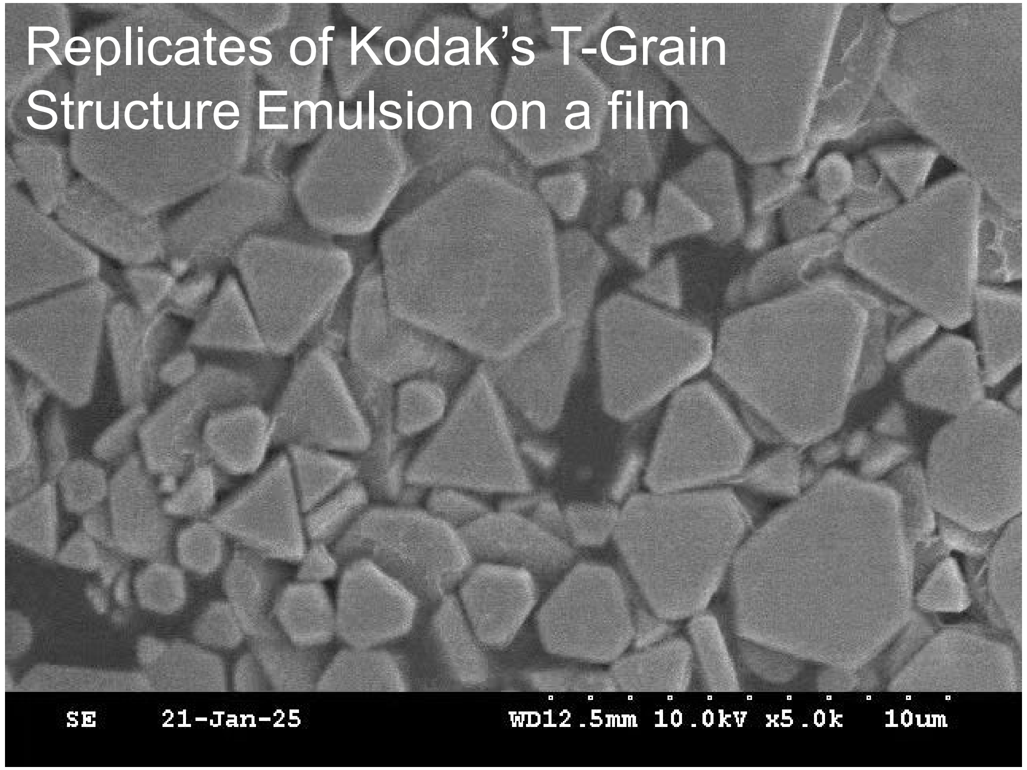
Reference read: https://writings.stephenwolfram.com/2015/12/untangling-the-tale-of-ada-lovelace/

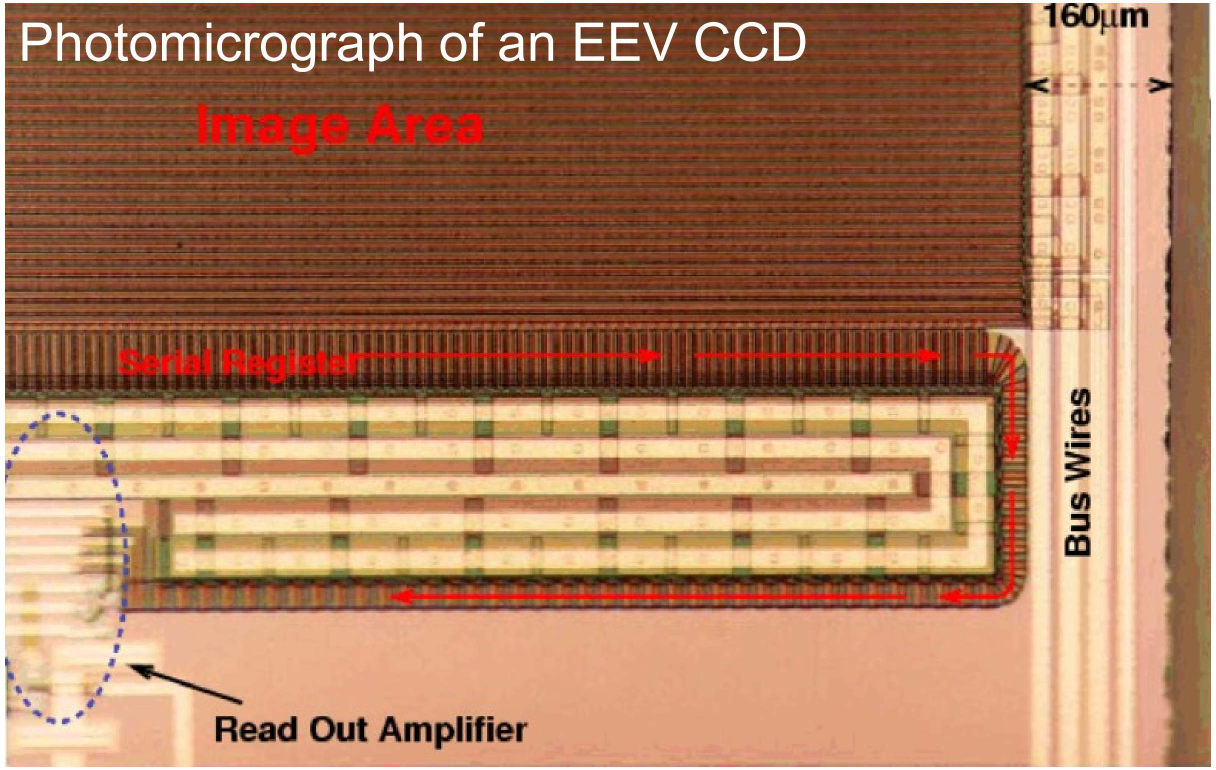
Why go digital? – the Phys/MicroE version (application)

Film camera vs CCD camera



Replicates of Kodak's T-Grain Structure Emulsion on a film

lightlenslab.com



Photomicrograph of an EEV CCD

http://spiff.rit.edu/classes/phys445/lectures/ccd1/ccd1.html

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Why go digital? – the Phys/MicroE version (application, continued)

Film vs CCD by Liam Kix

https://youtu.be/YBT7PZrjKvw?si=Fgy_3RfV8aZ65oU-

Why go digital? – the EE version

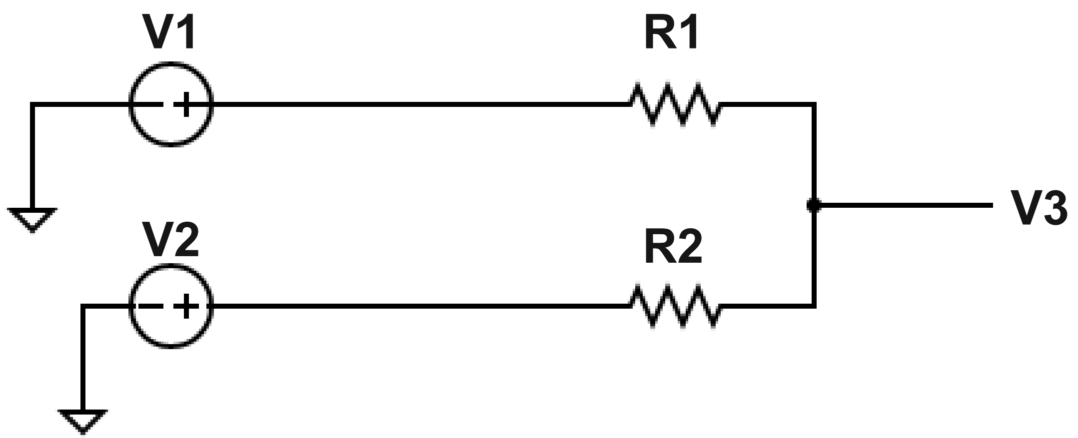
Because it's lazy and easy.

From analog circuits we learn:
LCA, KVL, KCL, node
For linear circuits: superposition, Thevenin, Norton

So instead of lumping matter, we will lump signal values, which will lead to the digital abstraction.

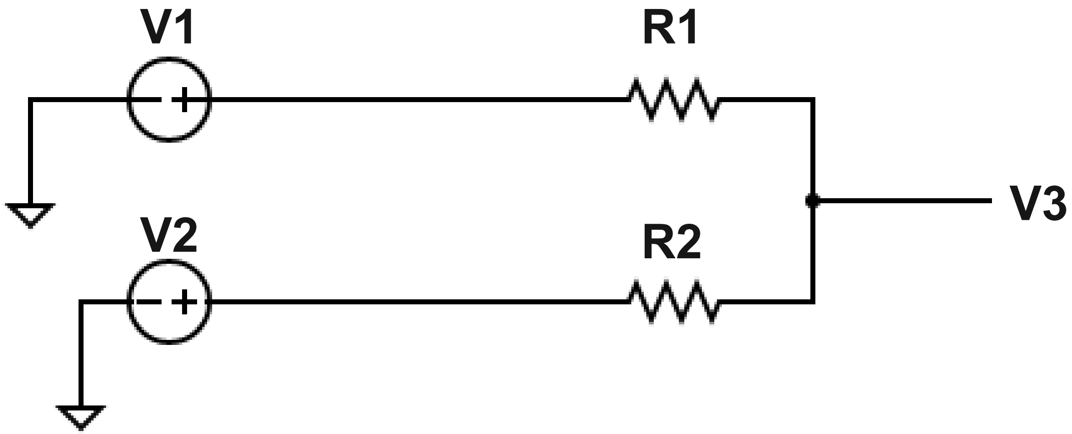
Why go digital? – the EE version

The classical demo in telecommunications: noise resistance



Why go digital? – the EE version

The classical demo in telecommunications: noise resistance



$$\mathrm{V3} = \mathrm{V1}\frac{\mathrm{R2}}{R1+R1} + \mathrm{V2}\frac{R1}{R1+R1}$$

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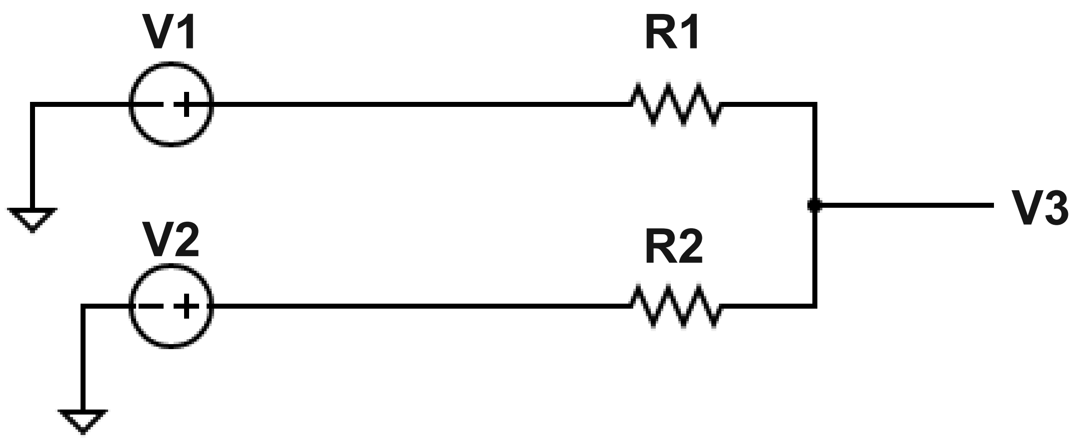
Why go digital? – the EE version

The classical demo in telecommunications: noise resistance



$$V3 = V1\frac{R2}{R1+R1} + V2\frac{R1}{R1+R1}$$

Two problems in telecommunications:

- Signals degrade over long distance.
- Noises introduced by… a lot of the things.

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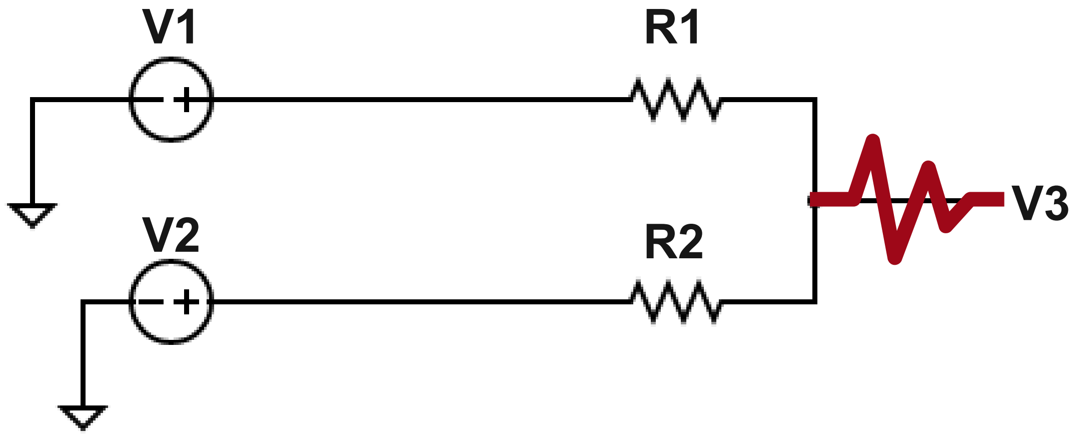
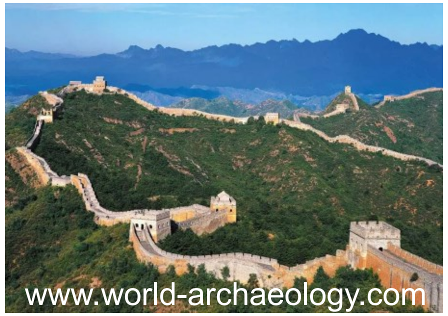
Why go digital? – the EE version

The classical demo in telecommunications: noise resistance



© 2021 Circuit Diagram

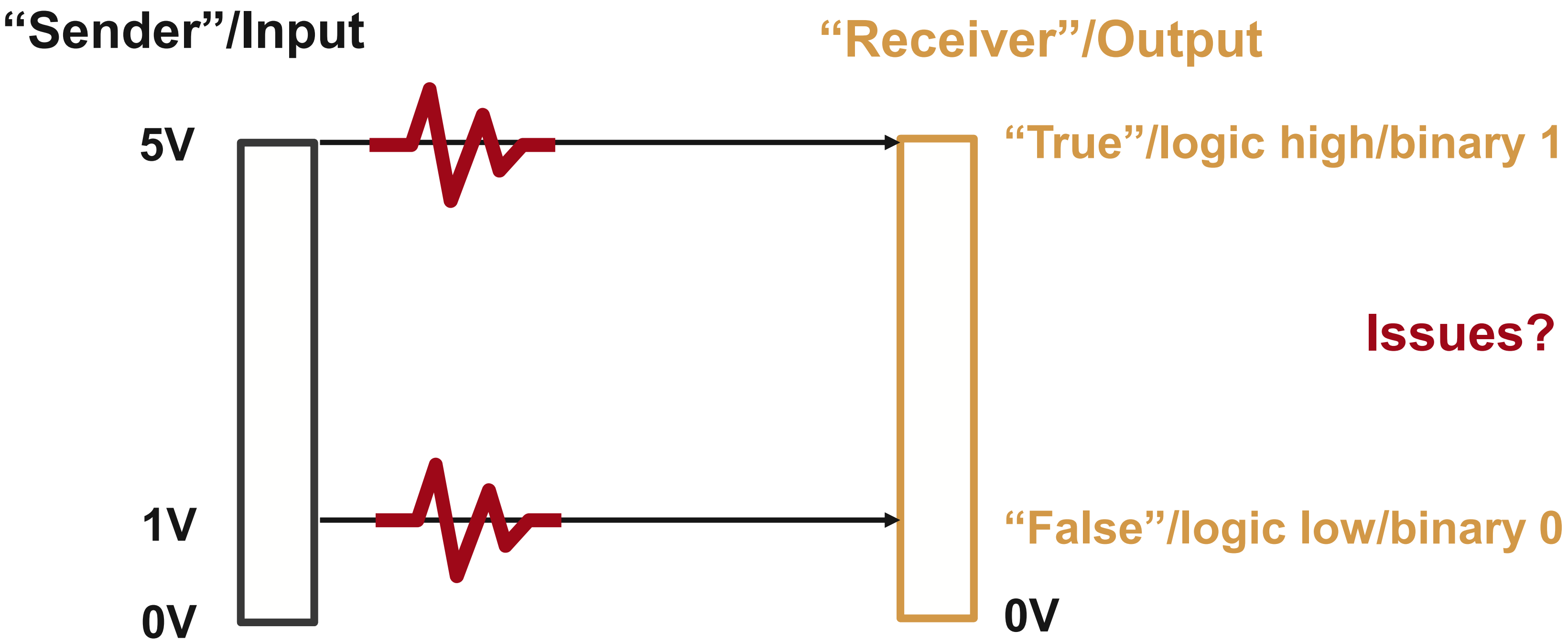
$$V3 = V1\frac{R2}{R1+R1} + V2\frac{R1}{R1+R1}$$



We can AMP signals along the way… but not forever.

Why go digital? – the EE version

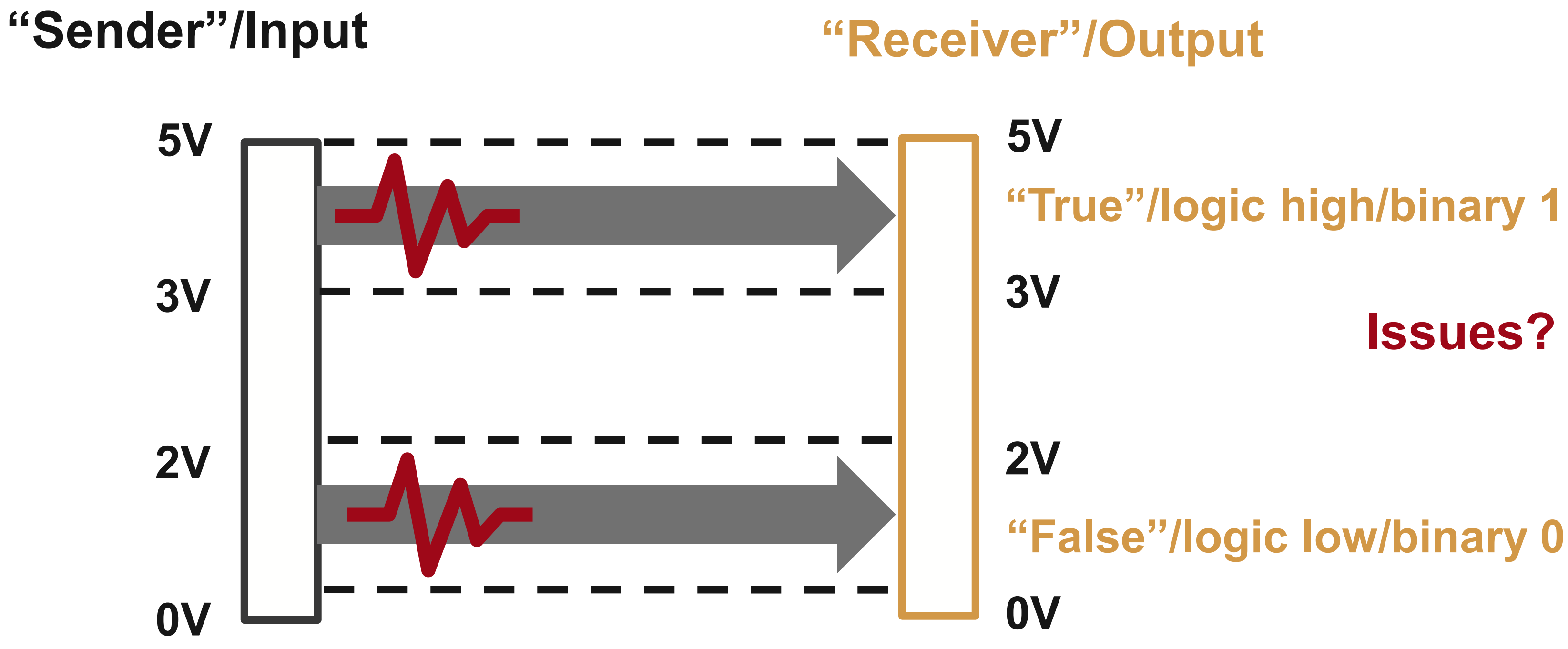
The classical demo in telecommunications: the very foundation of the digital abstraction



Issues?

Why go digital? – the EE version

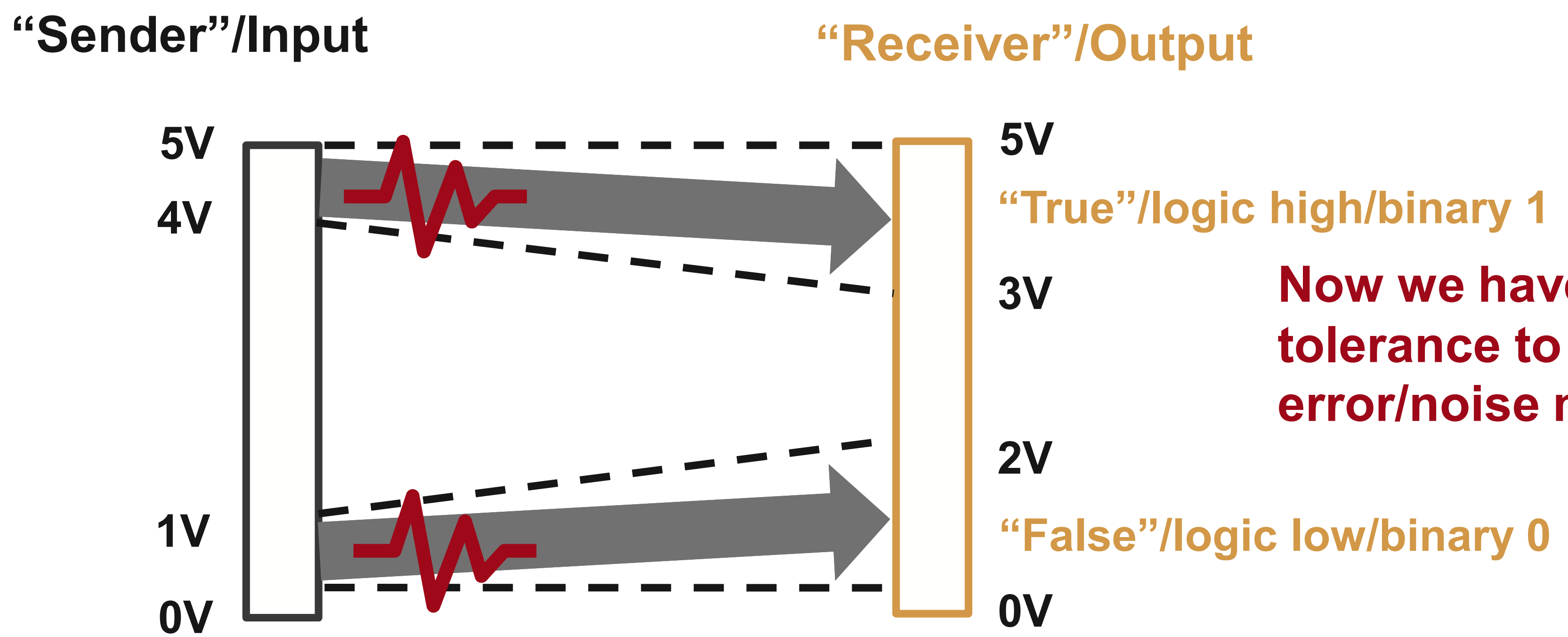
The classical demo in telecommunications: the very foundation of the digital abstraction



Issues?

Why go digital? – the EE version

The classical demo in telecommunications: the very foundation of the digital abstraction

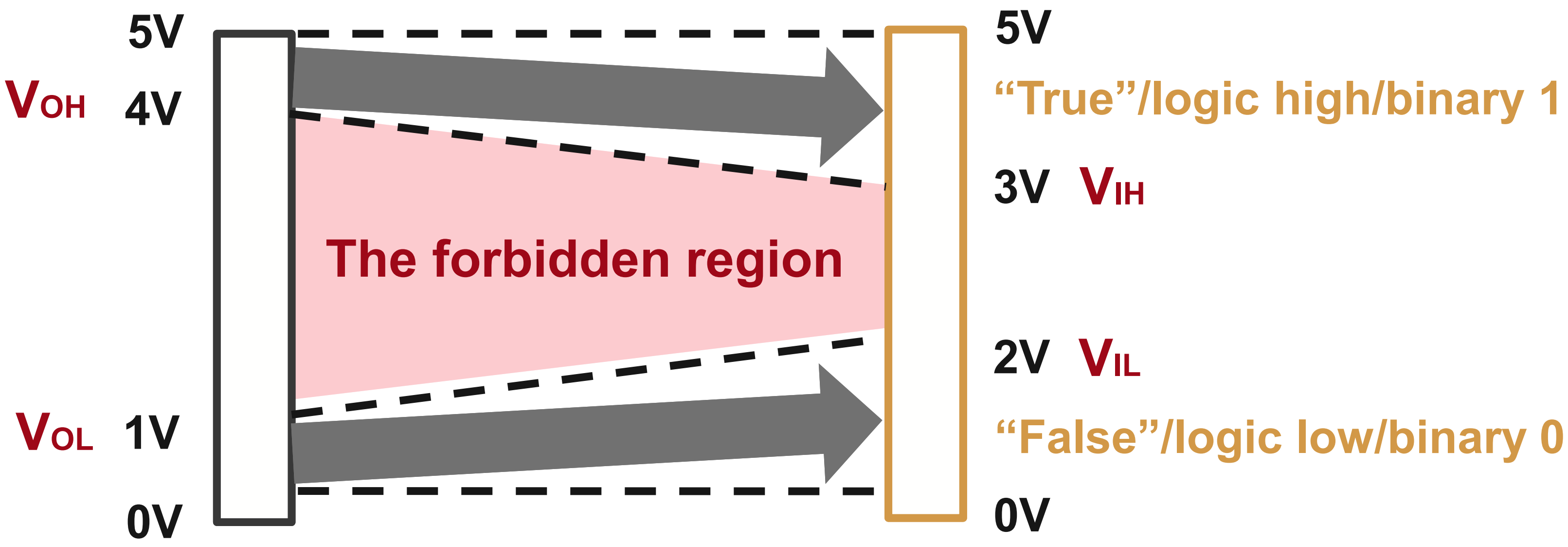


Now we have some tolerance to error/noise margin.

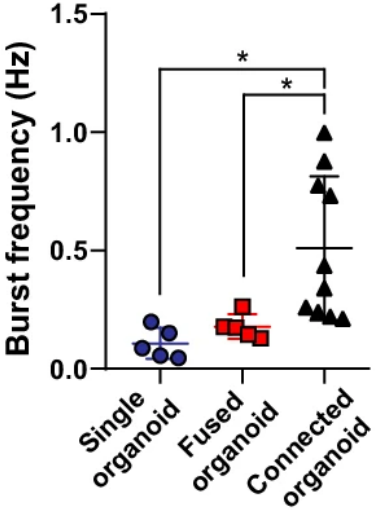
Why go digital? – the EE version

The very fundamental of the digital abstraction: the static discipline $V_{OL} < V_{IL} < V_{IH} < V_{OH}$

"Sender"/Input **"Receiver"/Output**



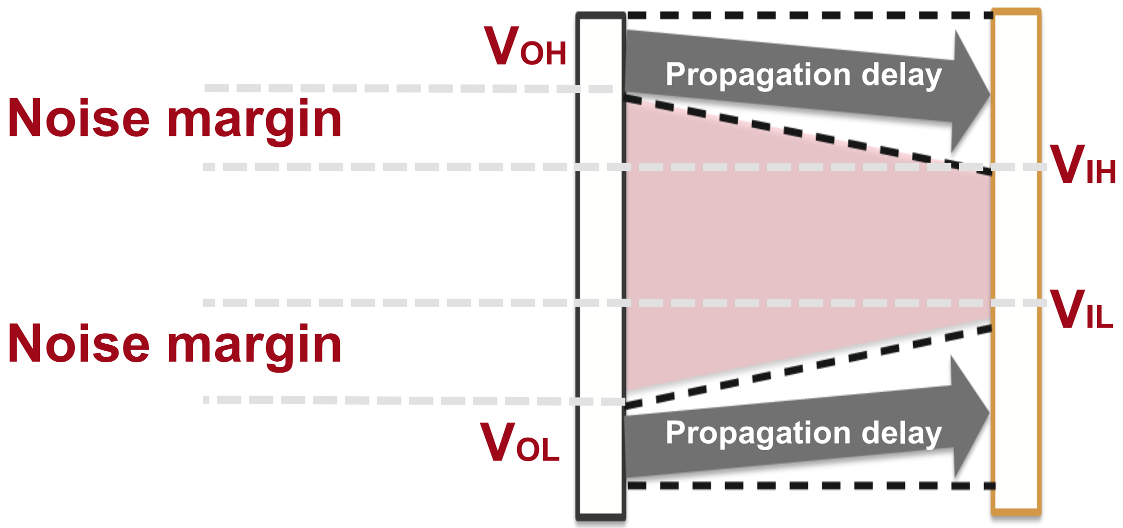
A good spreading between signals/data is how engineering works!



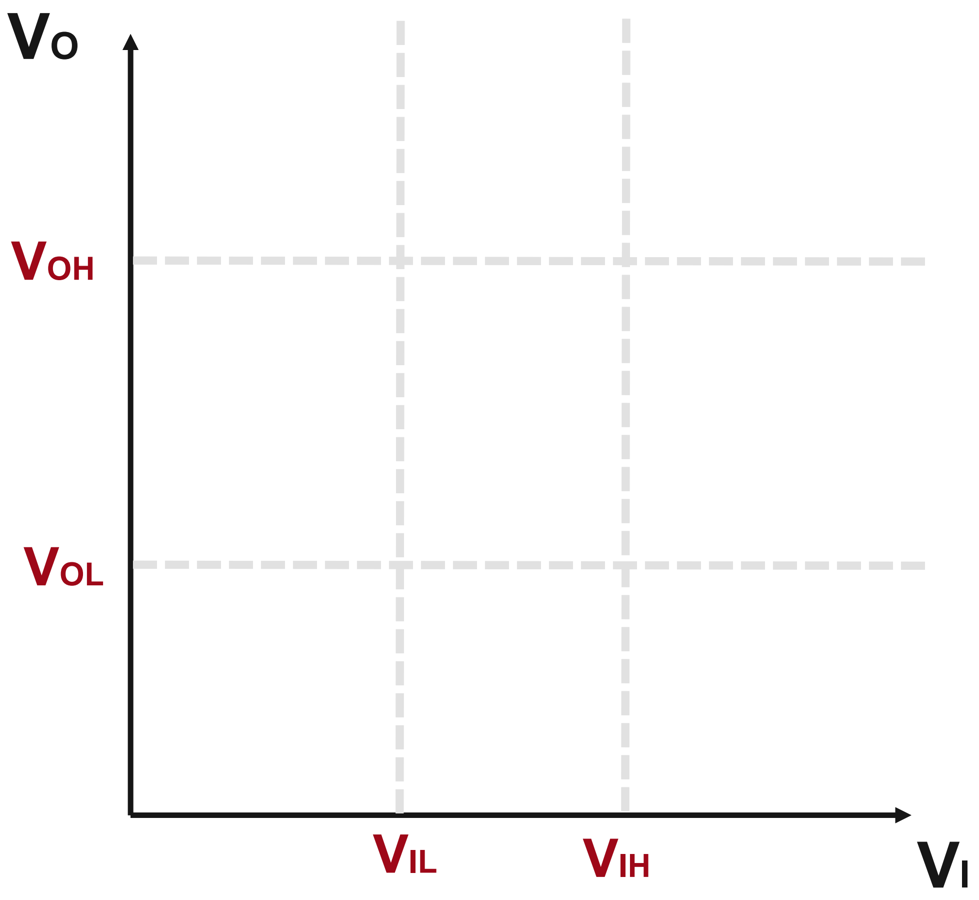
https://doi.org/10.1038/s41467-024-46787-7

Coe College

Technicality with this digitizing (quantizing)



Voltage transfer characteristics



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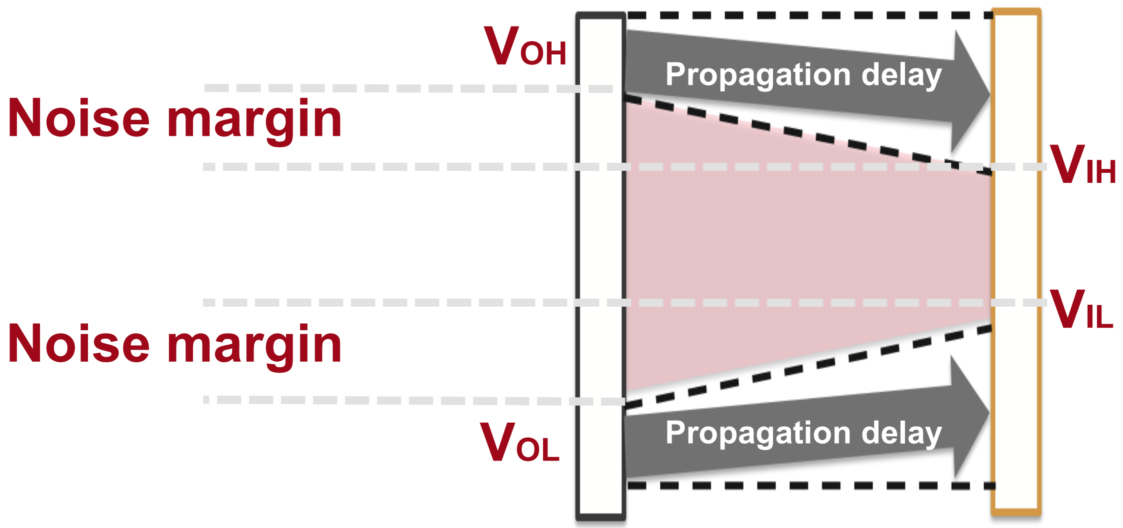
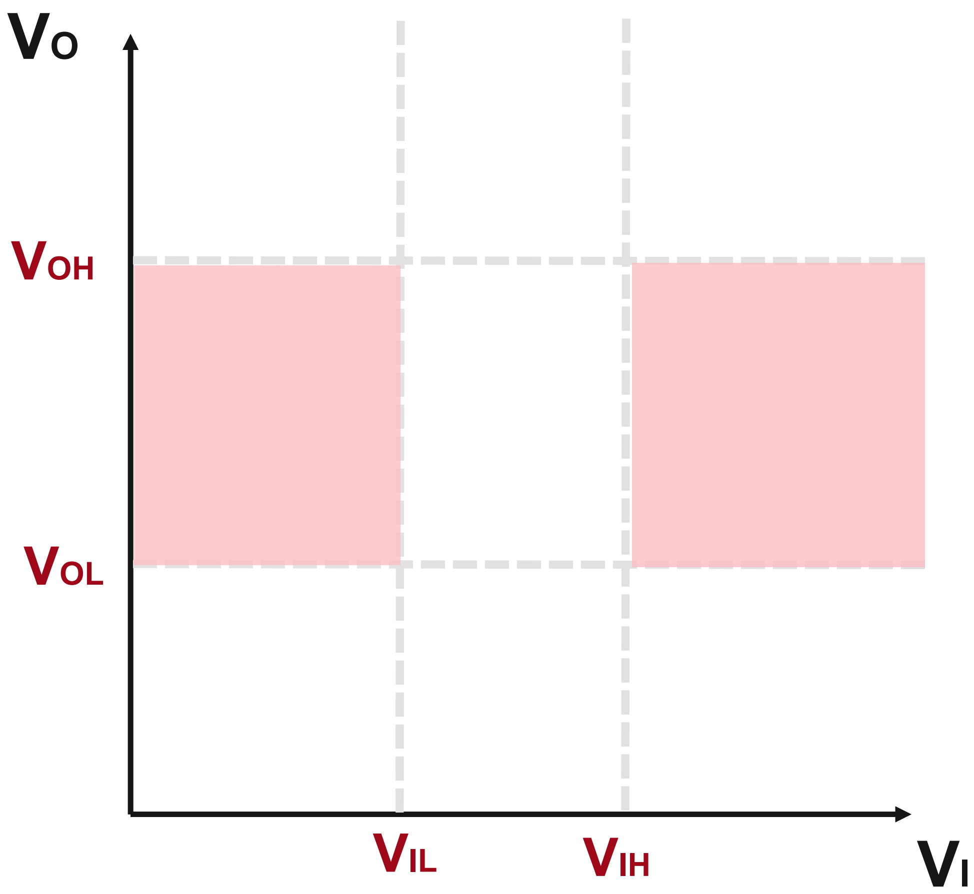
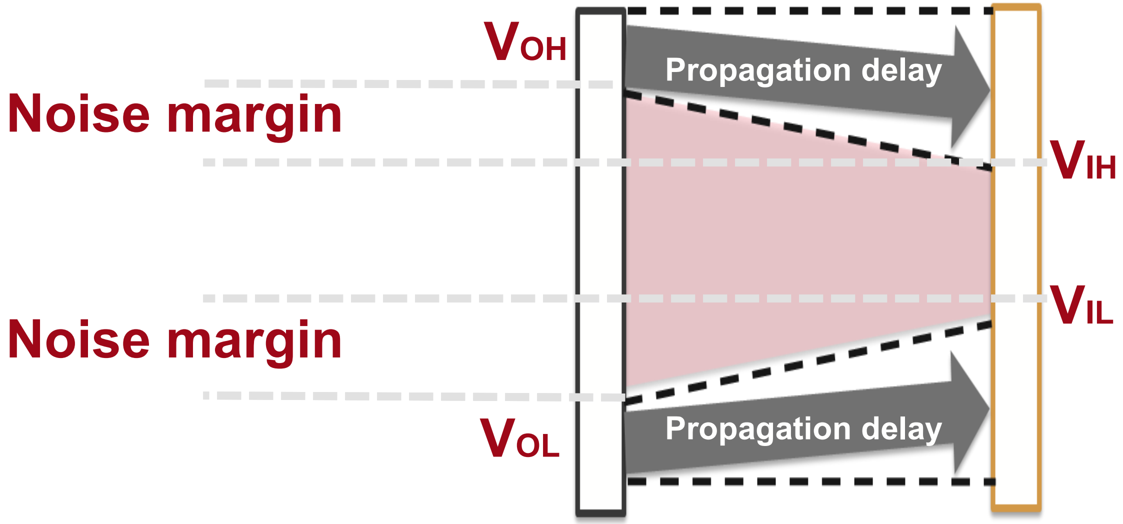
Technicality with this digitizing (quantizing)



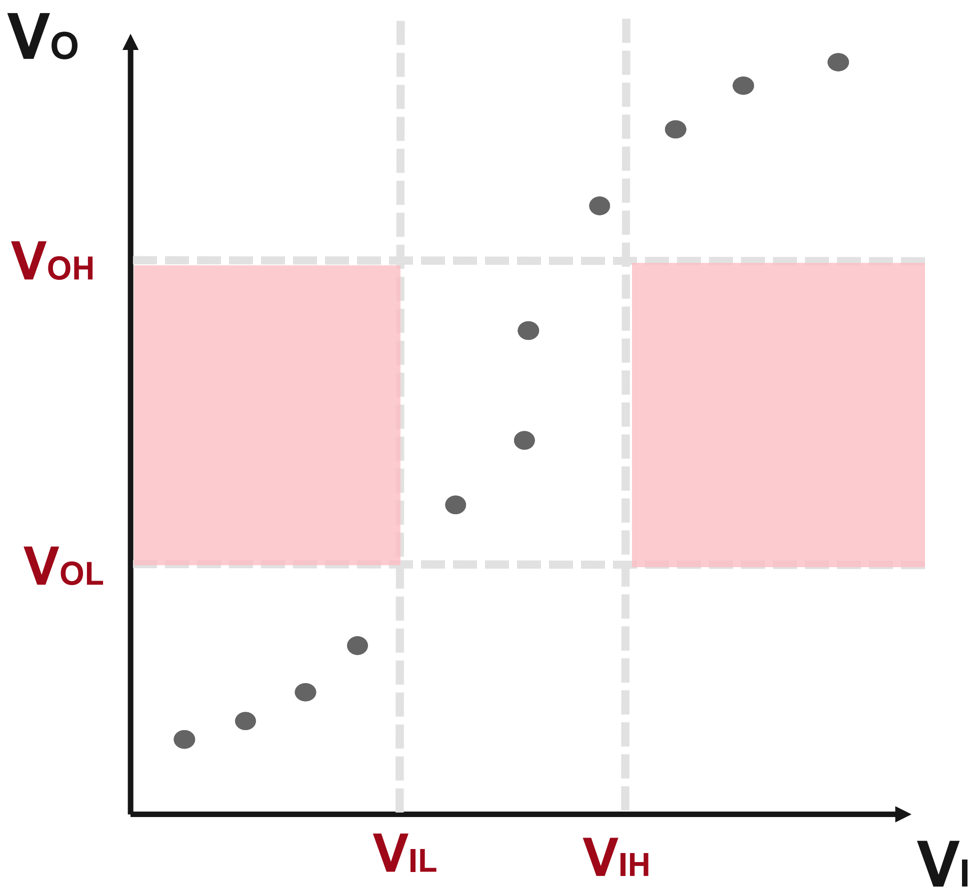
Voltage transfer characteristics



Technicality with this digitizing (quantizing)



Voltage transfer characteristics (VTC)



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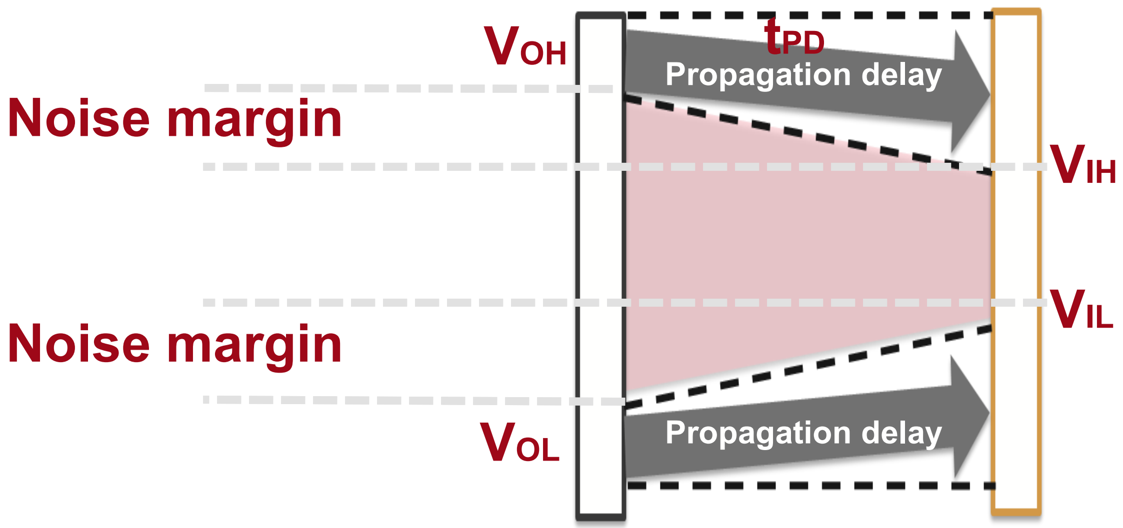
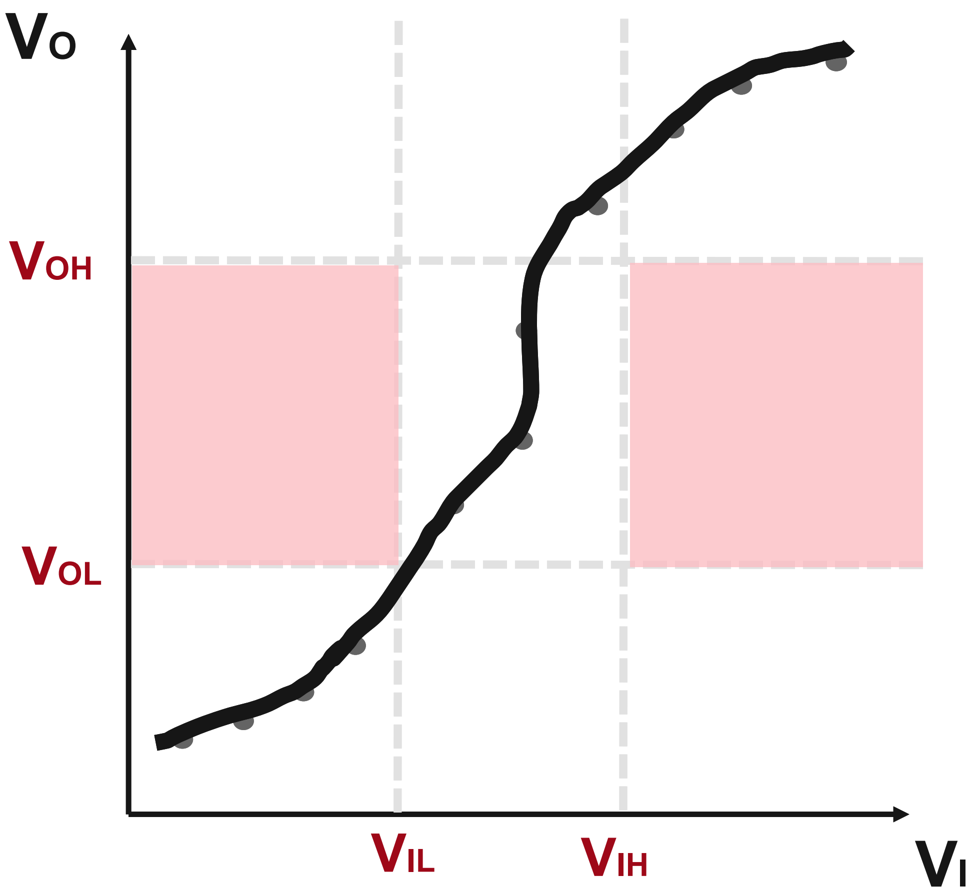
Technicality with this digitizing (quantizing)

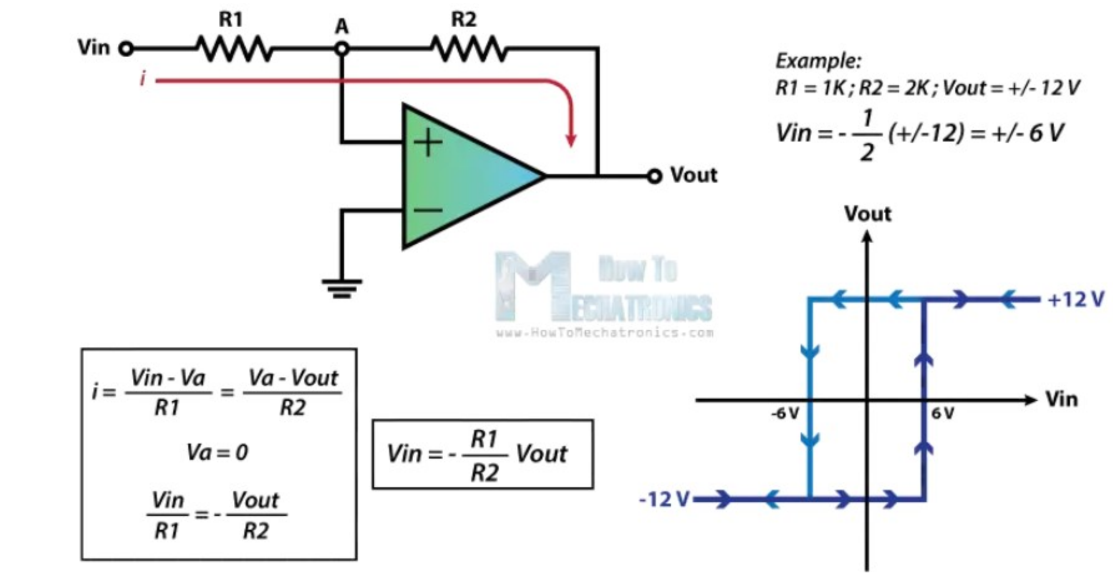


Voltage transfer characteristics (VTC)



Not all I/O can satisfy the static discipline, and it won't be linear.

Practical digitizing (quantizing)



Non-Symmetrical Schmitt Trigger

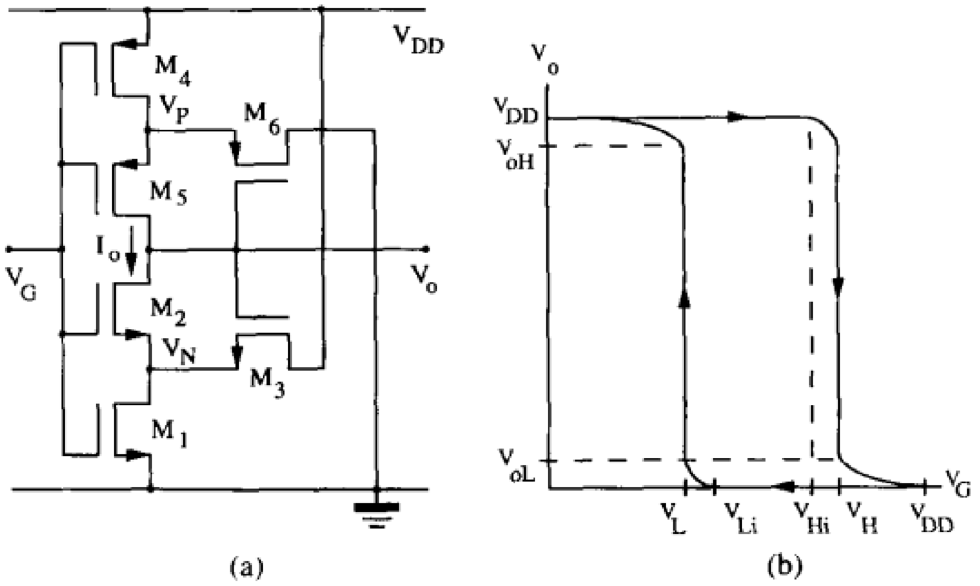
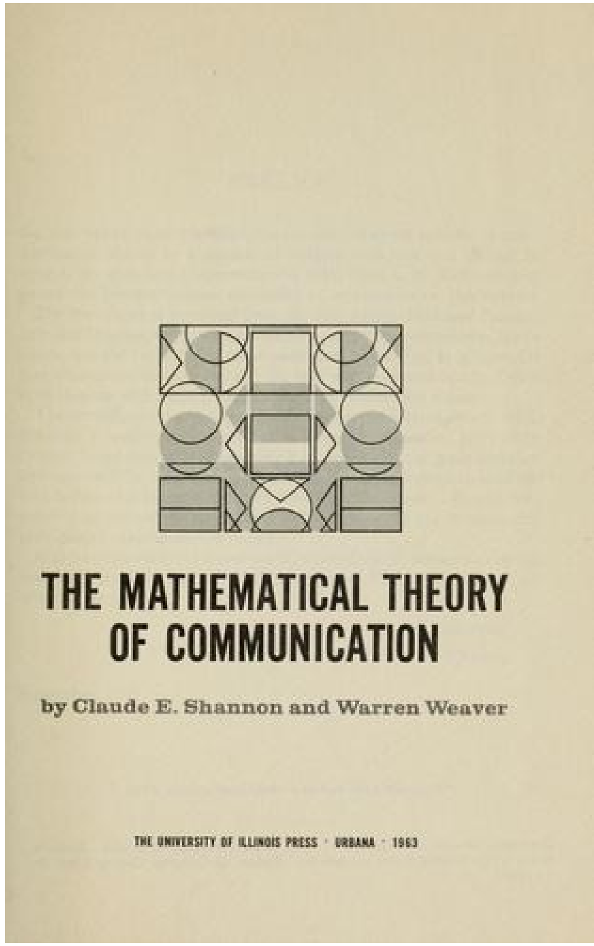


Fig. 1. CMOS Schmitt trigger and its transfer characteristic.

Filanovsky, I. M., and H. Baltes. "CMOS Schmitt trigger design." *IEEE Transactions on Circuits and Systems I: Fundamental Theory and Applications* 41.1 (1994): 46-49.

Why go digital? – the EE version

So now we can have stable 1s and 0s (in theory), so what?


THE MATHEMATICAL THEORY OF COMMUNICATION

by Claude E. Shannon and Warren Weaver

THE UNIVERSITY OF ILLINOIS PRESS · URBANA · 1963

It doubtless seems queer, when one first meets it, that information is defined as the *logarithm* of the number of choices. But in the unfolding of the theory, it becomes more and more obvious that logarithmic measures are in fact the natural ones.