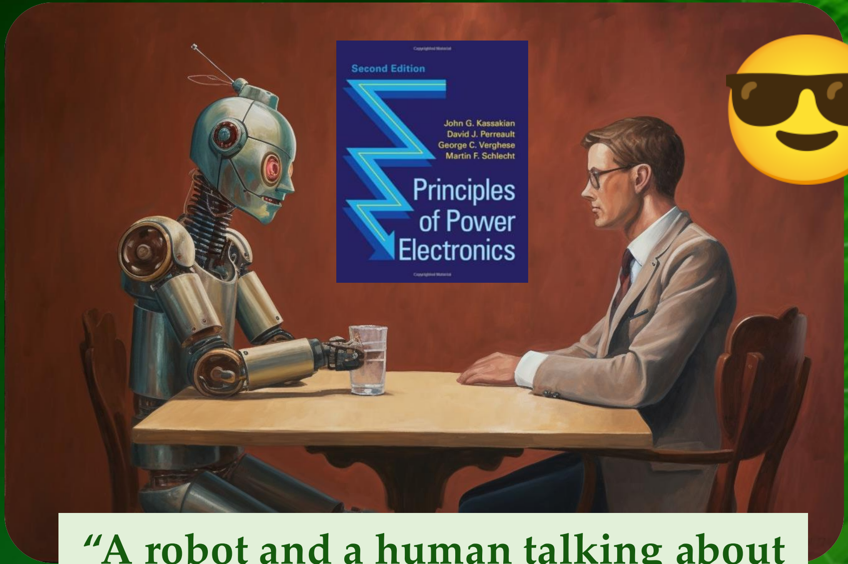
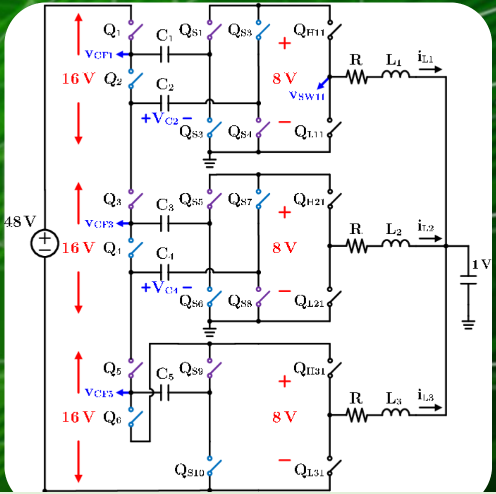


"A robot and a human talking about power electronics …"



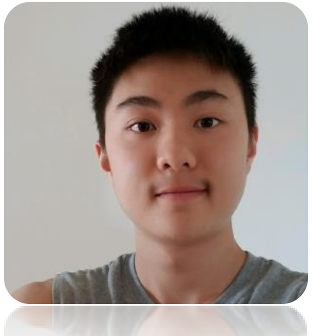
"A switched-capacitor dc-dc converter with series-input and parallel-output …"

Power Electronics Turing Test: A Path Toward Strong AI in Power Electronics

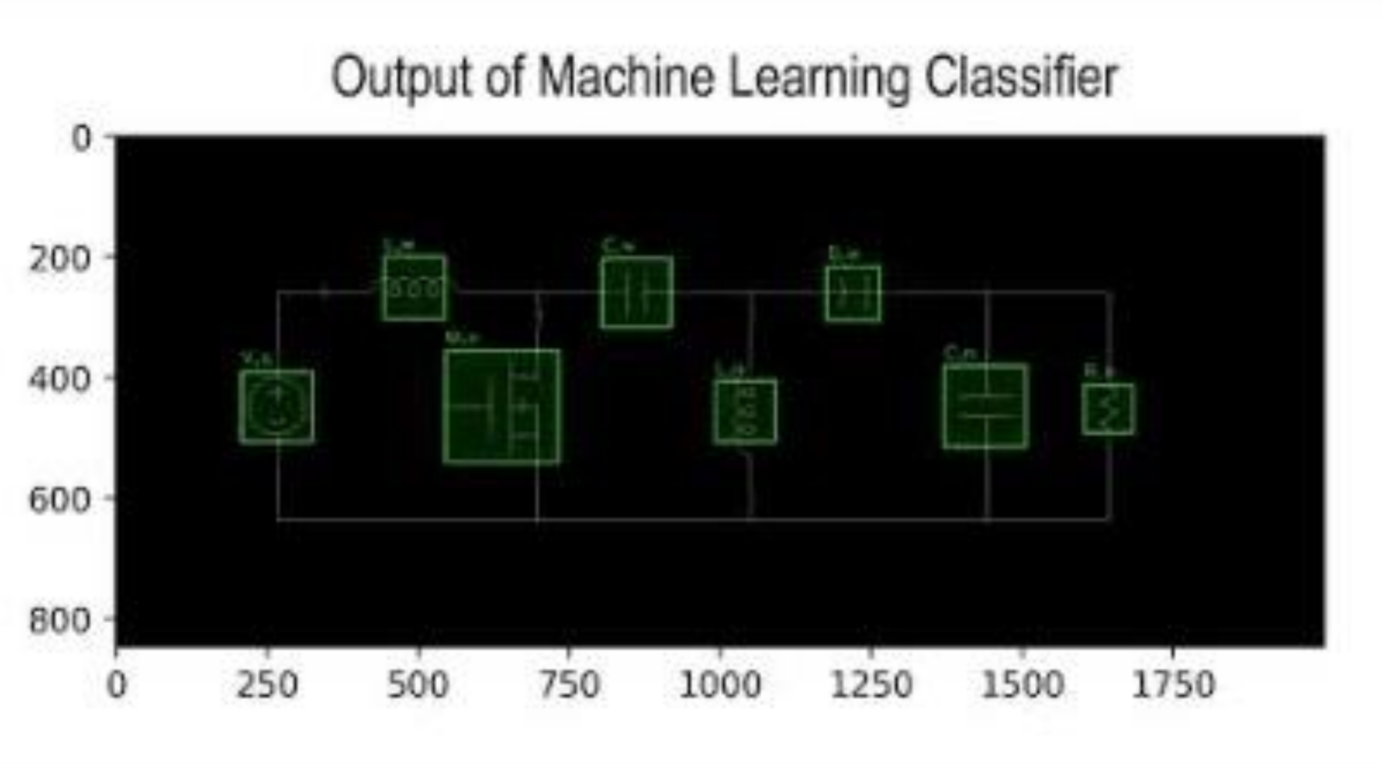
Minjie Chen and Dak C. Cheng
Princeton University

PRINCETON UNIVERSITY

Recording from Dak Cheng (Princeton ECE'25 Undergrad)



Dak Cheng
Princeton Undergrad



https://www.youtube.com/watch?v=Q_nJV8klBtk YouTube

Strong AI and Domain-Specific AI …

Artificial narrow intelligence (ANI)	Artificial general intelligence (AGI)	Artificial super intelligence (ASI)
"AI as a Tool"	"General Purpose AI"	"Domain Specific AI"

- Image Recognition
- Speech Recognition
- Alpha - Go

- ChatGPT - Language
- Sora - Vision
- GitHub Copilot – Logic Thinking

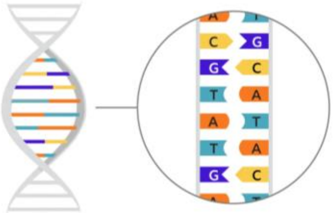
- Medicine Expert
- Materials Expert
- Power Electronics?

Power Electronics + AI?

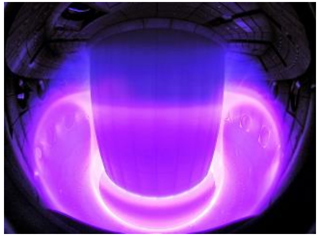
- Is *Strong* AI ready to learn Power Electronics? - Yes?
- Is Power Electronics ready for *Strong* AI? - No?

AI for Protein Prediction

AI for DNA Sequencing



AI for Fusion Control



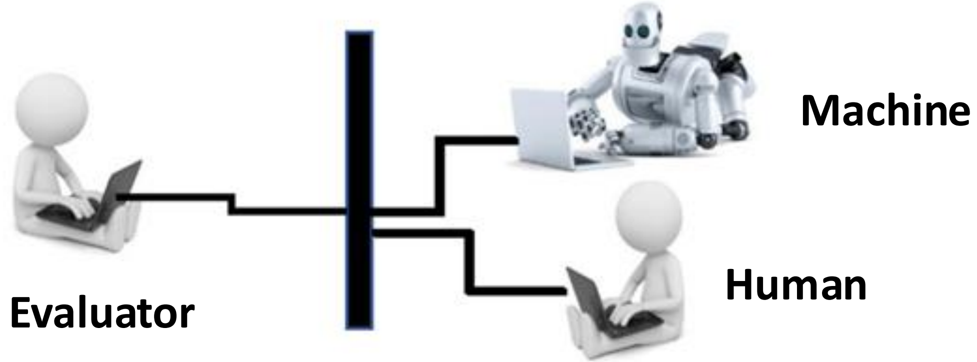
"Once data is ready, AI is ready!"

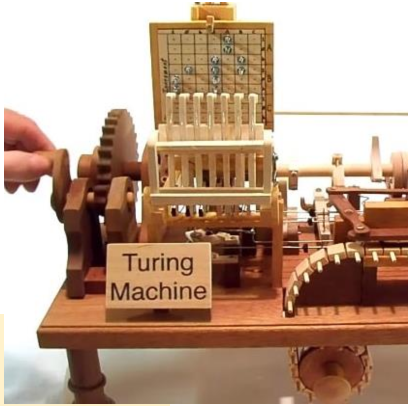
"Once question is ready, solution is ready!"

"How does human understand power electronics?"

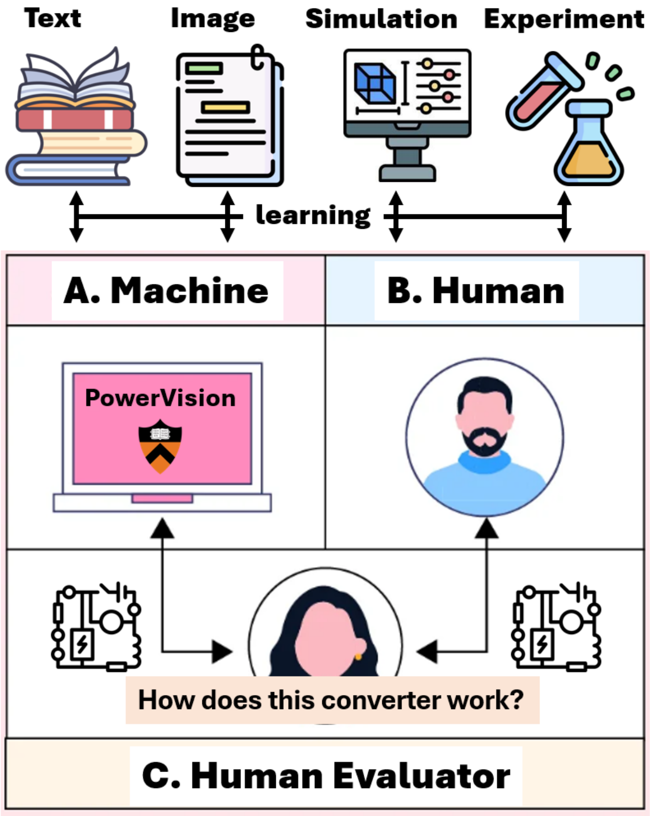
"How does machine understand power electronics?"

Turing Test in Power Electronics?

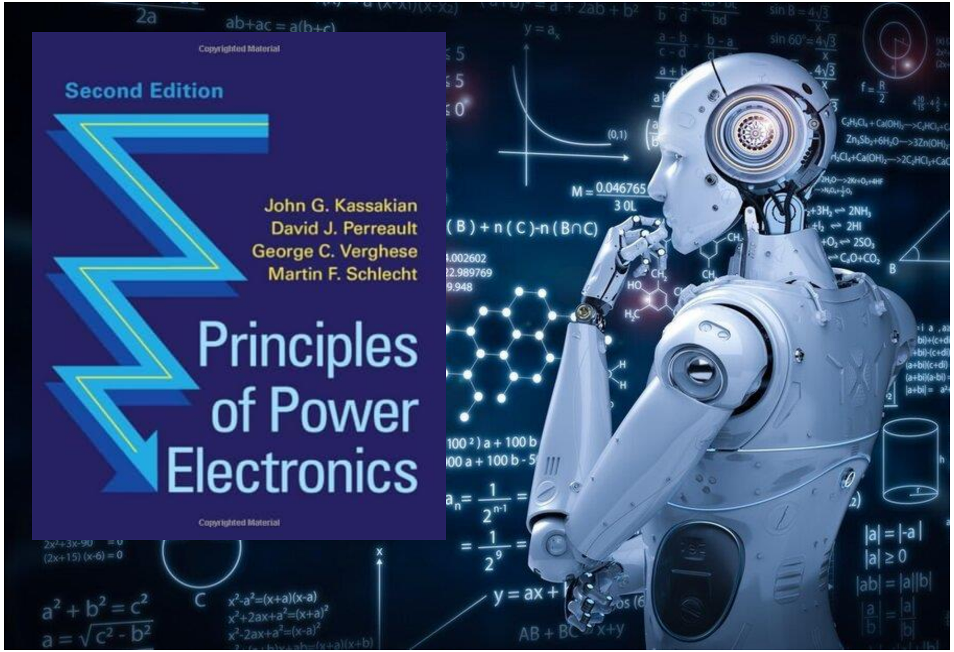


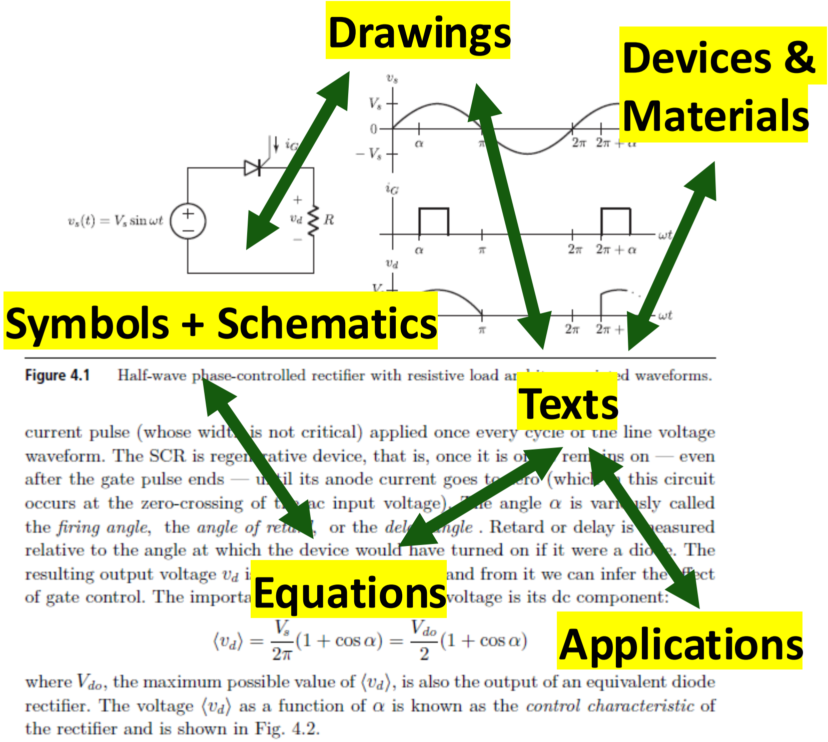


Dr. Alan Turing (born June 23, 1912)
PhD in math, Princeton
A. M. TURING, “I.—COMPUTING MACHINERY AND INTELLIGENCE,” Mind, vol. LIX, no. 236, pp. 433–460, 10 1950.



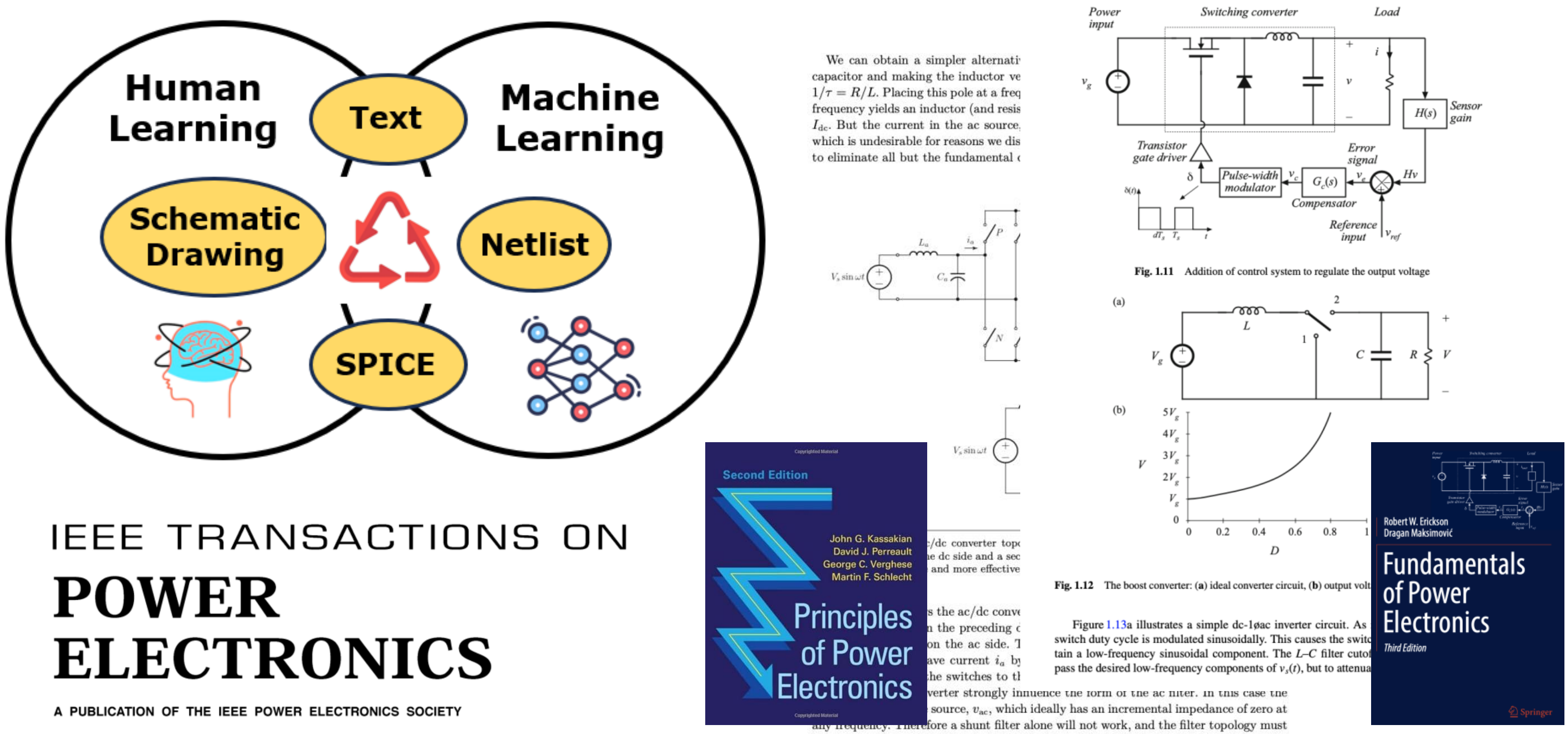
Teach AI to Understand Power Electronics?





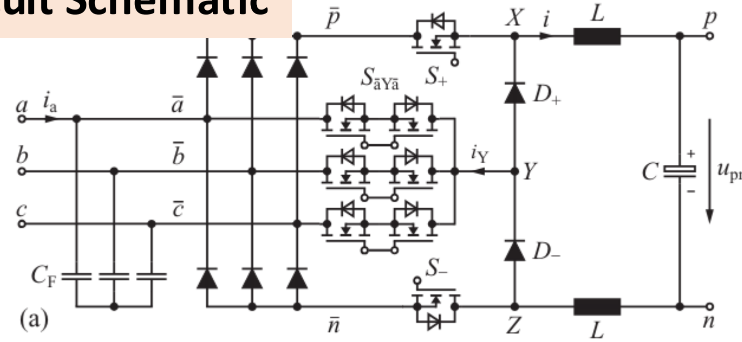
Page 81 of KPSV Textbook

Prepare Data for Massive Automated Learning …

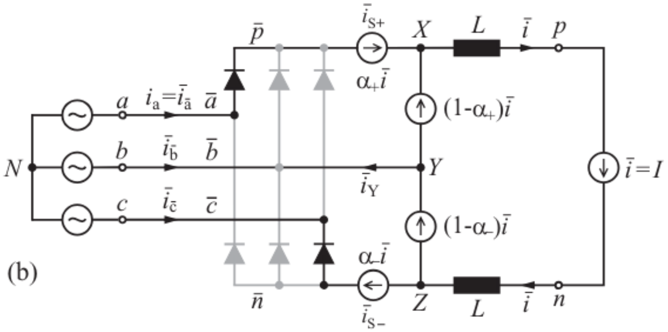


Structured Abstraction in Power Electronics

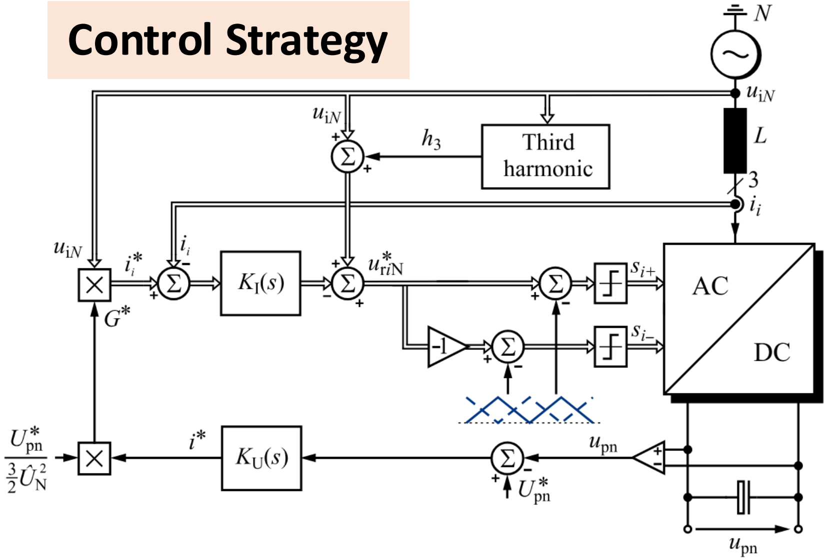
Circuit Schematic



Conceptual Abstract



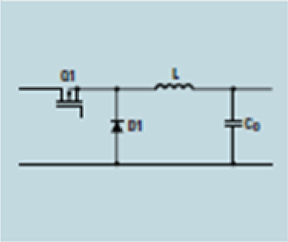
Control Strategy



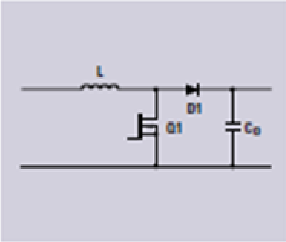
- *J. W. Kolar and T. Friedli, "**The Essence of Three-Phase PFC Rectifier Systems—Part I,**" in IEEE Transactions on Power Electronics, vol. 28, no. 1, pp. 176-198, Jan. 2013.*
- *T. Friedli, M. Hartmann and J. W. Kolar, "**The Essence of Three-Phase PFC Rectifier Systems—Part II,**" in IEEE Transactions on Power Electronics, vol. 29, no. 2, pp. 543-560, Feb. 2014.*

Teach AI to understand/classify Basic Schematics?

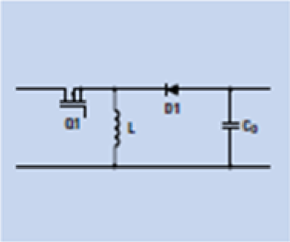
Buck



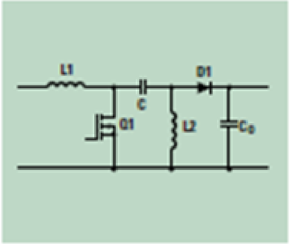
Boost



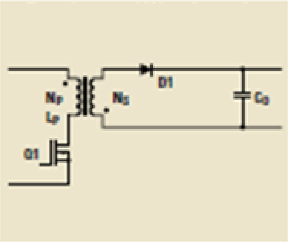
Buck Boost



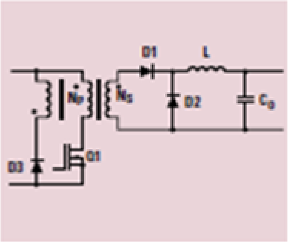
SEPIC



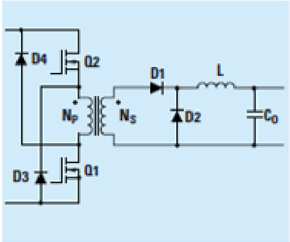
Flyback



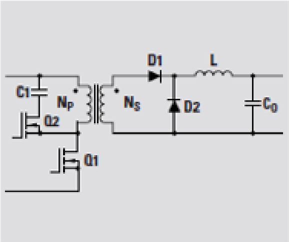
Forward



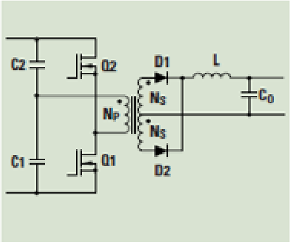
2 Switch Forward



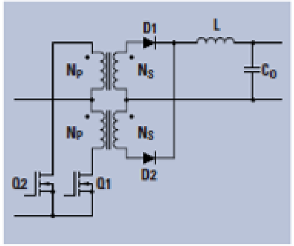
Active Clamp Forward



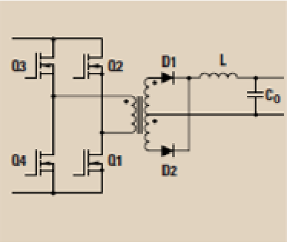
Half Bridge



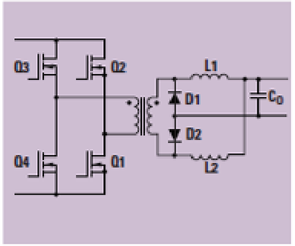
Push Pull



Full Bridge

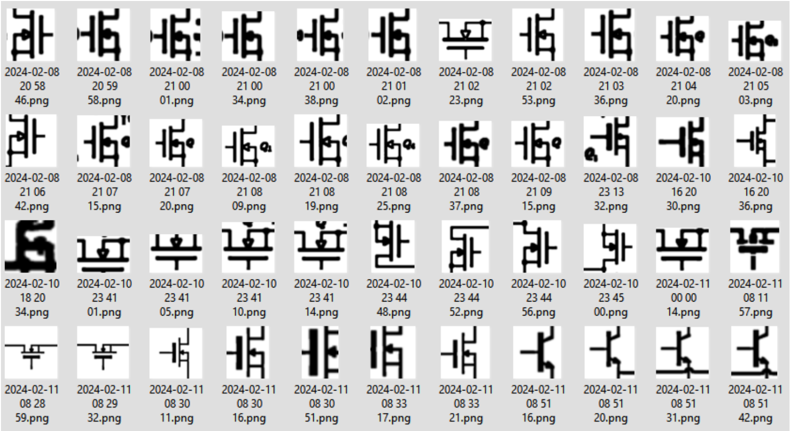


Phase Shift ZVT



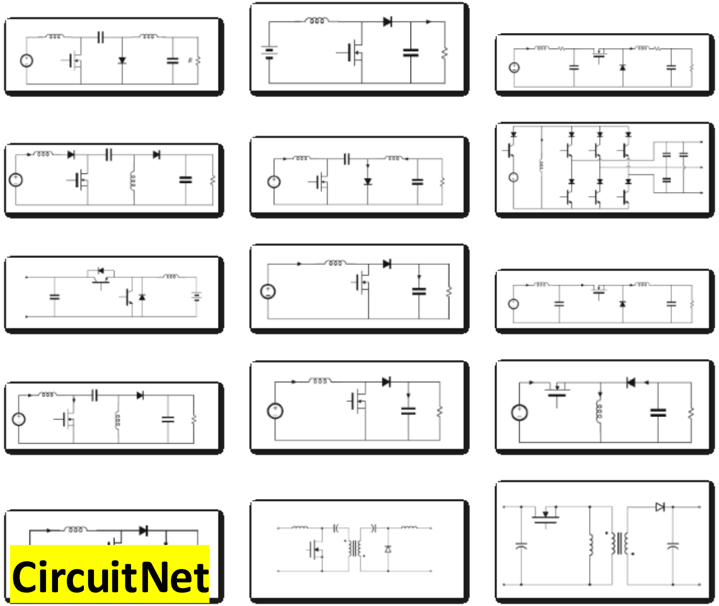
- 90% of power electronics in use are designed following these topologies
- 90% of power electronics designs already "exist" and are just "fine-tuning" efforts
- Texas Instruments power topology catalog: https://www.ti.com/lit/ml/sluw001g/sluw001g.pdf

Training Data Preparation



ComponentNet

- 2544 hand-collected component images
- Machine-drawn and hand-drawn
- Semiconductor switches, capacitors, magnetics, controllers, labels, symbols



CircuitNet

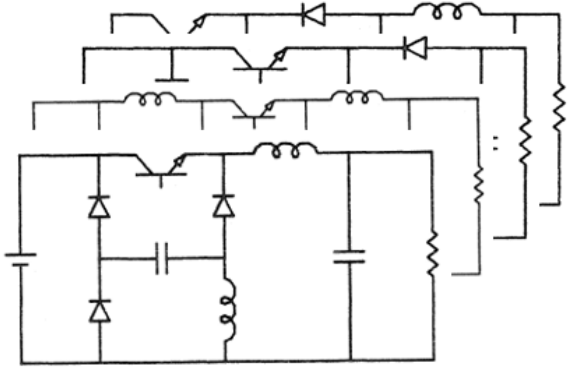
- 200 hand-classified schematics
- Machine-drawn and hand-drawn

Open-Sourced: https://github.com/minjiechen/PowerVision

NetlistMaker – Convert Schematics to Netlists

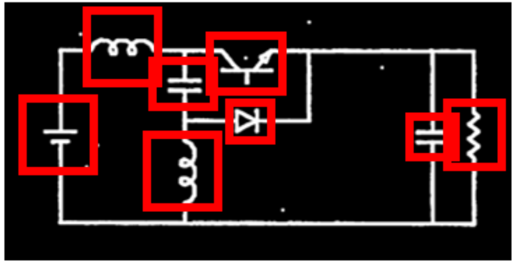
PRINCETON UNIVERSITY

Schematic Database (>100 schematics)



Segment

Component Detection (OpenCV)



Inference

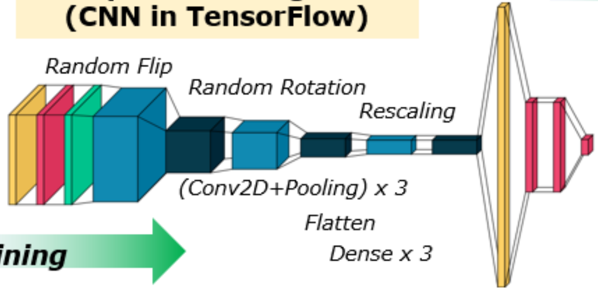
Netlist / Incidence Matrix (SPICE Simulations)

	N1	N2	N3	N4	N5
Inductor	1	1	0	0	0
capacitor	1	0	1	0	0
Battery	1	0	0	0	1
Diode	0	1	1	0	0
Resistor	1	0	1	0	0
Capacitor	0	1	0	1	0
Switch	0	0	1	1	0
Inductor	0	0	0	1	1

Component Database (2544 images in 11 categories)

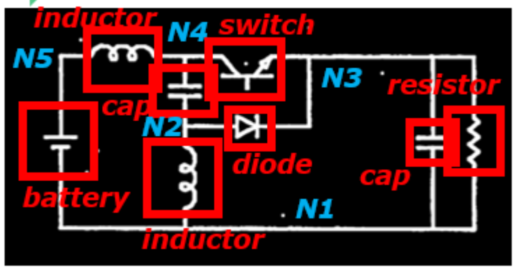
Training

Component Recognition (CNN in TensorFlow)



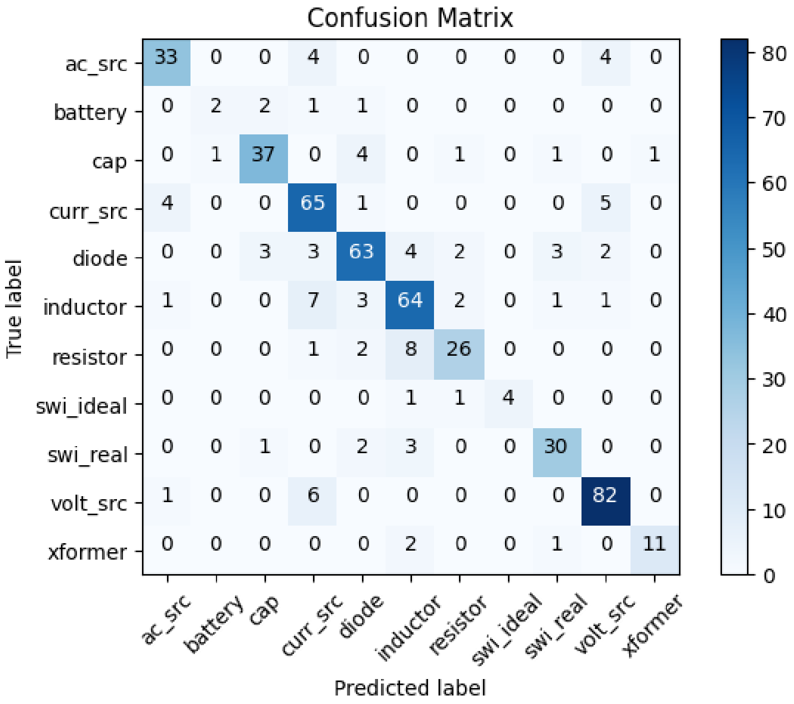
Classification

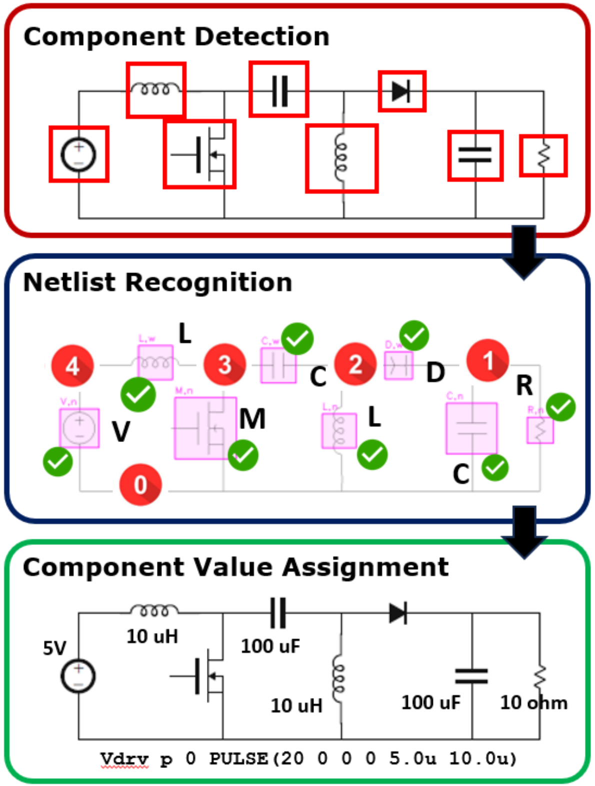
Netlist Generation



Performance of the NetlistMaker

>90% accuracy for component classification





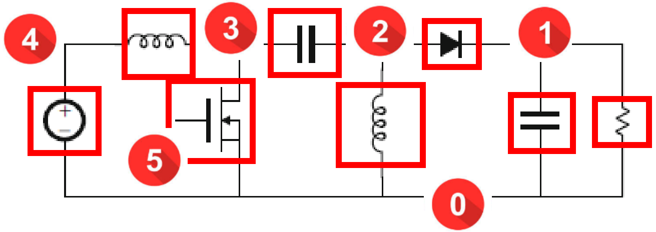
>90%

<70%

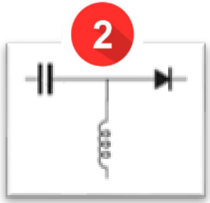
Hand-Assisted

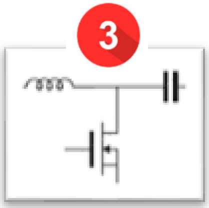
Advanced Understanding about the Schematic

Circuit Schematic



Key Patterns

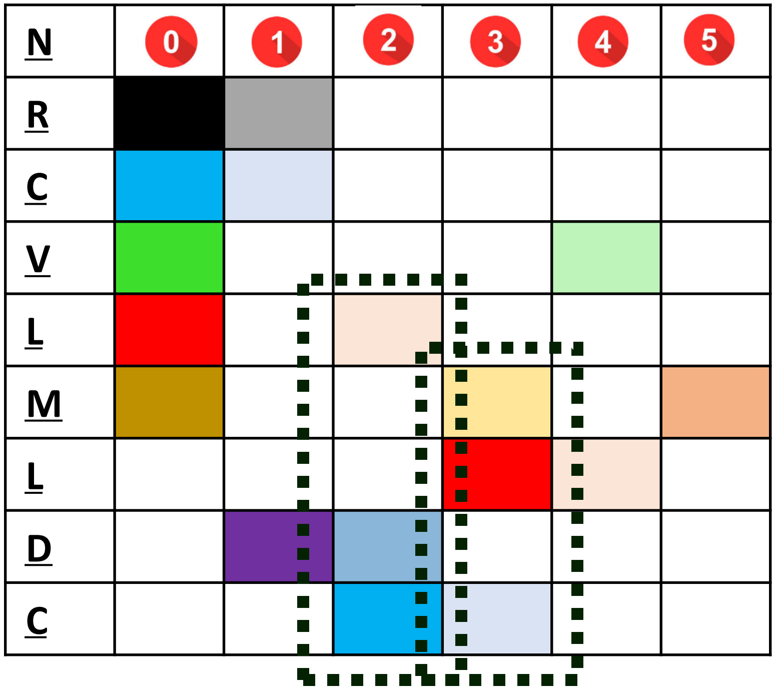




Incidence Matrix

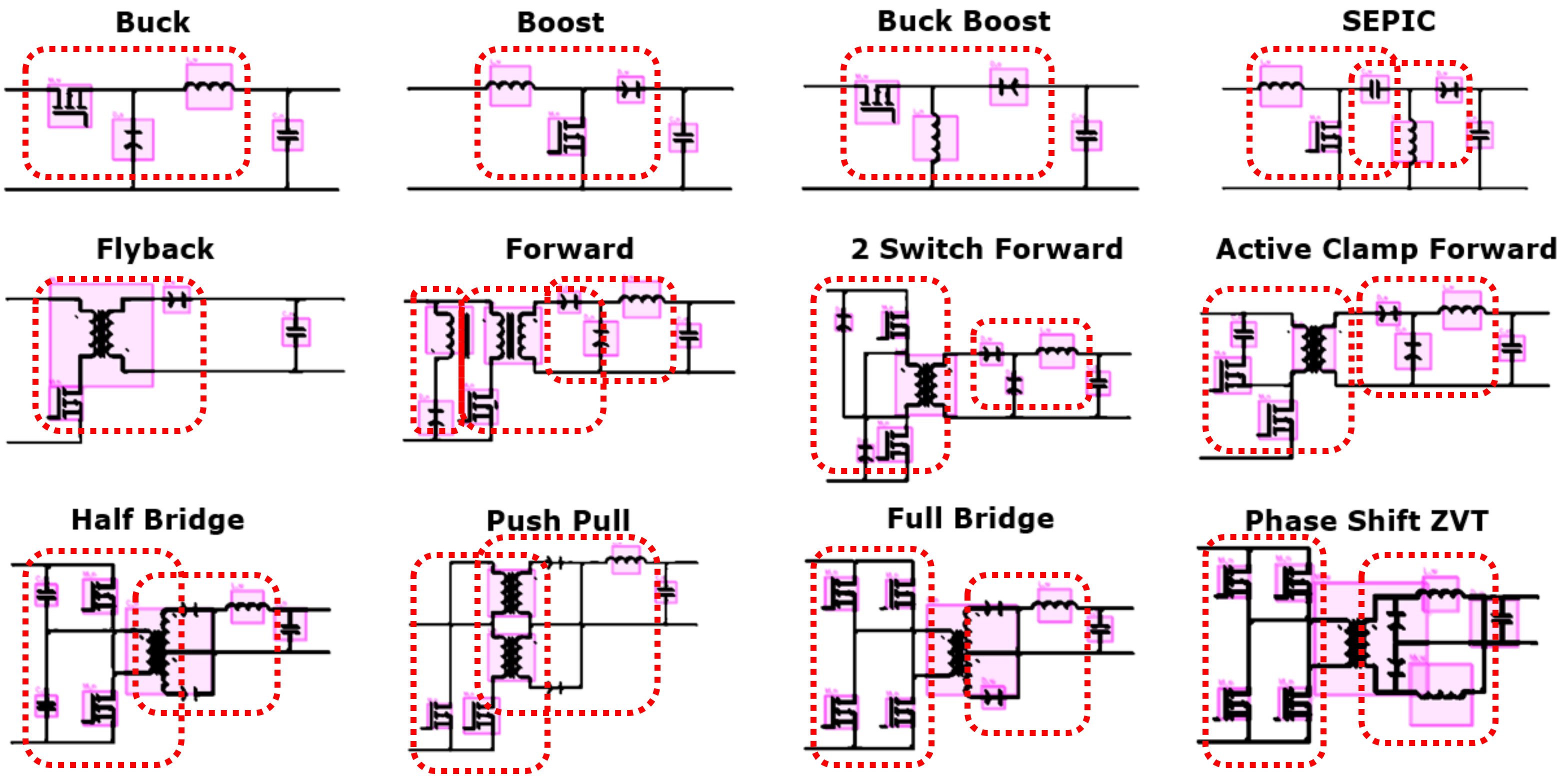
	N_0	N_1	N_2	N_3	N_4	N_5
R	2	1	0	0	0	0
C	2	1	0	0	0	0
V	2	0	0	0	1	0
L	2	0	1	0	0	0
M	3	0	0	1	0	2
L	0	0	0	2	1	0
D	0	2	1	0	0	0
C	0	0	2	1	0	0

Matrix Patterns <-> Circuit Functions



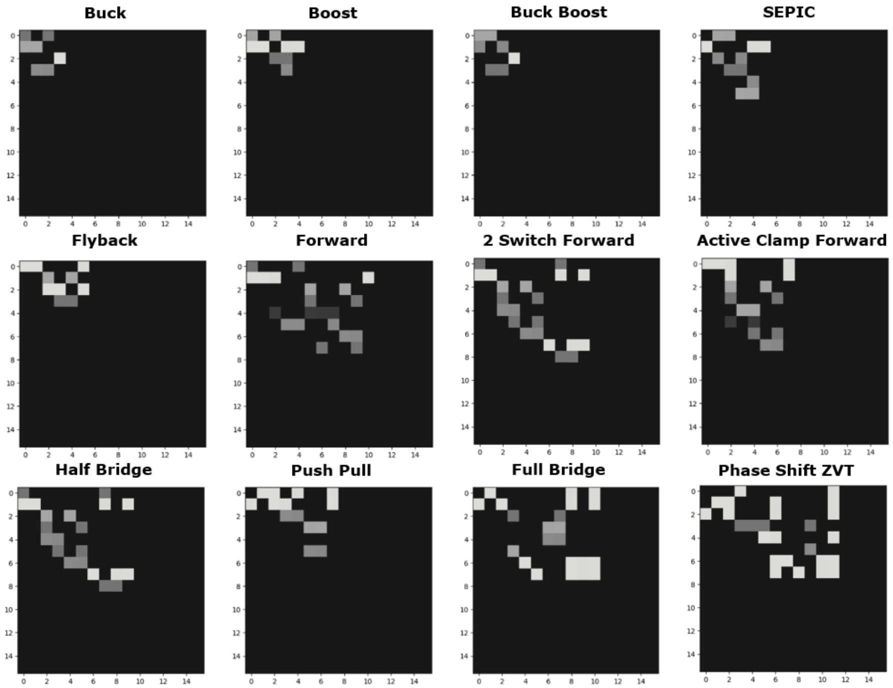
Train on a Large Number of Pre-Labeled Circuits

PRINCETON UNIVERSITY

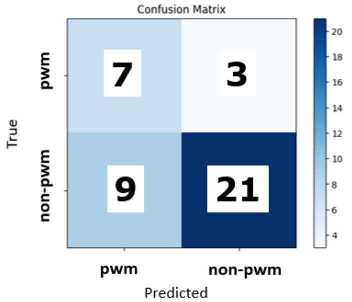


A Failed Turing Test, but A Successful First Attempt …

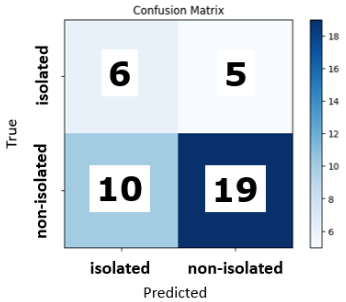
Power Electronic Topology "Fingerprints"



Classify and explain an existing circuit topology

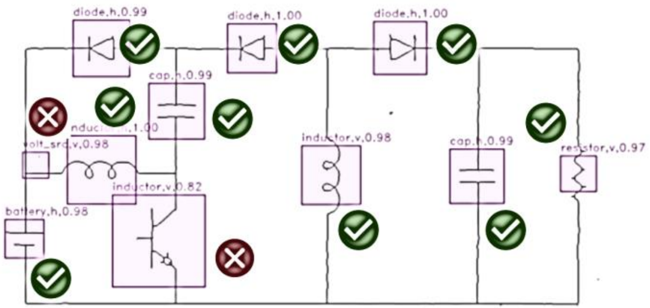


PWM or non-PWM?



Isolated or non-Isolated?

Try to interpret a new, unknown circuit topology



End-to-End Cognitive Intelligence beyond Schematics

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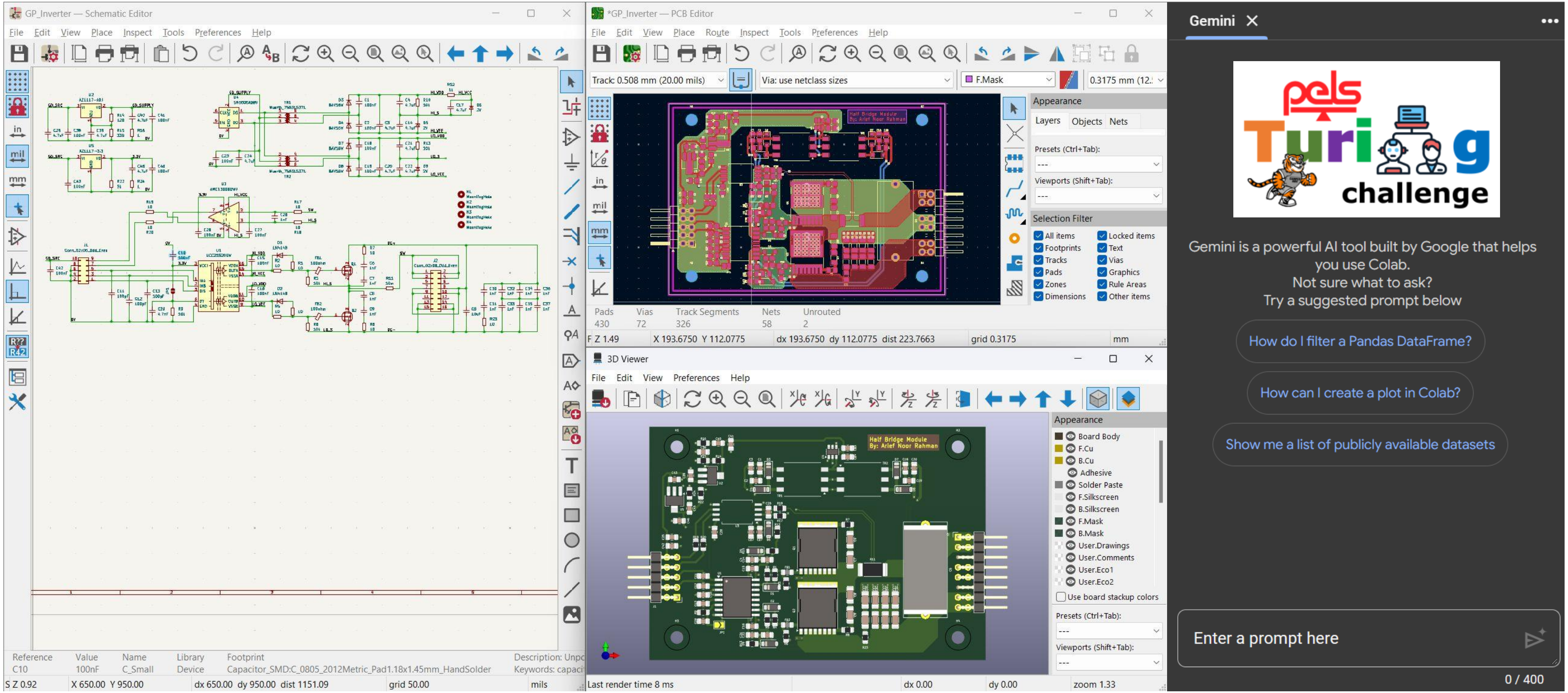


What is the true Artificial Intelligence in Power Electronics?

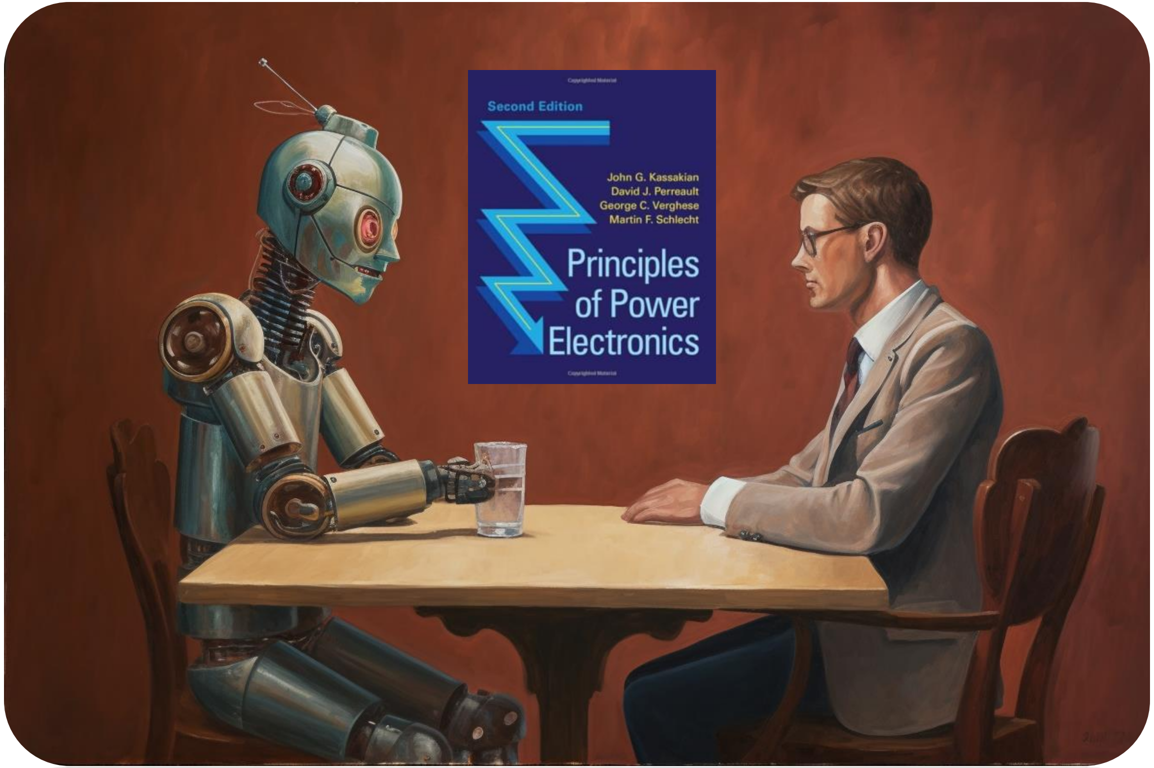


Image + Language

≠

General Intelligence

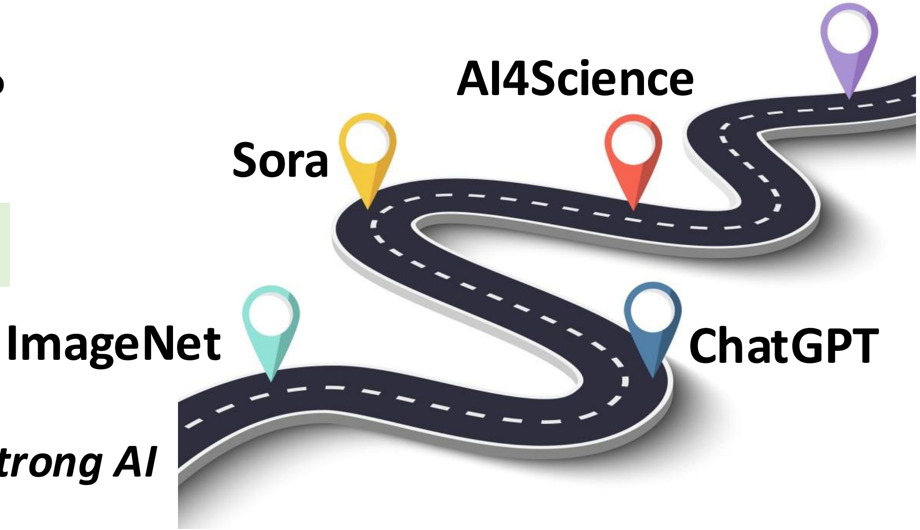
≠

Domain-Specific Intelligence

COMPEL community should think ahead of AI !!!

- How to enable AI to pass Power Electronics Turing Test?
  - Where is data?
  - How to organize the data?
  - What questions shall we ask?
  - Which tools are ready?
  - Where are our collaborators?
  - Who cares?

Embrace and think ahead of AI!



Pathway to Strong AI

A Path Toward Strong AI in Power Electronics

- Most human-created information documented/processed as 1-D time sequences (natural language) or 2-D arrays (computer vision).
- Most advanced AI models focus on **language** or **vision** processing.
- Convert interesting power electronics problems into time sequence (language) or vision (image) problems.
- Create the database –> migrate the tools –> build an open-source community –> advance the field collaboratively and competitively

pels MagNet challenge 2023

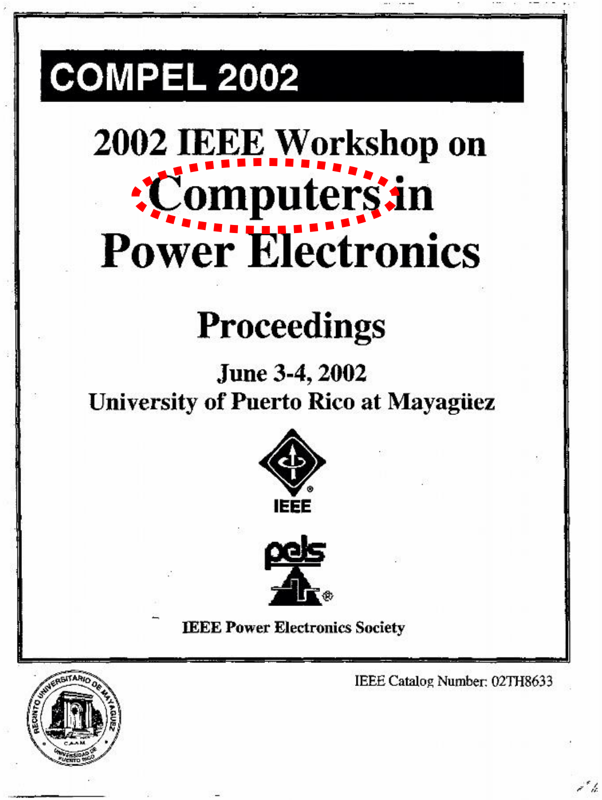
?

pels Turing challenge 2025

time-sequence processing (NLP)

image processing (computer vision)

Rethinking Human and Machine in Power Electronics


COMPEL 2002

2002 IEEE Workshop on
Computers in
Power Electronics

Proceedings

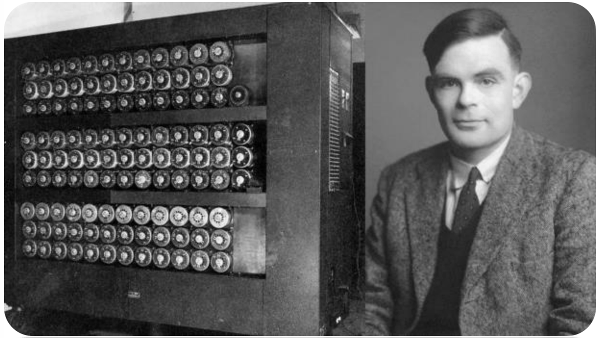
June 3-4, 2002
University of Puerto Rico at Mayagüez

IEEE

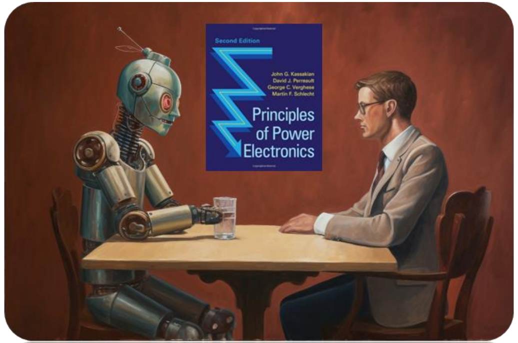
pels

IEEE Power Electronics Society

IEEE Catalog Number: 02TH8633



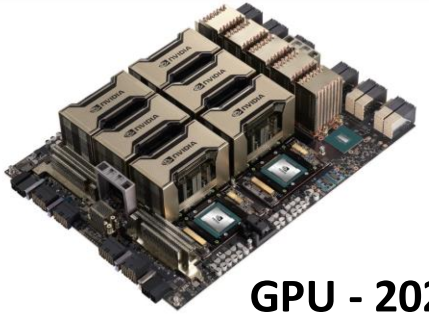
Turing and His Machine



Power Electronics & AI

ENIAC - 1945

PC - 1980



GPU - 2024