

Contact-controlled transistors: Specific applications and opportunities

Eva Bestelink

Advanced Technology Institute, University of Surrey, Guildford, GU2 7XH, UK

10 December 2020

r.a.sporea@surrey.ac.uk
teamsporea.info

Applications and opportunities for contact-controlled transistors

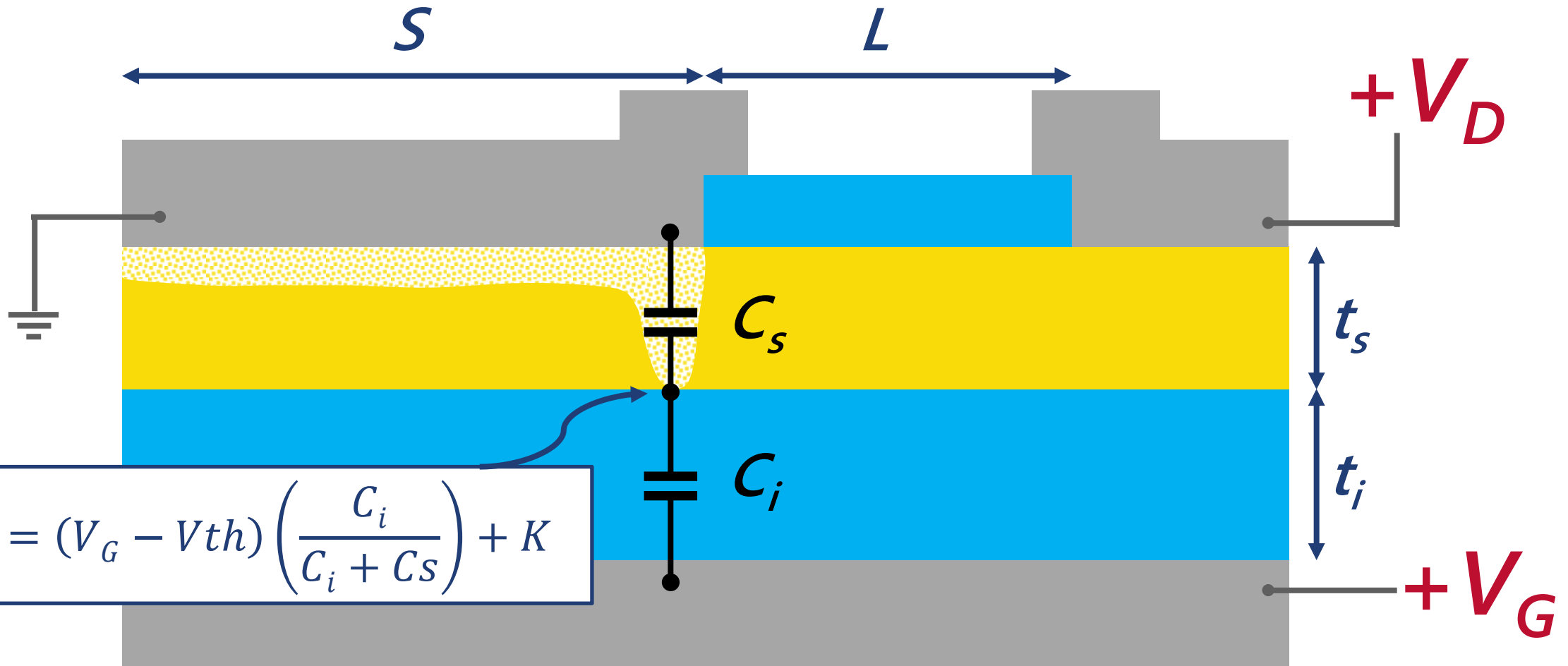
The Source-Gated Transistor - SGT

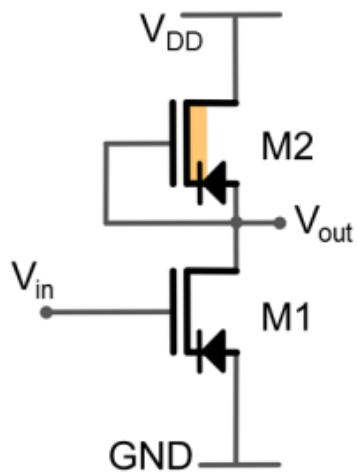
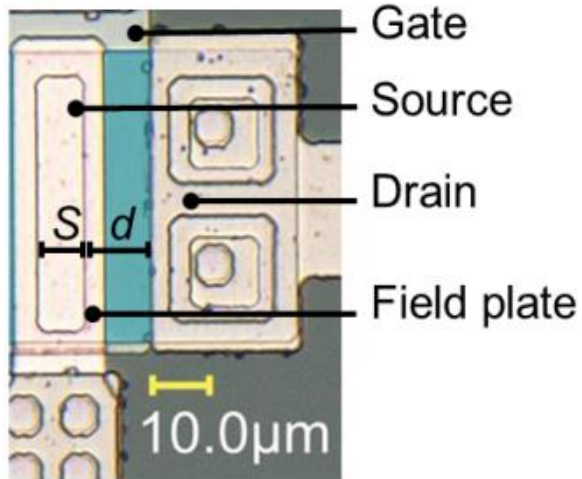
The Multimodal Transistor - MMT

The modelling challenge

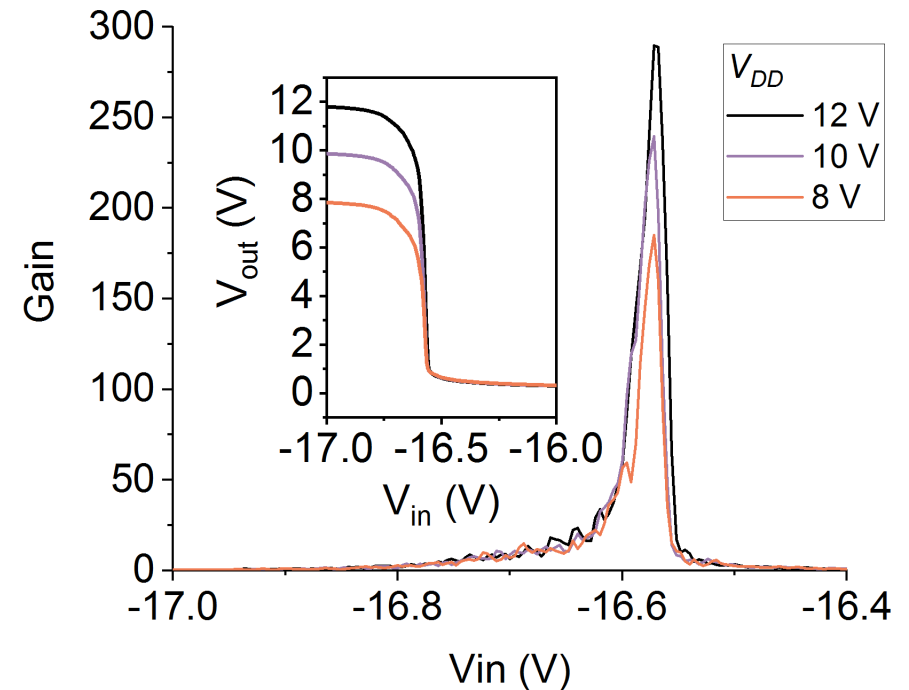
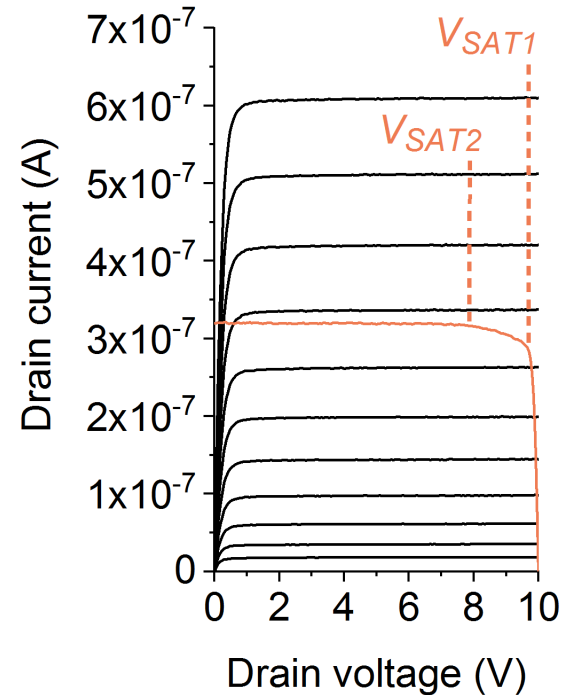
SGT operation

J. M. Shannon and E. G. Gerstner, "Source-Gated Thin-Film Transistors," *IEEE Electron Device Lett.*, vol. 24, no. 6, pp. 405–407, 2003.



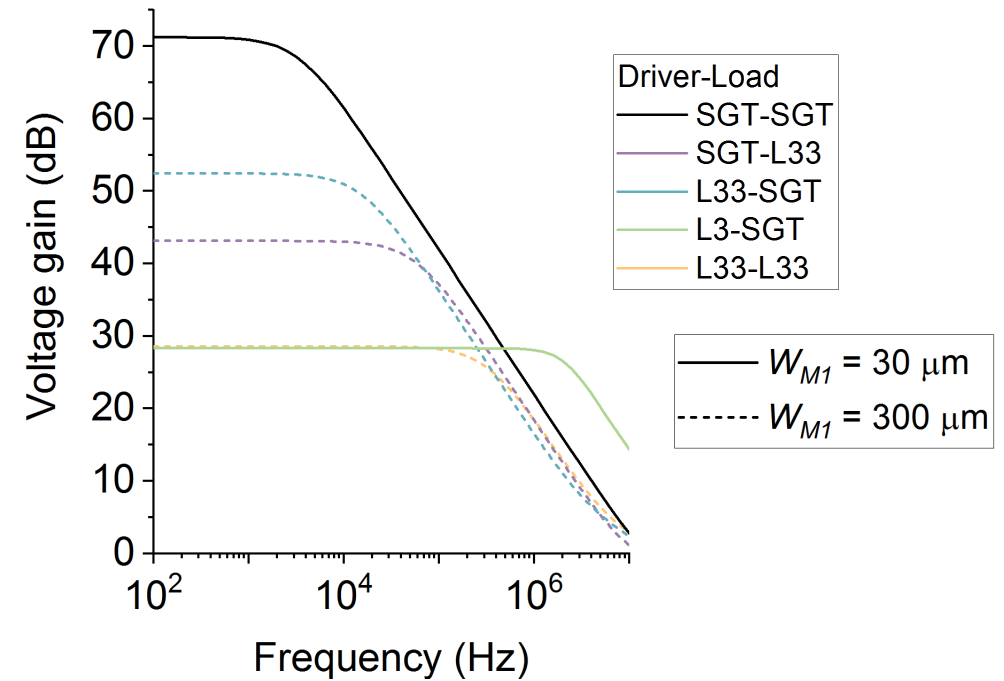
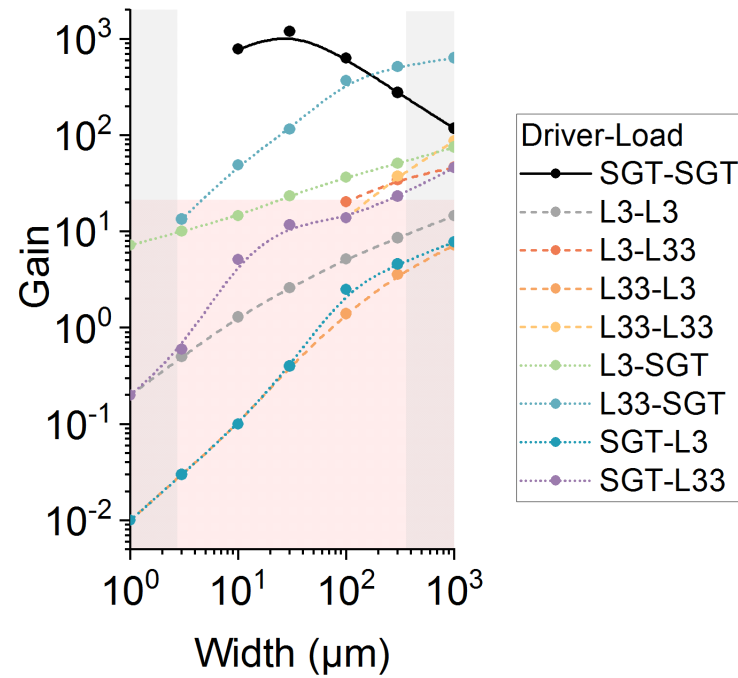
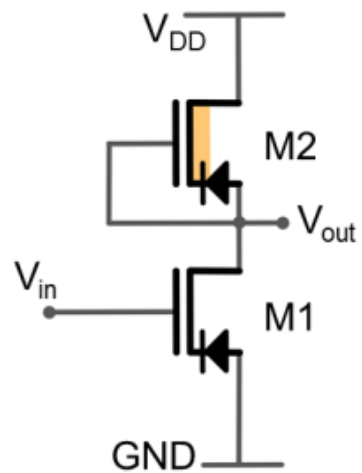
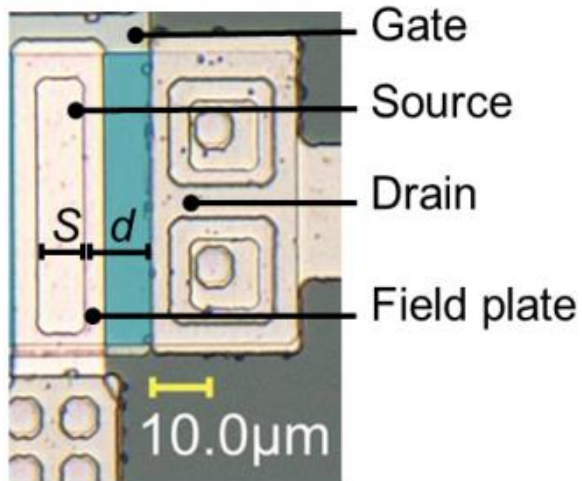


Two-SGT amplifier with world-leading gain (290x = 49dB) in polysilicon

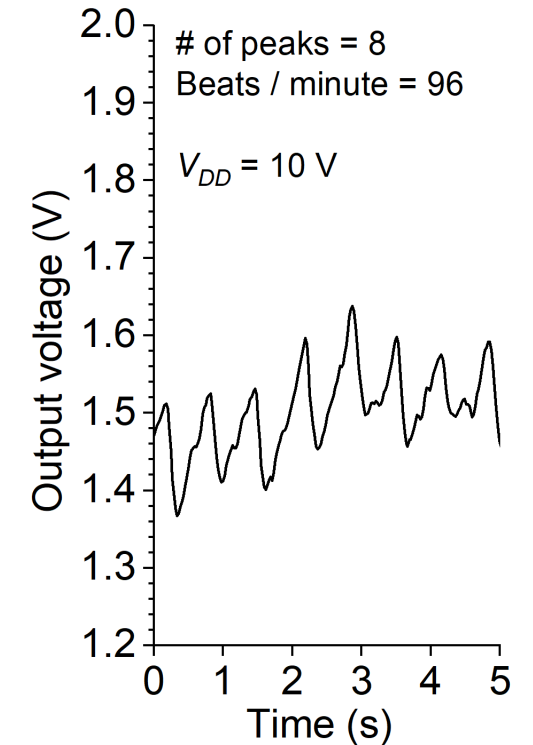
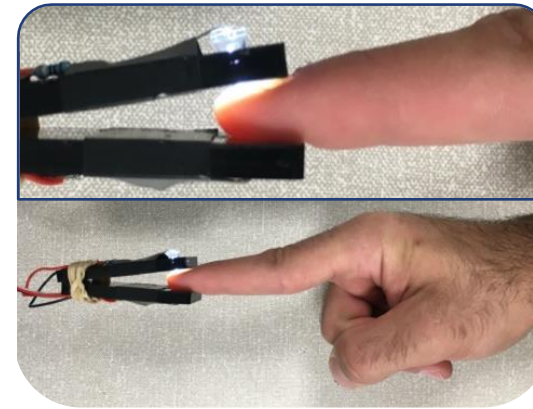
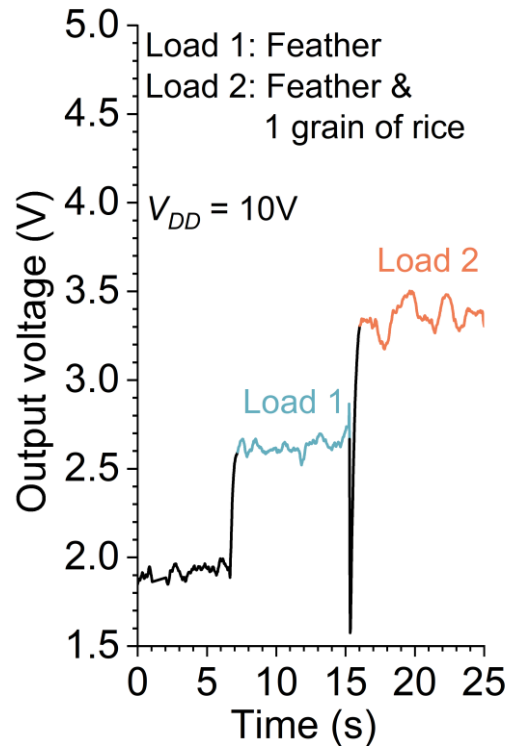
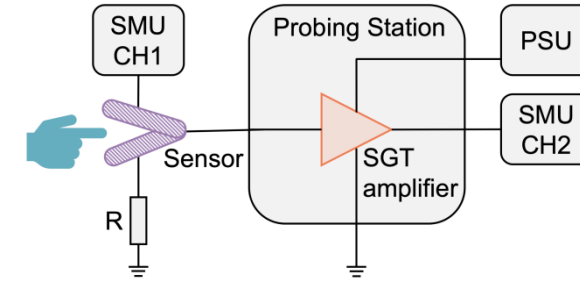
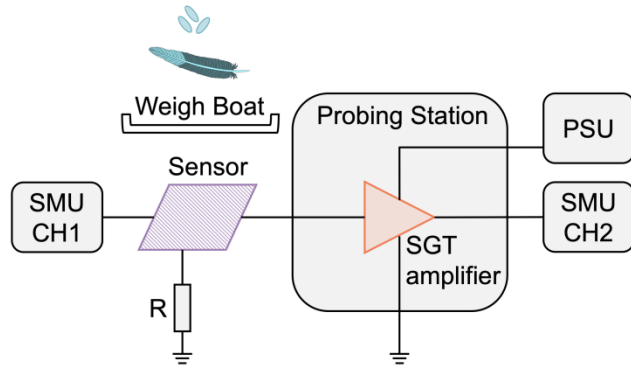


E. Bestelink, K. M. Niang, G. Bairaktaris, L. Maiolo, F. Maita, K. Ali, A. J. Flewitt, S. R. P. Silva, R. A. Sporea, "Compact Source-Gated Transistor Analog Circuits for Ubiquitous Sensors," IEEE Sens. J., vol. 20, no. 24, pp. 1–1, 2020

High-gain SGT amplifiers



Compact yet powerful... Simple circuits can do a lot

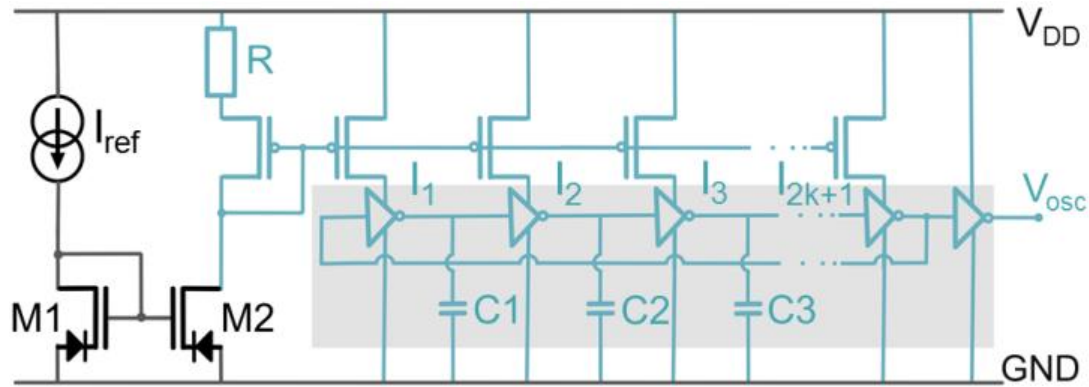


Compact yet powerful...

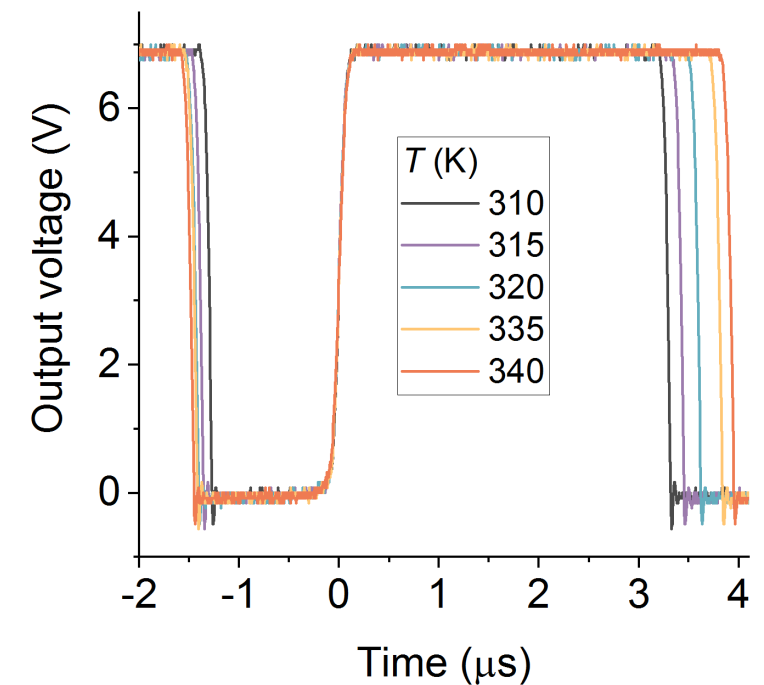
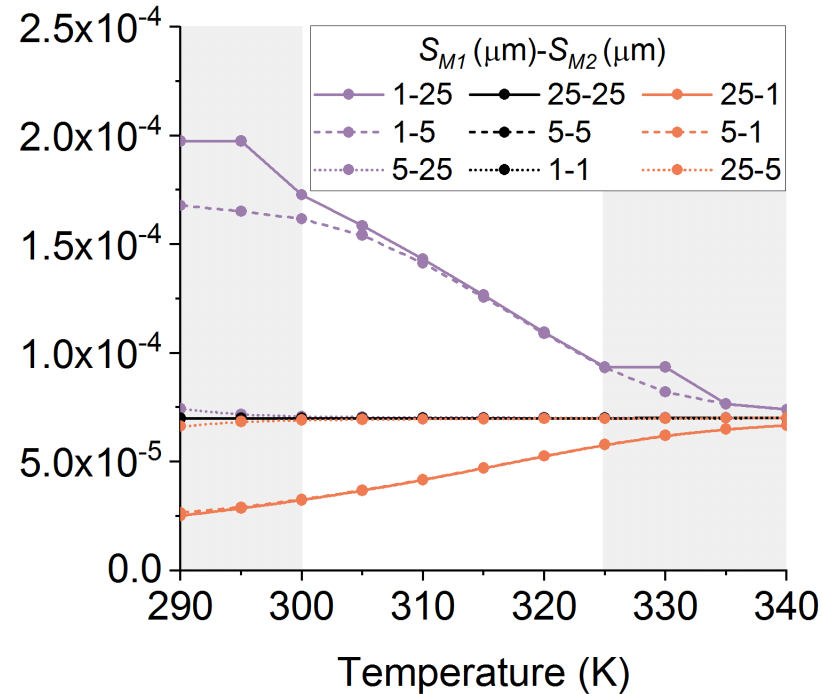
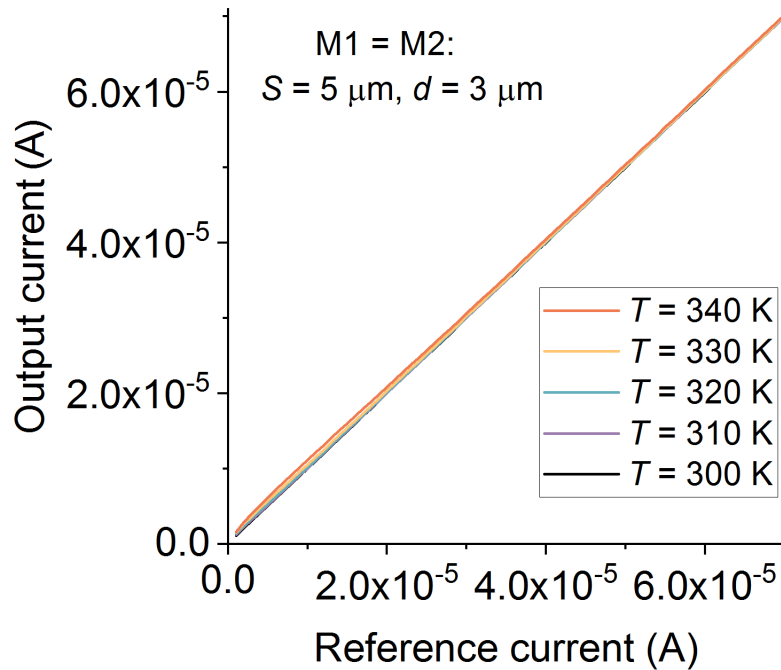
Simple circuits can do a lot

Compact yet powerful...

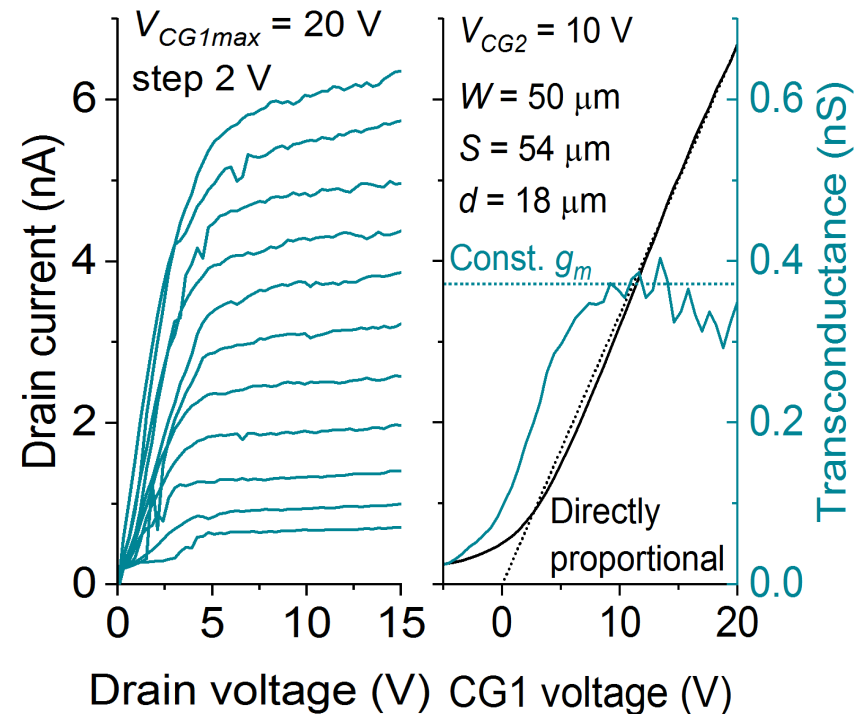
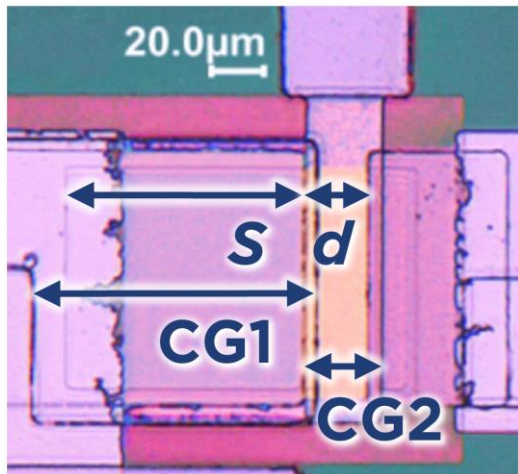
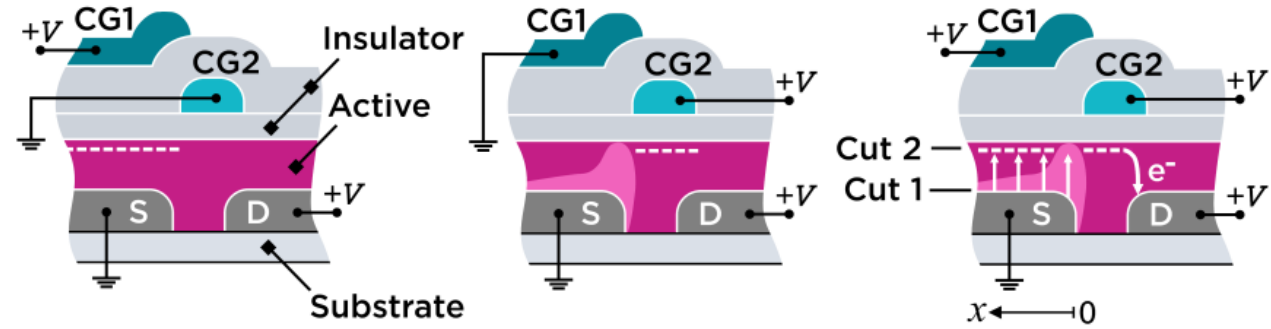
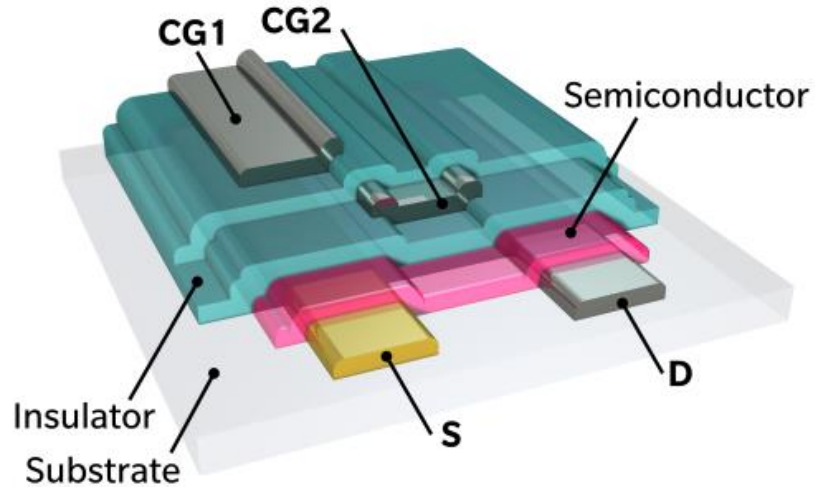
Simple circuits can do a lot



Two-SGT current mirrors copy current without cascoding
Unmatched S can produce negative temperature dependence

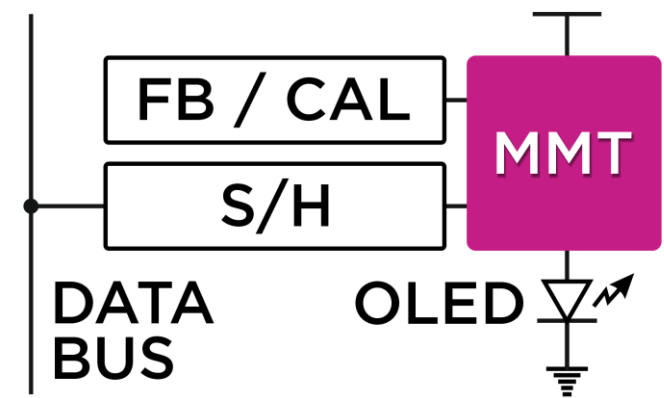
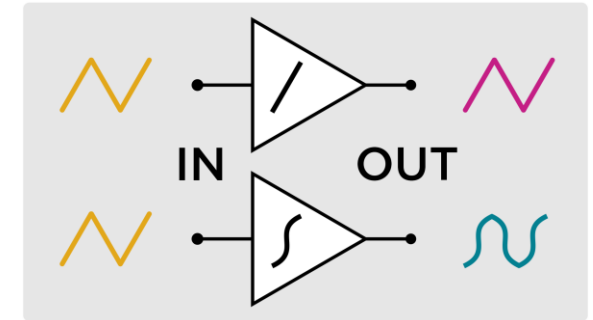
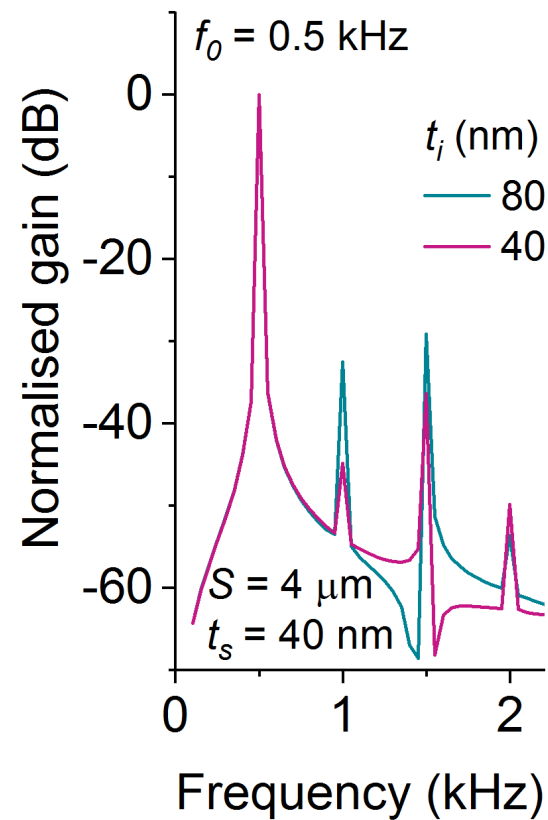
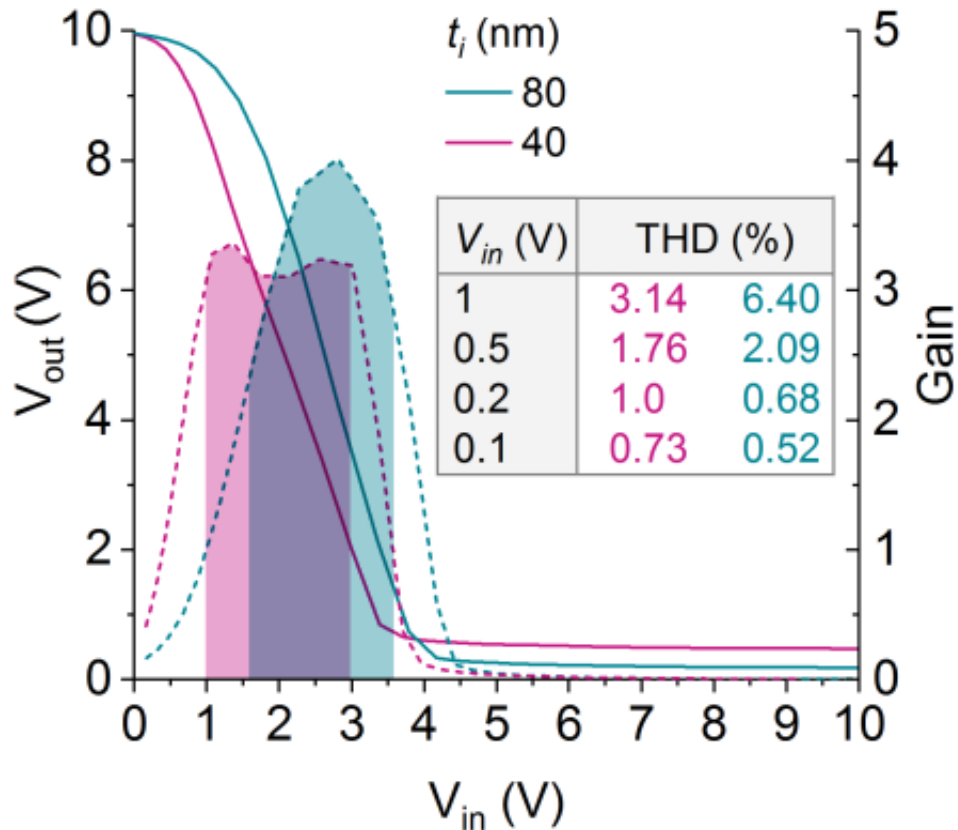


The Multimodal Transistor (MMT) Operation



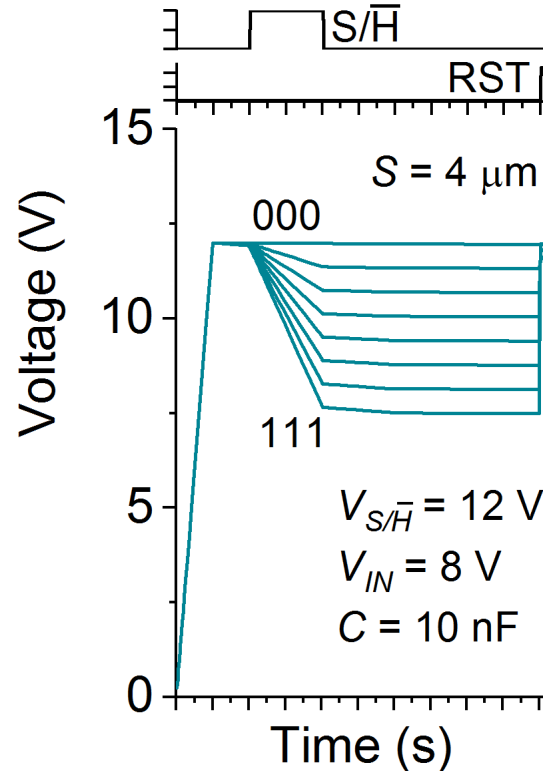
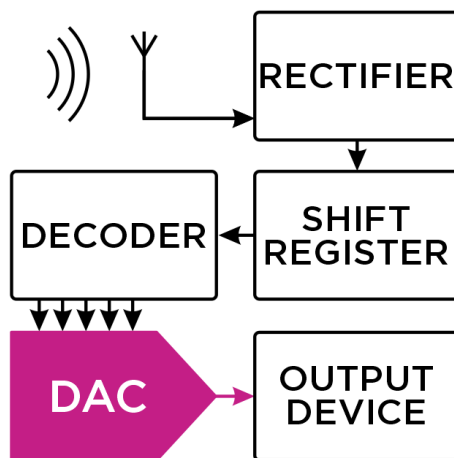
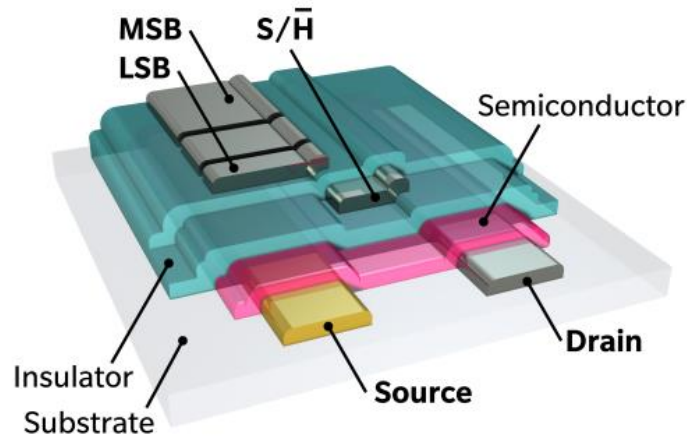
The Multimodal Transistor (MMT) Applications

Low-distortion, minimal-layout amplifiers

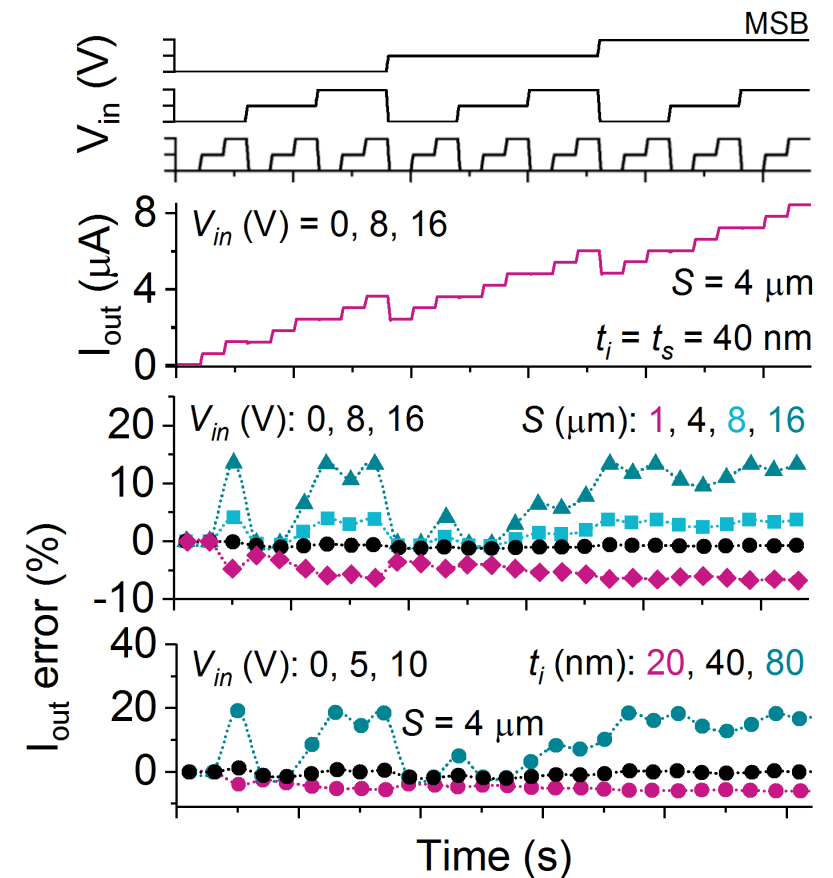


The Multimodal Transistor (MMT) Applications

Compact digital to analog conversion with multilevel logic

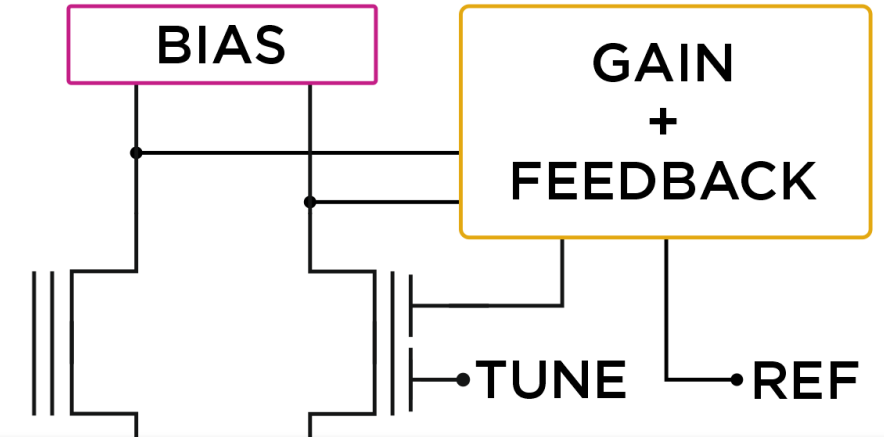
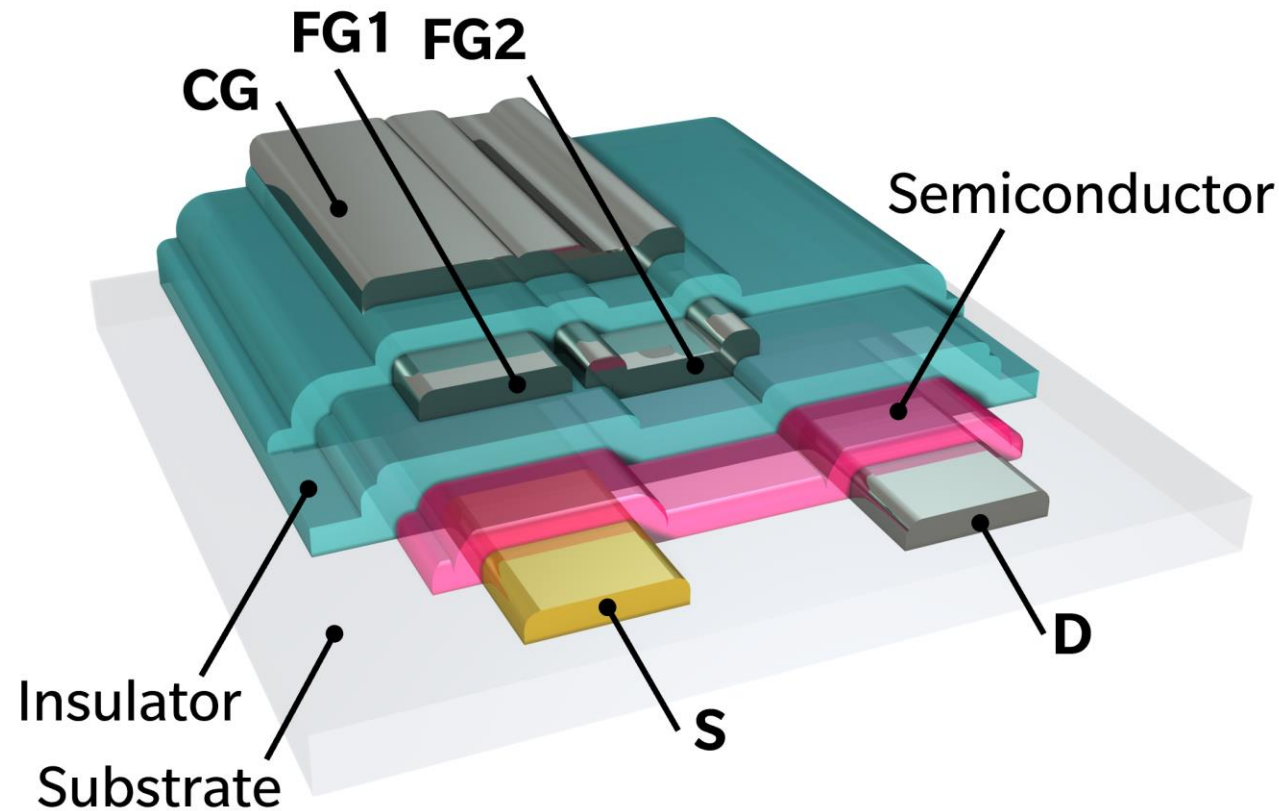


Output proportional to:
Gate width
Input voltage



The Multimodal Transistor (MMT) Applications

Floating gate analog memory and ultralow power voltage references



(12) **United States Patent** Sporea et al.

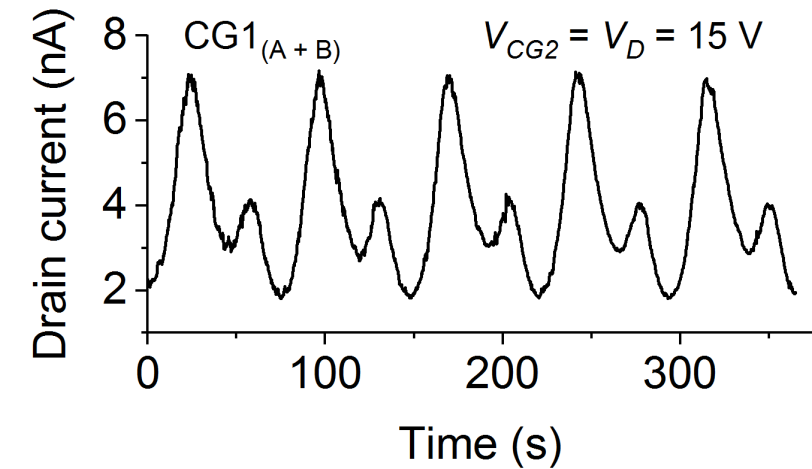
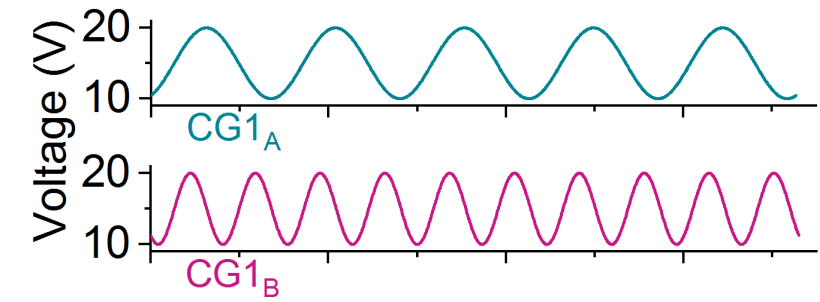
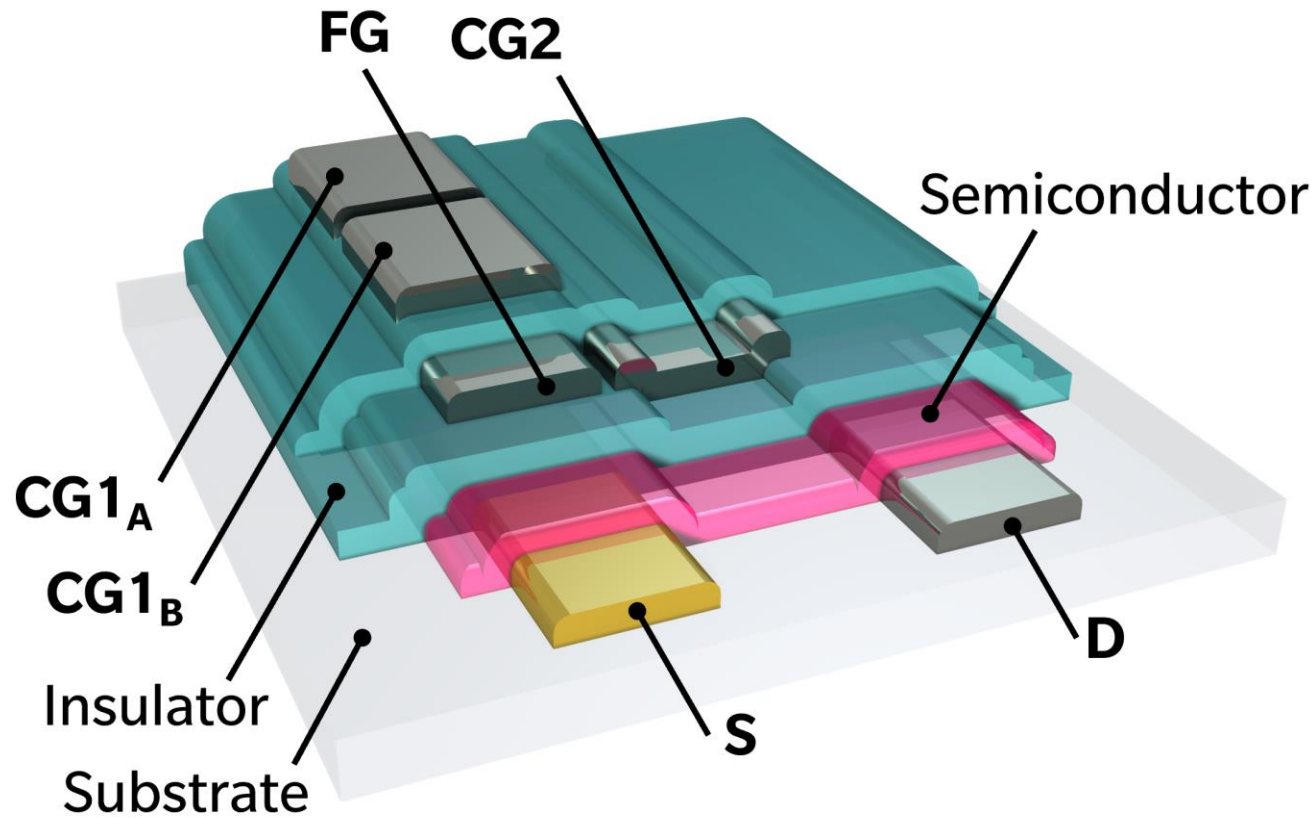
(54) **METHOD FOR REDUCING CHARGE LOSS
IN ANALOG FLOATING GATE CELL**

(75) Inventors: **Radu A. Sporea**, Surrey (GB); **Sorin S. Georgescu**, San Jose, CA (US); **Ilie Marian I. Poenaru**, Bucharest (RO)

(73) Assignee: **Semiconductor Components Industries, L.L.C.**, Phoenix, AZ (US)

The Multimodal Transistor (MMT) Applications

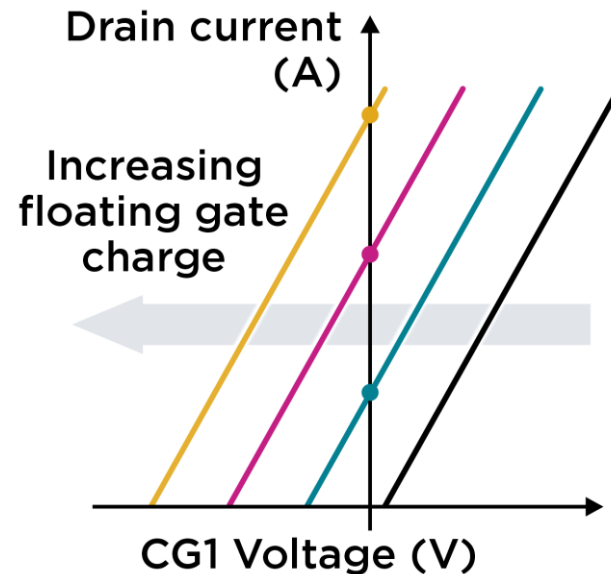
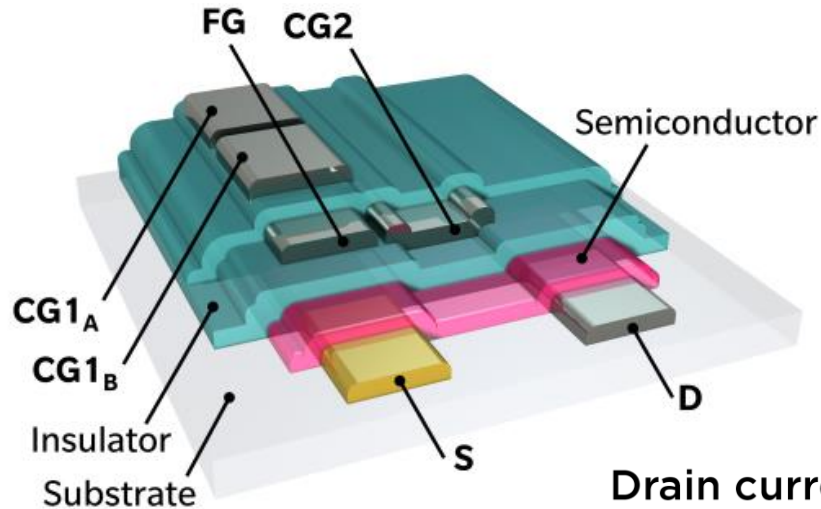
Floating gate *distortion-free, compact* summing of analog signals



The Multimodal Transistor (MMT)

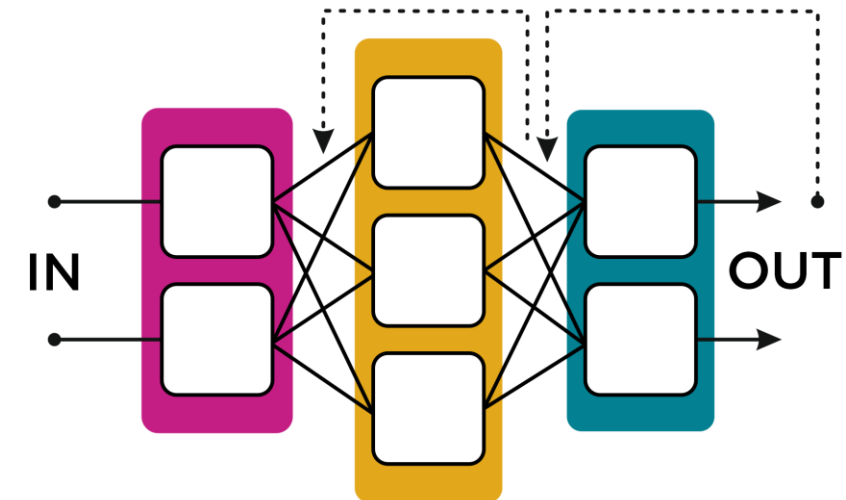
Bringing it all together

Compact yet powerful sensor-integrated neural networks



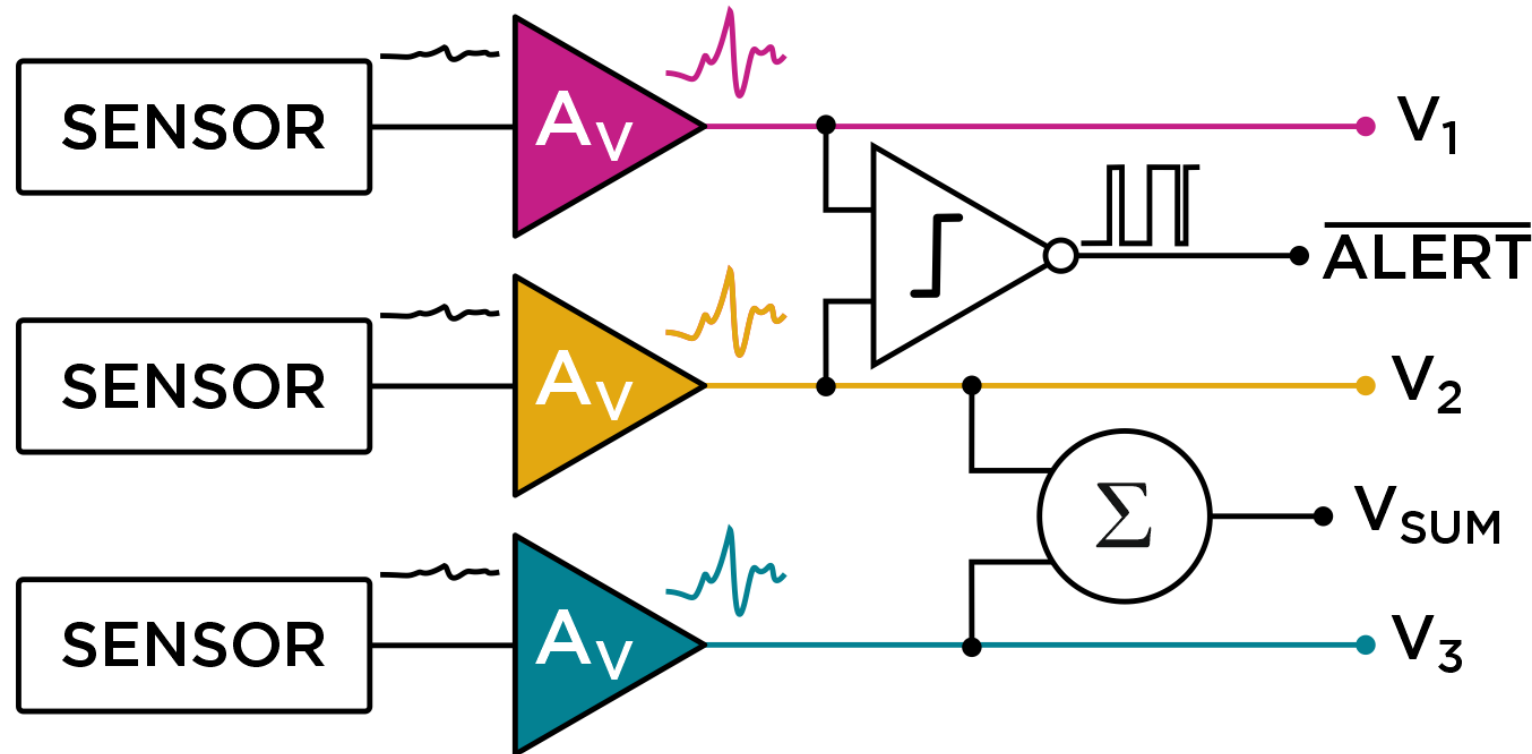
Linearity with input voltage and width
Weights by FG programming
ReLU - transfer characteristic
Quasi-logistic / sigmoid - inverter curve

Decision and classification
Adapting - training - learning



The Multimodal Transistor (MMT) Applications

Multimodal sensor output processing at the edge



The Multimodal Transistor (MMT)

Next steps

A new Low-complexity Paradigm for Analogue Computation and hardware learning

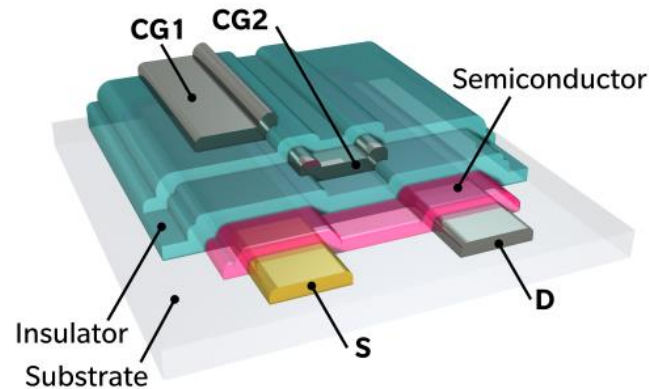
NanoRennes / IETR
Silvaco

National Physical Laboratory
University of Cambridge

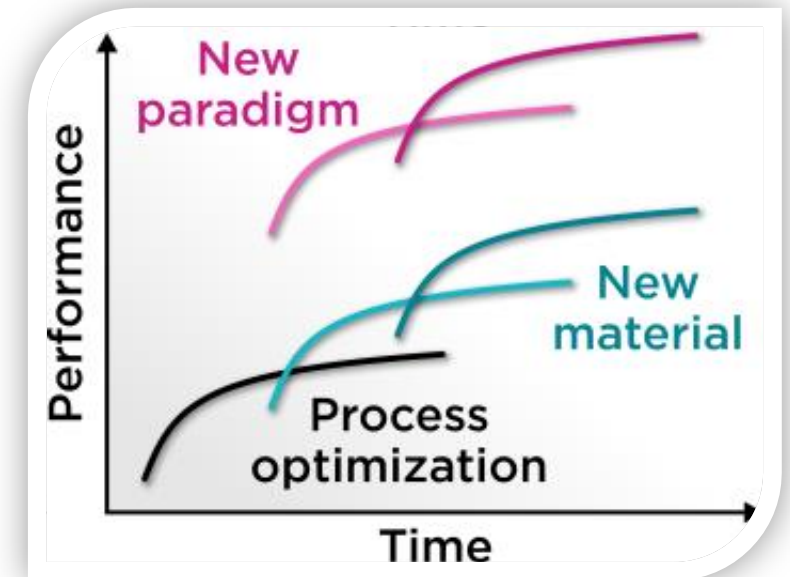
Sharp Laboratories of Europe Ltd
Yamagata University

+ U. Stuttgart, U. Sussex, SYSU, KHU

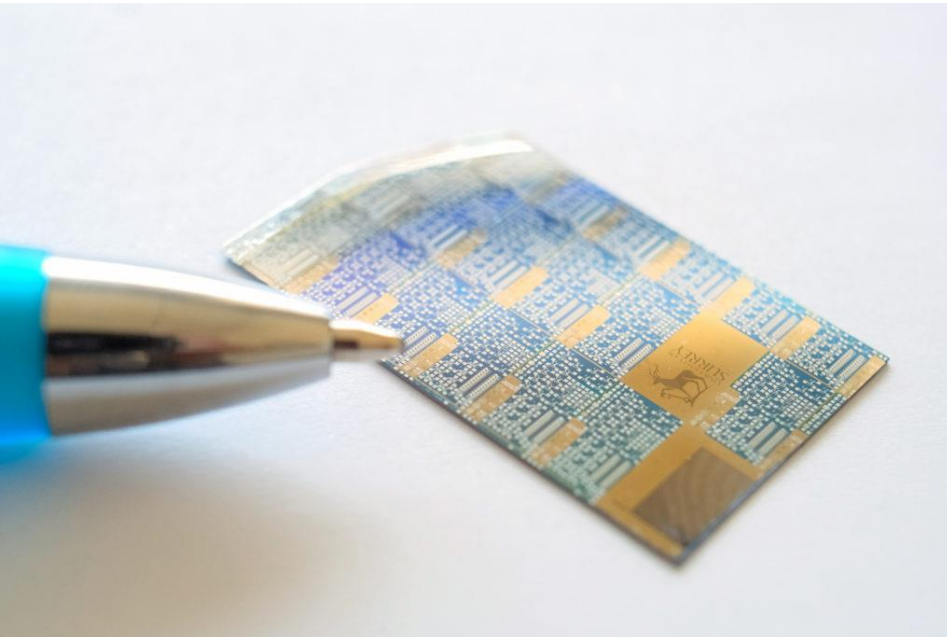
EP/V002759/1
£1.12M form EPSRC
2021-2026



Operation and applications of the multimodal transistor



The Multimodal Transistor (MMT) first publication



COMMUNICATION

28 October 2020

**ADVANCED
INTELLIGENT
SYSTEMS**
Open Access

www.advintellsyst.com

Versatile Thin-Film Transistor with Independent Control of Charge Injection and Transport for Mixed Signal and Analog Computation

*Eva Bestelink, Olivier de Sagazan, Lea Motte, Max Bateson, Benedikt Schultes, S. Ravi P. Silva, and Radu A. Sporea**

**Microcrystalline silicon
+ Silvaco TCAD**

Contact-controlled transistors

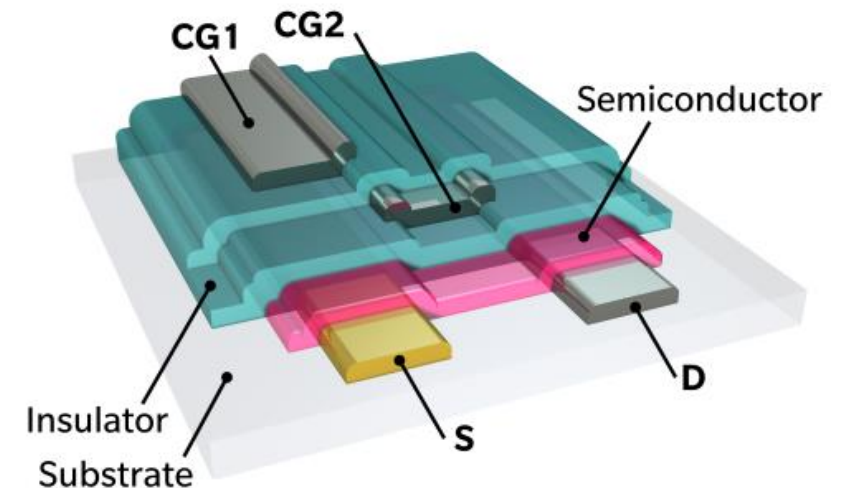
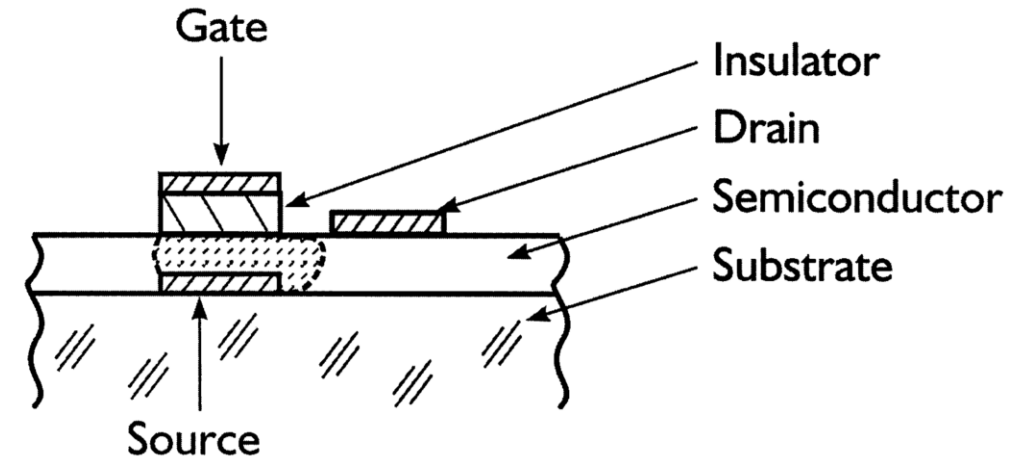
Reiterating the modelling challenge

Recently, the manufacturing challenge has been lowered by the acceptance of:

- ✓ Staggered electrodes
- ✓ Rectifying contacts

In these contact-controlled devices, conventional TFT models do not apply directly

Without realistic models, it is hard for designers to adopt these new technologies.



What next?

Let's talk!



EPSRC

Engineering and Physical Sciences
Research Council

EP/R028559/1

EP/R511791/1

EP/P02579X/1

EP/V002759/1



**Royal Academy
of Engineering**

Thank you for your attention!

www.surrey.ac.uk
teamsporea.info
r.a.sporea@surrey.ac.uk