

Reversing the history of computing

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Reversibility: The unassuming hero

physics

industrial
revolution

biology

chemical
plants

computing?

Exorcising Dæmons

What is reversibility

microscopic
reversibility

logical
reversibility

thermodynamic
reversibility

information
conservation

A bumpy road

newtonian
mechanics

industrial revolution

maxwell &
loschmidt
dæmons

dawn of computing

szilard
von neumann
landauer

scientific revolution

thermodynamics

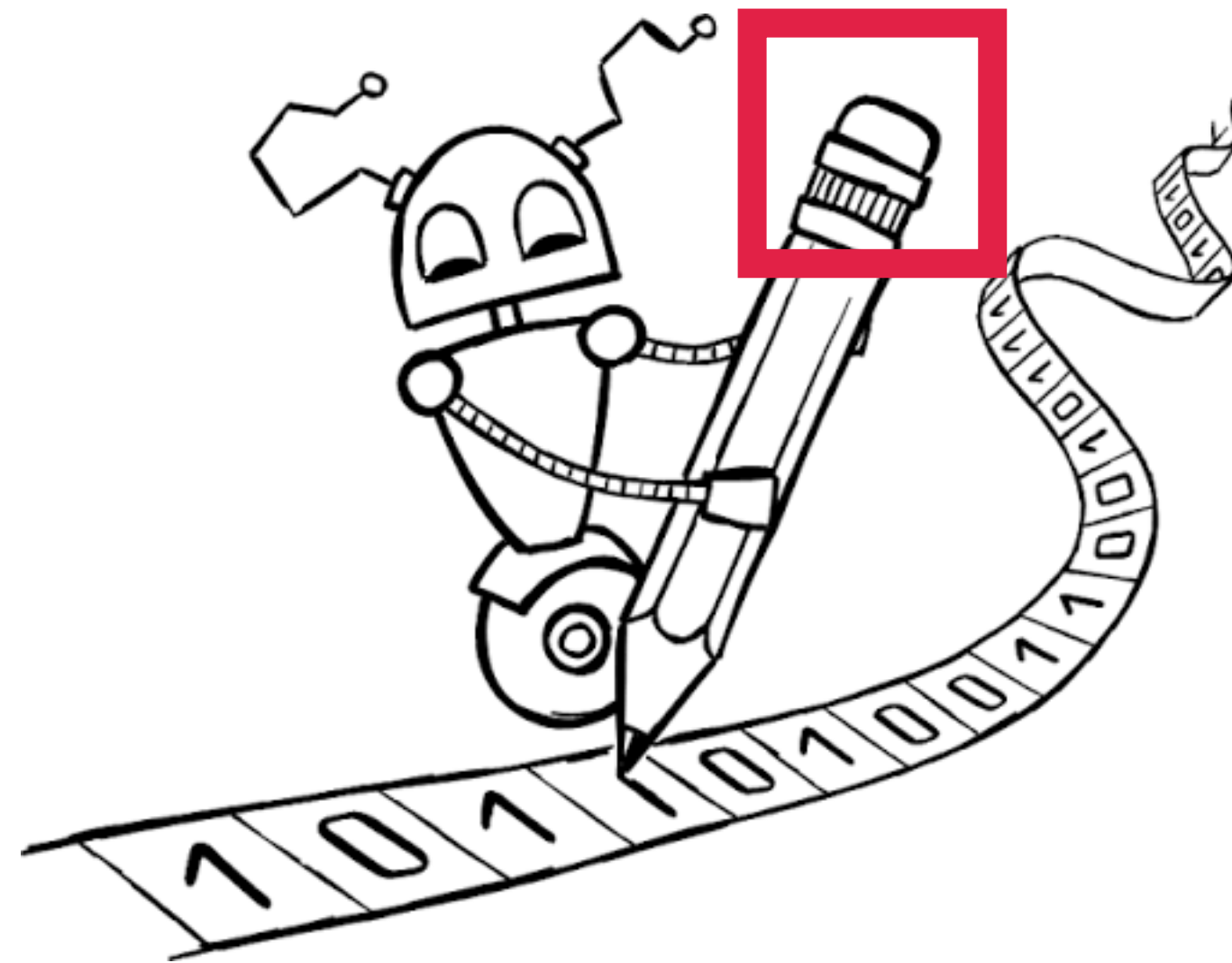
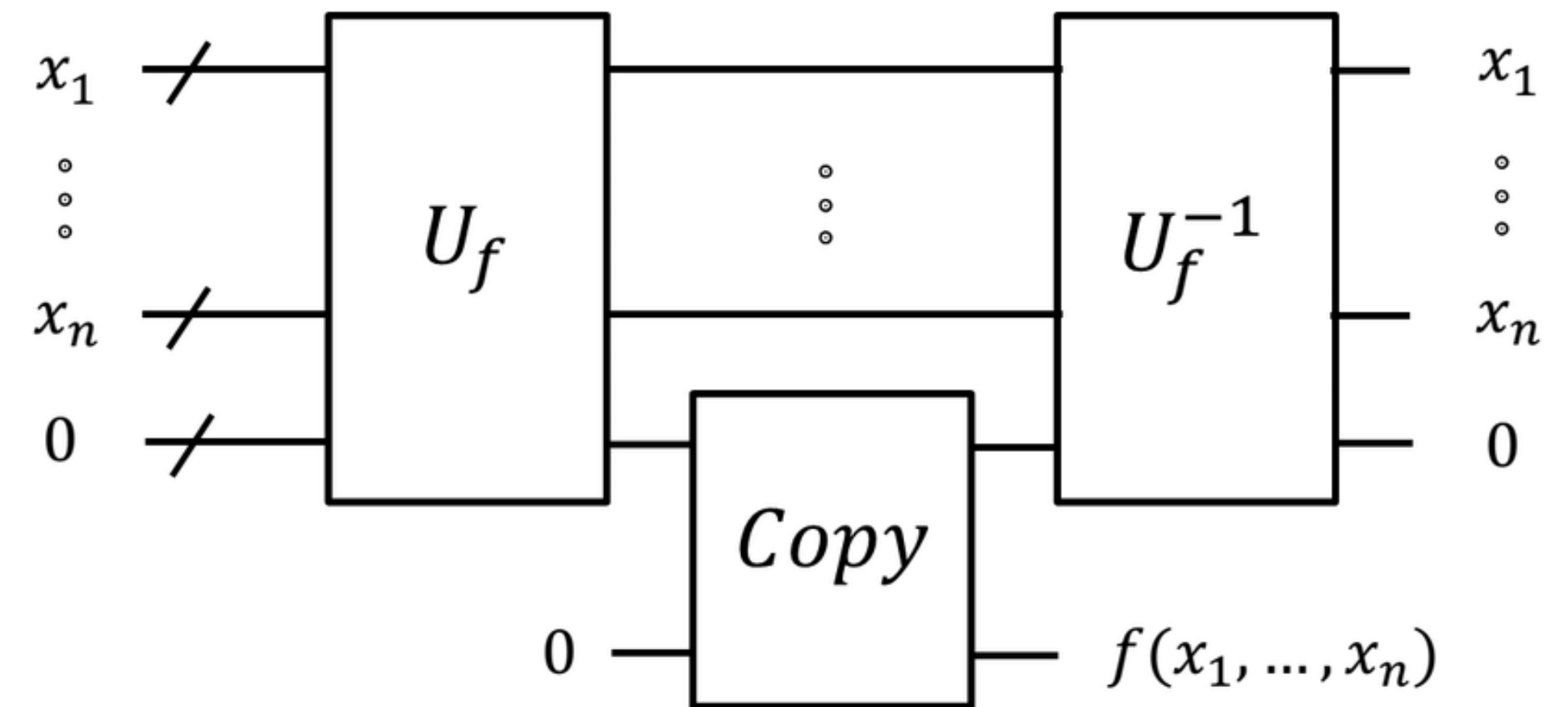
technological
revolution

quantum
mechanics

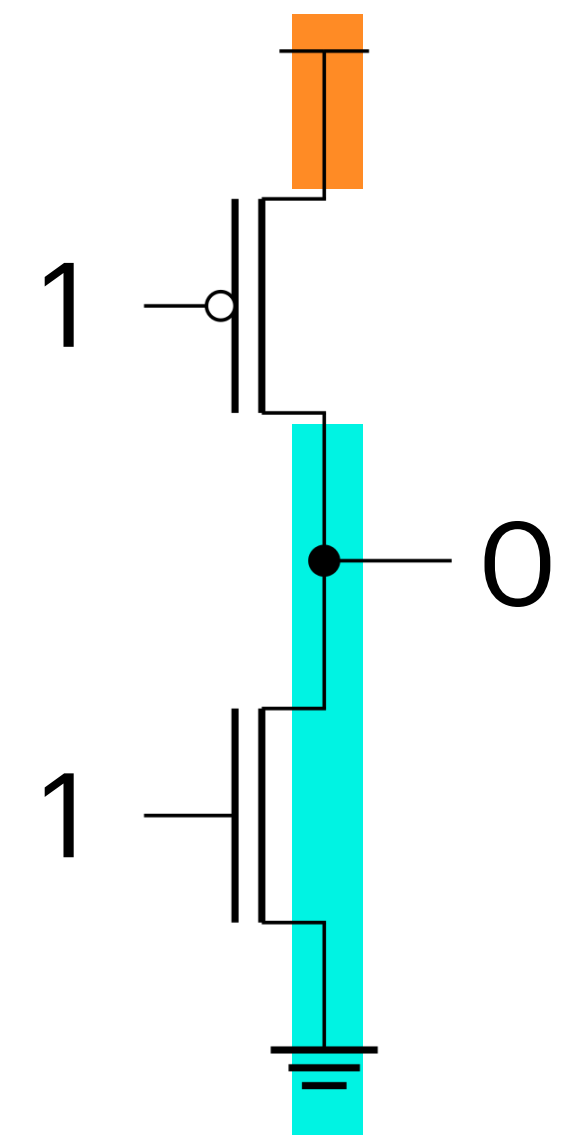
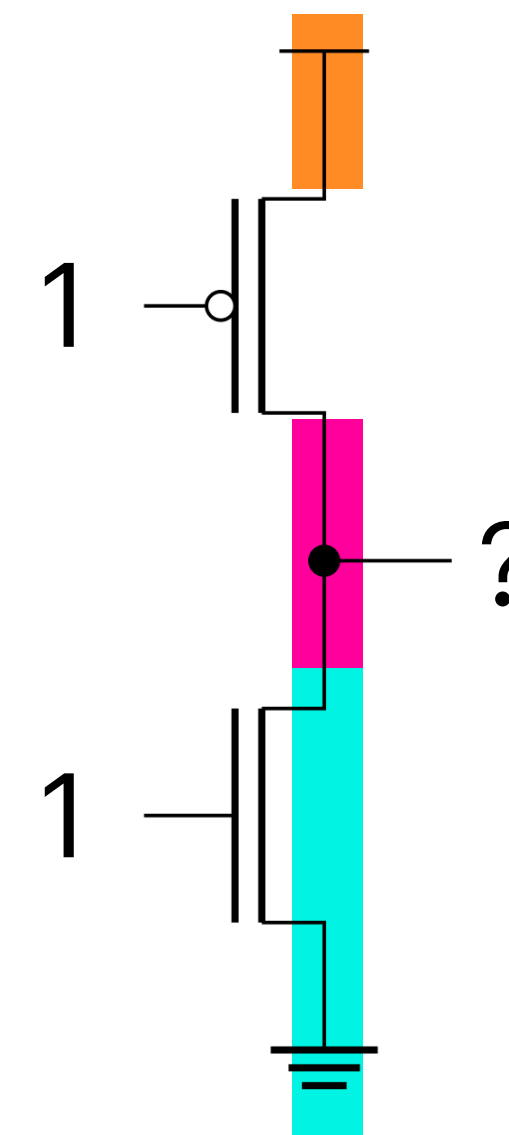
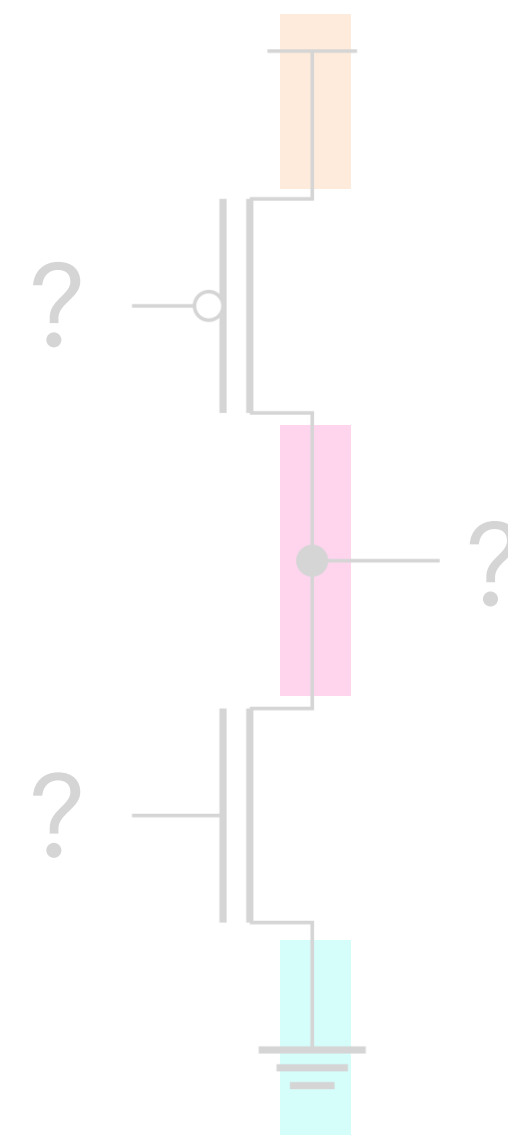
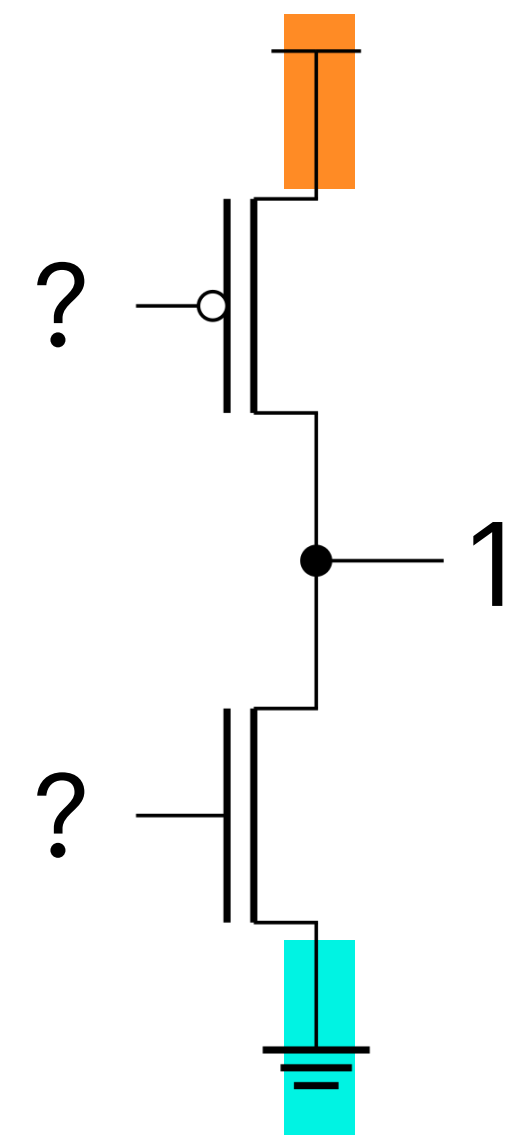
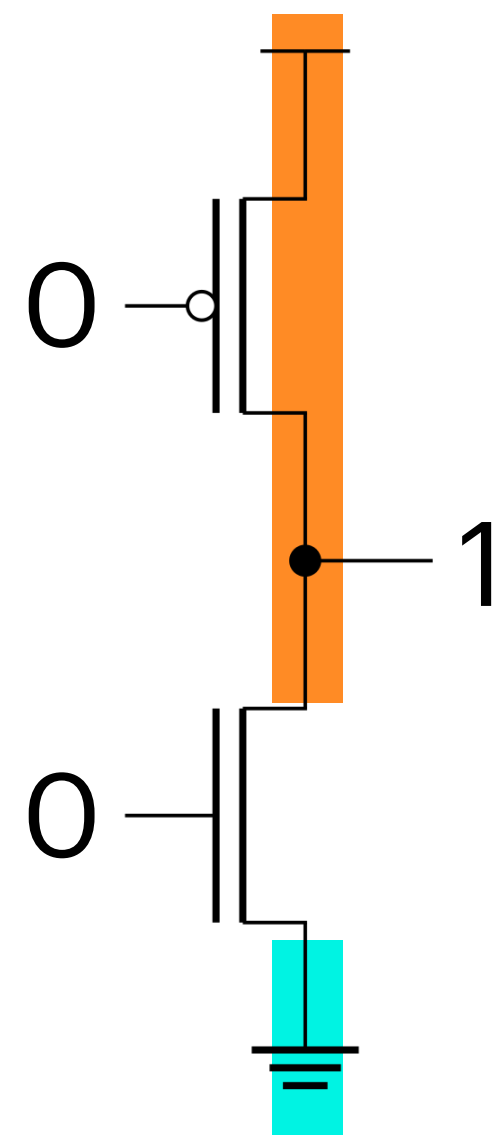
information age

Reversible... computing?

$$kT \ln 2$$

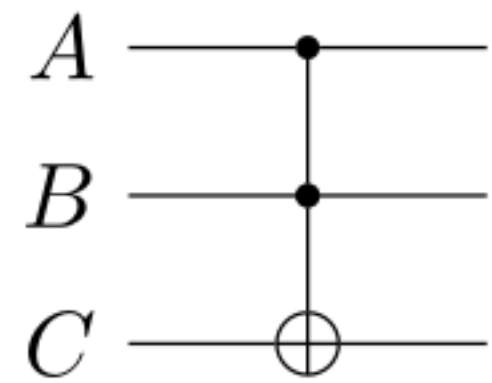


The ghost in the transistor



The Failed Revolution

The rise...



$n \ x[2]$

procedure *fib*

if $n = 0$

then $x_0 += 1$

$x_1 += 1$

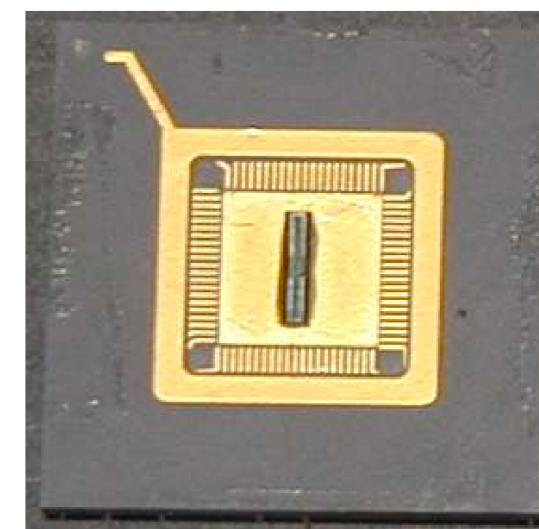
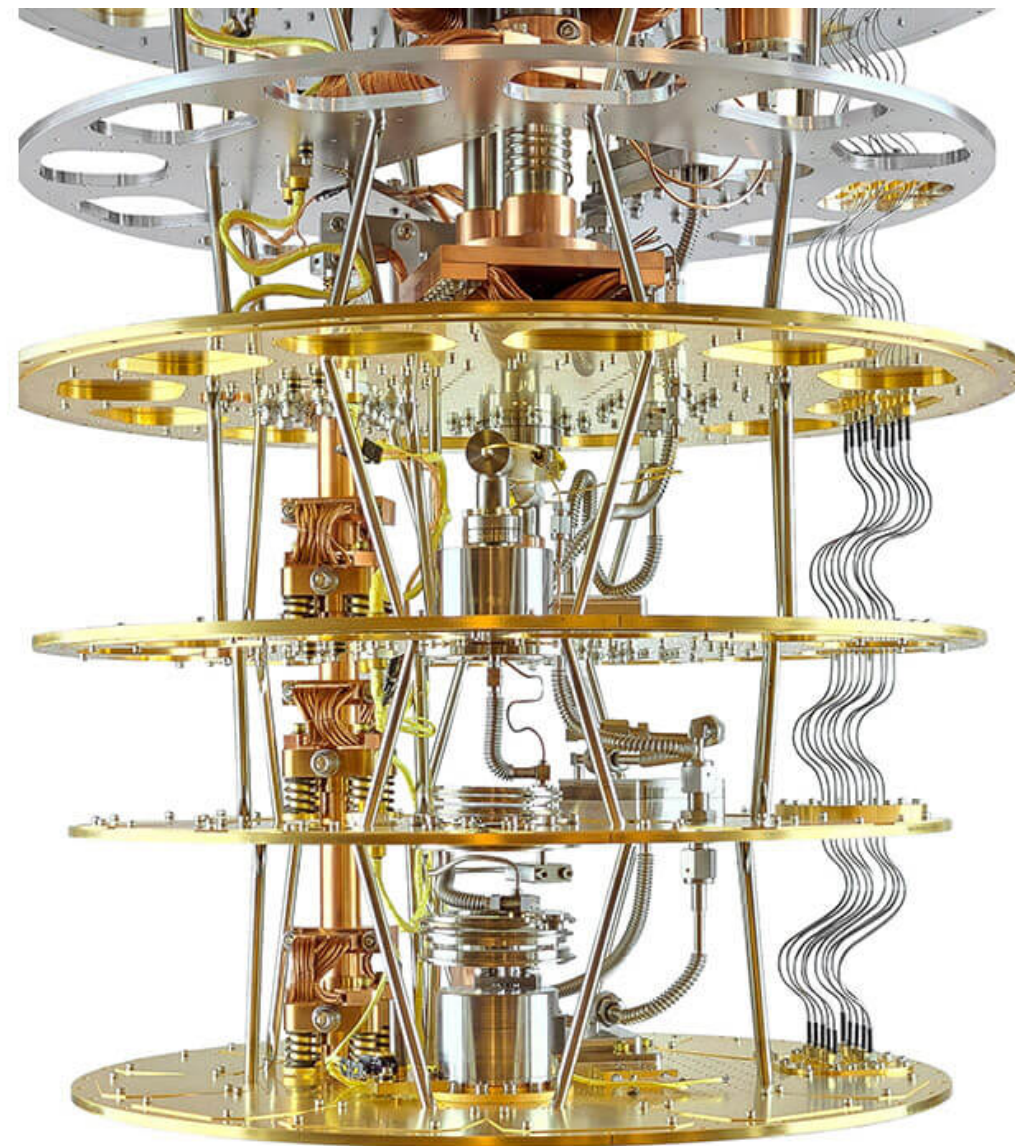
else $n -= 1$

call *fib*

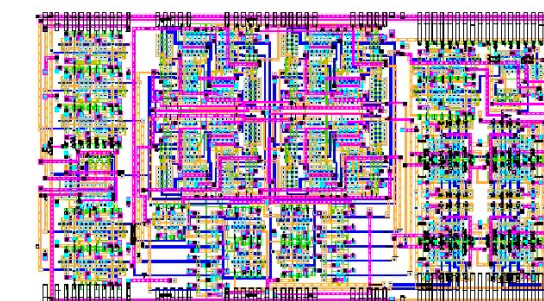
$x_0 += x_1$

$x_0 \Leftrightarrow x_1$

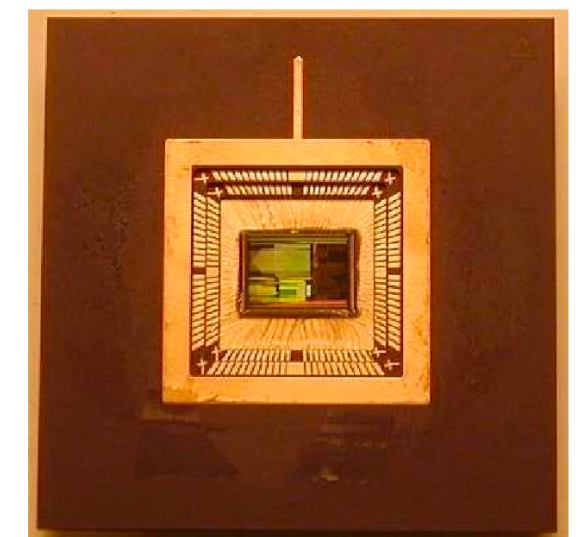
fi $x_0 = x_1$



(a) TICK

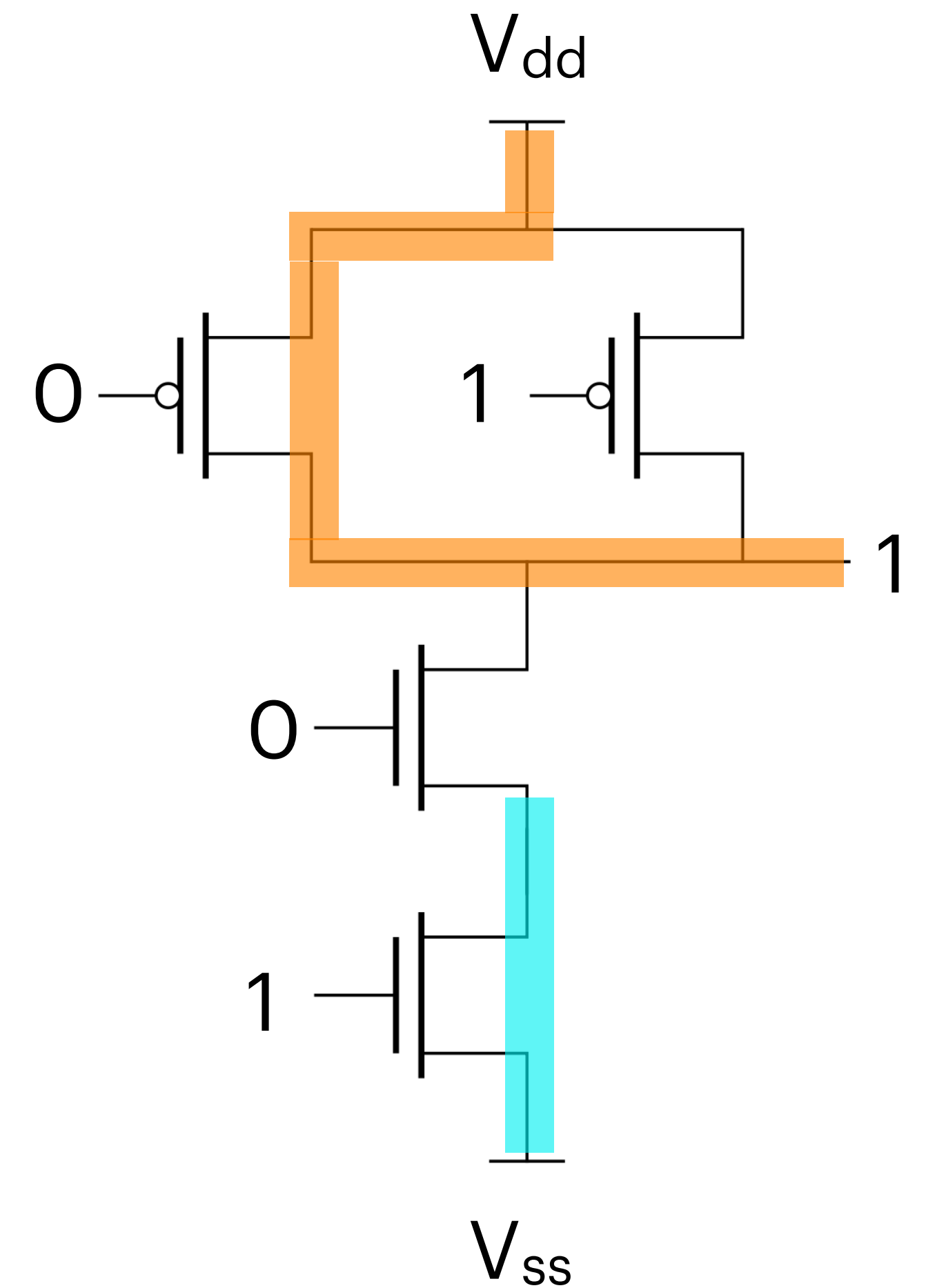
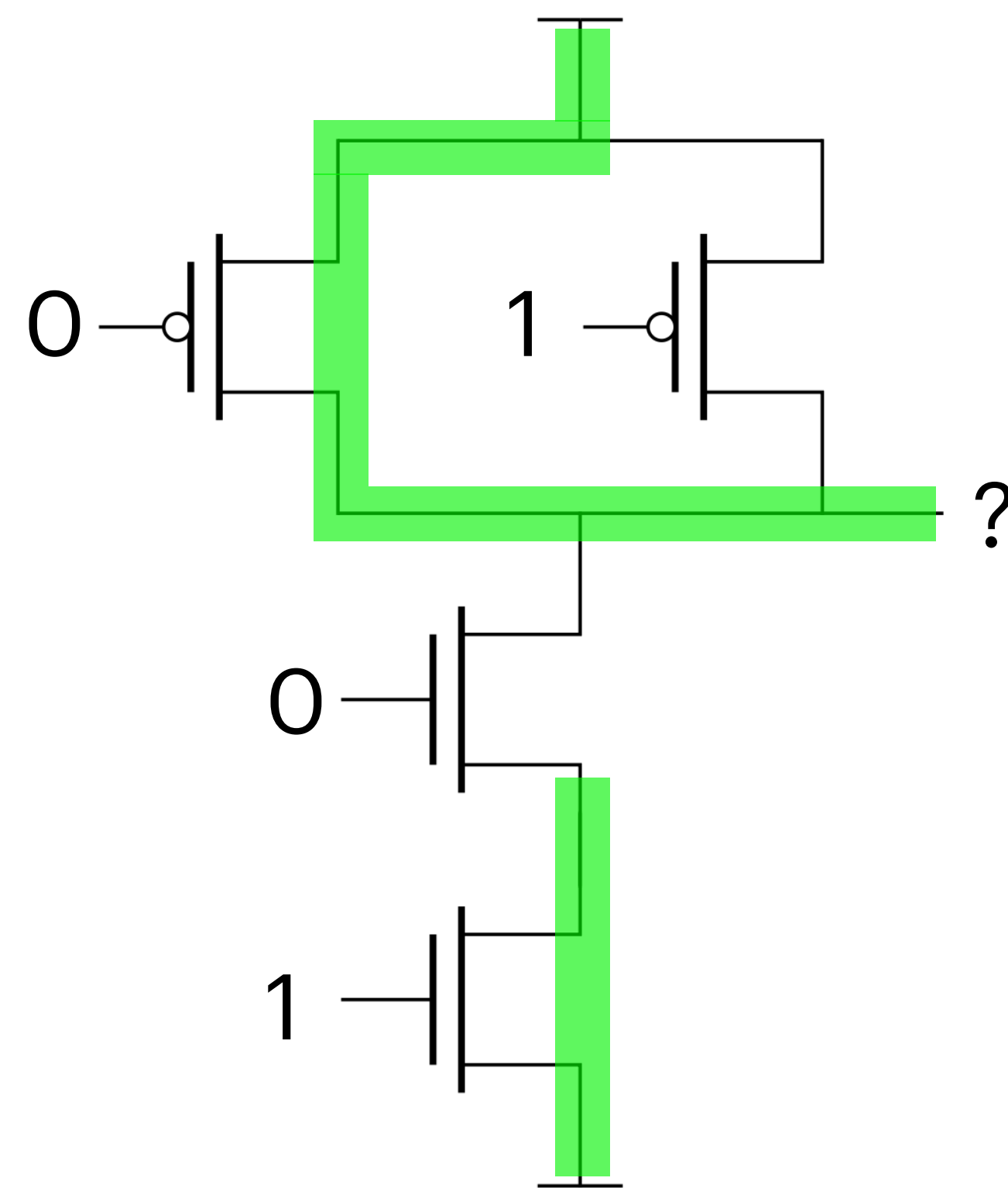
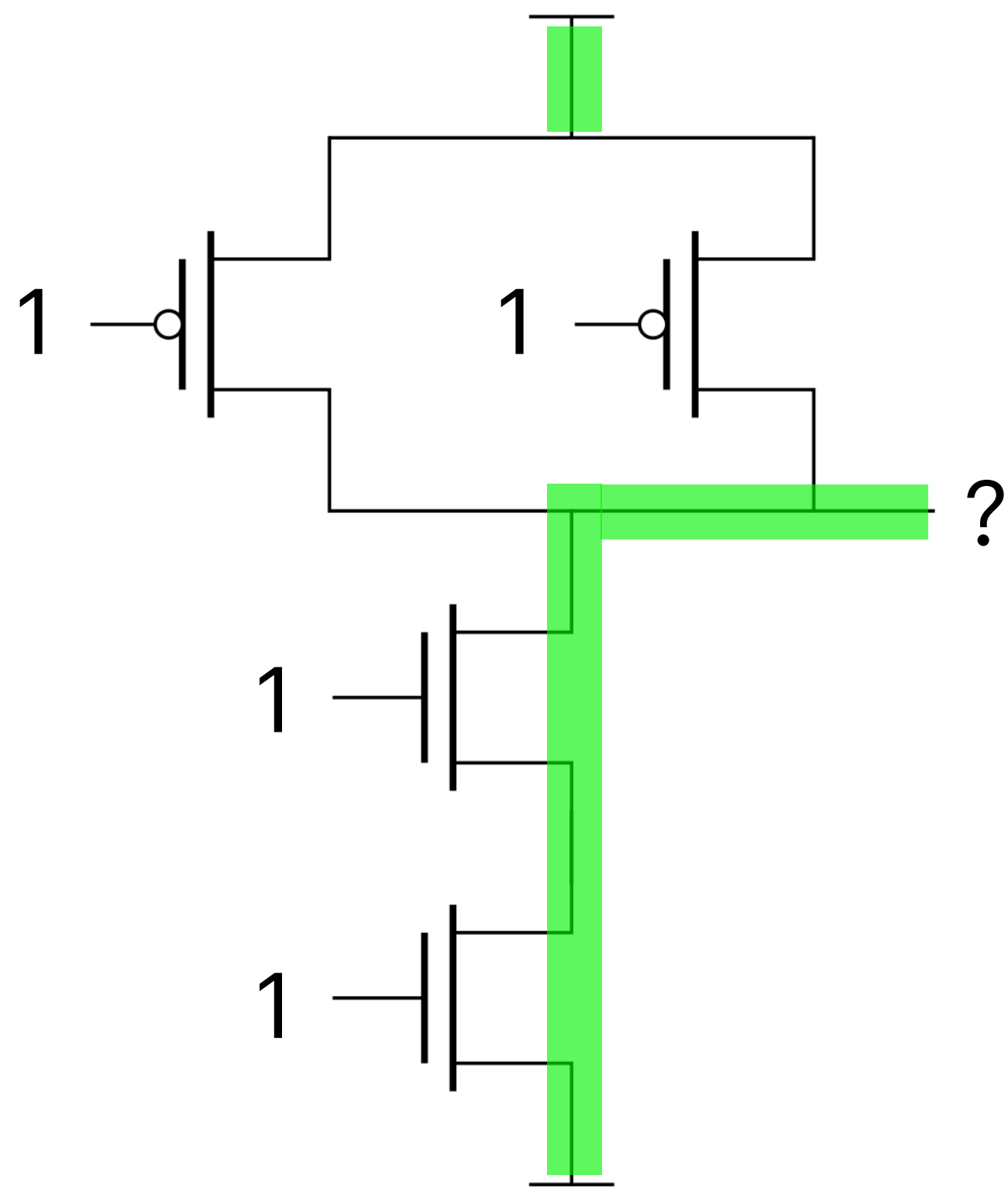


(b) FLATTOP and its unit cell



(c) PENDULUM

The transistor at peace



...the fall

slow clocks

area and circuit
overheads

reversible
programming
phobia

poor serial
performance

marginal benefit
or outright worse

Dennard
scaling

“They run slower, but they are very much smaller. I don’t make it reversible unless I need to. There is no point in making the machine reversible unless you are trying very hard to decrease the energy enormously, rather ridiculously, because with only 80 times kT the irreversible machine functions perfectly. That 80 is much less than the present day 10^9 or 10^{10} , so I have at least 10^7 improvement in energy to make, and can still do it with irreversible machines!”

Richard Feynman / The Computing Machines in the Future / 1985

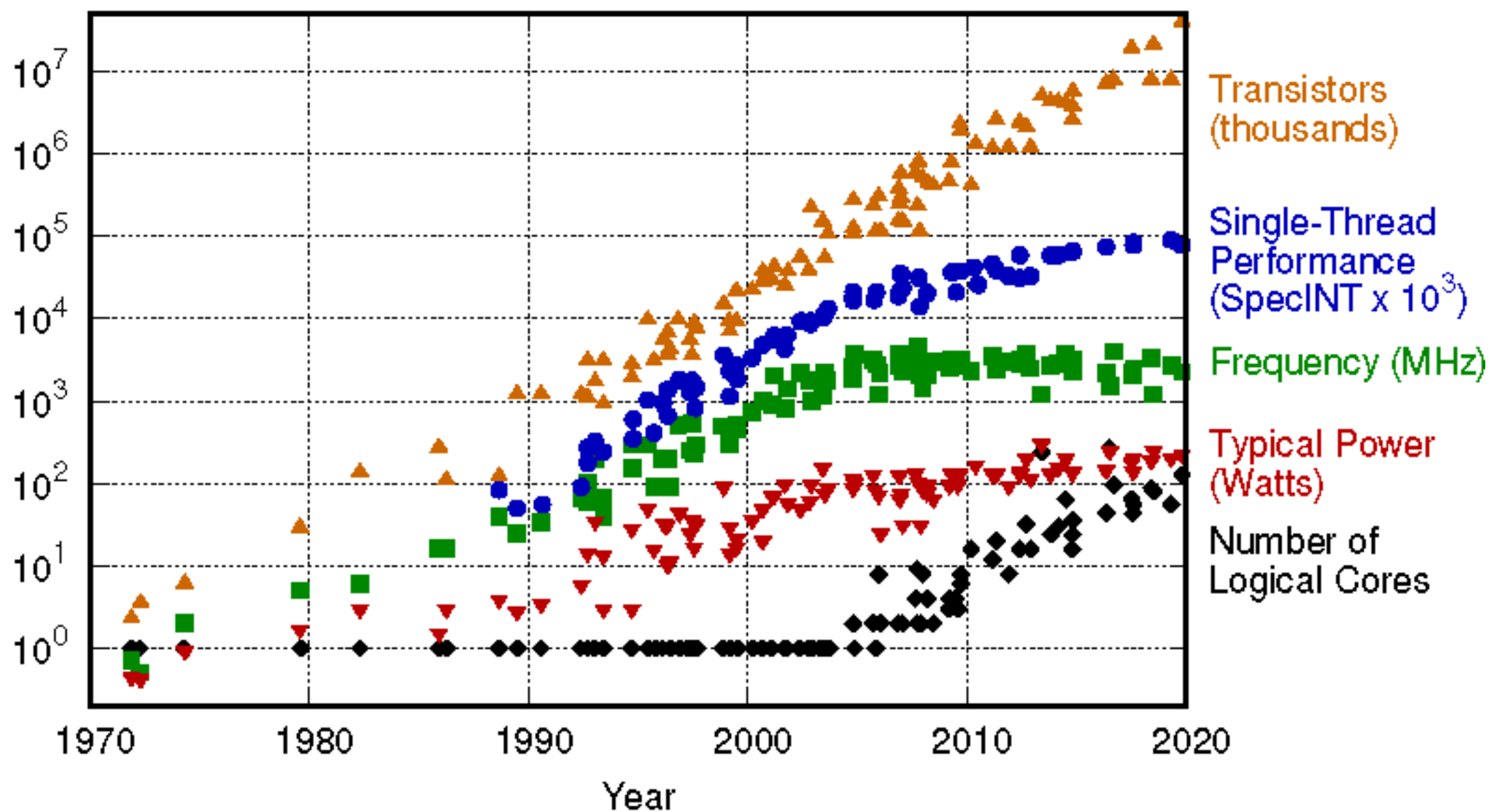
**Reversible supremacy is *not* about
breaking Landauer's limit**

The Redemption

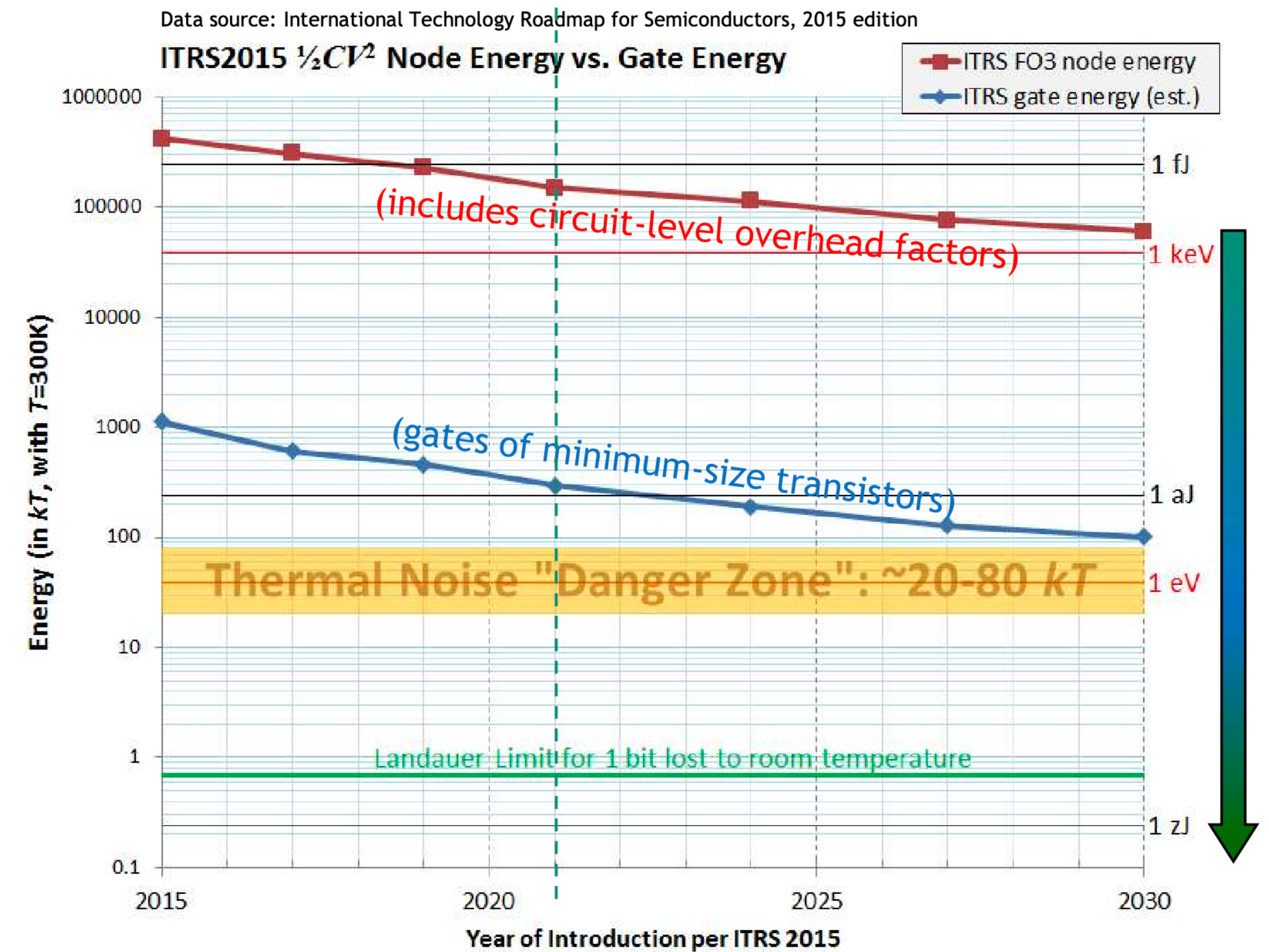
End of the line

Moore's law is dead

48 Years of Microprocessor Trend Data



Original data up to the year 2010 collected and plotted by M. Horowitz, F. Labonte, O. Shacham, K. Olukotun, L. Hammond, and C. Batten
New plot and data collected for 2010-2019 by K. Rupp



Reversibility is nigh

transistors
are fast

dark silicon
overshadows
Moore

net positive
recovery!

parallelism
is in

infrastructure
is not exponential

edge compute
demands

The promised land



Leaping without a ladder

academic theory

hand drawn circuits

small experiments

instructive mistakes

improved devices

low expectations

low stakes projects

learned heuristics

design automation

expensive mistakes

validation & verification

solidified abstractions

massive scale

The time is now

