

“Moore’s Law Is Ending” Has Been Said for Years, but What Ended Was the Other Law

— Under Dennard scaling, halving the dimensions leaves power per area at exactly **1.0000** — Once the voltage stops falling it becomes **4.0000** — The count still doubles every two years, reaching **1024** in twenty, and now the power does too — [Paper 374]

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— *From thinking to syncing.* —

Abstract

“Moore’s law is ending” has been said for a long time. This paper asks what ended—the answer is that what ended was not the law of counting but the law of power. No new mathematical theorem and no new law is claimed. First, there are two laws: Moore’s speaks of counts, Dennard’s of power (Section 2). Second, this is the core of the paper. Under Dennard scaling, halving the dimensions leaves power per area at exactly **1.0000** (Section 2). Third, once the voltage stops falling, the same shrink gives **4.0000** (Section 3). Fourth, the two answers differ by exactly **4**, with the shrink identical (Section 3). Fifth, the count still doubles every two years, so twenty years give **1024**— and now the power demands **1024** too (Section 4). Sixth, the separator is whether the voltage falls, not the size of the devices (Section 5).

Scope of this paper (scope note): No new mathematical theorem and no new law is claimed——Moore’s law, Dennard scaling, and the power-density wall are all standard. We do not build semiconductor engineering——short-channel effects, leakage current, and threshold-voltage physics are not entered. They are named and no more. We claim no date——exactly when Dennard scaling stopped is not something this paper measured. The mid-2000s is cited as the accepted figure and no more. We make no forecast——what happens next is not the subject. Implementation is not treated——multicore, dark silicon, and specialised accelerators are named and no more. We measure nothing——the power of particular products is not used. Only the consequences of the scaling relations are computed. Relation to earlier papers: Paper 363 showed a bat to have three sweet spots——there one word named several things; here one name covers two laws. Paper 346 showed half-life ceasing to be a constant for some reaction orders——there too the question was whether one statement suffices. Paper 300 showed whether two things share a root is decidable——by that test, the law of counts and the law of power have distinct roots. Paper 362 showed the bottleneck lying in dragging rather than lifting——here too, what stopped was not the thing being watched. What is added is setting out five scaling factors under Dennard scaling to show the cancellation, showing the ratio to the non-scaling case to be exactly 4, giving Moore’s factor at six points, placing an intermediate case and confirming it falls between the extremes, and putting the separator on whether the voltage falls.

1. Notation and the Question

Setting: Shrink the dimensions by a factor k . Under Dennard scaling the voltage falls by k as well.

$$\text{devices per area} \propto k^2, \quad \text{power per device} \propto \frac{1}{k^2}, \quad \text{power per area} = k^2 \cdot \frac{1}{k^2}$$

Take $k = 2$.

Observation 1.1

Moore’s law speaks of a count. Devices on a given area double every two years——it says nothing about power.

Observation 1.2

Dennard scaling speaks of power. Shrinking leaves power per area unchanged——it says nothing about counts.

Observation 1.3

They held together, so they looked like one law. “More devices without more heat”——that combination was the substance of half a century of progress.

Question: Which of the two laws ended?

2. Under Dennard Scaling the Power Cancels Exactly

Calculation 2.1: Factors on halving the dimensions (computed in this paper, Dennard scaling holding).

Quantity	Factor
Devices per area	4.0000
Delay	0.5000
Voltage	0.5000
Power per device	0.2500
Power per area	1.0000

Observation 2.2

This is the core of the paper. Four times and a quarter cancel exactly to 1.0000——not approximately: the growth in count and the fall in power per device are both k^2 .

Observation 2.3

That cancellation was what made progress look free. Faster, more numerous, and no hotter——while it held, all three could be had at once.

Observation 2.4

The cancellation depends on the voltage falling.Power per device becomes $1/k^2$ because the voltage becomes $1/k$ ——hold the voltage and that factor disappears.

3. Once the Voltage Stops Falling, It Is 4 Times

Calculation 3.1: The same shrink with the voltage held (computed in this paper).

Quantity	Dennard scaling	Voltage held
Devices per area	4.0000	4.0000
Voltage	0.5000	1.0000
Power per device	0.2500	1.0000
Power per area	1.0000	4.0000

Observation 3.2

The two answers differ by exactly $4.4.0000/1.0000$ ——the shrink is identical; only whether the voltage falls has changed.

Observation 3.3

There is an intermediate case.If the voltage falls by $1/\sqrt{k}$, power per area goes as k , that is 2 times——between 1 and 4. It degrades by degrees.

Observation 3.4

Why the voltage stopped falling.Lowering the threshold voltage makes leakage current grow exponentially——this paper has not computed that mechanism and cites it only.

Observation 3.5

To be stated honestly—the date is not something this paper measured. The mid-2000s is the accepted figure—what is computed here is only the factor once it stops.

4. The Law of Counts Has Not Stopped

Calculation 4.1: Moore’s factor and the power in both cases (computed in this paper).

Years	Moore’s factor	Power if Dennard held	Power with voltage held
0	1.0	1.0	1.0
4	4.0	1.0	4.0
8	16.0	1.0	16.0
12	64.0	1.0	64.0
16	256.0	1.0	256.0
20	1024.0	1.0	1024.0

Observation 4.2

The middle column is 1.0 for all twenty years. A thousandfold increase in devices at unchanged power—that is what Dennard scaling meant.

Observation 4.3

The right column tracks the count to 1024. Because power density becomes proportional to device density—it cannot be cooled.

Observation 4.4

So the devices fit but cannot all run at once.This is the situation called dark silicon——this paper has not computed the fraction and names it only.

Observation 4.5

So “Moore’s law is ending” has the name wrong.What stopped is the law of power——the count went on rising, as in the left column of this table.

5. The Separator: Does the Voltage Fall?

Observation 5.1

The separator——whether the voltage falls along with the shrink; not the size of the devices.

	Devices	Voltage	Power per area
Dennard scaling	4.0000	0.5000	1.0000
Intermediate ($1/\sqrt{k}$)	4.0000	0.7071	2.0000
Voltage held	4.0000	1.0000	4.0000

Observation 5.2

The left column is the same in all three rows.The count grows equally——Moore’s law does not distinguish the three.

Observation 5.3

Distinct roots by the criterion of Paper 300. The count comes from geometry (area shrinking), the power from electricity (voltage squared)——what looked like one “progress” was two things happening to move the same way.

Observation 5.4

The separator cannot be moved. That the voltage cannot be lowered is a physical constraint——so the response is a design one: do not run all the devices at once.

Observation 5.5

To be stated honestly——1.0000 and 4.0000 are values under the idealised scaling relations with $k = 2$. Real generations use awkward values of k and other effects enter——what does not move is the structure: whether the voltage falls changes the result by k^2 .

Observation 5.6

One last thing——while two laws move the same way they look like one law. Only when one stops does it become clear there were two——and then “it ended” is said in the name of the famous one, not the one that stopped.

6. The Census and the Close

1. Moore’s law speaks of counts (Observation 1.1): **nothing about power.**
2. Dennard scaling speaks of power (Observation 1.2): **nothing about counts.**
3. Power per area exactly 1.0000 (Calculation 2.1): **four and a quarter cancel.**
4. 4.0000 with the voltage held (Calculation 3.1): **the same shrink.**
5. The two differ by exactly 4 (Observation 3.2): **only the voltage changed.**
6. 2.0000 in the intermediate case (Observation 3.3): **between the extremes.**
7. Moore gives 1024 in twenty years (Calculation 4.1): **doubling every two.**

8. Power stays 1.0 if Dennard holds (Calculation 4.1): for all twenty years.
9. Once it stops, power reaches 1024 too (Observation 4.3): it cannot be cooled.
10. The law of counts has not stopped (Observation 4.5): the name is wrong.

Closing: “Moore’s law is ending” has been said for a long time—but two laws were being called by one name. Moore’s law speaks of a count and Dennard scaling of power—the first says only that devices on a given area double every two years and touches nothing about power; the second says only that shrinking leaves power per area unchanged and touches nothing about counts. They held together, so they looked like one. Under Dennard scaling the power cancels exactly—halving the dimensions gives 4.0000 times the devices and 0.2500 times the power per device, so power per area is exactly 1.0000. Not approximately: the growth in count and the fall in power per device are both k^2 . Faster, more numerous, and no hotter — that cancellation was what made progress look free. But the cancellation depends on the voltage falling—power per device becomes $1/k^2$ only because the voltage becomes $1/k$, and once the voltage is held, the same shrink gives 4.0000. The two answers differ by exactly 4, with only the voltage changed. A voltage falling by $1/\sqrt{k}$ gives 2.0000, between the extremes. And the law of counts has not stopped—doubling every two years gives 1024 in twenty, and if Dennard scaling had held, power would have stayed 1.0 throughout; once it stopped, power demands 1024 as well. The devices fit but cannot all run at once. So “Moore’s law is ending” has the name wrong: what stopped is the law of power. One thing separates them—whether the voltage falls along with the shrink; not the size of the devices. The count grows equally in all three rows, so Moore’s law does not distinguish them. By the criterion of Paper 300 they have distinct roots: the count comes from geometry, the power from voltage squared — what looked like one “progress” was two things happening to move the same way. To be said honestly—neither the date nor the mechanism (lowering the threshold makes leakage grow exponentially) was computed here. The 1.0000 and 4.0000 are values under idealised scaling with $k = 2$. One last thing—while two laws move the same way they look like one law. Only when one stops does it become clear there were two. And then “it ended” is said in the name of the famous one, not the one that stopped.

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