



THE LAW OF MOORE

After half a century of doublings, the eponymous law elucidated by Gordon Moore (PhD '54) has outlived even his own expectations and had an impact that goes far beyond its field.

It began quietly, with a 1965 article in *Electronics* magazine. But as if following Moore's Law itself—the prediction that states that the number of transistors that could fit on a single silicon chip would double approximately every two years—the concepts in that article grew quickly, exponentially, in import and influence.

Gordon Moore (PhD '54) started that article, titled “Cramming more components onto integrated circuits,” with other predictions that are equally—and almost spookily—accurate today. “The future of integrated electronics,” he wrote, “is the future of electronics itself. The advantages of integration will bring about a proliferation of electronics, pushing this science into many new areas.”

This year, as Moore's Law turned 50, many people turned to look at what it has meant for not just the computer industry, but for our world. In May, the *New York Times* columnist and Pulitzer Prize-winning author Thomas Friedman talked about the law with Gordon Moore himself at San Francisco's Exploratorium at an event hosted by Intel (the company Moore cofounded in 1968) and the Gordon and Betty Moore Foundation.

During that interview, Moore spoke of the *Electronics* article and the birth of his law, saying, “I had no idea that it was going to turn out to be a relatively precise prediction, but I knew that the general trend was in that direction.”

When asked if he was surprised by how long Moore's Law has lasted, Moore replied, “Oh, I'm amazed. The original prediction was to look at 10 years, which I thought was a stretch. This was going from about 60 elements on an integrated circuit, to 60,000—a thousandfold extrapolation over 10 years. I thought that was pretty wild. The fact that something similar is going on for 50 years is truly amazing.”

At Caltech's 121st commencement ceremonies, cultural anthropologist Genevieve Bell—who is, most notably, a vice president at Intel and an Intel Fellow—spoke about the wider impact of Moore's Law. Her address to the graduates, which follows in part, put into context its human, as well as its technological, import.

The class of 2015 has much to celebrate, and you'll remember this date—trust me on this, this will become a metric in your life—and you'll measure your progress against it for years to come. But for me, this is a significant date but for a very different reason . . . This year marks the 50th anniversary of Moore's Law. The logic of Silicon Valley, the law that predicts the rate of technology change and thus innovation was born 50 years ago this April. It's older than me (just), it's older than many of you, I hope, and it was imagined in a time when the world looked really different. There was no

web, no Internet, no talk of big data, no Internet of things, no wearable technology, no YikYak, no selfie sticks, no Facebook. Astonishing, right? But there was the integrated circuit and a man named Gordon Moore. And you all know he graduated from here with a PhD in chemistry and a minor in physics. So this is as much your history and legacy as it is mine.

And in 1965, ten years after Dr. Moore graduated from here, a popular trade magazine approached him and asked him to speculate about the future of his industry. Looking back over a decade of rapid transformation,

he predicted that integrated circuits, the building blocks of contemporary computing, would enjoy an unprecedented rate of growth. He wrote that the number of transistors on a densely integrated circuit would double every two years for at least the next decade. Basically integrated circuits would continue to get more powerful on a knowable rate. It was then a bold statement of engineering, and 50 years on, it's an observation that's continued to predict the rate of technological improvement, which is in and of itself kind of amazing.

But, for me, the thing that's more important is that Moore's Law is also a promise about the state of the future. After all, this is not a law describing the natural world, but rather the way we choose to configure it. In effect, it's a promise of a world that we better with every passing year. It's the promise of room to grow, room to imagine; of continuous innovation.

And in Gordon Moore's original article, he also articulated why this innovation was important. For him it wasn't just technology for technology's sake. He wrote, and I want to quote here because it's kind of remarkable, "Integrated circuits will lead to wonders such as home computers"—remember, 1965—"or at least terminals connected to a central computer, automatic controls for automobiles, and personal portable communication equipment." He then added, "The electronic watch only needs a display to be feasible today." Maybe 50 years off the pace on that one, but still.

Again, think about it. How many things do we hear today that you imagine will actually be true in 50 years? Can you sit there and tell me what the world will look like in 2065? I know I can't, and it's partly my job.

So there's something sort of amazing about it, right?

But Dr. Moore didn't stop at simply imagining that world. Instead he took a step that I think many of us will recognize, and I hope some of you will do, which is that he and his colleagues Robert Noyce and Andy Grove left the company they were working in, Fairchild Semiconductor, and started their own company. They backed themselves. They made in some ways one of Silicon Valley's original start-ups. They conceived a big idea and they founded Intel on it. Silicon Valley grew up out of this idea and out of the computing power it unleashed; so did many other technology centers and many other companies. In fact, all of us have grown up in that world of wonders that Dr. Moore imagined. Every time you post a photo, send an email, flirt long distance—which I suspect some of you do—Skype, send remittance payments, use hashtags to participate in debates, back political candidates and then wonder why they're still emailing you (we all know this one and it's only gonna get worse), worry about the venom in the comments sections of every paper we read, fund someone's big idea on Kickstarter, binge on *Game of Thrones* for a whole season, or—my personal favorite—share that video with the cat in a shark suit on a Roomba being chased by a duck, because you can, you are living in the world that Dr. Moore and all of his contemporaries built for us. They have given us 50 years of technological innovation and change.

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Friedman interview video:
bit.ly/1M9nInm

Genevieve Bell commencement address:
bit.ly/1U18gpz

