Rajeev Bansal

Don't Drop That Cell Phone!

The Solid State, however, kept its grains
Of Microstructure coarsely veiled until
X-ray diffraction pierced the Crystal Planes
That roofed the giddy Dance, the taut Quadrille
Where Silicon and Carbon Atoms will
Link Valencies, four-figured, hand in hand
With common Ions and Rare Earths to fill
The lattices of Matter, Glass or Sand,
With tiny Excitations, quantitatively grand.

—John Updike [1]

This ode to the solid-state devices was quoted in the preface to a special issue [1] of the *Scientific American*, which reported on the remarkable history of the transistor, invented in 1947 at Bell Laboratories. One of the articles in [1] led to the following quiz question [2] in the inaugural issue of the *IEEE Microwave Magazine* in March 2000:

If a digital cell phone were made with vacuum tubes instead of transistors, it would be as large as

a) a microwave oven
b) a minivan
c) a British telephone booth
d) the Washington Monument

Digital Object Identifier 10.1109/MAP.2024.3362131
Date of current version: 3 April 2024

Munroe notes that UNIVAC, the first vacuum-tube-based commercial computer, was the size of a room to accommodate its 5,000 vacuum tubes.

The correct answer was (d) the Washington Monument, which, at over 555 feet, is still the tallest stone structure in the world [3].

Of course, propelled by Moore's law, cell phones have continued to pack in more and more transistors into the same physical envelope over the ensuing decades. Recently, thanks to a book [4] I received as a Christmas gift, I had the chance to revisit the issue of a hypothetical cell phone made of vacuum tubes. Randall Munroe, a former National Aeronautics and Space Administration engineer, takes up the question in *What If? 2* [4], the sequel to his bestseller *What If?*

Munroe [4] notes that UNIVAC, the first vacuum-tube-based commercial computer, was the size of a room to accommodate its 5,000 vacuum tubes. An iPhone 12 has nearly 12 billion transistors. If those transistors were replaced with vacuum tubes using the same packing density as the UNIVAC, "the phone would be about the size of *five* city blocks when resting on one edge" [4]. (To compare apples to apples, one should note that a "typical" city block is around 300 feet long [5], so the Washington Monument lying sideways will be less than two city blocks.)

An additional complication with our vacuum-tube-based iPhone 12 is the heat it will generate. Munroe [4] points out that the 7AK7 tubes used by UNIVAC consumed several watts of energy per tube. Extrapolating that to our 12-billion-tube phone will result in some 100 GW of heat dissipation, raising the temperature of the phone to around 1,800 °C. Since that is above the melting point of granite, such a hot phone (assuming it did not somehow self-destruct), if dropped, would "melt its way through the Earth's crust" [4].

REFERENCES

[1] J. Updike, "'The Dance of the Solids.' Quoted by J. Rennie in a special issue 'The Solid-State Century: The Past, Present, and Future of the Transistor,'" *Scientific Amer.*, vol. 8, no. 1, 1997.
[2] R. Bansal, *From ER to E.T.: How Electromagnetic Technologies Are Changing Our Lives*. Hoboken, NJ, USA: Wiley, 2017.
[3] "Washington Monument." National Park Services. [Online]. Available: Accessed: Jan. 7, 2024. https://www.nps.gov/wamo/learn/historyculture/index.htm
[4] R. Munroe, *What If? 2*. New York, NY, USA: Riverhead Books, 2022.
[5] "How many feet are in a city block?" Reference. Accessed: Jan. 7, 2024. [Online]. Available: https://www.reference.com/science-technology/many-feet-city-block-3cd5b079ba790626?utm_content=params%3Aad%3DdirN%26qo%3DserpIndex%26o%3D740005%26ag%3Dfw81&ueid=1141D322-BB5B-4104-9E54-3A042D8B4FF7