D. M. Fleetwood, “75th anniversary of the transistor – a Boilermaker reflects,” Excerpt: IEEE NPSS News, Issue 2: June 2022, pp. 7-8.
See below.

75th Anniversary of the Transistor – a Boilermaker Reflects

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2022 is the 75th anniversary of the invention of the transistor by Bardeen, Brattain, and Schockley; their original transistor is shown schematically in [1]. Thanks to more than six decades of Moore’s Law scaling of integrated circuits (ICs) [2], as illustrated in Fig. 2 [3], [4], advanced chips such as the Apple M1 Ultra now feature more than 100 billion transistors [5]. Moore’s Law scaling has profoundly affected the radiation response of transistors and ICs [4], a topic explored in detail in the NPSS Distinguished Lecturers Program [6].

I received my Ph. D. in Physics from Purdue University in 1984. At Purdue, the transistor is known as “the one that got away,” for reasons I will now discuss briefly. During the Second World War, Purdue developed high-quality, miniaturized germanium (Ge) rectifiers to serve as microwave detectors in support of the MIT Radiation Laboratory’s radar project. The work at Purdue helped to establish Ge as a useful and valuable semiconductor [7]. During these investigations, Ralph Bray, then a graduate student working with Karl Lark-Horovitz, Chair of the Purdue Physics Department, observed anomalously low spreading resistance around point contacts to Ge. Soon after, using a Ge crystal grown at Purdue, Bardeen and Brattain demonstrated at Bell Labs that this effect was due to minority carrier injection, which could be induced and controlled in a triode configuration (Fig. 1) to form a transistor [1], and of course the rest is history.

Although missing the opportunity to invent the transistor, the Purdue group under the leadership of Lark-Horovitz made many significant contributions to the understanding of semiconductor physics, including early and fundamental research on the effects of ionizing radiation. For example, Fig. 3 shows that neutron irradiation of n-type germanium (curve **b**) initially causes a decrease in conductance as electrons are removed from the conduction band by the introduction of traps, but at higher fluences the dominant conductivity changes to p-type as a result of point-defect creation. The conductance then increases with fluence, similarly to curve **a** [8]. Displacement-damage-induced type inversion in germanium and silicon remains important in semiconductor radiation detectors [9].

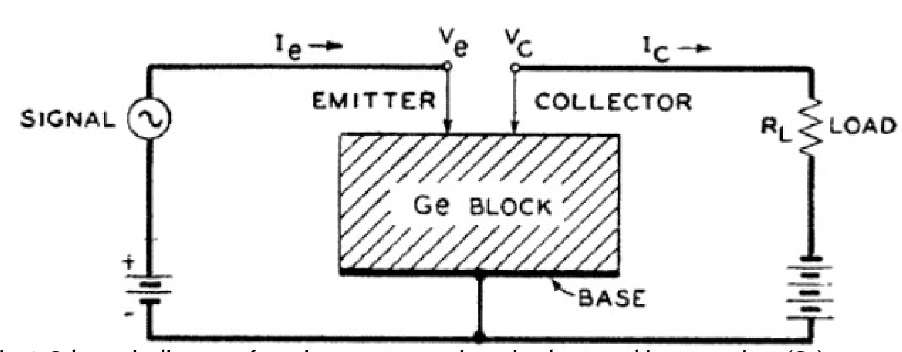

Fig. 1. Schematic diagram of a point contact transistor, implemented in germanium (Ge). (After [1], © American Institute of Physics, AIP, 1948.)

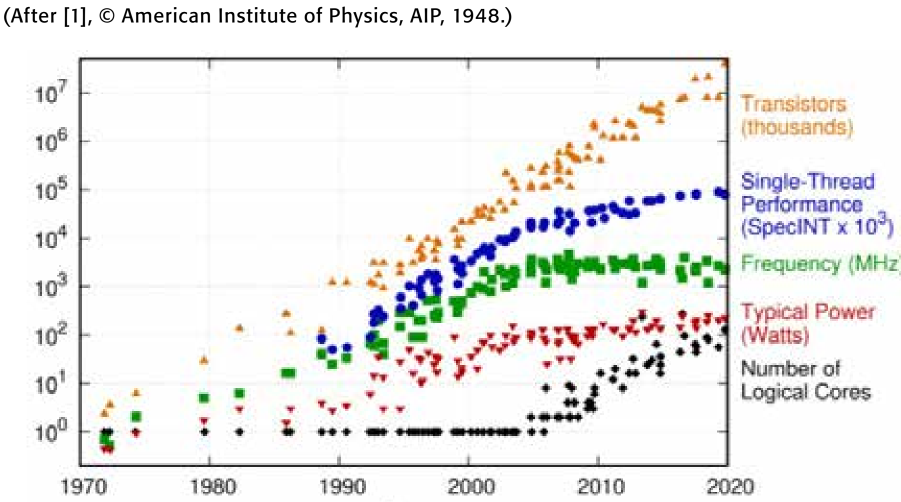

Fig. 2. Transistor count and IC performance, frequency, power, and number of logical cores from 1971 through 2020. The geometrically increasing trend in transistor count reflects Moore’s Law scaling. (After [3], [4].)

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Karl-Lark Horovitz served as Physics Department Head at Purdue from 1932 until he died in his office in 1958 [7], which happened to be the year that I was born. The Lark-Horovitz Award for graduate research at Purdue is named in his honor; I was fortunate to be a co-recipient in 1984 for my graduate work on low-frequency noise in thin metal films and nanowires. Professor Ralph Bray was my instructor in graduate solid-state physics in Fall 1980. He was enthusiastic in teaching us all about Ge semiconductor physics, and never bitter about missing his opportunity to have potentially been the inventor of the transistor [7], [10]. In fact, he did not even mention his early, fundamental contributions to semiconductor physics. So I only learned about his and Purdue's historic contributions to semiconductor physics, the transistor, and radiation effects much later in my career when working in similar research areas first at Sandia National Laboratories (1984-1999) and now at Vanderbilt University. Coincidence or Boilermaker legacy? Perhaps a bit of each.

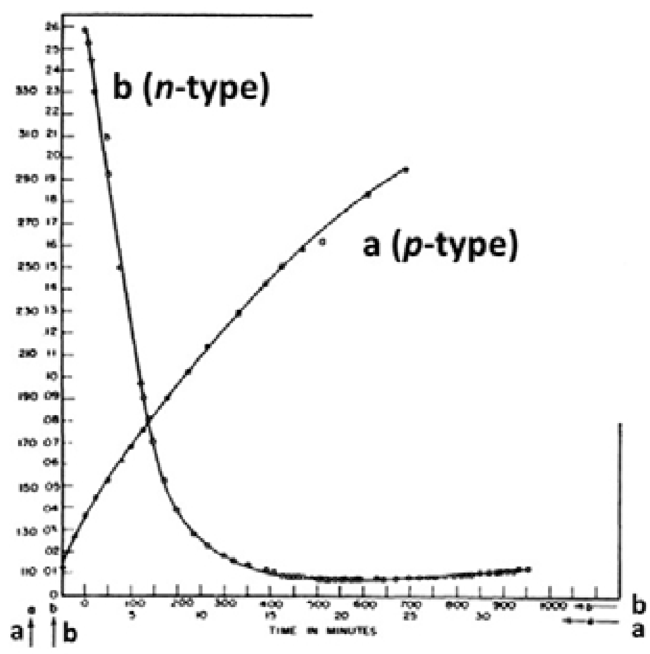

Fig. 3. Conductance of (a) p-type and (b) n-type germanium. (After [8], © AIP, 1949)

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