The making of high-tech clusters: Evidence from early-mover corporate labs in the US microchip breakthrough

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- **Do these unanticipated leaders continue to disseminate ideas to the industry after they achieve product market advantage?**
- Why focus on early technology leaders? High-tech first-mover firms → oligopolies after industrial shake-out (market selection) (Klepper, 1996, 2002; Buenstorf and Klepper, 2009, 2010);
- Innovation & market structure (Aghion et al., 2001; Acemoglu and Akcigit, 2012; Akcigit and Ates, 2021, 2023); Early industrial takeoff (Gross and Sampat, 2022; Mokyr et al., 2022; Kantor and Whalley, 2022; Saxenian, 1994; Giorcelli and Li, 2021);

The 1950's microchip breakthrough: one of the most radical innovation

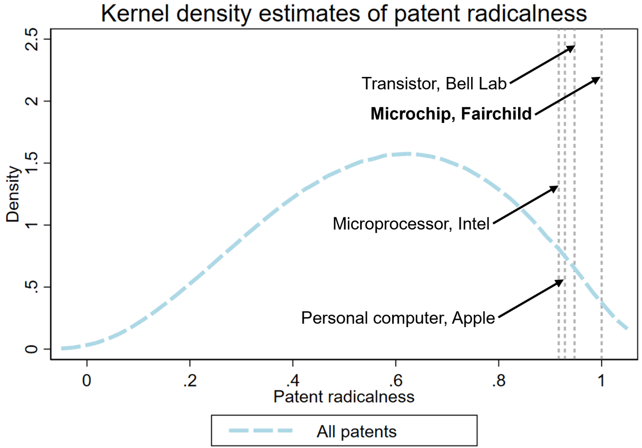
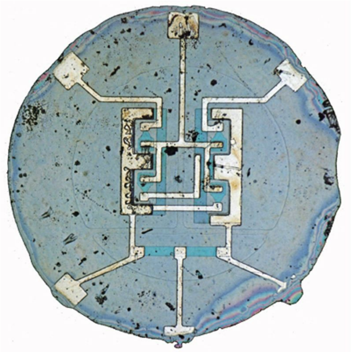


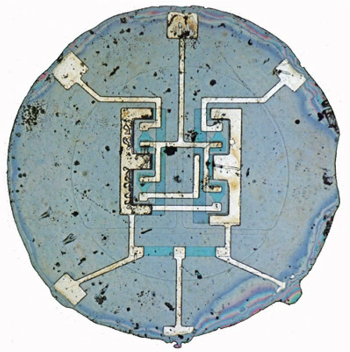
Figure: Patent radicalness: share of similar patents granted later (analogous to Kelly et al. (2021)).

The "parallel" microchip breakthrough



(a) Fairchild, Silicon

The "parallel" microchip breakthrough



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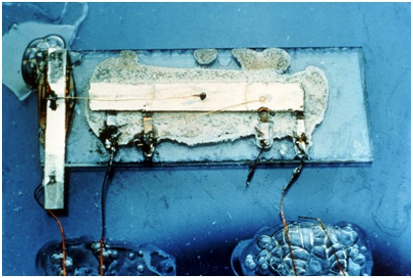


(b) Texas Instruments, Germanium

Figure: Simultaneous microchip design in late 1950s.

The planar technique

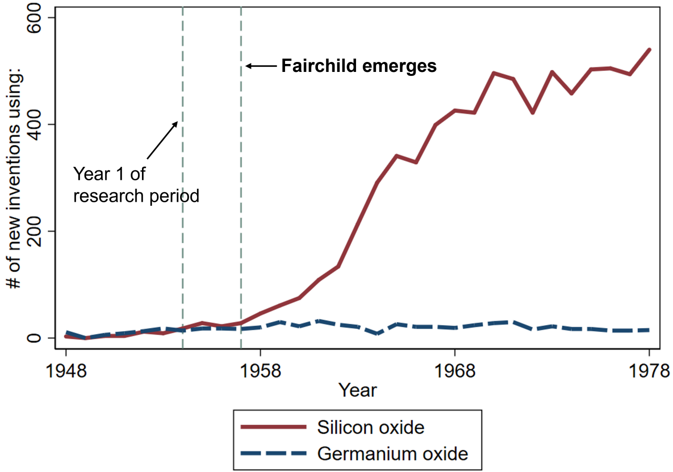


Figure: Silicon oxide v.s. Germanium oxide new patent flow.

The 1957 Fairchild-Shockley breakaway

- The rise of Fairchild Semiconductor (Oct. 1957) and the initial planar (microchip) idea (Dec. 1957) was driven by an unanticipated breakaway across a group of ambitious (genius) engineers;

(a) William Shockley (Nobel prize laureate)

(b) Founders of Fairchild semiconductor division (the traitorous eight)

Figure: The Fairchild-Shockley breakaway happened in 1957 due to personal resentment with Shockley (nonanticipatory by other labs).

Identification setting

- **Pre-Fairchild:** Silicon vs Germanium → similar and good enough substitutes;
- Fairchild Semiconductor Div emerged in 1957;
- **Silicon patent holders:** → creative construction → head start in microchip-related research fields;
- **Germanium patent holders:** → only for "old tech" (hearing aids, etc.);
- Conditional on the same research field: Silicon corporate labs v.s. Germanium corporate labs; pre-Fairchild v.s. post-Fairchild periods.

Treatment: a quasi-random head start

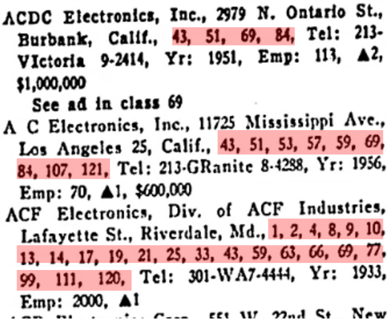
- **Unit of analysis: firm R&D lab×research field (6-digit CPC class) pairs** (170 labs are firm-county pairs compiled from cataloging reports from Division of Technical Information in the US Atomic Energy Commission, see 1958.)

- **Observations:** Total lab×field×year obs: 13793.

- (Pre-Fairchild) quasi-random selection of Silicon & Germanium:
  - Balancing test → most lab/county/technology characteristics are balanced;
  - Conditional on microchip never-adopters: Silicon & Germanium labs perform the same after Fairchild emerged (conditional on the same research field).

Lab×research field level product data

- Product data from (a) *Institute of Radio Engineer* membership directory; (b) *Electronic Industries* trade journal.



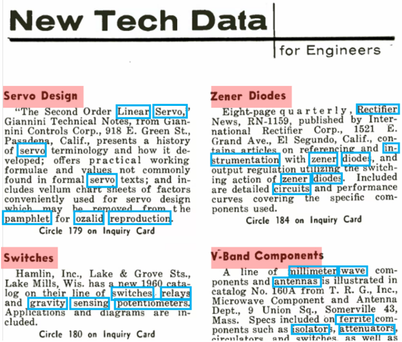
ACDC Electronics, Inc., 2979 N. Ontario St., Burbank, Calif., 43, 51, 69, 84, Tel: 213-Victoria 9-2414, Yr: 1951, Emp: 113, ▲2, $1,000,000

See ad in class 69

A C Electronics, Inc., 11725 Mississippi Ave., Los Angeles 25, Calif., 43, 51, 53, 57, 59, 69, 84, 107, 121, Tel: 213-GRanite 8-4288, Yr: 1956, Emp: 70, ▲1, $600,000

ACF Electronics, Div. of ACF Industries, Lafayette St., Riverdale, Md., 1, 2, 4, 8, 9, 10, 13, 14, 17, 19, 21, 25, 33, 43, 59, 63, 66, 69, 77, 99, 111, 120, Tel: 301-WA7-4444, Yr: 1933, Emp: 2000, ▲1

(a) Digitized product lines.



New Tech Data

for Engineers

Servo Design

"The Second Order Linear Servo," Giannini Technical Notes, from Giannini Controls Corp., 918 E. Green St., Pasadena, Calif., presents a history of servo terminology and how it developed; offers practical working formulae and values not commonly found in formal servo texts; and includes vellum chart sheets of factors conveniently used for servo design which may be removed from the pamphlet for ozalid reproduction.

Circle 179 on Inquiry Card

Switches

Hamlin, Inc., Lake & Grove Sts., Lake Mills, Wis. has a new 1960 catalog on their line of switches, relays and gravity sensing potentiometers. Applications and diagrams are included.

Circle 180 on Inquiry Card

Zener Diodes

Eight-page quarterly, Rectifier News, RN-1159, published by International Rectifier Corp., 1521 E. Grand Ave., El Segundo, Calif., contains articles on referencing and instrumentation with zener diodes, and output regulation utilizing the switching action of zener diodes. Included are detailed circuits and performance curves covering the specific components used.

Circle 184 on Inquiry Card

V-Band Components

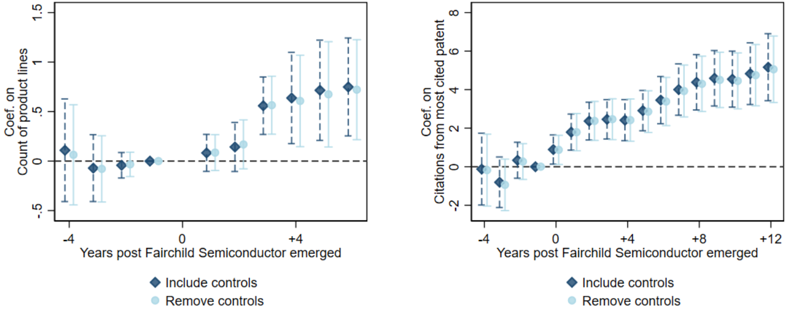
A line of millimeter wave components and antennas is illustrated in catalog No. 160A from T. R. G., Inc., Microwave Component and Antenna Dept., 9 Union Sq., Somerville 43, Mass. Specs included on ferrite components such as isolators, attenuators,

(b) Digitized new product manuals.

Figure: Newly digitized product-level datasets.

Head start → rise of early industrial leaders

- ATT: +0.482/+13.7% more product lines per year.



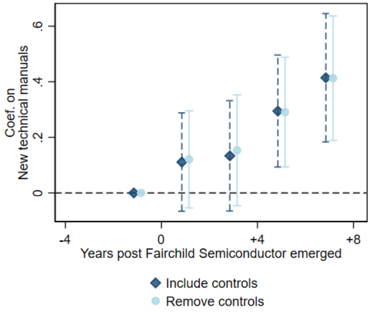
(a) Count of product lines

(b) Life-long citations of "best" patent

Figure: Silicon head start and the creation of early industrial leaders.

Persistent new product designs

- Persistent rise of new product designs even after year + 4; .

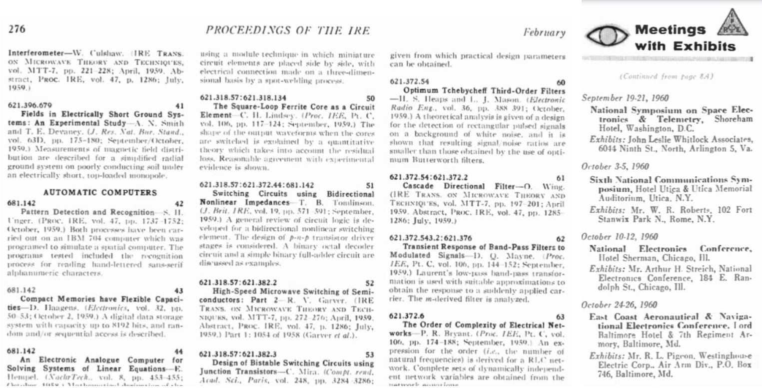


(a) New product manuals

Figure: Head start and expansion of product varieties.

Diffusion: a proxy for voluntary knowledge disclosure

- Conference publications/proceeding papers;
- Among which IEEE (Institute of Electrical and Electronics Engineers) is the largest platform.



276 *PROCEEDINGS OF THE IRE* *February*

Interferometer—W. Culshaw. (IRE Trans. on Microwave Theory and Techniques, vol. MTT-7, pp. 221–228; April, 1959. Abstract, Proc. IRE, vol. 47, p. 1286; July, 1959.)

621.396.679 41
Fields in Electrically Short Ground Systems: An Experimental Study—A. N. Smith and T. E. Devaney. (*J. Res. Nat. Bur. Stand.*, vol. 63D, pp. 175–180; September/October, 1959.) Measurements of magnetic field distribution are described for a simplified radial ground system on poorly conducting soil under an electrically short, top-loaded monopole.

AUTOMATIC COMPUTERS

681.142 42
Pattern Detection and Recognition—S. H. Unger. (Proc. IRE, vol. 47, pp. 1737–1752; October, 1959.) Both processes have been carried out on an IBM 704 computer which was programed to simulate a spatial computer. The programs tested included the recognition process for reading hand-lettered sans-serif alphanumeric characters.

681.142 43
Compact Memories have Flexible Capacities—D. Haagens. (*Electronics*, vol. 32, pp. 50–53; October 2, 1959.) A digital data storage system with capacity up to 8192 bits, and random and/or sequential access is described.

681.142 44
An Electronic Analogue Computer for Solving Systems of Linear Equations—E. Hempel. (*NachrTech.*, vol. 8, pp. 453–455;

using a module technique in which miniature circuit elements are placed side by side, with electrical connection made on a three-dimensional basis by a spot-welding process.

621.318.57:621.318.134 50
The Square-Loop Ferrite Core as a Circuit Element—C. H. Lindsey. (*Proc. IEE*, Pt. C, vol. 106, pp. 117–124; September, 1959.) The shape of the output waveforms when the cores are switched is explained by a quantitative theory which takes into account the residual loss. Reasonable agreement with experimental evidence is shown.

621.318.57:621.372.44:681.142 51
Switching Circuits using Bidirectional Nonlinear Impedances—T. B. Tomlinson. (*J. Brit. IRE*, vol. 19, pp. 571–591; September, 1959.) A general review of circuit logic is developed for a bidirectional nonlinear switching element. The design of *p-n-p* transistor driver stages is considered. A binary octal decoder circuit and a simple binary full-adder circuit are discussed as examples.

621.318.57:621.382.2 52
High-Speed Microwave Switching of Semiconductors: Part 2—R. V. Garver. (IRE Trans. on Microwave Theory and Techniques, vol. MTT-7, pp. 272–276; April, 1959. Abstract, Proc. IRE, vol. 47, p. 1286; July, 1959.) Part 1: 1054 of 1958 (Garver *et al.*).

621.318.57:621.382.3 53
Design of Bistable Switching Circuits using Junction Transistors—C. Mira. (*Compt. rend. Acad. Sci., Paris*, vol. 248, pp. 3284–3286;

given from which practical design parameters can be obtained.

621.372.54 60
Optimum Tchebycheff Third-Order Filters—H. S. Heaps and L. J. Mason. (*Electronic Radio Eng.*, vol. 36, pp. 388–391; October, 1959.) A theoretical analysis is given of a design for the detection of rectangular pulsed signals on a background of white noise, and it is shown that resulting signal/noise ratios are smaller than those obtained by the use of optimum Butterworth filters.

621.372.54:621.372.2 61
Cascade Directional Filter—O. Wing. (IRE Trans. on Microwave Theory and Techniques, vol. MTT-7, pp. 197–201; April 1959. Abstract, Proc. IRE, vol. 47, pp. 1285–1286; July, 1959.)

621.372.543.2:621.376 62
Transient Response of Band-Pass Filters to Modulated Signals—D. Q. Mayne. (*Proc. IEE*, Pt. C, vol. 106, pp. 144–152; September, 1959.) Laurent's low-pass band-pass transformation is used with suitable approximations to obtain the response to a suddenly applied carrier. The *m*-derived filter is analyzed.

621.372.6 63
The Order of Complexity of Electrical Networks—P. R. Bryant. (*Proc. IEE*, Pt. C, vol. 106, pp. 174–188; September, 1959.) An expression for the order (*i.e.*, the number of natural frequencies) is derived for a RLC network. Complete sets of dynamically independent network variables are obtained from the

Meetings with Exhibits

(Continued from page 8A)

September 19-21, 1960
National Symposium on Space Electronics & Telemetry, Shoreham Hotel, Washington, D.C.
Exhibits: John Leslie Whitlock Associates, 6044 Ninth St., North, Arlington 5, Va.

October 3-5, 1960
Sixth National Communications Symposium, Hotel Utica & Utica Memorial Auditorium, Utica, N.Y.
Exhibits: Mr. W. R. Roberts, 102 Fort Stanwix Park N., Rome, N.Y.

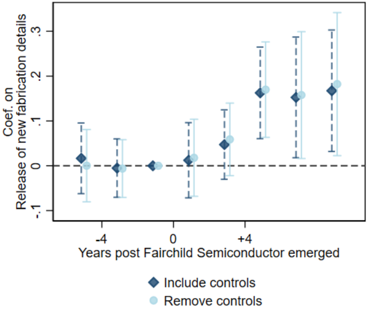
October 10-12, 1960
National Electronics Conference, Hotel Sherman, Chicago, Ill.
Exhibits: Mr. Arthur H. Streich, National Electronics Conference, 184 E. Randolph St., Chicago, Ill.

October 24-26, 1960
East Coast Aeronautical & Navigational Electronics Conference, Lord Baltimore Hotel & 7th Regiment Armory, Baltimore, Md.
Exhibits: Mr. R. L. Pigeon, Westinghouse Electric Corp., Air Arm Div., P.O. Box 746, Baltimore, Md.

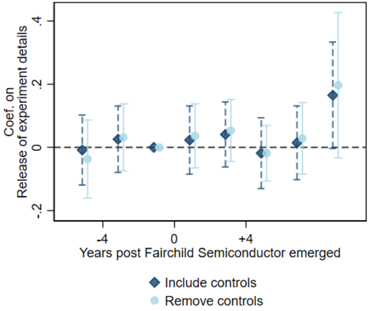
Figure: IEEE Xplore compiles rich historical records of corporate publications since 1890s.

Diffusion: the disclosure is likely strategic

- Since year 4, head start $\rightarrow +9.1\%$ release of **fabrication details** per 2 years.



(a) Release of **fabrication** techniques



(b) Release of **experimental** details

Figure: Knowledge disclosure.

More on leader knowledge disclosure

- Likely framework: expansion of product designs $\rightarrow$ compete for downstream users;
- A tradeoff;
- Ex ante product lines from parent firm $= 0 \rightarrow$ insignificant effect on disclosure;

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- A tradeoff;
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- **Counterfactual without vertical knowledge disclosure:** research fields without IEEE coverage $\rightarrow$ significant innovation, negligible production/new product designs;
  - Mostly comes from **face-to-face** conferences/symposiums arranged by Institute of Radio Engineer (IRE);
  - The IRE's "regional section" policy $\rightarrow$ corporate assignees $\uparrow$ in leader lab locations.

Thank you!

Any comments are hugely appreciated: j.zeng15@lse.ac.uk

Appendix: Ruling out alternative explanations

- Limited evidence found for:
  - Exclusivity to the valley/California/west coast.
  - Prior semiconductor choice impacts innovation outcomes beyond pathways of microchip (exclusion restriction);
  - The 1958 NASA Space Act favor Silicon (head start) labs over Germanium labs (see a more in depth discussion on the context in paper).
  - "Winner-takes-all": The effect is exclusive to the first assignees that applied microchip into each technology class.
  - Scouting via conferences.
  - Close research fields are strategic substitutes or between-lab R&D reallocation/negative treatment spillover.
  - Sensitivity to non-linear estimation methods on key outcomes.