



TE346
Engenharia Elétrica e Sociedade
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UFPR
 UNIVERSIDADE FEDERAL DO PARANÁ

DELT
 DEPARTAMENTO DE ENGENHARIA ELÉTRICA

Do transistor ao microprocessador
[1.ª Parte]

1

Eletrônica

eletrônica

[Var. de *electrônica*, fem. substantivado do adj. *electrônico*.]

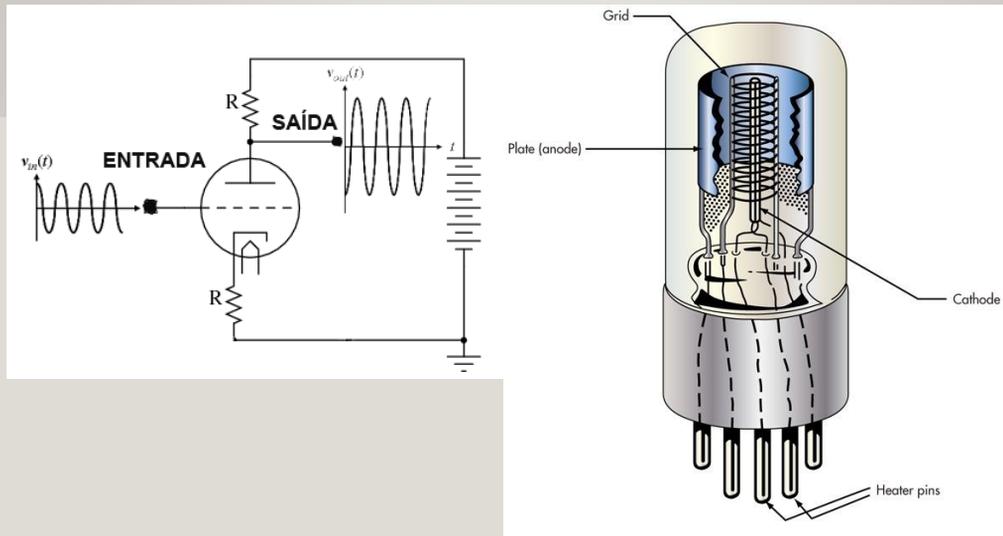
S. f.

Parte da engenharia dedicada ao estudo do comportamento de circuitos elétricos que contenham válvulas, semicondutores, transdutores, etc., ou à fabricação de tais circuitos.



2

Válvulas eletrônicas



5



6

Apesar de serem consideradas geralmente *obsoletas*, ainda existem empresas fabricantes de válvulas eletrônicas, que são usadas em equipamentos de áudio de preço elevado e principalmente em amplificadores para guitarras e baixos elétricos.

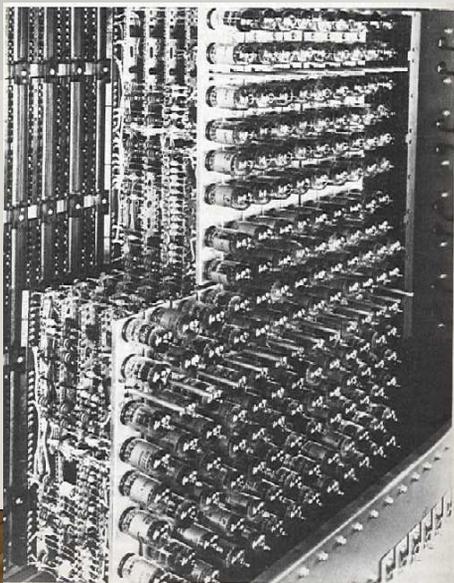
<https://spectrum.ieee.org/the-cool-sound-of-tubes>



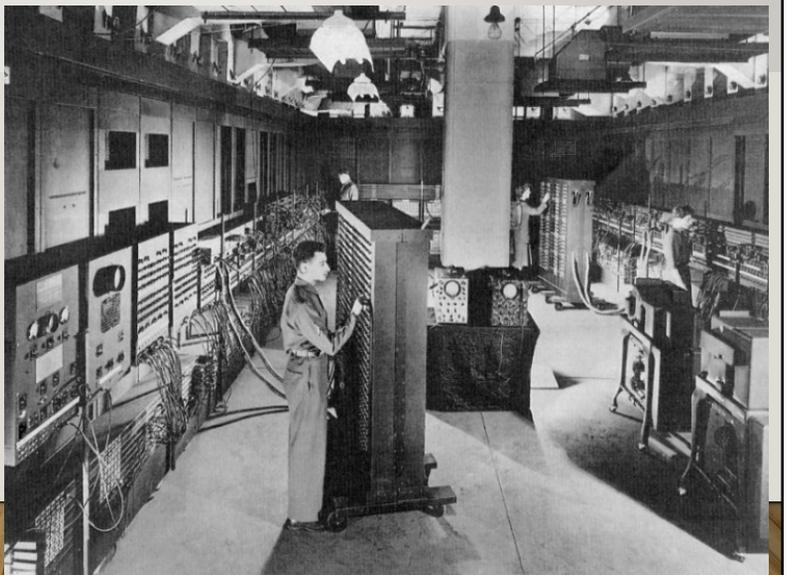
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Origens...

Memória de válvulas de um computador IBM, 1950. Cerca de 1,5 kbits.



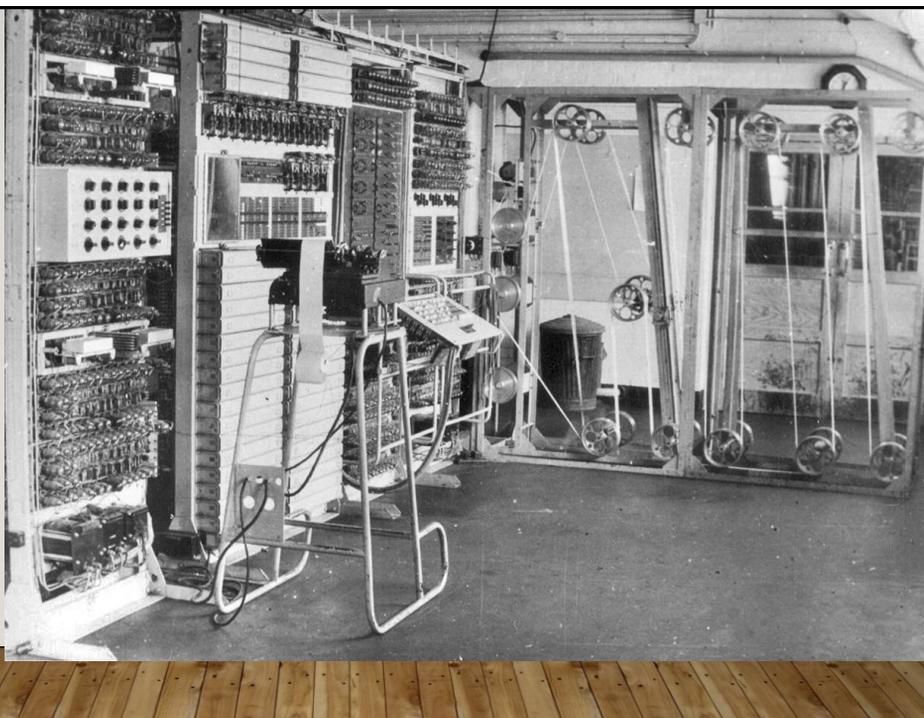
Computador ENIAC (1943-1945), com 17.468 válvulas e consumo de 150 kW, Peso: 27 ton, Área: 62 m².



8

Computador COLOSSUS (1943-1944), com 1600 válvulas (protótipo, chamado de modelo Mark I) e 2400 válvulas (modelo Mark 2).

Destinava-se a decifrar o código gerado pelas máquinas de criptografia *Lorenz*, usadas pelo alto comando nazista da Alemanha na II Guerra Mundial.



9

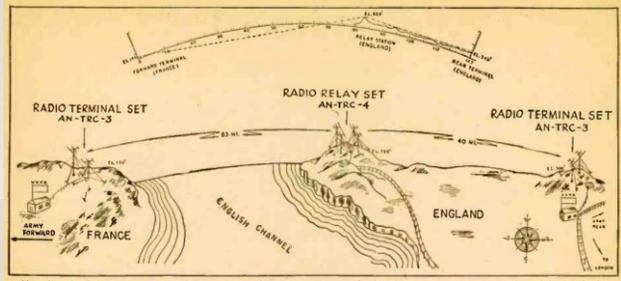
Até o final da II Guerra Mundial 10 unidades do Computador COLOSSUS modelo Mark 2 foram construídos e usados em *Bletchley Park* pela equipe liderada por Allan Turing. Uma 11.^a unidade foi parcialmente montada.

Após a Guerra, foi ordenado que todos os computadores Colossus fossem destruídos, exceto dois que foram levados para uso pelo *Government Communications Headquarters* britânico e supostamente desmontados na década de 1960. Também há suposições que uma destas unidades foi levada aos EUA para uso pela *National Security Agency* (NSA).

Em 2008 foi colocado em operação uma réplica do modelo Mark II em Bletchley Park, atualmente sede do *National Museum of Computing*. →



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11

Eletrônica na II Guerra Mundial

Crescente demanda por equipamento eletrônico militar

Grande investimento militar no desenvolvimento da eletrônica

Ficou demonstrada a importância estratégica das telecomunicações e do radar

Grande investimento militar no desenvolvimento das telecomunicações

Cristais de germânio usados como detectores de radar deram uma vantagem estratégica aos aliados

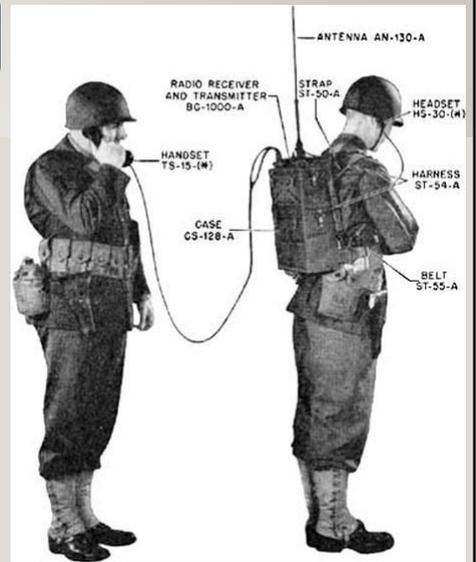
Grande investimento militar nas pesquisas sobre semicondutores

Equipamentos portáteis de rádio-comunicação foram essenciais para a vitória aliada

Necessidade de diminuir o tamanho dos equipamentos

Desenvolvimento dos primeiros computadores (cálculos balísticos & criptografia)

Necessidade desse ter alguma coisa mais confiável que as válvulas



12

MATERIAIS SEMICONDUTORES

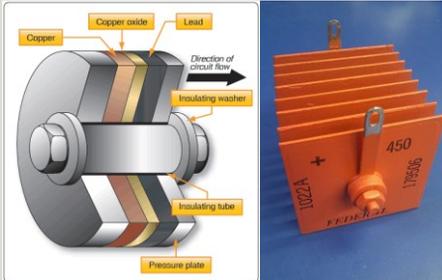
Ao contrário de que muitos acreditam, matérias semicondutores eram conhecidos e estudados muito antes da invenção dos transistores e foram usados para construir alguns equipamentos

1876: Adams & Day descobrem o efeito fotovoltaico no **selênio**.

1883: Charles Fritts constrói a primeira fotocélula de **selênio** (eficiência < 1%). Lançamento de diversos tipos de fotômetros para fotografia.

1925: E. Presser patenteou o retificador a óxido de selênio

1926: O. Grondahl patenteou o retificador a óxido de cobre



Retificador com óxido de cobre

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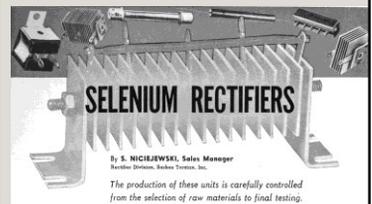
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MATERIAIS SEMICONDUTORES



George Clarke Southworth (1890-1972)

Bell Labs

Cristais de galena (PbS) em radares

Russel Shoemaker Ohl (1898-1987)

Penn State University

Bell Labs

Junção PN, Diodos de Ge, Célula Solar



Karl Lark-Horovitz (1892-1958)

Purdue University

Propriedades elétricas dos cristais de Germânio

14

BELL LABS

1941: A AT&T (ex **Bell Telephone Co.**) inaugura as novas instalações do Bell Labs, em Murray Hill, New Jersey, EUA.

1945: Com a Segunda Guerra Mundial próxima ao seu fim, a Diretoria do Bell Labs estabelece o **Solid State Physics Group**. O físico **William Shockley** é nomeado Chefe deste grupo de pesquisa.

Shockley convida o físico **Walter Houser Brattain**, que já trabalhava no Bell Labs, para integrar o grupo. Brattain era conhecido por sua habilidade em montar experimentos inéditos.

John Bardeen foi admitido no Bell Labs em outubro de 1945 e passa a integrar também o grupo de Shockley. Bardeen era graduado em Engenharia Elétrica e PhD em Física, e tinha trabalhado em um laboratório de pesquisas da Marinha dos EUA durante a Guerra. A admissão de John Bardeen no Bell Labs foi resultado de uma indicação pessoal de Walter Brattain (John Bardeen era amigo do seu irmão Robert Brattain, que sempre elogiava a inteligência prodigiosa do amigo ao irmão).

Gordon Teal, que trabalhava no Bell Labs desde 1930, também passou a fazer parte do grupo de Shockley. Em sua Tese de Doutorado, Gordon Teal havia conseguido produzir cristais de germânio de alta pureza usando o processo de Czochralski.



William Shockley



Walter Brattain



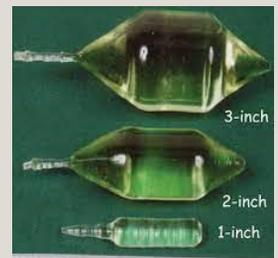
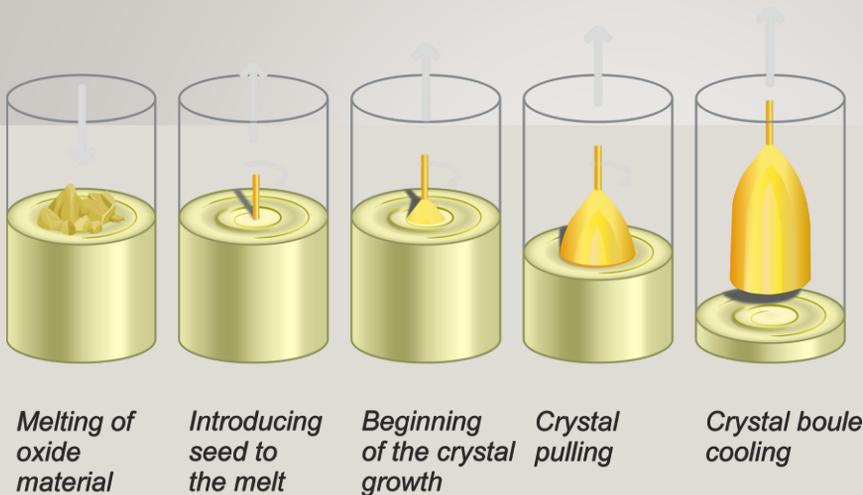
John Bardeen



Gordon Teal

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PROCESSO DE CZOCHRALSKI



Jan Czochralski (1918) "Ein neues Verfahren zur Messung der Kristallisationsgeschwindigkeit der Metalle" [A new method for the measurement of the crystallization rate of metals], Zeitschrift für Physikalische Chemie, 92 : 219–221.

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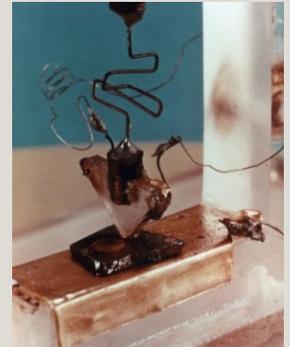
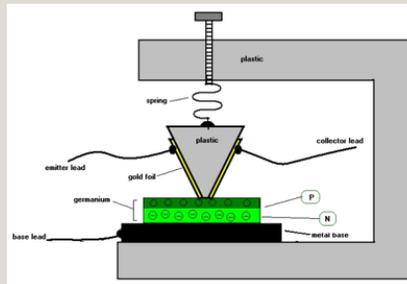
A INVENÇÃO DO TRANSÍSTOR

Logo no início das atividades do *Solid State Group*, William Shockley lança a ideia de um dispositivo amplificador baseado no efeito do campo elétrico em uma barra de material semiconductor. No entanto as tentativas de construção de um dispositivo físico baseado neste princípio falham (este é o princípio de funcionamento do transistor de 'efeito de campo' que se tornou realidade anos depois).

1947 John Bardeen acha que o dispositivo vislumbrado por Shockley não funcionava devido a “cargas superficiais” na interface entre o semiconductor e o eletrodo de metal. Shockley não concorda com esta explicação, mas Bardeen mesmo assim publica um artigo com a sua teoria.

1947 John Bardeen & Walter Brattain, desejando demonstrar praticamente a influência das “cargas superficiais”, constroem um dispositivo amplificador baseado em um cristal de de germânio.

No dia 23 de dezembro de 1947 Bardeen & Brattain apresentam formalmente o dispositivo (ainda sem nome) aos membros do *Solid State Group*.



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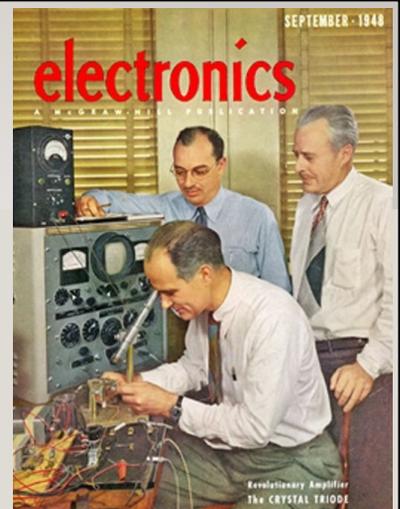
1948: John Bardeen & Walter Brattain publicam um trabalho descrevendo o dispositivo que construíram, usando pela primeira vez a palavra ‘transistor’ (o nome foi uma sugestão de um funcionário do Bell Labs)

1948: John Shive constrói um transistor de germânio com o coletor e o emissor em lados opostos de uma fina lâmina de germânio provando que o ‘efeito transistor’ se dava no interior do semiconductor e não na superfície como imaginavam Bardeen & Brattain.

Tentativas de fabricar transistores com Silício em vez de Germânio mostram-se sem resultados. Motivo: **O Silício disponível na ocasião não tinha o grau de pureza necessário para a fabricação de transistores.**

Em janeiro de 1948 Shockley preenche um formulário de patente do transistor constando apenas com o seu nome como inventor. Bardeen e Brattain ao saber da manobra de Shockley protestam violentamente. Os advogados do *Bell Labs* acabam registrando duas patentes, uma com os nomes de **Bardeen e Brattain** como “**inventores do transistor de germânio**” e outra apenas com o nome de **Shockley** como “**inventor do transistor de junção**”.

1956: Bardeen, Brattain & Shockley são agraciados com o **Prêmio Nobel de Física**. Nesta época, apenas Brattain ainda trabalhava no Bell Labs, mas em um setor diferente do *Solid State Group*.



Na capa da revista *Electronics* de setembro de 1948 foi publicada uma fotografia feita no Bell Labs por ocasião do anúncio público da invenção do transistor. Shockley é o que observa o protótipo do transistor de germânio de 1947 com um microscópio. Bardeen está com os braços sobre um instrumento e Brattain, o mais velho dos três, observa atrás de Shockley.

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O Transistor

230 LETTERS TO THE EDITOR

to have a positive dv/dI and is considered to have large homopolar bonding, similar reasoning predicts that dv/dI is positive; i.e., $\lambda > 1$. In crystals containing radicals and in many glasses, positive dv/dI values are frequently obtained although their dv/dI values are negative. In those materials there are effects within the radical which contribute mainly to dv/dI and only slightly to dv/dI . A more complete treatment of these subjects will be presented in a forthcoming paper.

- 1. Mueller, *Phys. Rev.*, **47**, 94 (1942).
- 2. J. Bardeen and W. H. Brattain, *Phys. Rev.*, **84**, 336 (1951).
- 3. W. Shockley, *Phys. Rev.*, **85**, 86 (1951).
- 4. J. Bardeen and W. H. Brattain, *Proc. Ind. Acad. Sci. A26*, 87 (1951).
- 5. J. Bardeen and W. H. Brattain, *Phys. Rev.*, **84**, 336 (1951).
- 6. J. Bardeen and W. H. Brattain, *Phys. Rev.*, **84**, 336 (1951).
- 7. J. Bardeen and W. H. Brattain, *Phys. Rev.*, **84**, 336 (1951).
- 8. J. Bardeen and W. H. Brattain, *Phys. Rev.*, **84**, 336 (1951).
- 9. J. Bardeen and W. H. Brattain, *Phys. Rev.*, **84**, 336 (1951).
- 10. J. Bardeen and W. H. Brattain, *Phys. Rev.*, **84**, 336 (1951).

The Transistor, A Semi-Conductor Triode

J. BARDEEN AND W. H. BRATTAIN
Bell Telephone Laboratories, Murray Hill, New Jersey
June 25, 1948

A THREE-ELEMENT electronic device which utilizes a newly discovered principle involving a semi-conductor as the basic element is described. It may be employed as an amplifier, oscillator, and for other purposes for which vacuum tubes are ordinarily used. The device consists of three electrodes placed on a block of germanium as shown schematically in Fig. 1. Two, called the emitter and collector, are of the point-contact type and are placed in close proximity (separation ~ 0.05 to 0.25 cm) on the upper surface. The third is a large area low resistance contact on the base.

The germanium is prepared in the same way as that used for high back-voltage rectifiers.¹ In this form it is an N-type or excess semi-conductor with a resistivity of the order of 10 ohm cm. In the original studies, the upper surface was subjected to an additional anodic oxidation in a glycol borate solution after it had been ground and etched in the usual way. The oxide is washed off and plays no direct role. It has since been found that other surface treatments are equally effective. Both tungsten and phosphor bronze points have been used. The collector point may be electrically formed by passing large currents in the reverse direction.

Each point, when connected separately with the base electrode, has characteristics similar to those of the high

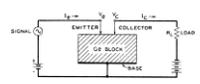


FIG. 1. Schematic of semi-conductor triode.

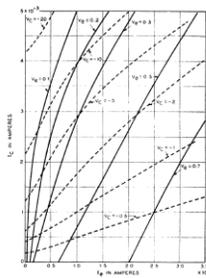


FIG. 2. Characteristics of an experimental semi-conductor triode. The currents and voltages are as indicated in Fig. 1.

back-voltage rectifier. Of critical importance for the operation of the device is the nature of the current in the forward direction. We believe, for reasons discussed in detail in the accompanying letter,² that there is a thin layer next to the surface of P-type (defect) conductivity. As a result, the current in the forward direction with respect to the block is composed in large part of holes, i.e., of carriers of sign opposite to those normally in excess in the body of the block.

When the two point contacts are placed close together on the surface and d.c. bias potentials are applied, there is a mutual influence which makes it possible to use the device to amplify a.c. signals. A circuit by which this may be accomplished is shown in Fig. 1. There is a small forward (positive) bias on the emitter, which causes a current of a few milliamperes to flow into the surface. A reverse (negative) bias is applied to the collector, large enough to make the collector current of the same order or greater than the emitter current. The sign of the collector bias is such as to attract the holes which flow from the emitter so that a large part of the emitter current flows to and enters the collector. While the collector has a high impedance for flow of electrons into the semi-conductor, there is little impedance to the flow of holes into the point. If now the emitter current is varied by a signal voltage, there will be a corresponding variation in collector current. It has been found that the flow of holes from the emitter into the collector may alter the normal current flow from the base to the collector in such a way that the change in collector

current is larger than the change in emitter current. Furthermore, the collector, being operated in the reverse direction as a rectifier, has a high impedance (10^4 to 10^6 ohms) and may be matched to a high impedance load. A large ratio of output to input voltage, of the same order as the ratio of the reverse to the forward impedance of the point, is obtained. There is a corresponding power amplification of the input signal.

The characteristics of a typical experimental unit are shown in Fig. 2. There are four variables, two currents and two voltages, with a functional relation between them. If two are specified the other two are determined. In the plot of Fig. 2 the emitter and collector currents I_e and I_c are taken as the independent variables and the corresponding voltages, V_e and V_c , measured relative to the base electrode, as the dependent variables. The conventional directions for the currents are as shown in Fig. 1. In normal operation, I_e , I_c , and V_e are positive, and V_c is negative. The emitter current, I_e , is simply related to V_e and I_c . To a close approximation:

$$I_e = \beta(V_e + R_e I_c) \quad (1)$$

where R_e is a constant independent of bias. The interpretation is that the collector current lowers the potential of the surface in the vicinity of the emitter by $R_e I_c$, and thus increases the effective bias voltage on the emitter by an equivalent amount. The term $R_e I_c$ represents a positive feedback, which under some operating conditions is sufficient to cause instability.

The current amplification factor is defined as

$$\alpha = \partial I_c / \partial I_e \text{ at constant } V_e$$

This factor depends on the operating bias. For the unit shown in Fig. 2, α lies between one and two if $V_e < -2$.

Using the circuit of Fig. 1, power gains of over 20 db. have been obtained. Units have been operated as amplifiers at frequencies up to 100 Mc.

We wish to acknowledge our debt to W. Shockley for initiating and directing the research program that led to the discovery on which this development is based. We are also indebted to many other of our colleagues at these Laboratories for material assistance and valuable suggestions.

¹ While the effect has been found with both silicon and germanium, we describe the germanium version. The germanium was furnished by J. H. Sault and H. C. Thompson, a method of preparation and purification on which they are U. S. Patent 2,462,800, issued to General Electric Company, Inc., New York, New York, 1949, Class. 12.
² The surface treatment is due to Dr. G. L. Gilmer, University of Bell Telephone Laboratories, now at Los Alamos Scientific Laboratory.
* W. H. Brattain and J. Bardeen, *Phys. Rev.*, this issue.

Nature of the Forward Current in Germanium Point Contacts

W. H. BRATTAIN AND J. BARDEEN
Bell Telephone Laboratories, Murray Hill, New Jersey
June 25, 1948

THE forward current in germanium high back-voltage rectifiers is much larger than that estimated from the formula for the spreading resistance, R_s , in a medium

of uniform resistivity, ρ . For a contact of diameter d ,

$$R_s = \rho / 2d.$$

Taking as typical values $\rho = 10$ ohm cm and $d = 0.025$ cm, the formula gives $R_s = 2000$ ohms. Actually the forward current at one volt may be as large as 5 to 10 ma, and the differential resistance is not more than a few hundred ohms. Bray¹ has attempted to account for this discrepancy by assuming that the resistivity decreases with increasing field, and has made tests to observe such an effect.

In connection with the development of the semi-conductor triode discussed in the preceding letter² the nature of the excess conductivity has been investigated by means of probe measurements of the potential in the vicinity of the point. Measurements were made on the plane surface of a thick block. Various surface treatments, such as anodizing, oxidizing, and sand blasting were used in different tests, in addition to the etch customarily employed in the preparation of rectifiers.

The potential, $F(r)$, at a distance r from a point carrying a current, I , is measured relative to a large area low resistance contact at the base. In Fig. 1 we have plotted some typical data for a surface prepared by grinding and etching, and then oxidizing in air at 500°C for one hour. The ordinate is $2\pi r^2 \rho I / V$ which for a body of uniform resistivity, ρ , should be a constant equal in magnitude to ρ . Actually it is found that the ratio is much less than ρ at small distances from the point, and increases with r , approaching the value ρ asymptotically at large distances. The departure from the constant value indicates an excess conductivity in the neighborhood of the point.

The manner in which the excess conductivity varies with current indicates that two components are involved. One ohmic and is represented by the upper curve of Fig. 1 which applies for reverse (negative) currents and for small forward currents. This component is attributed to a thin conducting layer on the surface which is believed to be P-type (i.e., of opposite type to that of the block). A layer with a surface conductivity of 0.02 mho is sufficient to account for the departure of the upper curve from a constant value. The second component of the excess conductivity increases with increasing forward current, and

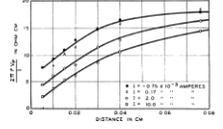
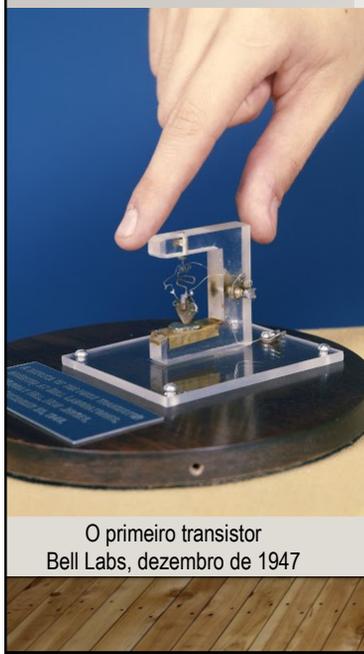


FIG. 1. Measurements of potential, V_c , at a distance r from a point contact through which a current, I , is flowing into a germanium surface.

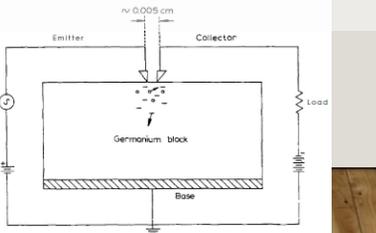
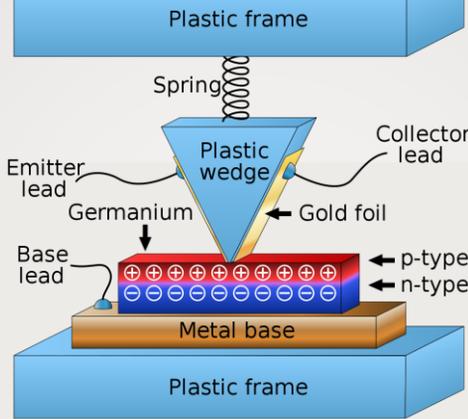
O primeiro artigo técnico onde a palavra transistor foi mencionada tem como autores BARDEEN & BRATTAIN (não contém o nome de Shockley...)

Phys. Rev. 74, p230-p231 – Published 15 July 1948

O Transistor



O primeiro transistor
Bell Labs, dezembro de 1947



Dr. William Shockley, who directed the research, Dr. John Bardeen, who developed the theory, and Dr. W. H. Brattain, whose equipment realized it, observe operation of Transistor.

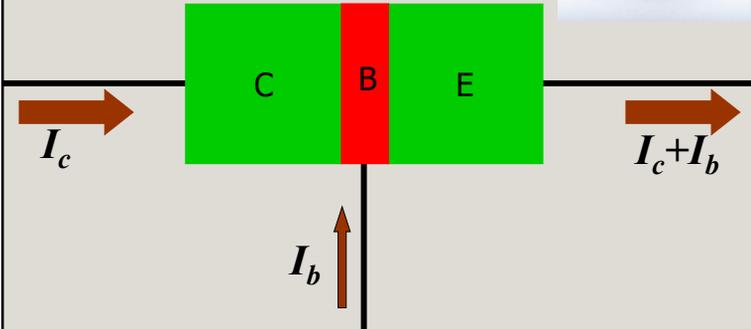
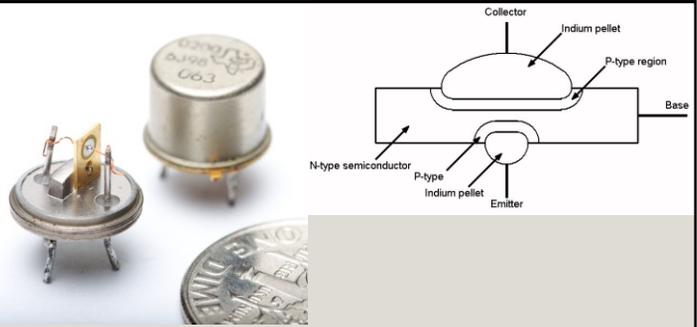
The TRANSISTOR—A Crystal Triode

Germanium crystal with two cat-whisker contacts has characteristics of grounded-grid triode amplifier, provides 20 db gain, 25 milliwatts output at frequencies up to 10 megacycles. It will replace vacuum tubes in many applications and open new fields for electronics.

Bardeen, Brattain & Shockley
(1956: Prêmio Nobel de Física)

O transistor:

- *transfer resistor*
- Dispositivo de chaveamento da corrente elétrica
- Dimensões reduzidas em relação às válvulas eletrônicas



Uma pequena corrente possibilita o controle de uma grande corrente!

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A partir de 1950 os transistores de germânio começaram a ser produzidos em série pela Western Electric, braço industrial da AT&T, em Allentown. Esta fábrica havia sido projetada para a produção de válvulas e teve uma parte adaptada para a fabricação de transistores.

No entanto, no início os transistores eram somente destinados a uso próprio em equipamentos de telecomunicações da própria Western Electric. Nos raros casos em que eram comercializados, a Western Electric cobrava de US\$16 a US\$25 por cada transistor.

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OS PRIMEIROS TRANSISTORES

1952: A *Western Electric* inicia o licenciamento da fabricação de transistores a empresas interessadas

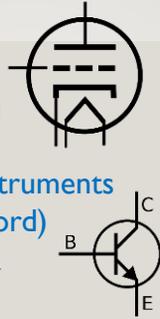
Licença: US\$ 25 mil

Curso de 9 dias

1ª turma 1952: 40 empresas



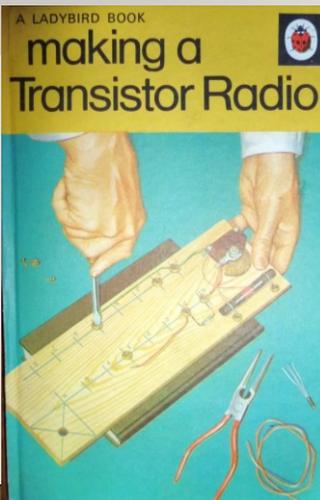
- RCA
- GE
- Raytheon
- Sylvania
- Texas Instruments
- Philco (Ford)
- Motorola
-



OS PRIMEIROS TRANSISTORES



Transistor OC71 fabricado em 1954 pela Mullard Ltd na Inglaterra



Capacitors
Two metal plates near each other but not in contact form a capacitor and can store a charge [45]. If we connect a voltage to X-X a deficiency of electrons arises at one plate, and a surplus at the other. Electrostatic stress arises in the insulating space between plates. The capacitor is 'charged' with a power depending on 'capacity' or charge-storing ability. Unit of capacitance = farad (F).
If X-X are joined together, the capacitor gives up its charge. We can increase the capacity to hold a charge by placing the plates nearer each other, and in other ways. The insulation between plates is the 'dielectric'. Capacitors are made with mica and ceramic insulation, or foil rolled up with insulating paper and in a tube [46]. Or metallic conductors may be deposited on an insulator.
'Electrolytic' capacitors are so made that an applied voltage must be of the correct polarity. These capacitors are of some set value and are called 'fixed capacitors'.
We may need to change the capacitance at any time and

45 A fixed capacitor

46 Some capacitors for electronic equipment

47 Variable capacitor

48 2-gang and trimmer capacitors

for this we want a 'variable capacitor'. A small variable capacitor can have one fixed plate, and one moving plate attached to a spindle [47]. Rotating the spindle changes the extent to which moving and fixed plates overlap each other, and thus alters the capacity. Capacity is least with the plates not overlapping at all.

We may wish to tune two circuits simultaneously in a radio receiver and can then use a 2-gang capacitor [48]. By having many fixed and many moving plates, the total capacity of each section can be increased. Sometimes the capacity has to be adjusted when first putting a circuit into proper working condition. A 'trimmer' is then used. It is adjusted with a screwdriver or other tool, and brings moving and fixed plates closer to increase the capacity.

CIRCUIT DIAGRAM

To Aerial

To Earpiece

To Earth

9 volt Battery (PP3) and Connector

Raytheon CK722:



- PNP germânico
- 1953: US\$ 7.60
- 1954: US\$ 3.50

A Raytheon assume a liderança mundial fabricação de transistores

- 1956: US\$ 0.99
- anúncios em revistas de eletrônica
- concurso de projetos
- à venda nas lojas RADIO SHACK



TRANSISTORS ARE IN STOCK

FOR IMMEDIATE DELIVERY IN ANY QUANTITY... AT RADIO SHACK!

Raytheon PNP germanium junction transistors are now available for the first time. Heralded as the most revolutionary device since the vacuum tube, PNP transistors are now being used in hearing aids and other units now being sold or shortly to reach the market. Every lab and technician with a future in this business should become familiar NOW with this remarkable Raytheon product!

AV. CHARACTERISTICS AT 30° C		(CK722) (150-344)
Description	CK721	CK722
Collector voltage	-1.0	-1.0
Collector current	2.0	4.0
Base current (I _b)	-1.0	-1.0
Output signal device*	50	20
Power gain**	100	20
Power output†	22	22

* At 1000 cycles per second.
† At 1000 cycles per second.

12 PARTS TO BUILD YOUR OWN EXPERIMENTAL TRANSISTOR RECEIVER, \$21.95

DESCRIBED (Pg. 35) IN THE FEBRUARY 1953 ISSUE OF RADIO & TELEVISION NEWS

IMPORTANT FACTS ABOUT TRANSISTORS

Many new uses for PNP transistors will be released in radio magazines from month to month — others will appear in your bench. We suggest that the transistors you purchase for building the Radio & Television News receiver be kept on hand for future use. Watch this, and other magazines for new circuits!

RADIO SHACK CORPORATION
167 Washington St., Boston 8, Mass.

Only 400 buys... THE SMALLEST, LIGHTEST HEARING AID IN ZENITH'S HISTORY!

ZENITH HEARING AIDS



Aparelho de Surdez Zenith, 1953
Com 3 transistores Raytheon
Preço: US\$ 100

25

O TRANSISTOR DE SILÍCIO



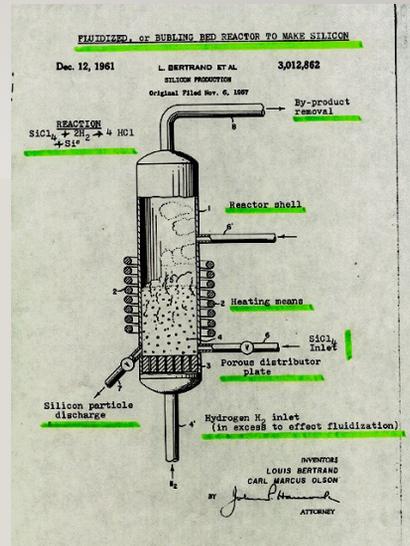
1953: Carl Marcus Olson, na empresa DuPont (EUA) consegue produzir silício em grau de pureza elevado (0,001% de impurezas).



Janeiro 1954: Morris Tanenbaum fabrica protótipos de transistores de silício no Bell Labs, com silício “grau eletrônico” fornecido pela DuPont, mas a direção da Western Electric, de forma surpreendente, não se interessa em produzi-los industrialmente.



1954: Gordon Teal, que havia pedido demissão do Bell Labs para trabalhar na Texas Instruments (Dallas, Texas, EUA) apresenta o primeiro transistor de silício disponível comercialmente.



<https://spectrum.ieee.org/tech-history/silicon-revolution/the-lost-history-of-the-transistor>

26

Texas Instruments

- 1930: *Geophysical Service*
- II Guerra Mundial: detector de submarinos por anomalia magnética
- 1951: *General Instruments* muda de nome para *Texas Instruments* (Dallas, Texas, EUA)
- 1952: TI compra a licença de fabricação do Transistor
- Gordon Teal: deixa o *Bell Labs* → emprego na *TI*
- 1953: Início da produção de transistores na *TI* (Ge): US\$ 2.50
- 1953: A empresa *DuPont* consegue produzir silício em grau de pureza elevado.
- Janeiro 1954: Morris Tanenbaum fabrica protótipos de transistores de silício no *Bell Labs*, com silício "grau eletrônico" fornecido pela *DuPont*, mas a direção da *Western Electric* não se interessa em produzi-los industrialmente
- 1954: Gordon Teal apresenta o primeiro transistor de silício disponível comercialmente
- Durante alguns anos como única empresa com tecnologia para a fabricação de transistores de silício, a *TI* assume a liderança mundial na fabricação de semicondutores (que era até então da *Raytheon*)



Instruções de montagem do transistor de silício da TI



silicon transistors now in production!

silicon transistors — long awaited by the electronics industry — are finally out of the laboratory and on the market. Brought to you first by Texas Instruments, a leading transistor manufacturer, a new and unexcelled degree of design freedom is created by the TI repair group's powerful silicon transistor, now available in production quantities with plans to meet further needs. silicon transistors radically improve temperature stability and power handling while retaining the best amplification and frequency characteristics of previous semiconductor devices.

write today for detailed information on the silicon transistor

TEXAS INSTRUMENTS
3000 LEMMON AVE., DALLAS, TEXAS

900

ELECTRONICS — JULY, 1955

27

WORLD'S FIRST POCKET RADIO

Regency

\$4.95
less battery

Uses tiny transistors . . . no bulky tubes, combines amazingly compact size, high performance

- First truly personal radio! Weighs only 12 ounces, measures 3" x 5" x 1 1/4". Slips in pocket or purse, available with leather carrying case. Genuine superheterodyne circuit; astonishingly clear tone . . . through acoustically-baffled speaker or tiny earphone. Shock-resistant, virtually service-free . . . engineered for lifetime performance. Uses standard 22 1/2 V. battery. Smart plastic case in black, ivory, mandarin red, cloud gray, mahogany or olive green. See it! Hear it! Get it!

REGENCY DIVISION, I. D. E. A. INC., INDIANAPOLIS, INDIANA

Goes anywhere . . . plays everywhere!

In tune with outdoor living!

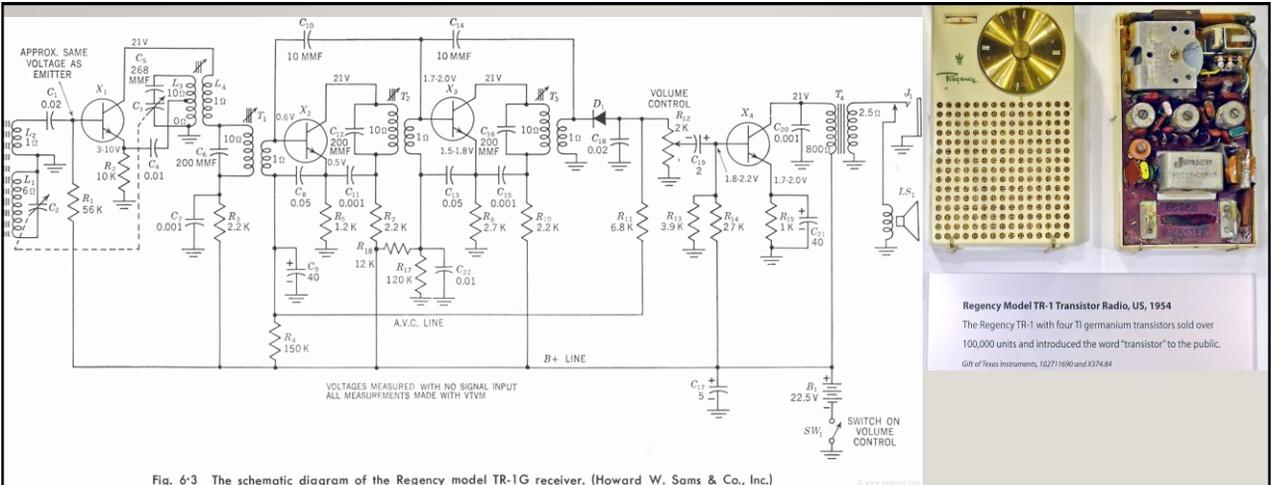
Year's most exciting new gift ideal!

ACCESSORIES

Leather carrying case has belt loop, pocket for earphone or spare battery. **\$3.95**

Feather-light earphone is no larger than a hearing aid, fastens comfortably to ear. **\$7.50**

28



Regency Model TR-1 Transistor Radio, US, 1954
The Regency TR-1 with four TI germanium transistors sold over 100,000 units and introduced the word "transistor" to the public.
Gift of Texas Instruments, 15271690 and X37484

Diagrama esquemático do circuito eletrônico do rádio portátil modelo TR-1G marca **REGENCY**. Cada rádio usava 4 transistores de germânio fabricados pela *Texas Instruments*. Apesar de ter mais de 100 mil unidades vendidas, o rádio tinha sintonia difícil, baixa qualidade de áudio e a bateria de 22,5V era cara.

<https://www.petervis.com/Radios/am-pocket-radio-solid-state/circuit-diagrams/early-pocket-radio-circuit-diagram-large-image.gif>

TRANSÍSTOR DE SILÍCIO (TEXAS INSTRUMENTS)

I. M. Ross, "The invention of the transistor," in Proceedings of the IEEE, vol. 86, no. 1, pp. 7-28, Jan. 1998, doi: 10.1109/5.658752.

Silicon Epitaxial Junction Transistor (cont.)

BAR FROM GROWN JUNCTION SILICON CRYSTAL

P-TYPE (.0005" WIDE)

PURE TIN SOLID

N-TYPE

N-TYPE

MINIMUM WIDTH .002"

SKETCH 3

INSTRUÇÕES DE MONTAGEM DO TRANSISTOR DE SILÍCIO DA TI

COLLECTOR

BASE

EMITTER

EO NO. 9614

DATE 8/5/54

silicon transistors now in production!

silicon transistors - long awaited by the electronic industry - are finally out of the laboratory and into the marketplace through the production of Texas Instruments' silicon transistor model 201. A new and unusual degree of design freedom is created by the TI silicon grown junction silicon transistor, now available in production units with plan to normal tolerance grading. Silicon transistors indicate superior temperature stability and power handling while retaining the best amplification and frequency characteristics of previous semiconductor devices.

write today for detailed information on the silicon transistor!

TEXAS INSTRUMENTS
300 LEBRON AVE. DALLAS, TEXAS

900

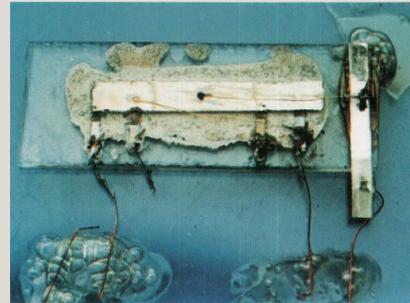
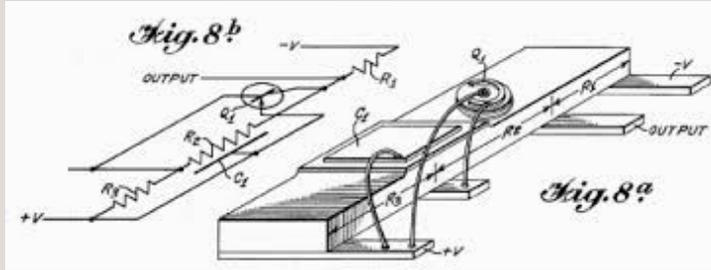
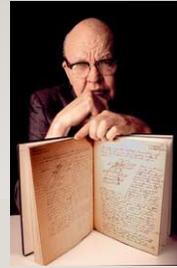
201

ELECTRONICS - June, 1954

Texas Instruments

1958: Jack Kilby

- Concepção do circuito integrado
- Fabricação experimental de um protótipo em 1959



Protótipo em Ge

- Polêmica: a Patente de Jack Kilby é mais um “system in a package”(SIP) do que um verdadeiro “circuito integrado”!

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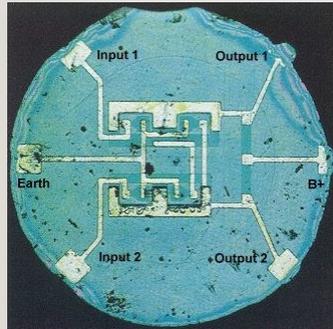
Fairchild Semiconductor

1958: Jean Hoerni: método epitaxial para fabricação de transistores

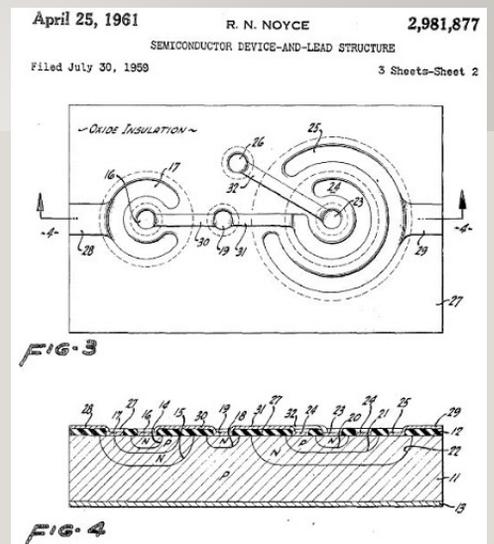
1959: Robert Noyce: circuitos integrados em Si



Robert “Bob” Noyce



1959: Primeiro CI Fairchild, com 4 transistores, em substrato de silício e fabricação epitaxial



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