

History and role of vacuum tube components: diodes, triodes and pentodes

Davide Bucci

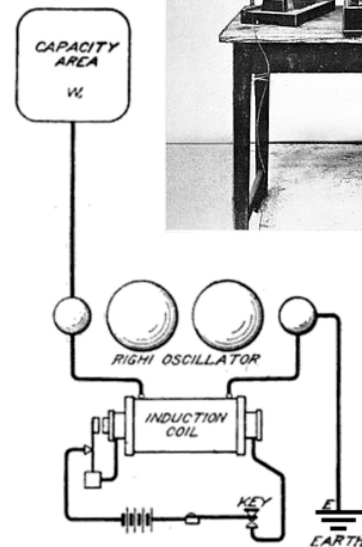
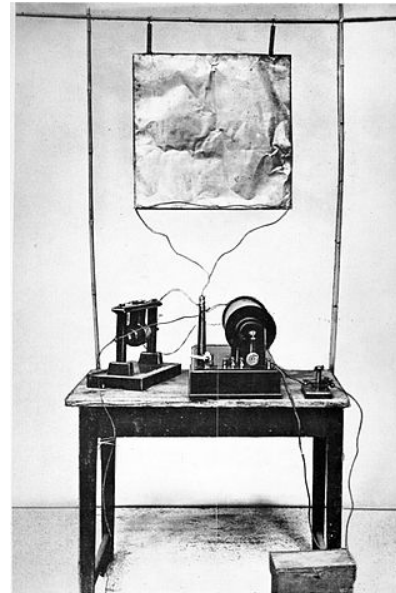


Plan

- Radio
- Vacuum diodes
 - Vintage curve tracers
 - Modern parameter analysers
- Triodes
- Pentodes
- Examples
- Conclusion

1895 Radio!

- Guglielmo Marconi (1874-1937)



But elsewhere Popov, Tesla, ...

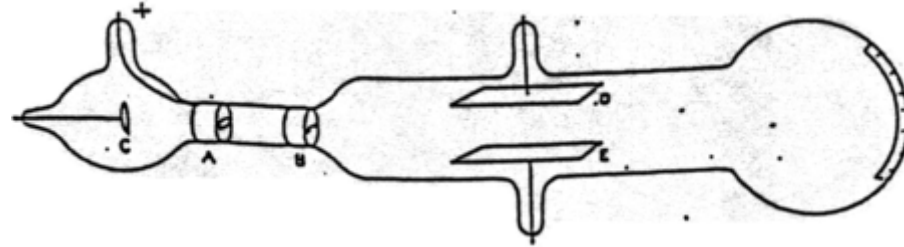
Untuned!

1897: Discovery of electron

- Joseph John Thomson
- Cathode-ray tube



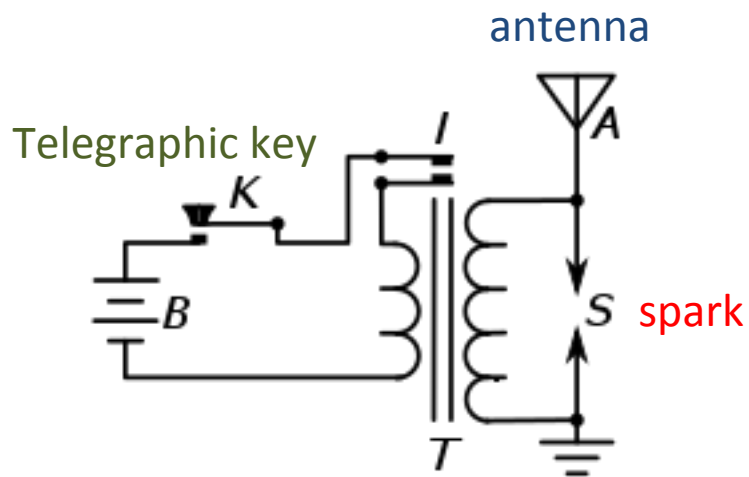
1906 Nobel prize in physics



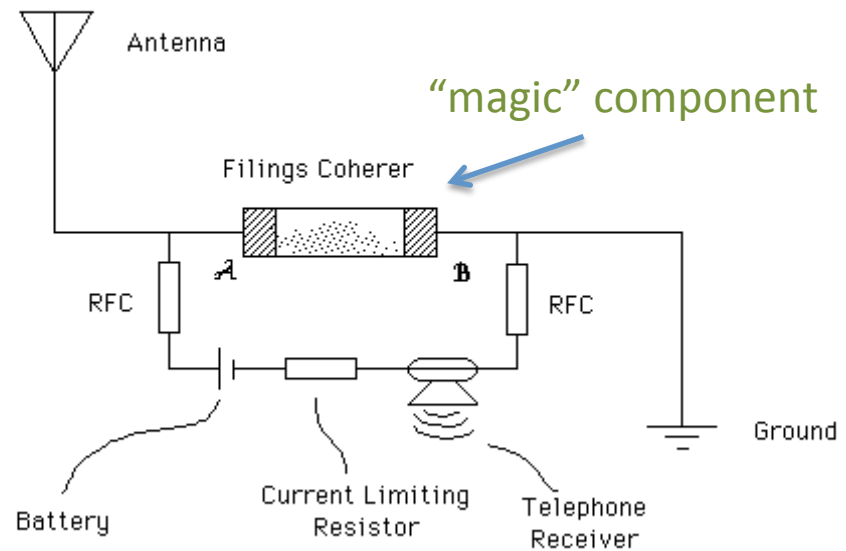
- But the term “electronics” did not exist, yet!

Radio challenges

- Create HF signals
- Modulate them (OOK)
- Radiate them efficiently
- Receive signals
- “Detect” them (rectify)
- Notify (or record)



Ruhmkorff coil



[T.M. Cuff, 1993]

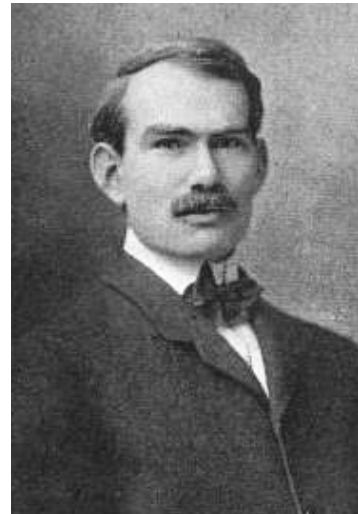
No amplification!

1901 radio trivia

- August: New York Yacht Race interference!



Lee de Forest (1873-1961)



- December: first radio transmission across the Atlantic



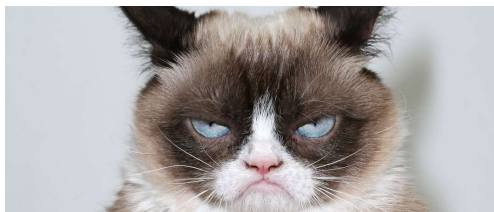
John Ambrose Fleming (1849-1945)



Marconi 1909 Nobel prize in physics

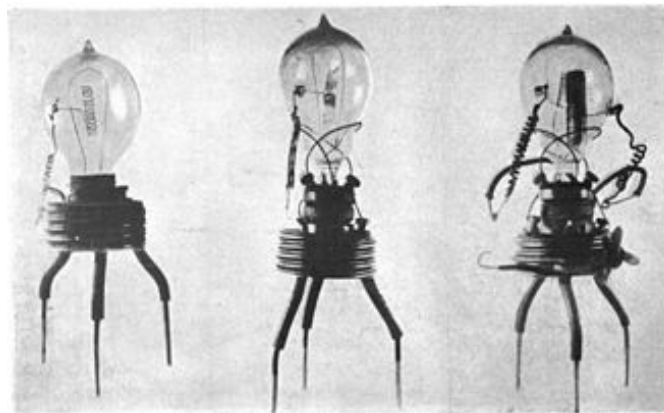
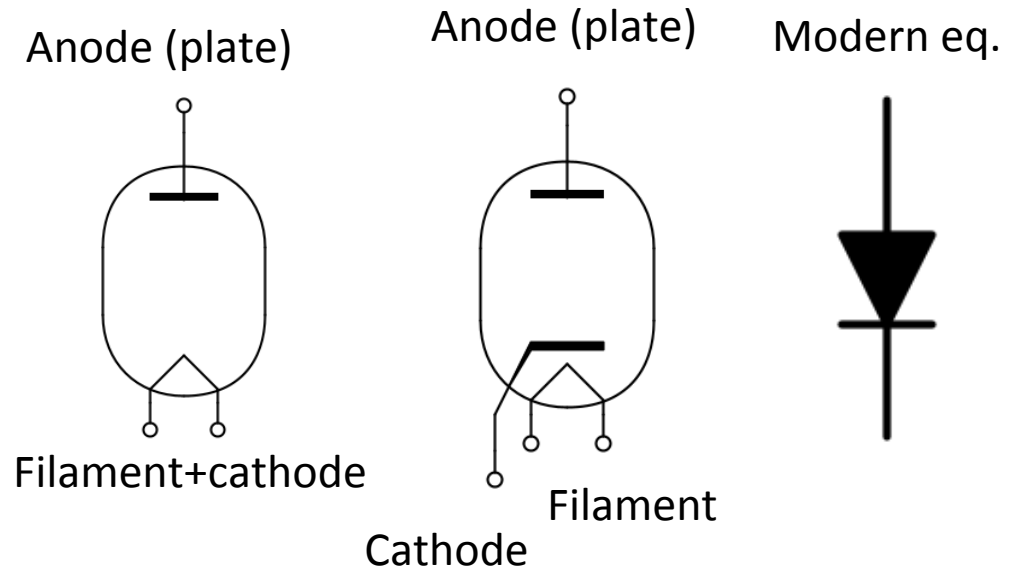
Fail!

10:58 – 13:50



1903: Fleming diode

- 1873 - Guthrie
- 1880 –Edison
- After 1897 Owen Richardson
- 1903 Fleming diode



Almost
light bulbs!

Detection, rectification

Measuring tube characteristics?

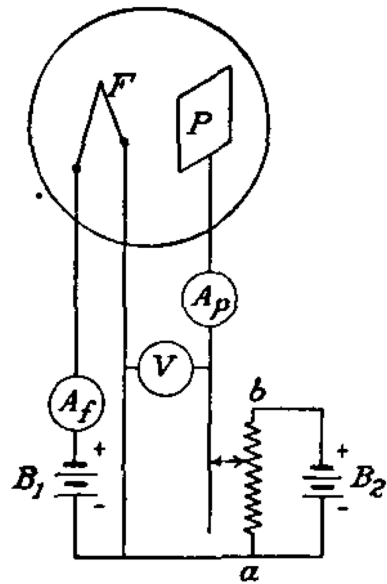


FIG. 3.—Connections for obtaining characteristics.

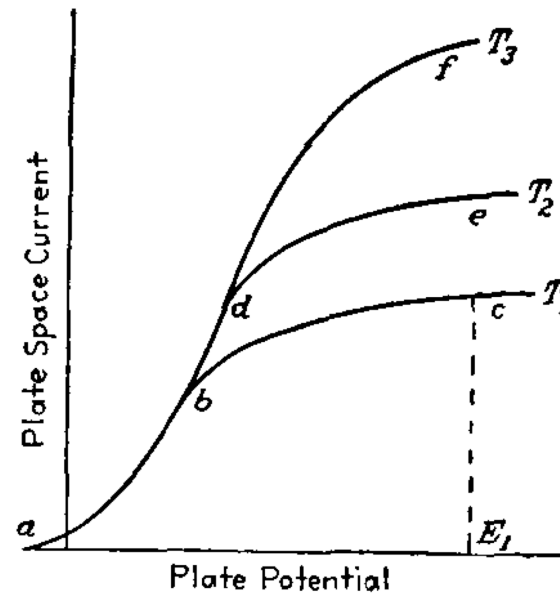
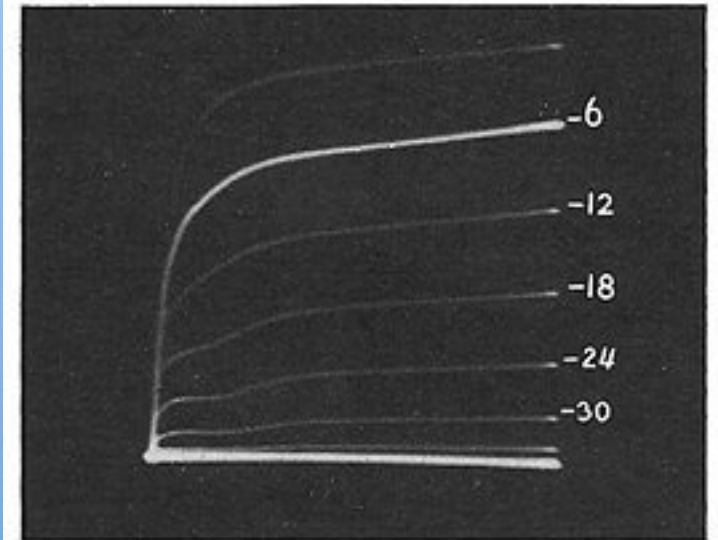
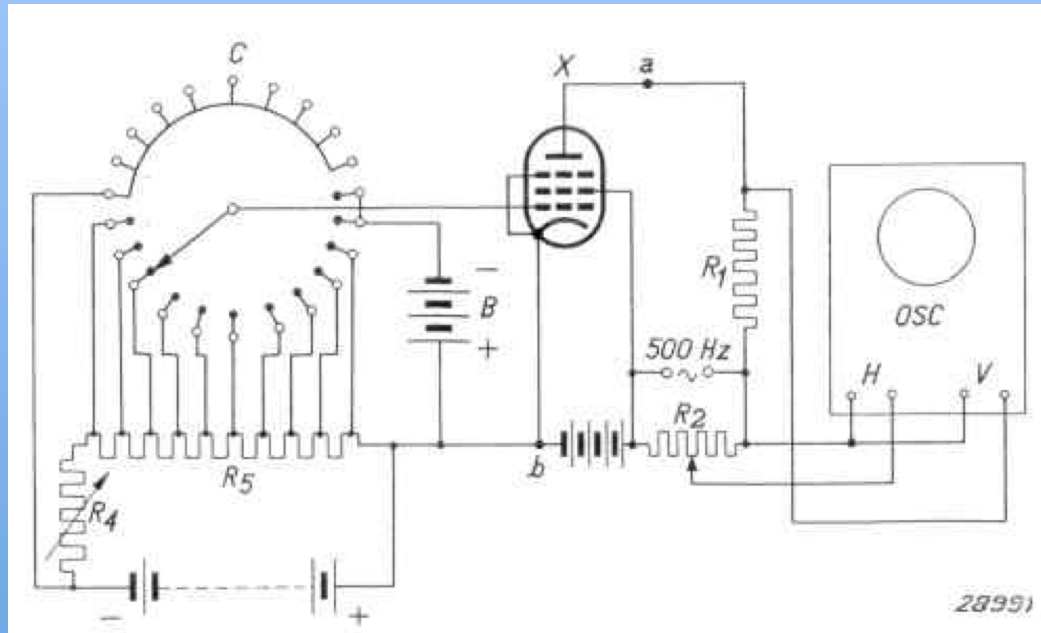


FIG. 3a.—Characteristic curves of two element tube.

Peters, Theory of thermionic vacuum tube circuits, McGraw Hill 1927

1938 the first “curve tracer”?



Philips Technical Review, November 1938

https://www.dos4ever.com/uTracerlog/PTT_1938_small.pdf

1969: transistorized curve tracers

Tek 577 (1969-1990)

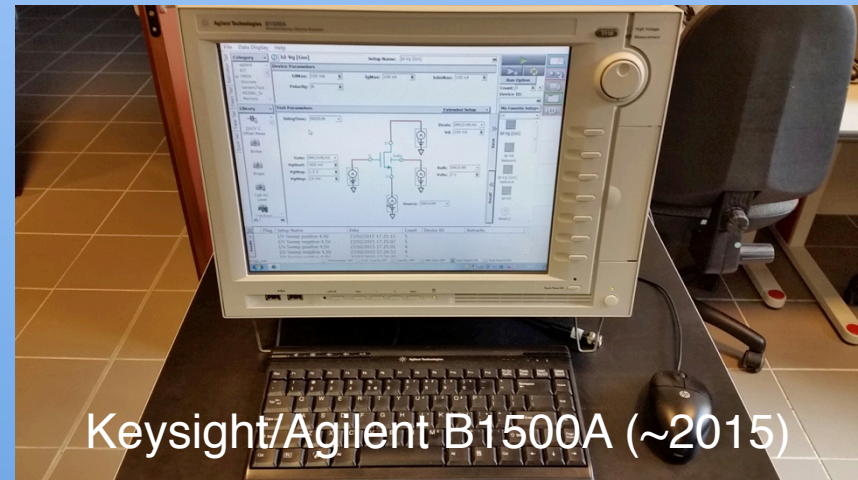
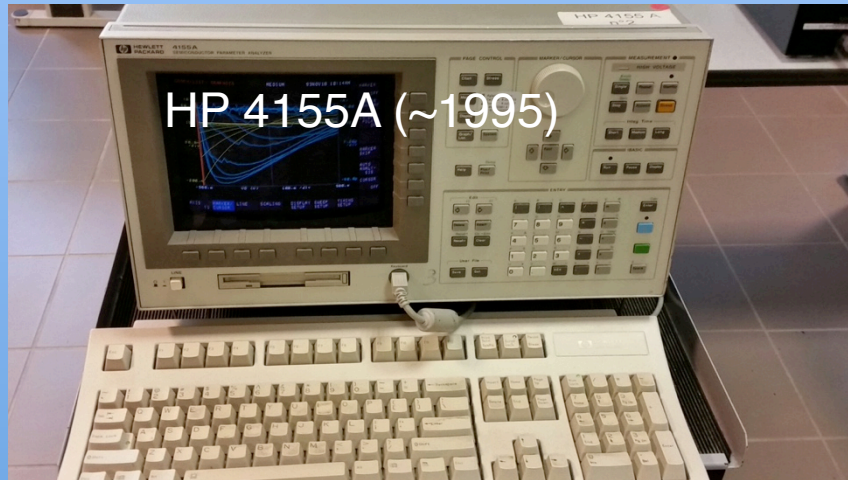


Tek 576 (1969-1990)



18:25 – 19:20

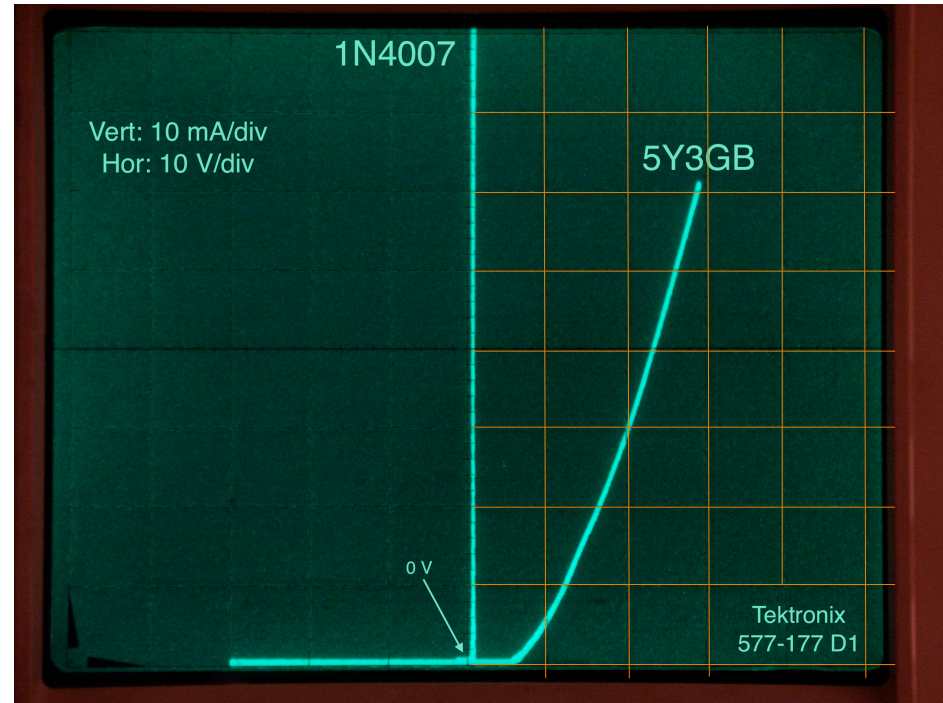
1995-today: computers and data!



Back to measuring diodes



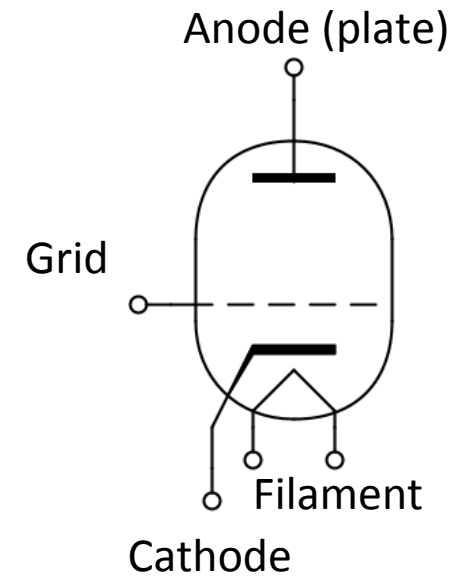
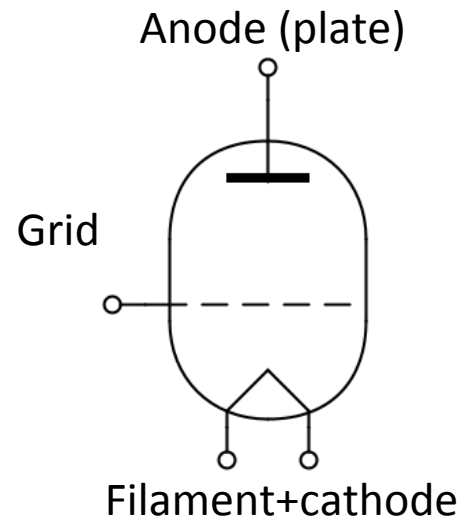
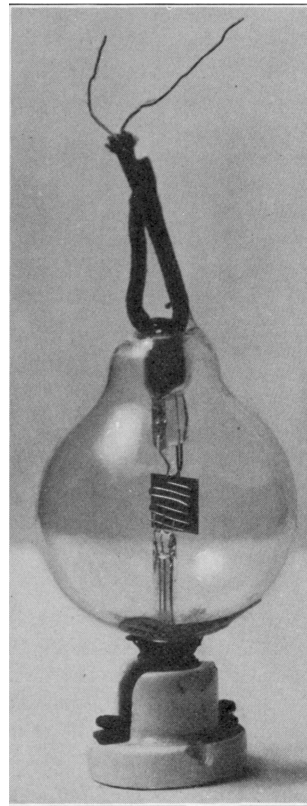
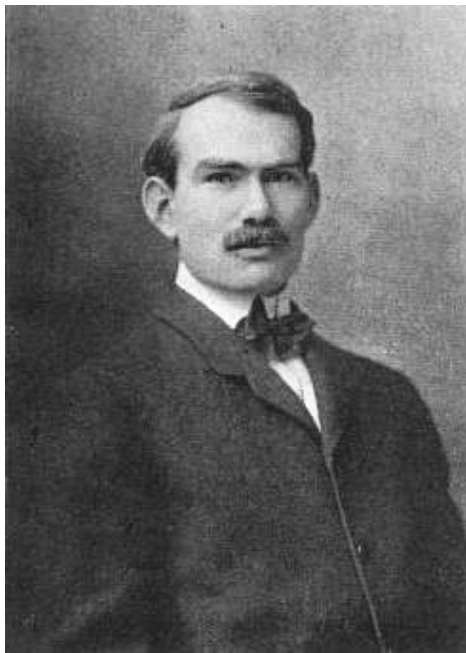
5Y3GB (1937) – full-wave rectifier
5V, 1.6A → 8W for the filament!



Forward drop: 27V for 50mA!
Compare with 0,7V for the 1n4007!

1906 Triode

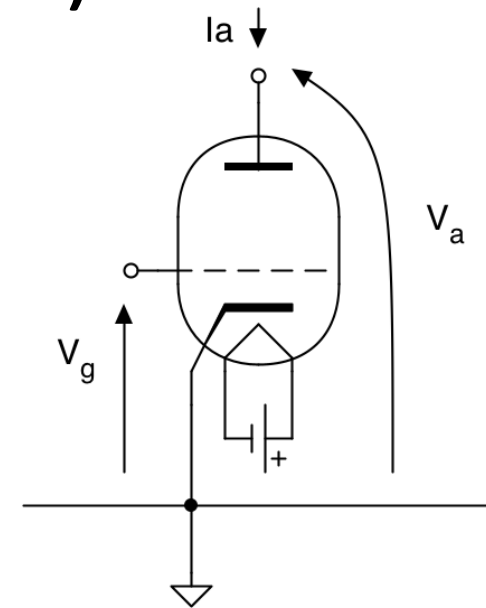
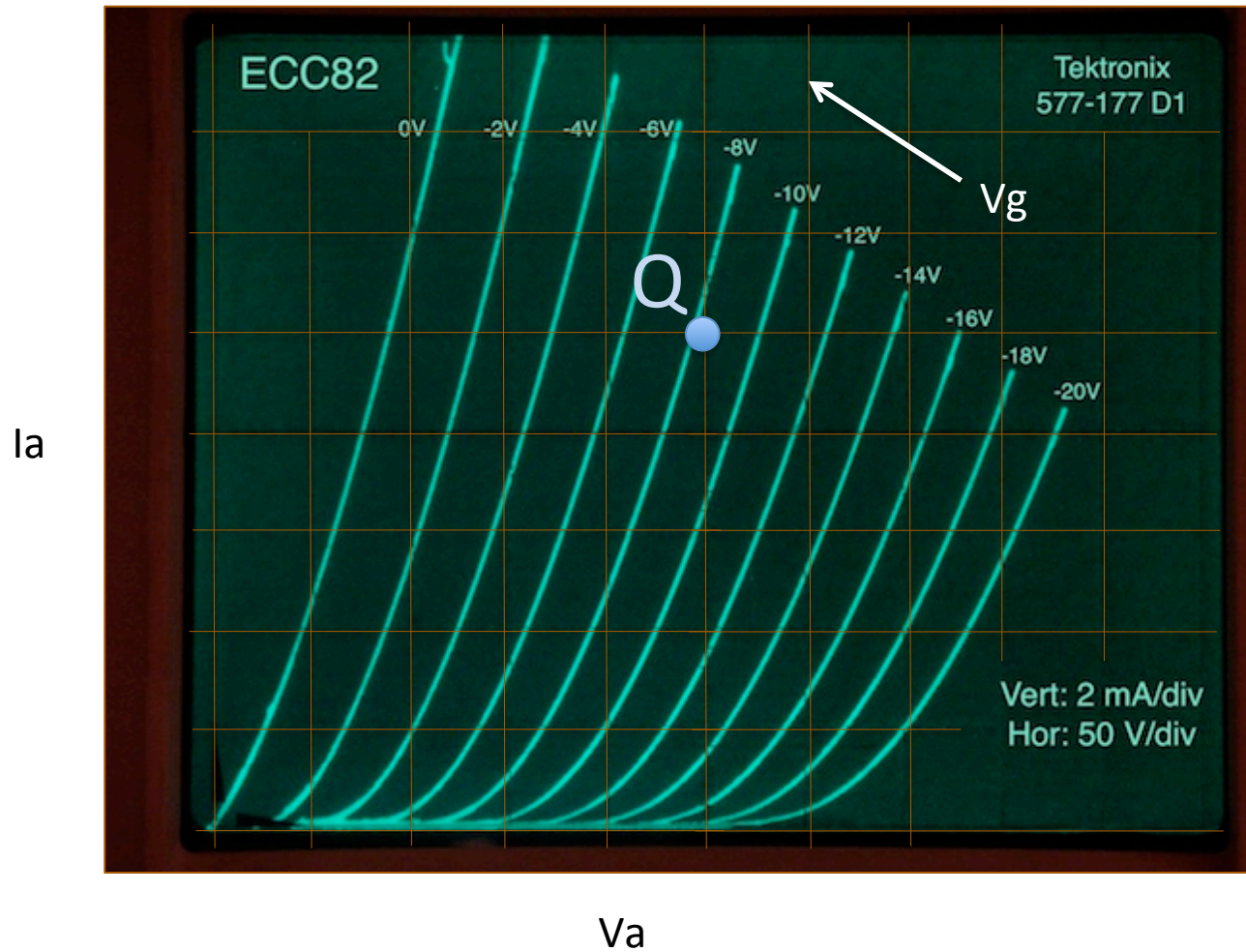
- Lee de Forest
- Audion tube



Grid: negative with respect to cathode

Amplification!
Birth of electronics

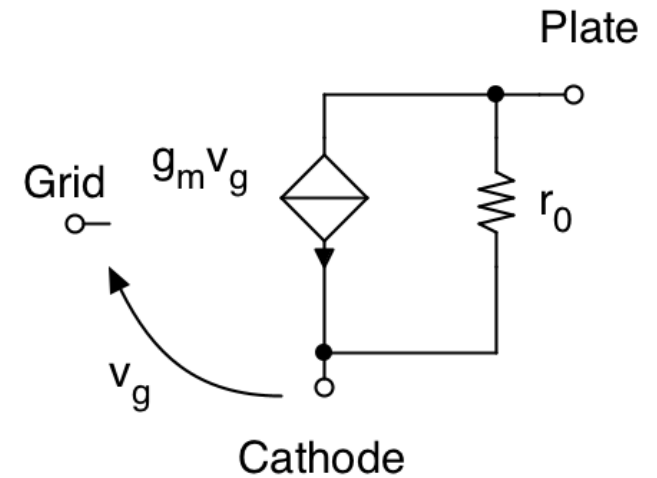
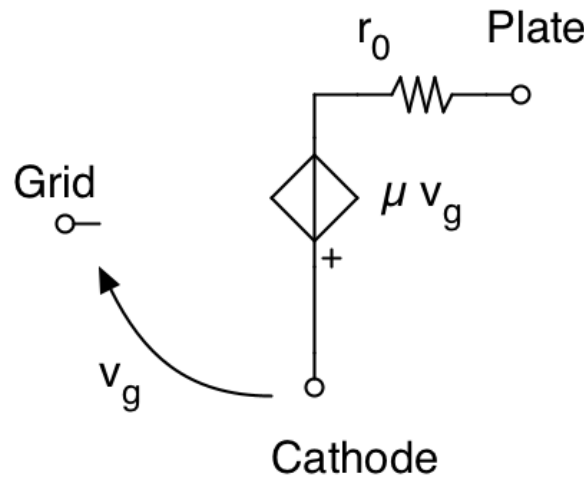
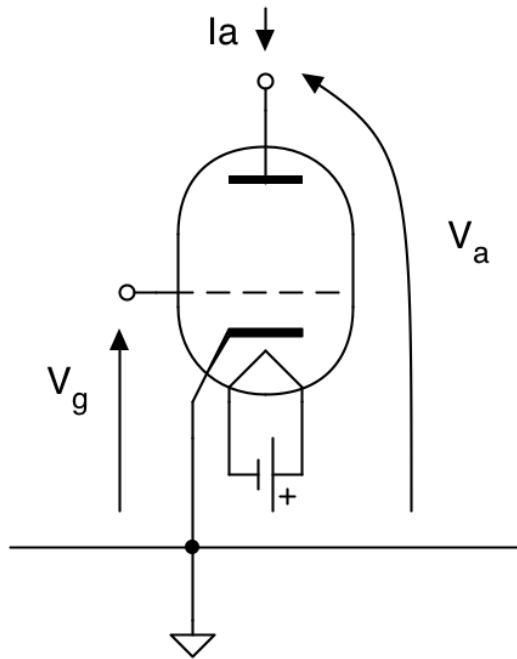
Triode curves ($\frac{1}{2}$ ECC82/12AU7)



~ Depletion N-channel
MOSFET

Q: bias point
 $V_g = -8.5V$
 $V_a = 250V$
 $I_a = 10mA$

Circuit modelling (low freq.)



½ ECC82, Q (10mA, 250V, -8.5V)
 μ : amplification factor (17)
 r_0 : internal resistance (7.74k Ω)
 g_m : transconductance (2.2mS)

$$\mu = - \left. \frac{\partial V_a}{\partial V_g} \right|_Q \quad r_0 = \left. \frac{\partial V_a}{\partial I_a} \right|_Q$$

$$g_m = \left. \frac{\partial I_a}{\partial V_g} \right|_Q$$

28:00 – 31:30

$$\frac{g_m}{I_d} = 0.22 \text{ V}^{-1} \text{ vs. } 38 \text{ V}^{-1} (\text{BJT})$$

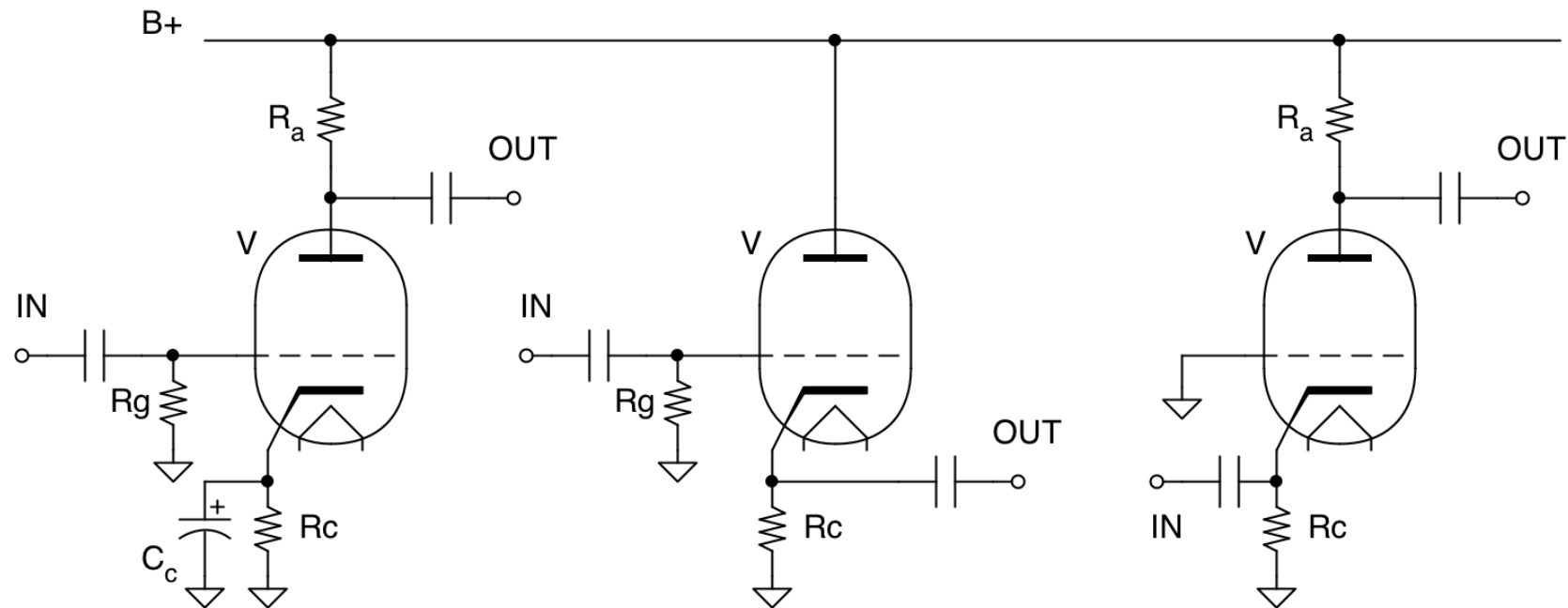
[for device physics, see W.G. Dow, 1937]

Basic (LF) amplifiers

Common cathode

Common plate

Common grid



Same as transistors, but no complementary device

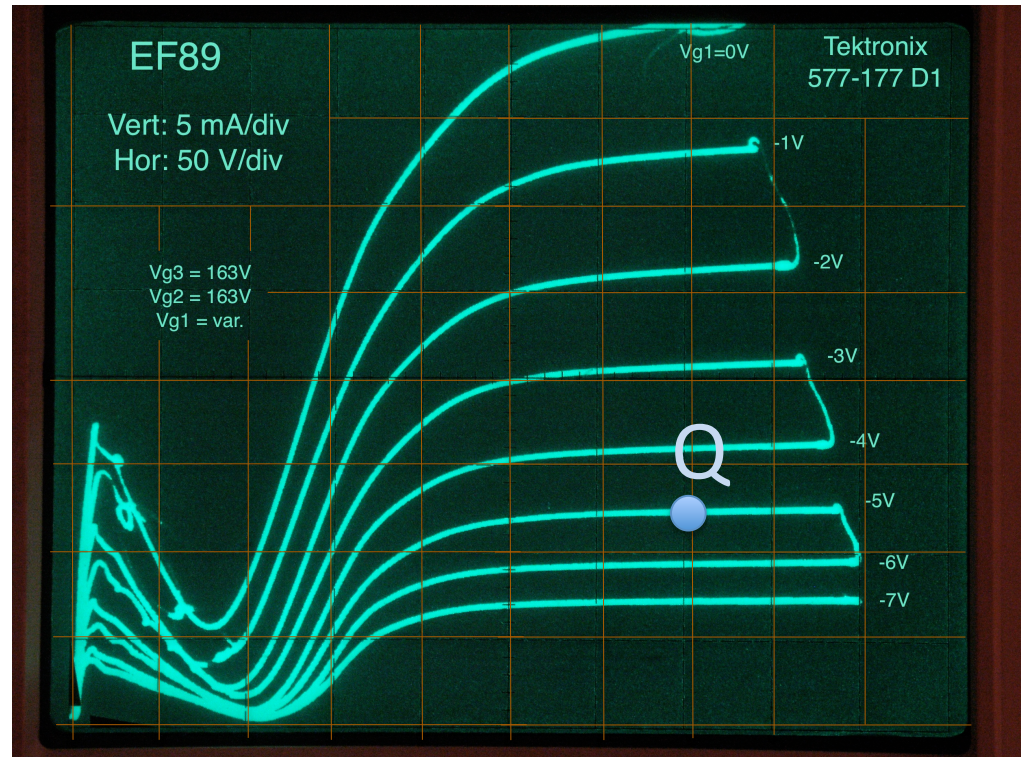
But low μ , in general

1915 Add another grid! Tetrodes



(W. Schottky
1886-1976)

- “Tetrode kink”



(a pentode in tetrode mode, not a real tetrode)

Q(350V,12.5mA,-5V) $\rightarrow g_m=2.7\text{mS}$, $r_o=150\text{k}\Omega$, $\mu=400$

(+++)

Anode (plate)

(++), fixed

Grid 2 “screen”

Grid 1 “control”

(-)

Filament

Cathode (0V)

33:20 – 36:10

1915 Add another grid! Tetrodes



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(+++)

Anode (plate)

(++), fixed

Grid 2 “screen”

Grid 1 “control”

(-)

Filament

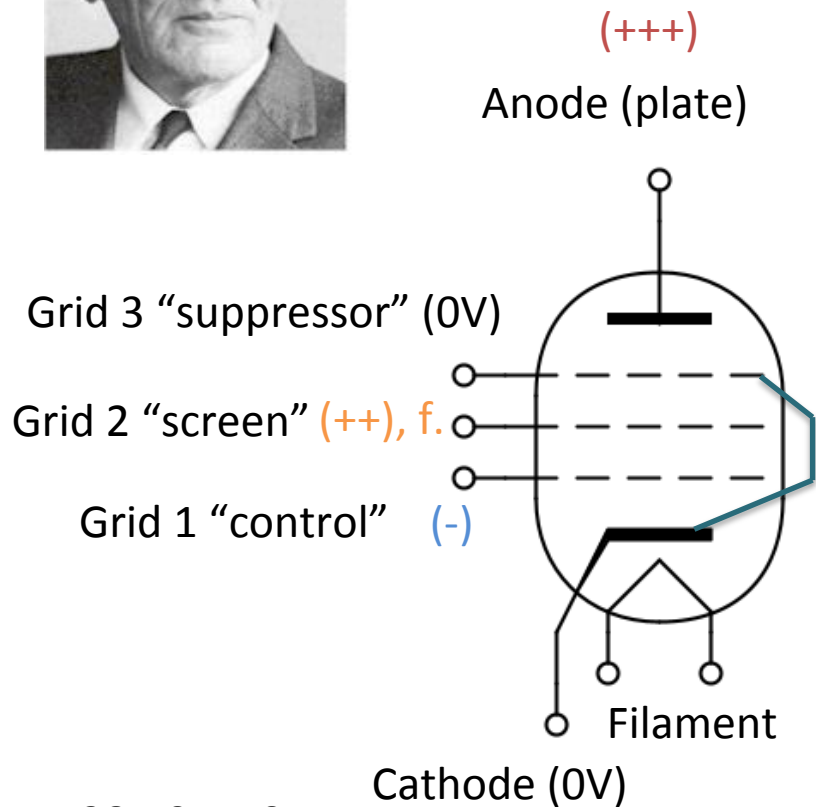
Cathode (0V)

36:10 – 38:10

1926 Pentodes!



B. D. H. Tellegen
(1900-1990)
in Philips



38:10 – 40:55

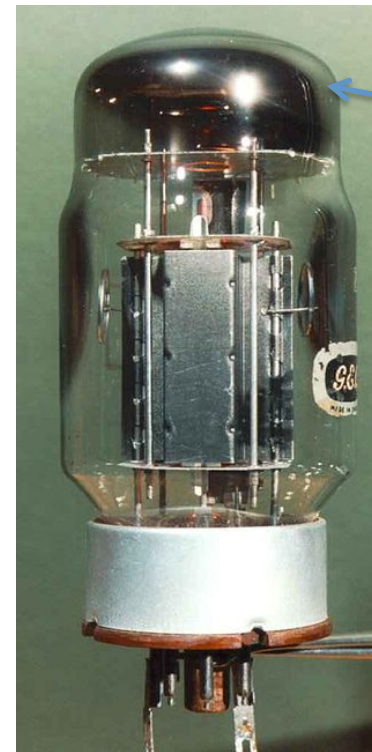


$Q(350V, 12.5mA, -1V) \rightarrow g_m = 4mS, r_0 = 350k\Omega, \mu = 1400$

The “Kinkless Tetrode”

- Problem: pentode patent was Philips’
- Solution:
shaped electrode instead
of a suppressor grid

- Example: KT88



The getter
(every vacuum
tube has this)

A.K.A “beam tetrode”

Strategic war components

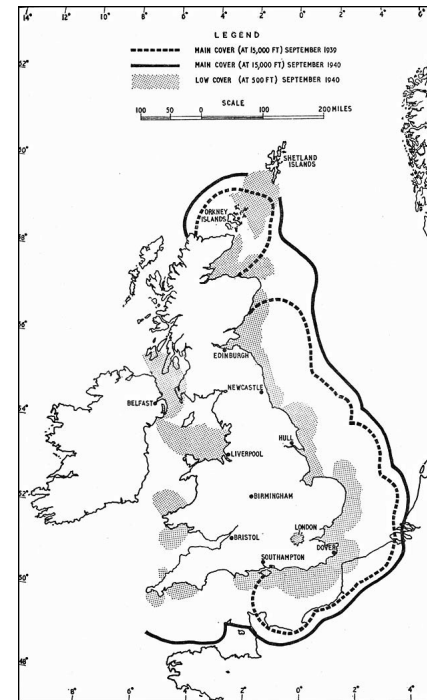
- 1939 EF50: new techniques for HF



Developed for TV sets
Used in airborne radars

May 9th, 1940: flight from
Holland

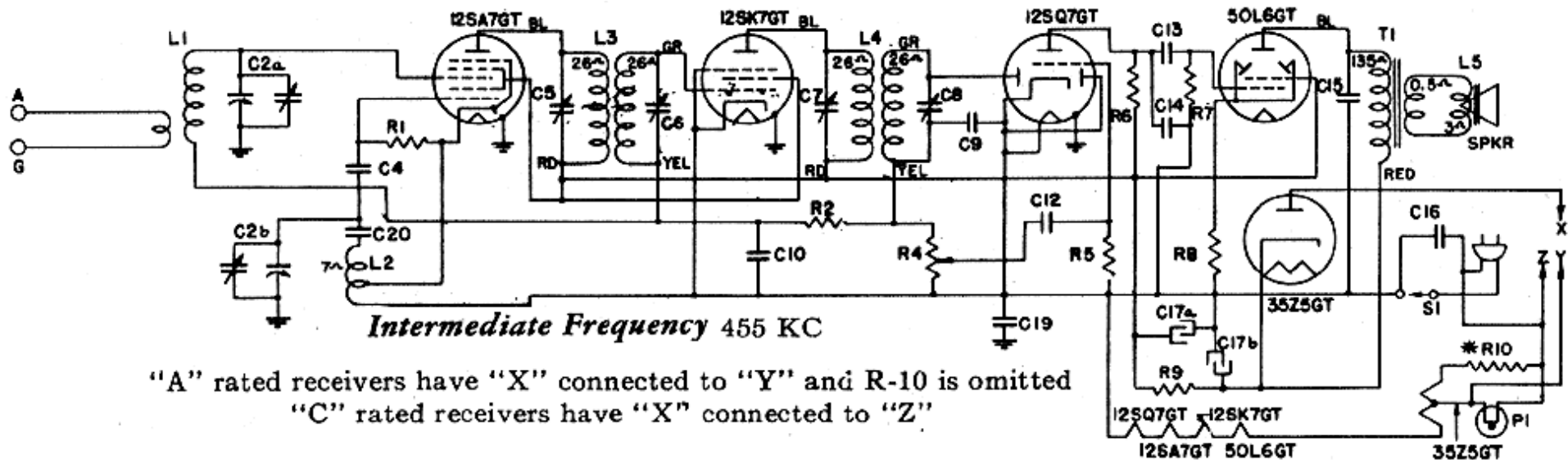
- Battle of Britain, RADAR



[R. Dekker: ["The EF50, the tube that helped to win the war"](https://www.dos4ever.com/EF50/EF50.html)
<https://www.dos4ever.com/EF50/EF50.html>]

Consumer electronics of 1939:

AA5



[<https://antiqueradios.com/chrs/journal/aa5.html>]

One rule: keep the cost DOWN!!!

- No power transformer, **live chassis**
- Multiple functions for tube (heptode, diode+triode)
- Filaments in parallel to reach mains voltage

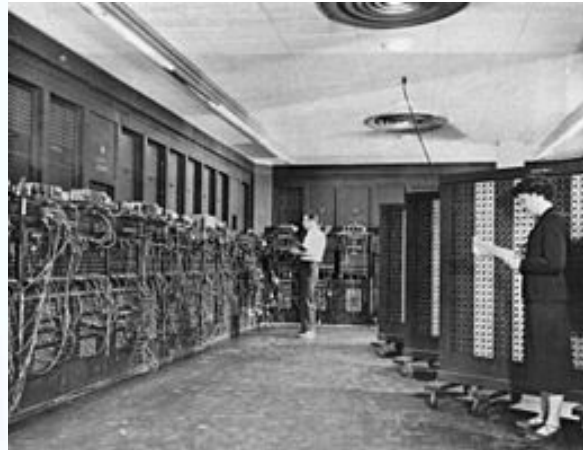


1940-1950: the peak

- OPAMP's, computers
- Radio, TV, distorted guitars!



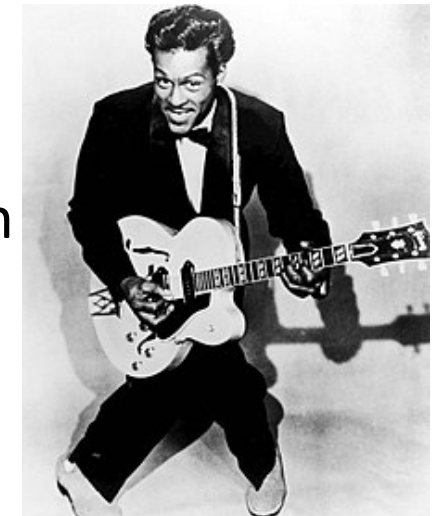
K2-W, Philbrick, 1952



ENIAC: 1945-1955

Julius Barnard
Goree Carter
Howlin' Wolf
Jackie Brenston
Chuck Berry

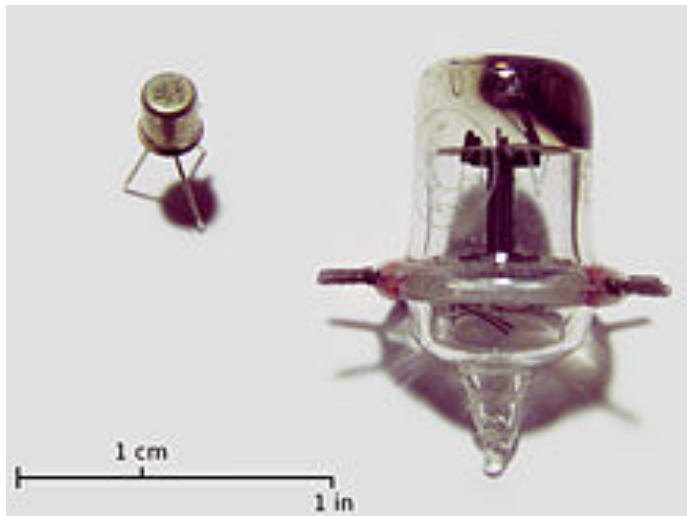
...



[<https://www.youtube.com/watch?v=iYU90XajYmU>]

1960's the decline

- Advantages of tubes
 - Rugged (electrically)
 - Well known
 - HUUUUUGE industry
 - Wide variety



53:20 – 55:20

- Advantages of transistors
 - High gain
 - Small size
 - Low cost
 - Integration!
 - Unlimited lifetime
 - High current capability at low voltages
 - No filament



1970's the end of an era



General Electric Portacolor
(1966-1978)



IMEP-LAHC

Diodes, triodes pentodes today

- Some very high power RF applications (declining)
- Still produced (Russia, China, Czech and Slovak Republics)
- Guitar amplifiers, effects
- **Circuit fun!**
- SPICE models exist
- BEWARE of magic thinking and audiophile nonsense!

Conclusion

- Diodes, triodes, pentodes
 - Real solutions for real problems
 - Tightly linked to lightbulbs until 1930's
 - Created the field of electronics
 - Paved the way for transistors

Bibliography

- Wikipedia for biographies, many pictures
- R. Dekker's website www.dos4ever.com
- L. J. Peters "Theory of Thermionic Vacuum Tubes Circuits," McGraw-Hill 1927
- L. Chaffee "Theory of Thermionic Vacuum Tubes," McGraw-Hill 1933
- W.G. Dow, "Fundamentals of Engineering Electronics," Wiley 1937