Vacuum Tube Logic

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Some Early Digital Computers

- ENIAC, 1946 18000+ tubes
- UNIVAC I, 1951 first commercial machine
- ERA 1101, 1955 most powerful scientific
- IBM 650, 1954 first > 1000 units delivered
- IBM 70x, 195x
- anything before 1959 is vacuum tubes

How was it done ?

- Lee deForest 1906 invented Triode
- Vacuum tube as digital switch / inverter
- Several tubes/diodes for OR / AND
- Theory: any digital machine can be built from
  - inverter
  - either OR or AND gate

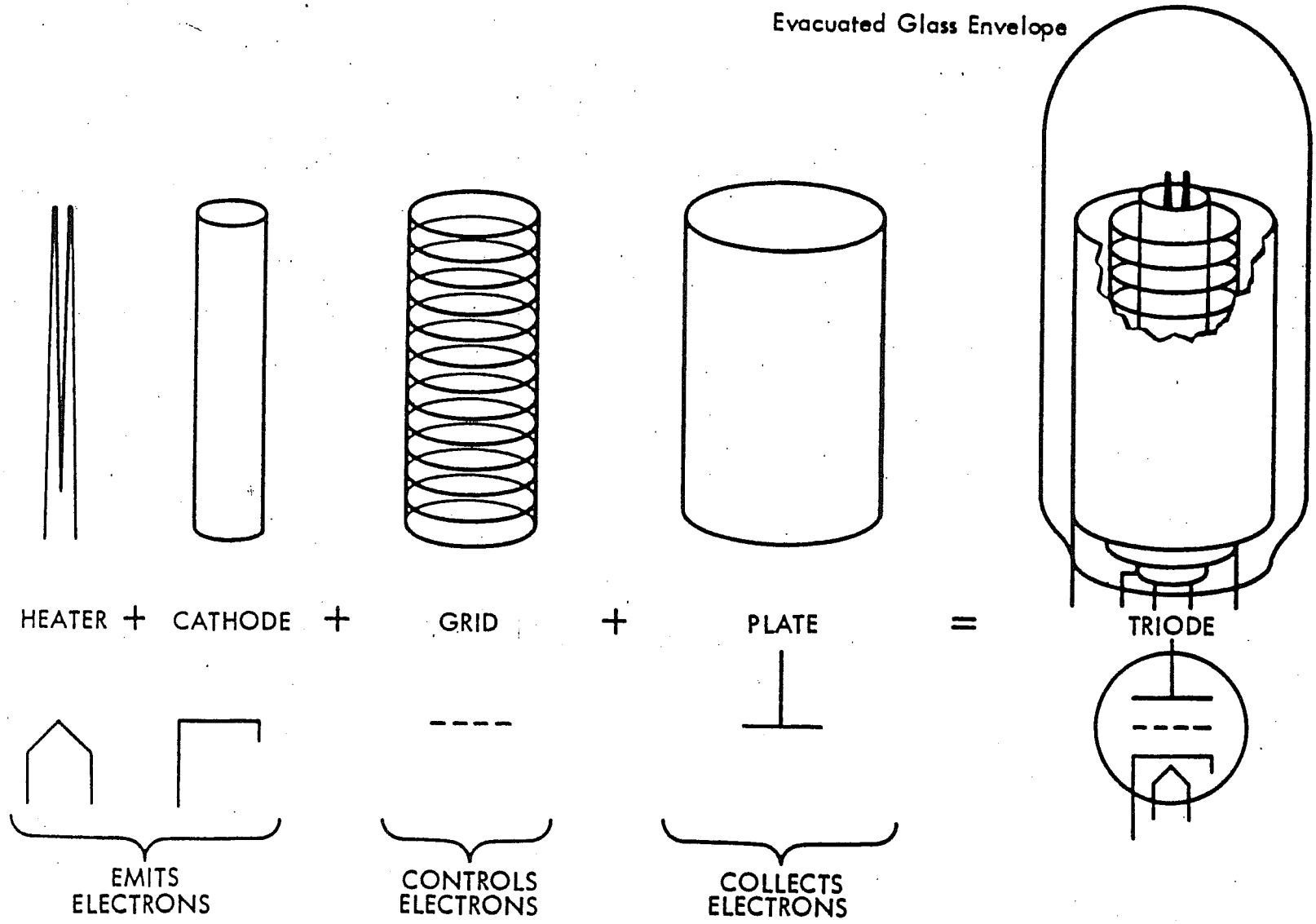


Figure 20. Development of the Triode Tube

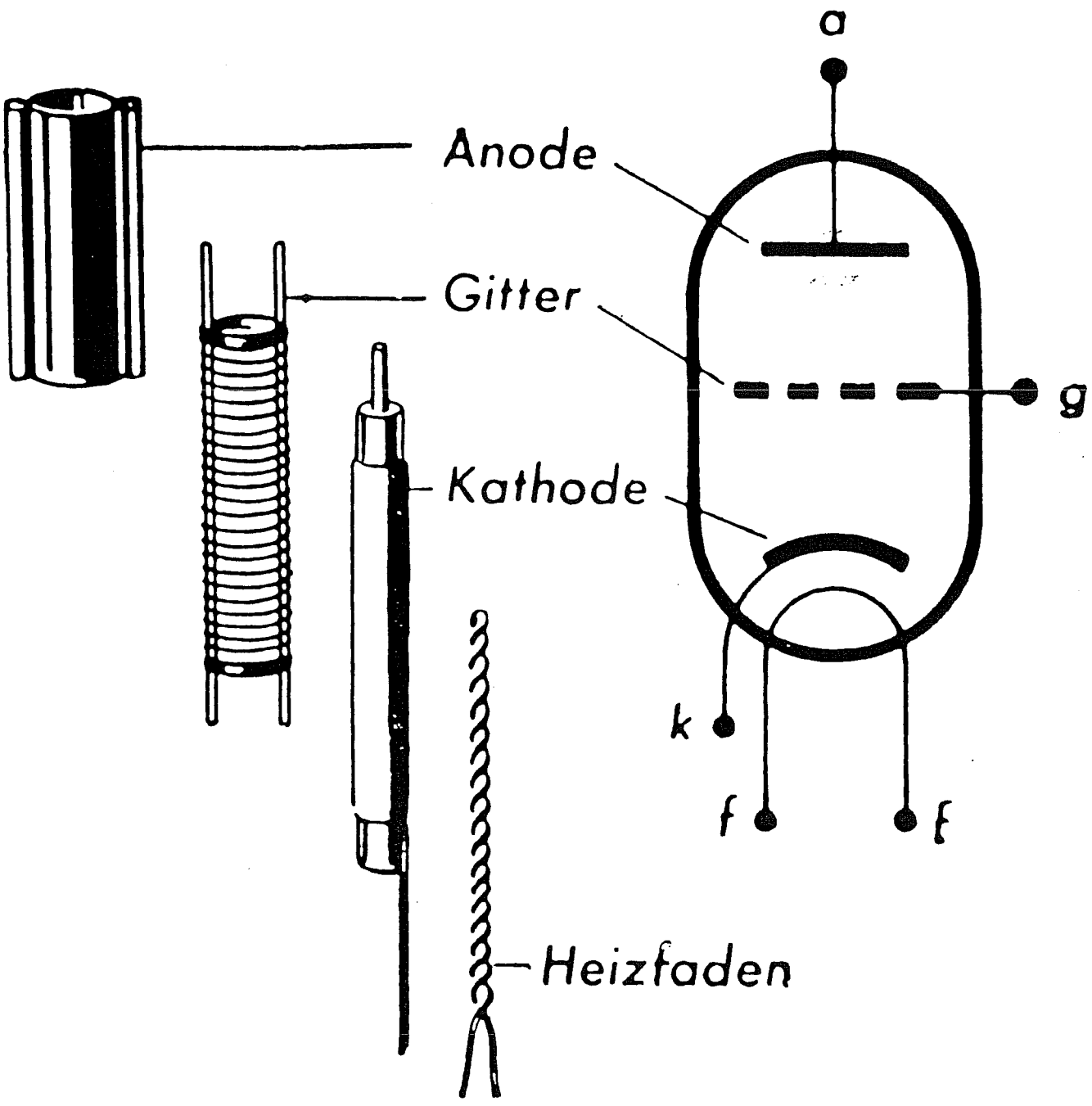
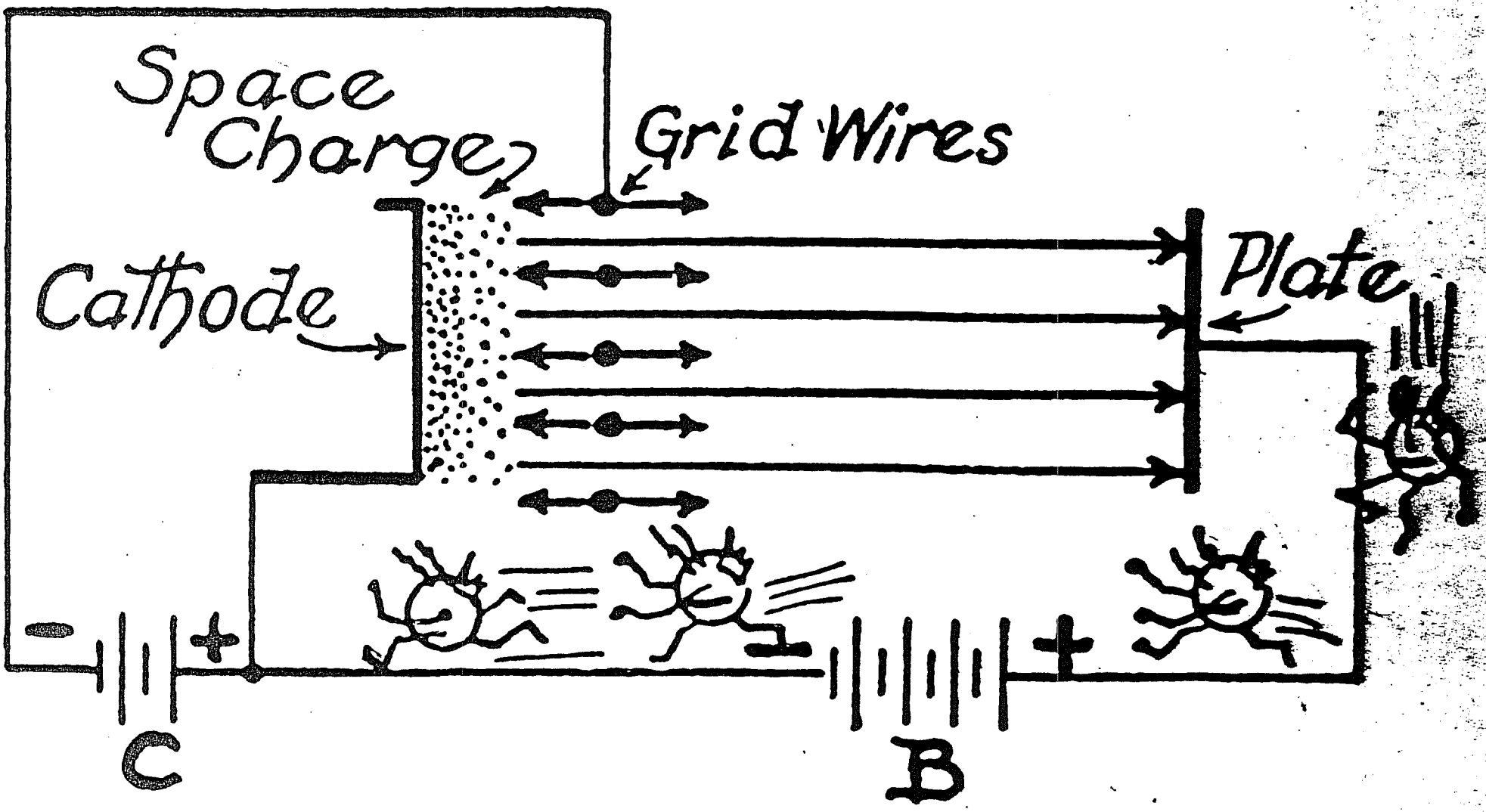
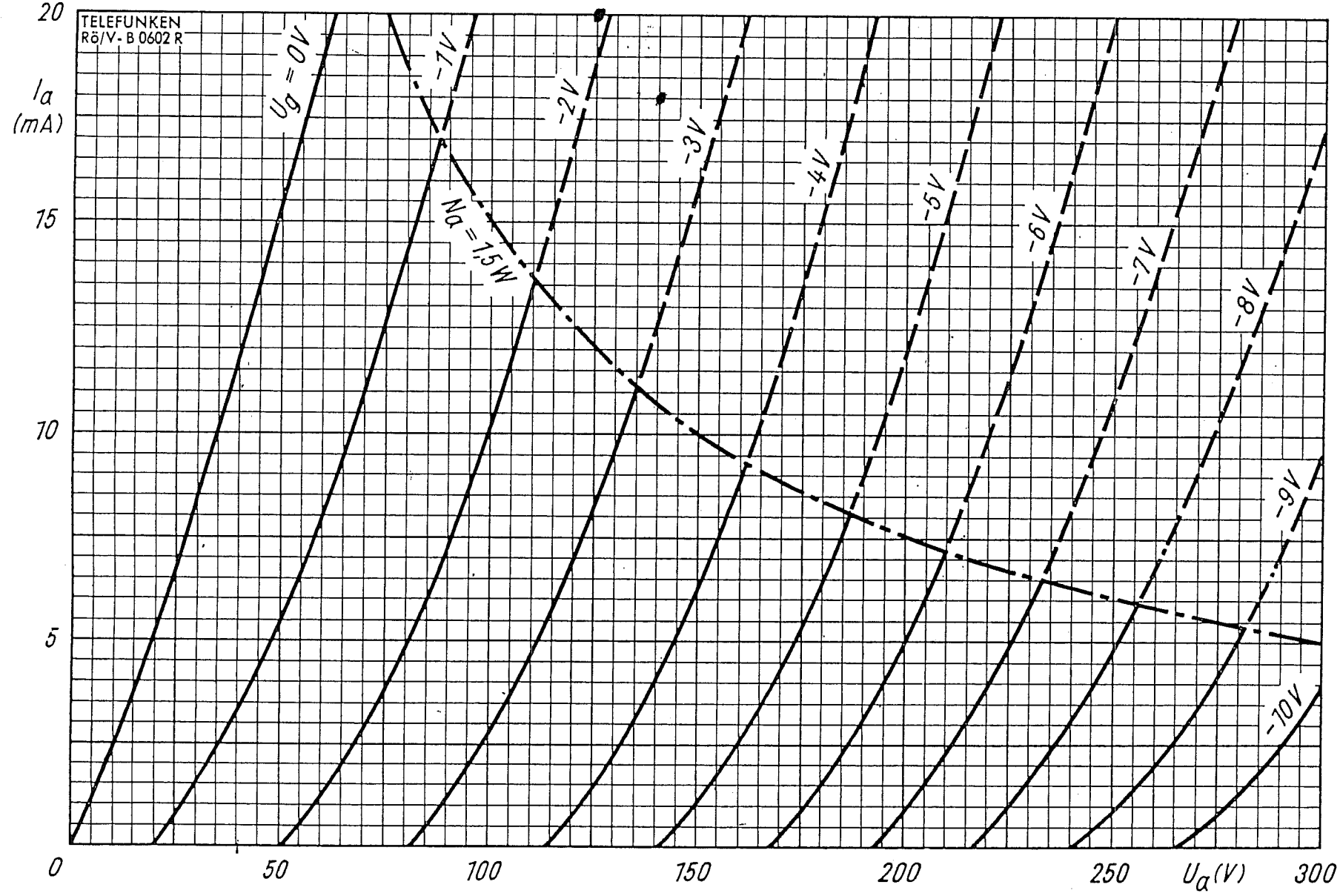


Bild 21. Schaltschema und Systemteile einer indirekt geheizten Eingitterröhre (Triode).

die jeweils abgelesenen Anodenstromwerte Ia maßstäblich über die Gitterspannung Ug aufzeichnet (Bild 24). Sie wird als IaUg-Kennlinie bezeichnet. Allerdings gilt eine solche Kennlinie nur für einen bestimmten Wert der



a direction which is *away* from the control
hich originate at each of the grid wires point



$I_a = f(U_a)$

U_g = Parameter

) the plate, electrons boiled off the cathode will
acted to the plate, as with the simple diode,
that they will now have to pass between the
f the grid wires. If a negative, repelling voltage

trons will flow through the tube a
resistor in its plate circuit, causing a
from one end of the resistor to the othe
type used in the 604, at the supply vo

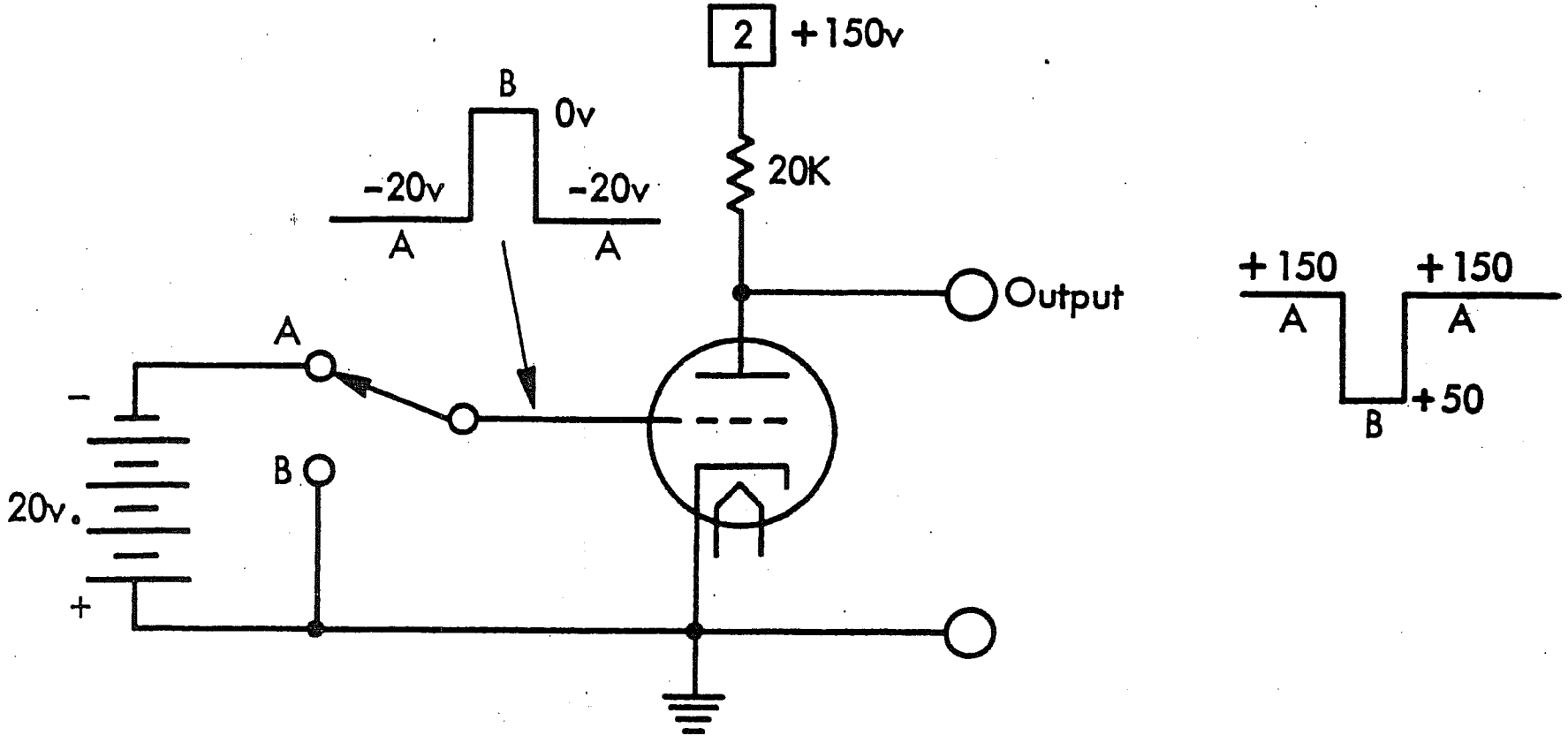
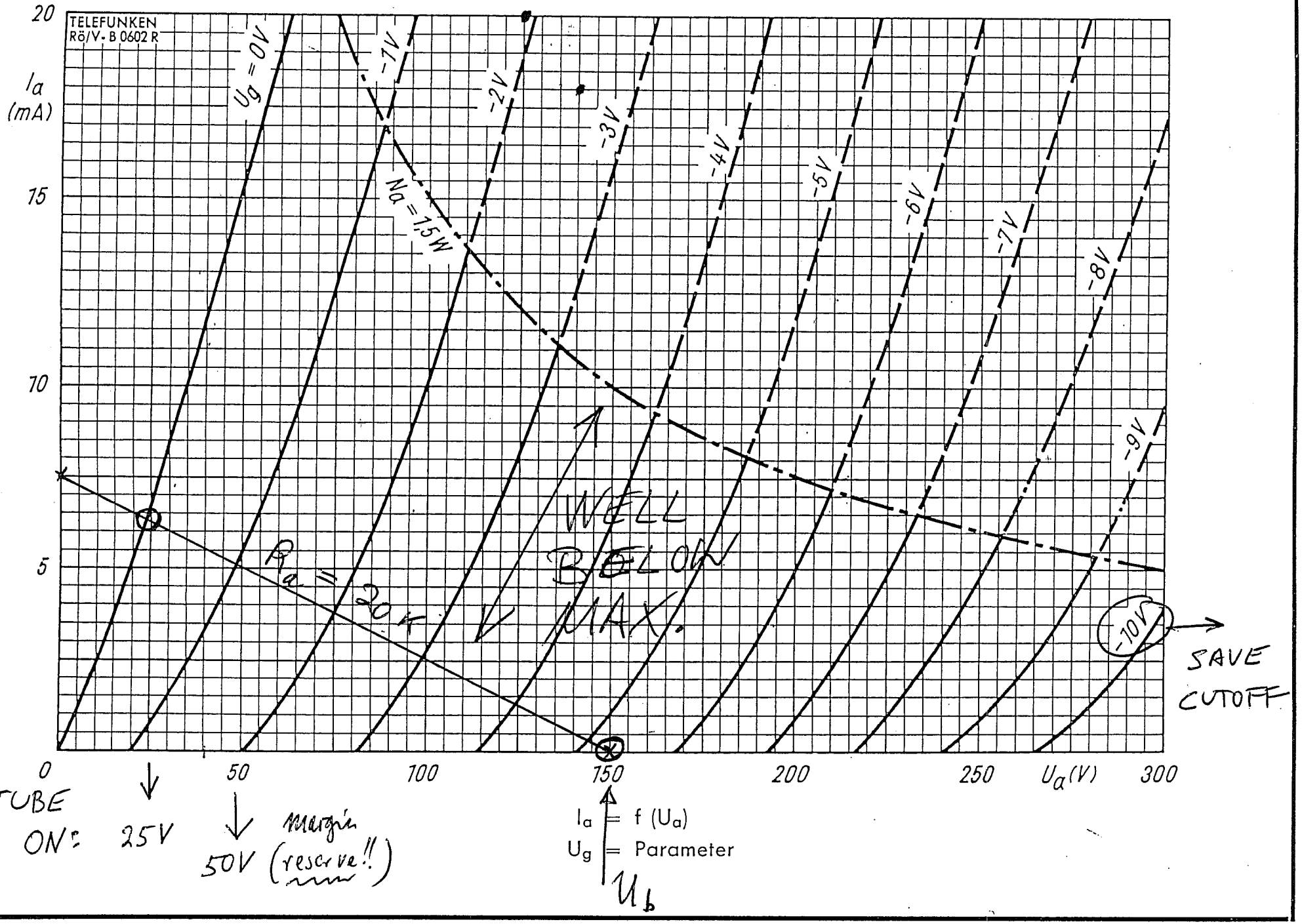


Figure 21. Basic Inverter Circuit



E88CC
CCa

TELEFUNKEN

of the tube as drawn in the manufacturers' tube basing diagrams (Figure 22 and in the Appendix). A subscript 2 is used to indicate the circuits for the right half of the tube (such as 4-7E_2).

Because almost all vacuum tubes have heaters and their presence is so widely understood, it is common practice to omit the symbol for the heater wire itself when drawing a circuit diagram. This convention will

through the 470k and 390k resistors and up thro
the 20k plate load of the driving stage, the voltag
the plate of the driving stage rests at about +140 v
with the tube cut off rather than the +150 volt l
considered earlier. Point C, the connecting point of
three grid circuit resistors, will be found to be at al
+30 volts if Ohm's law is applied to the voltage div
network. It would seem that the grid of the inve

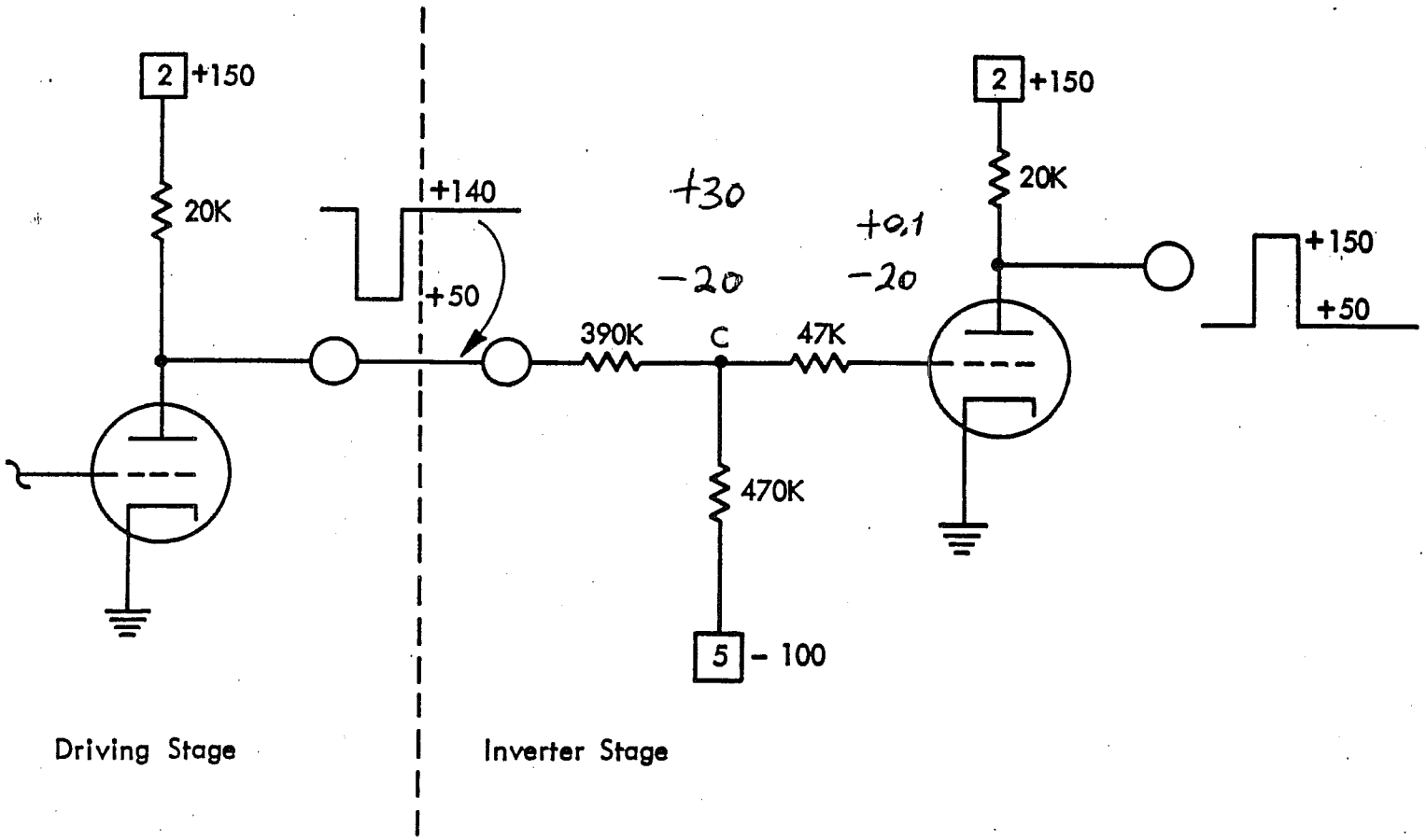


Figure 23. A Practical Inverter Circuit

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electrons
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30 volts.
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resistors,
y drawn.
nt could

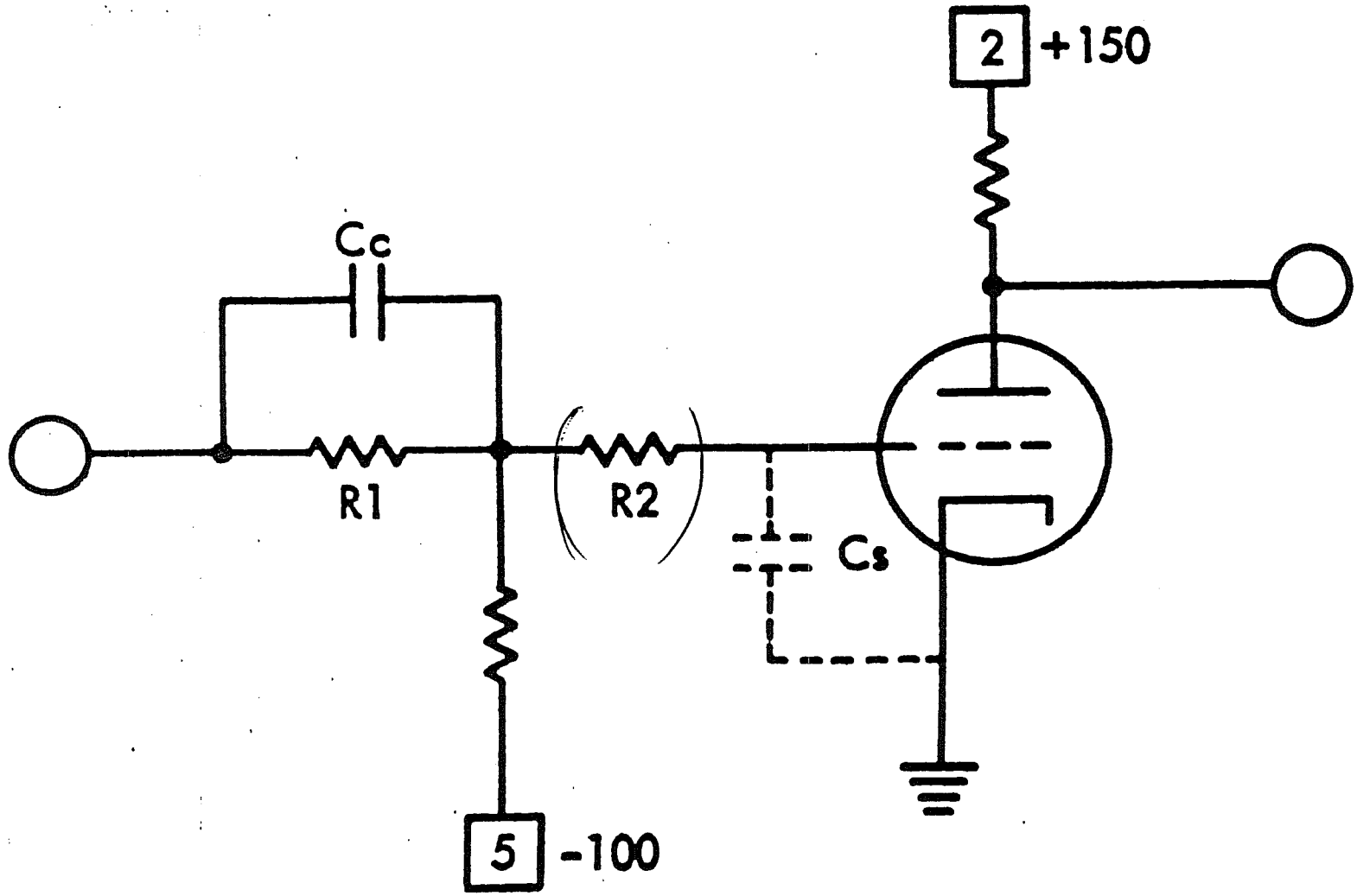


Figure 24. The Compensating Capacitor

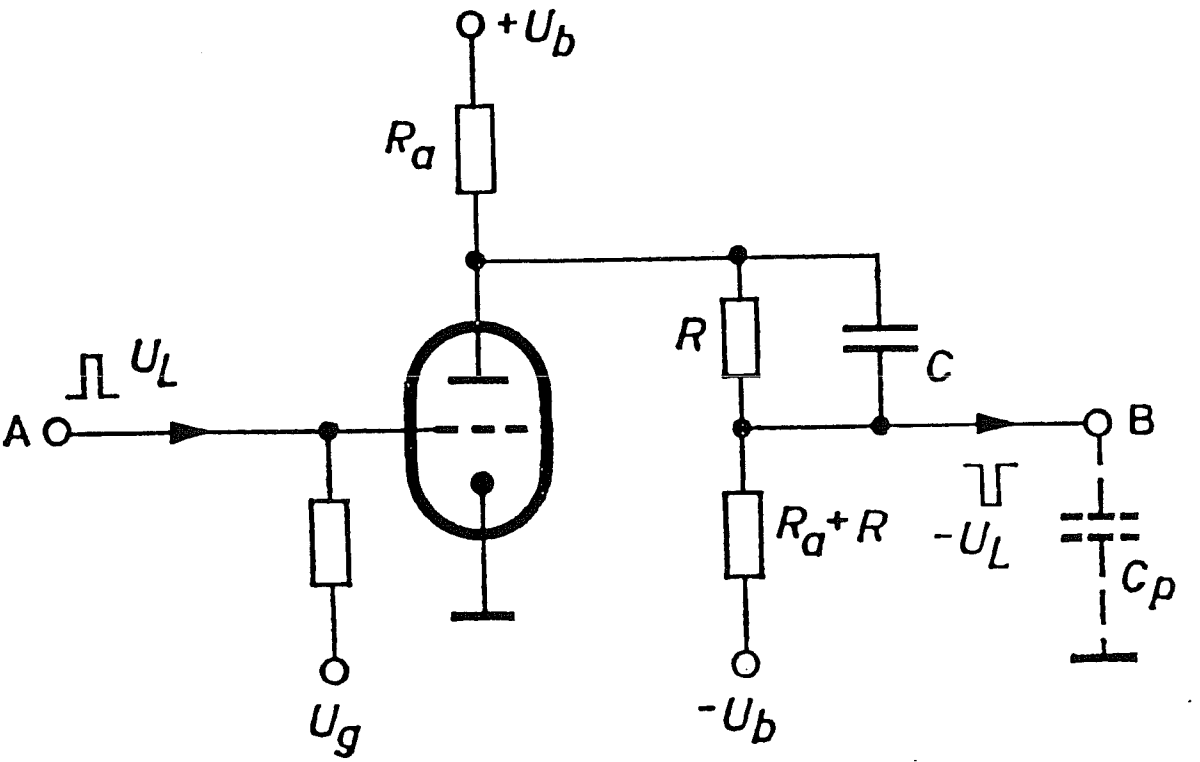


Abb. 4.1 Umkehrschaltung mit einer Triode

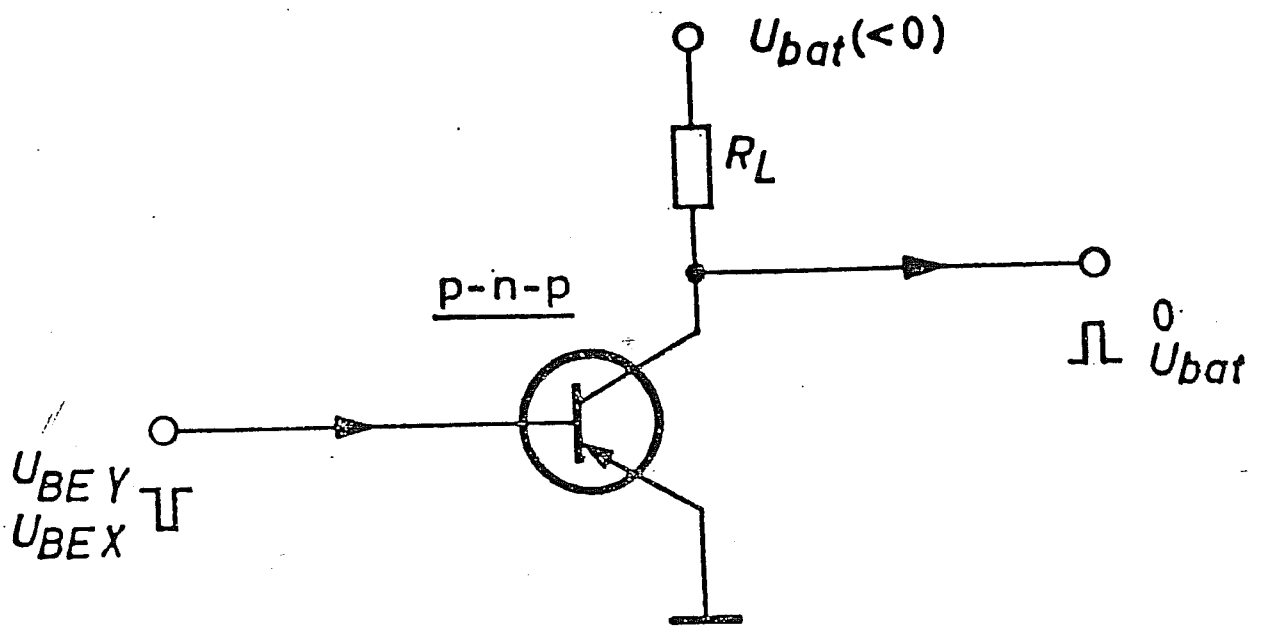
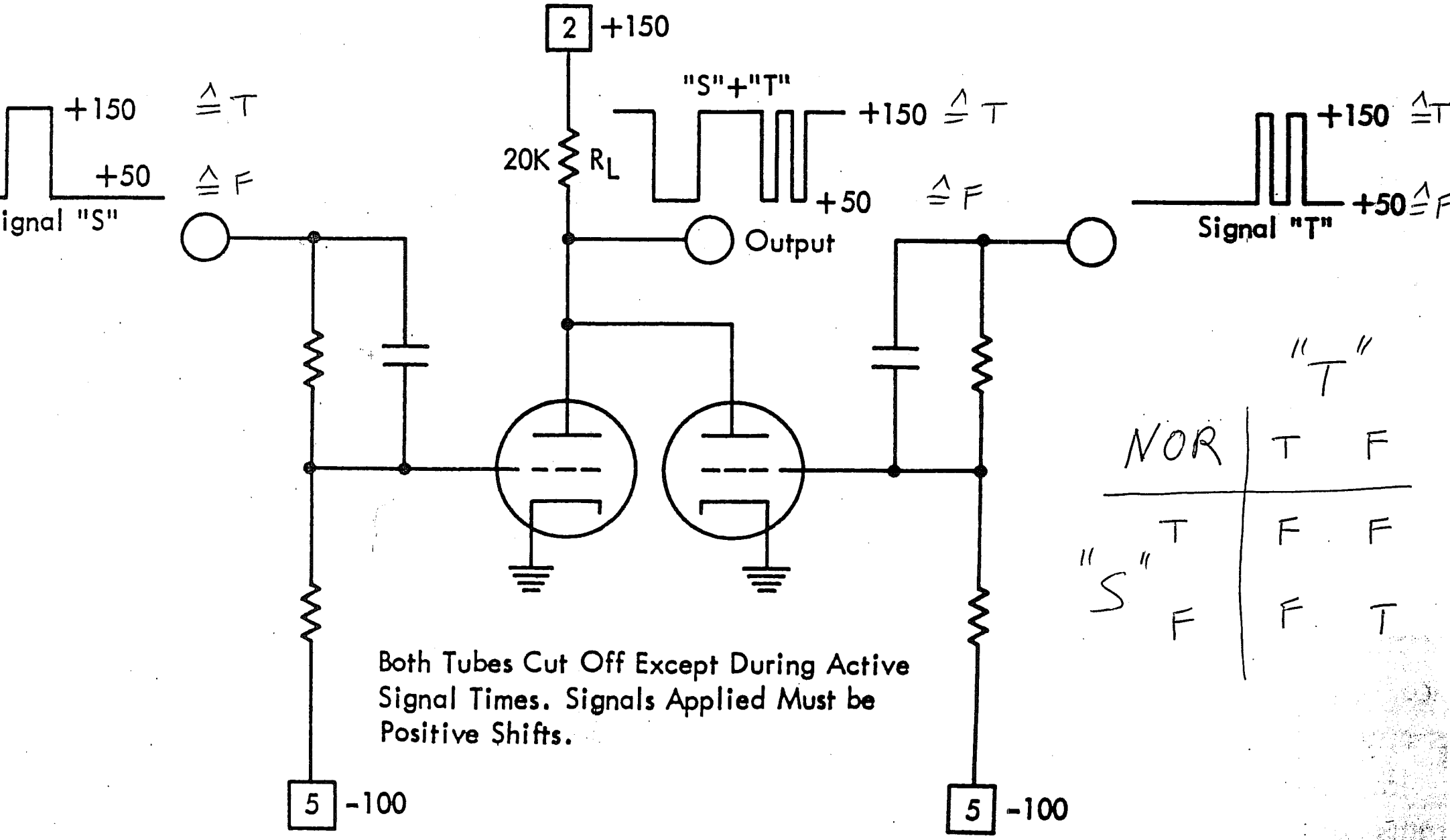


Abb. 4.3 Umkehrschaltung mit einem p-n-p-Transistor



NOR	"T" T	"T" F
"S" T	F	F
"S" F	F	T

Figure 37. The Inverted OR Circuit (Mixer)

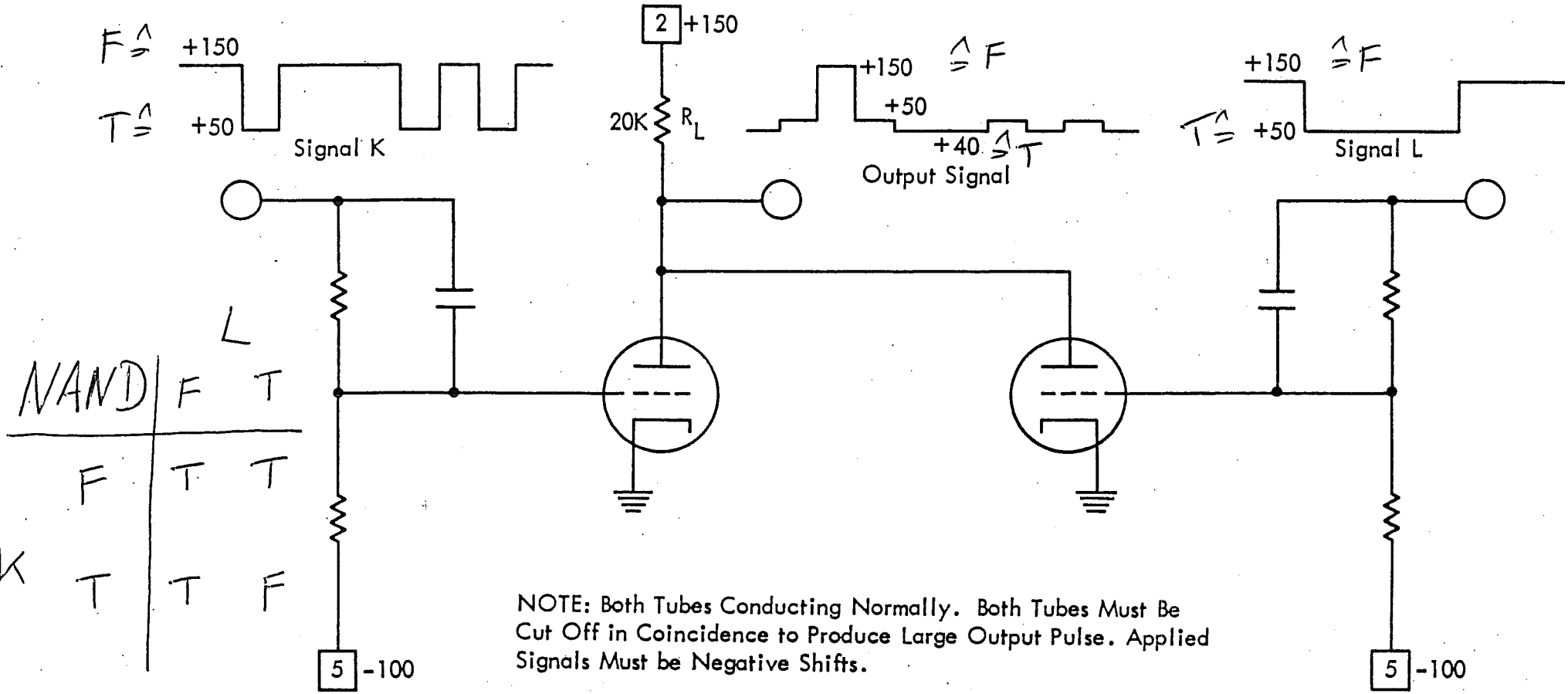


Figure 39. The Inverter NAND Circuit (Switch)

fact that one inverter triode conducting through a normal 20k plate load will reduce the potential on the plate down to about +50 volts. When a second inverter triode is connected to share the same plate load and is conditioned to conduct, a current sharing action takes place. When the second triode is told to conduct while the first triode is also conducting, only a plus 50 volt potential is available on the second plate to attract electrons. Electrons leaving the second triode cathode are

action. This will be found true of any circuits in which a load resistor is shared by two or more units. It should be noted that the Inverter Switch is more frequently used than the Inverter Mixer.

Power (PW) Units (G and H)

The inverter units previously discussed are designed to work with tubes capable of passing safely a current

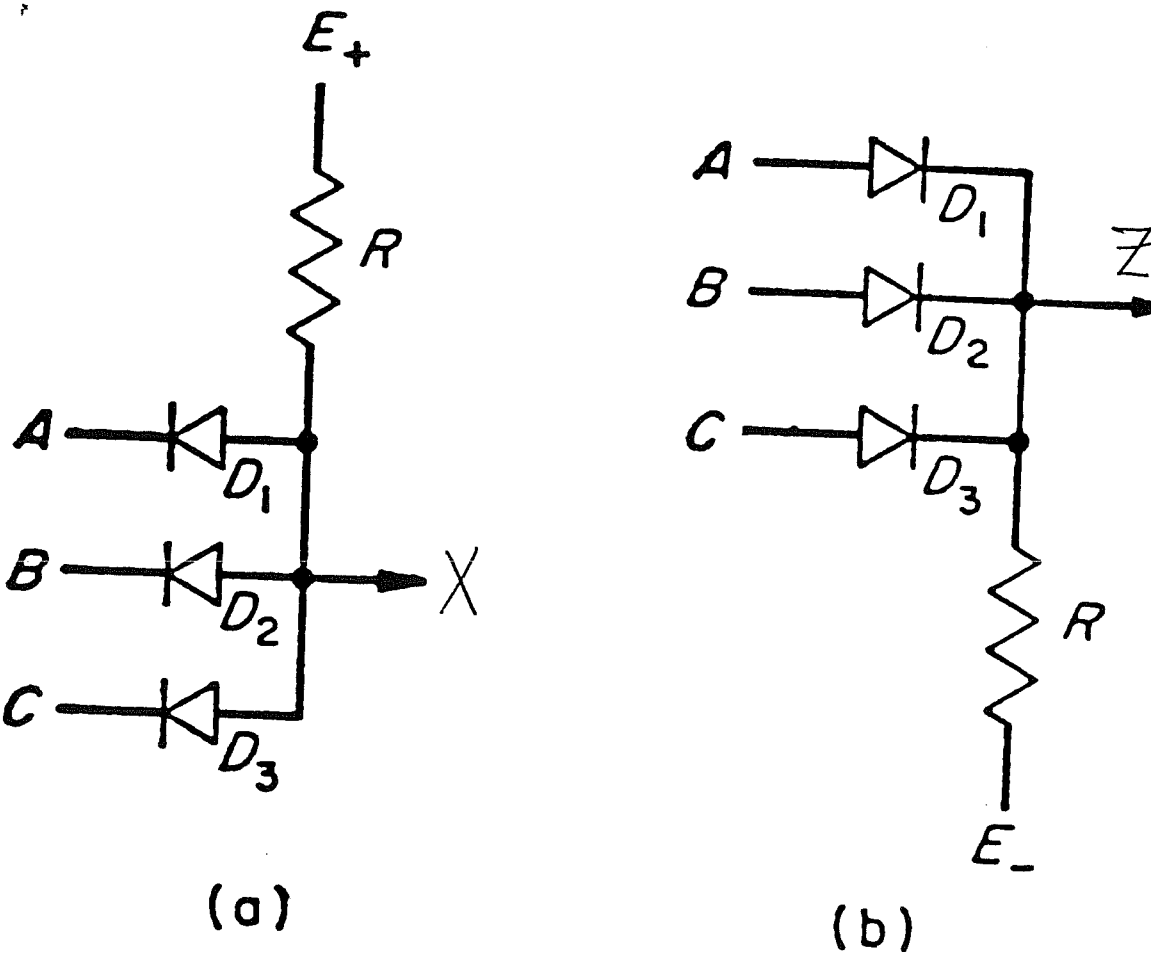


FIG. 2-1. Diode AND and OR circuits.

X = HIGH IFF A, B, AND C ALL HIGH

ANY A, B, C LOW WOULD PULL X LOW

Z = HIGH IFF A, B, OR C ANY HIGH

ANY A, B, C HIGH WILL PULL Z HIGH

$X = A \text{ AND } B$

$Y = C \text{ AND } D$

$Z = X \text{ OR } Y$

$= AB + CD$

AND – OR – INVERT GATE

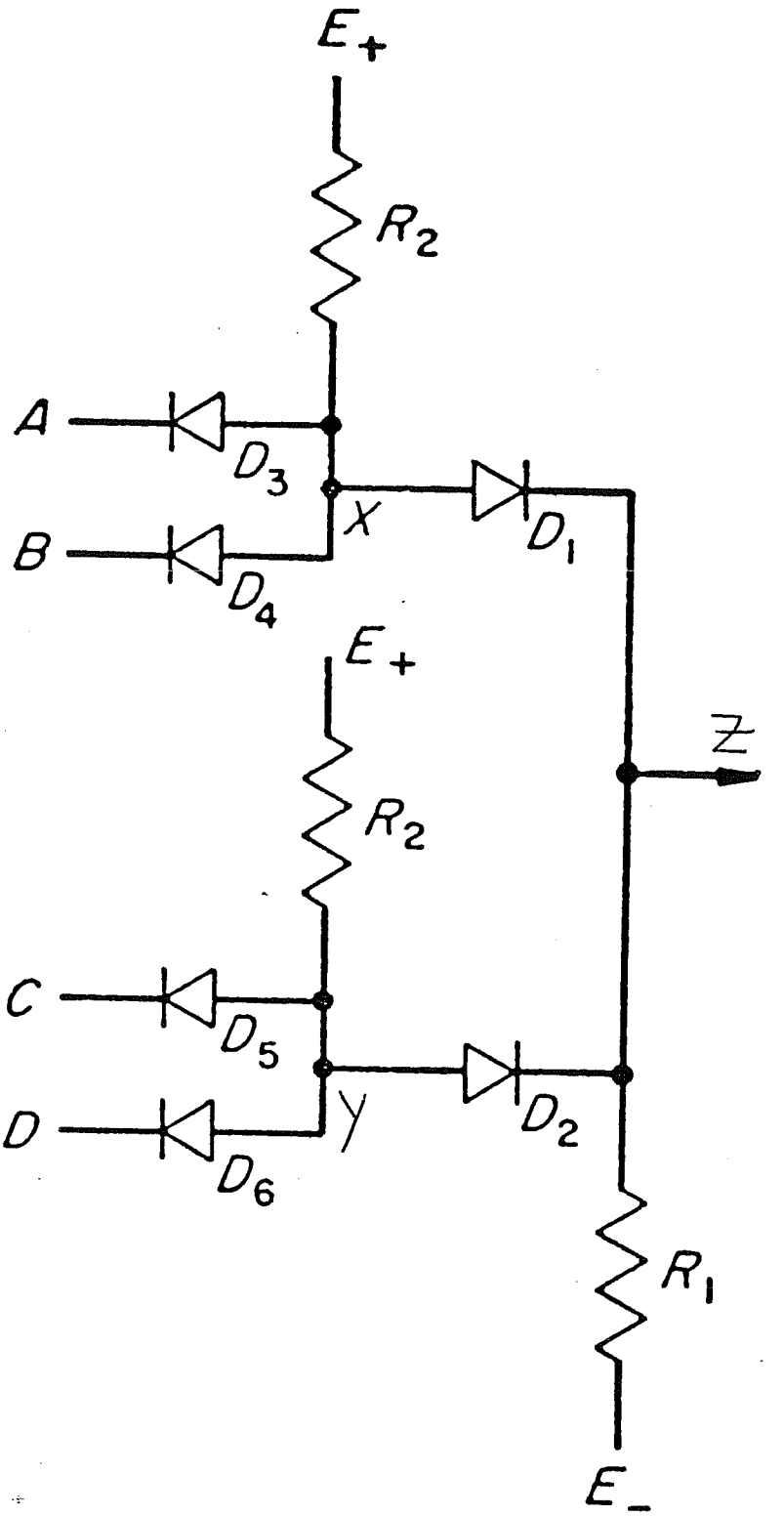


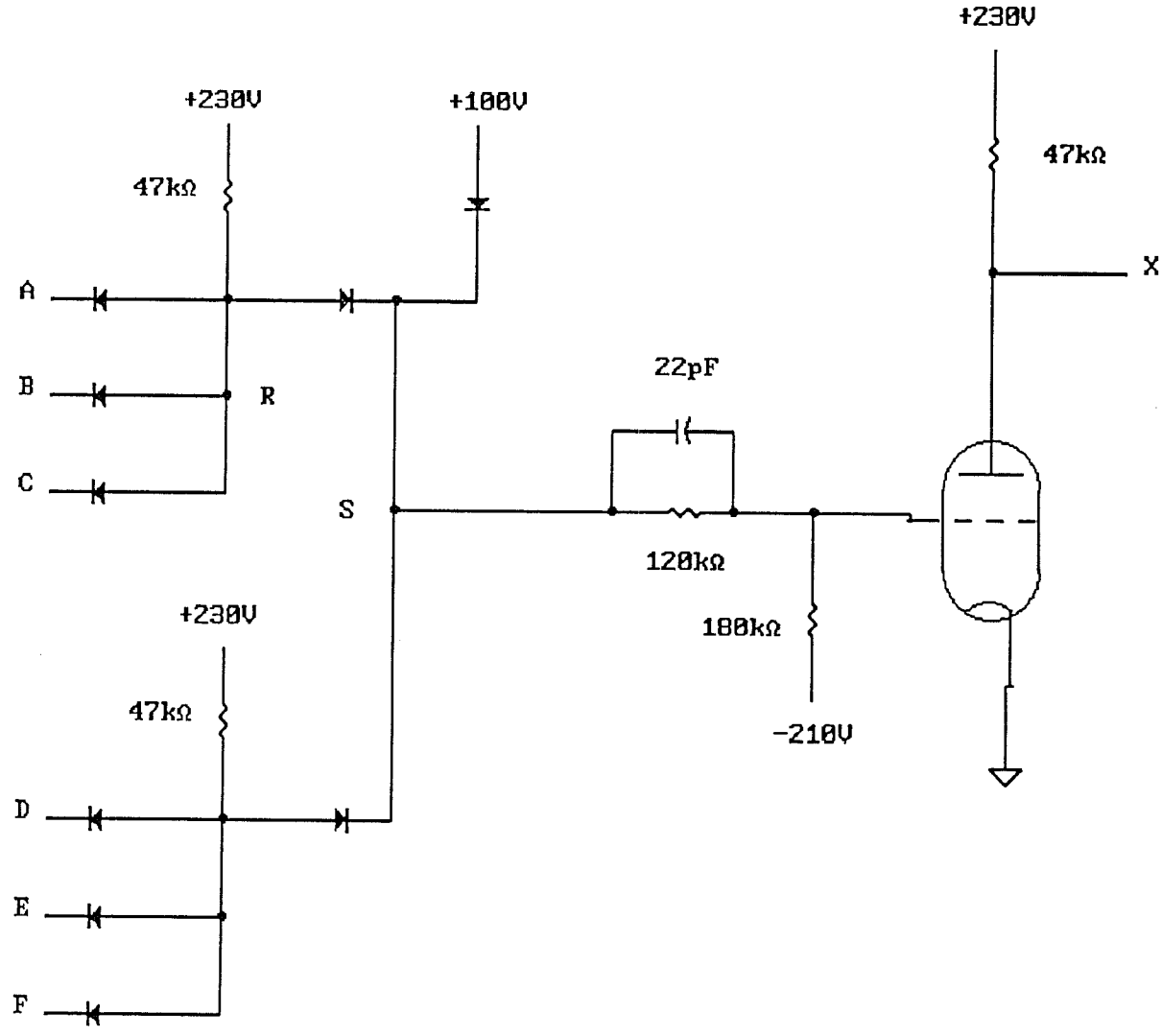
FIG. 2-2. Two-level diode switching circuit.

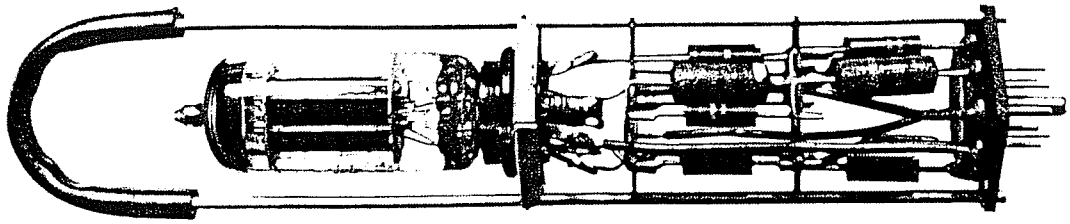
AND-OR-INVERT GATE

$$X = \overline{ABC + DEF}$$

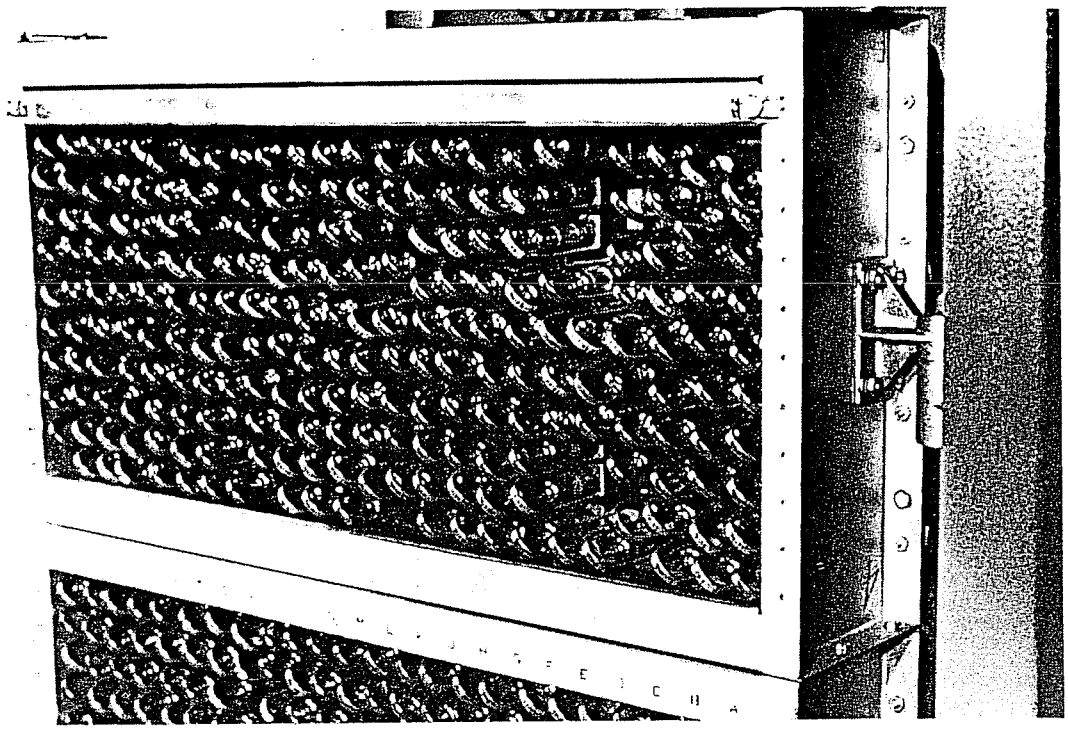
$$R = ABC$$

$$S = ABC + DEF$$

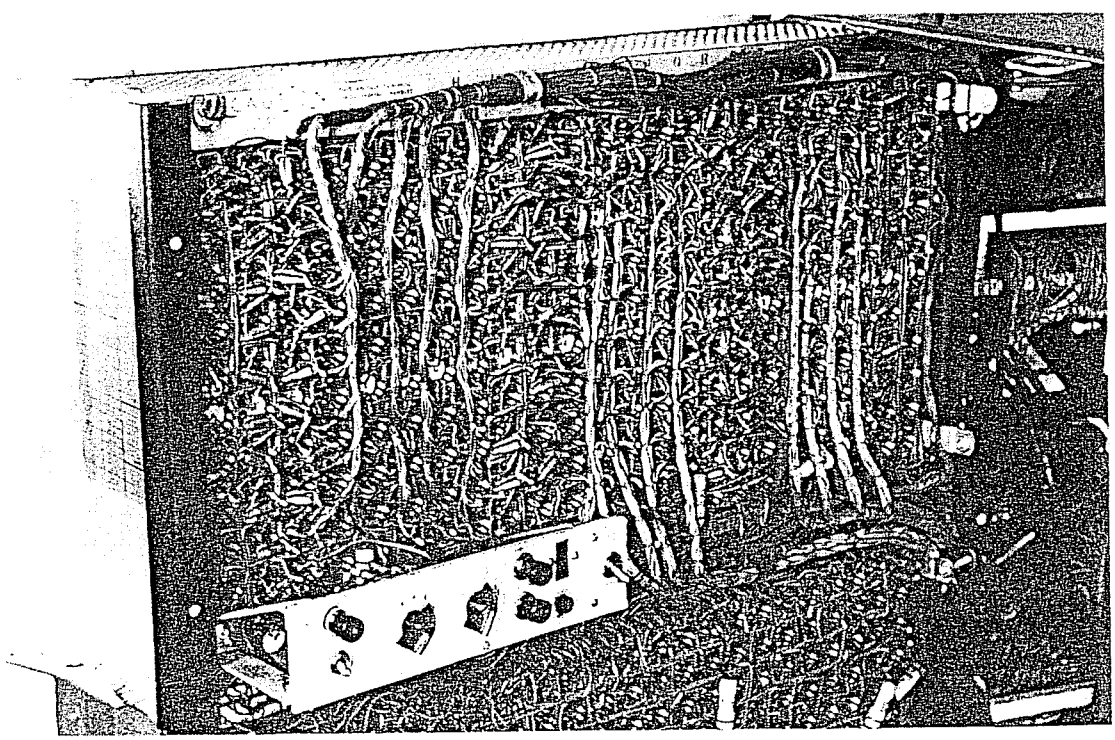




a



b



c

Figure 2.8
Packaging of electronic circuits in the IBM 604. A pluggable circuit unit is shown in *a*. A panel containing such units is seen in *b* from the pluggable unit insertion side. The same panel is seen in *c* from the opposite side, showing the wires that interconnect the sockets of the pluggable units.

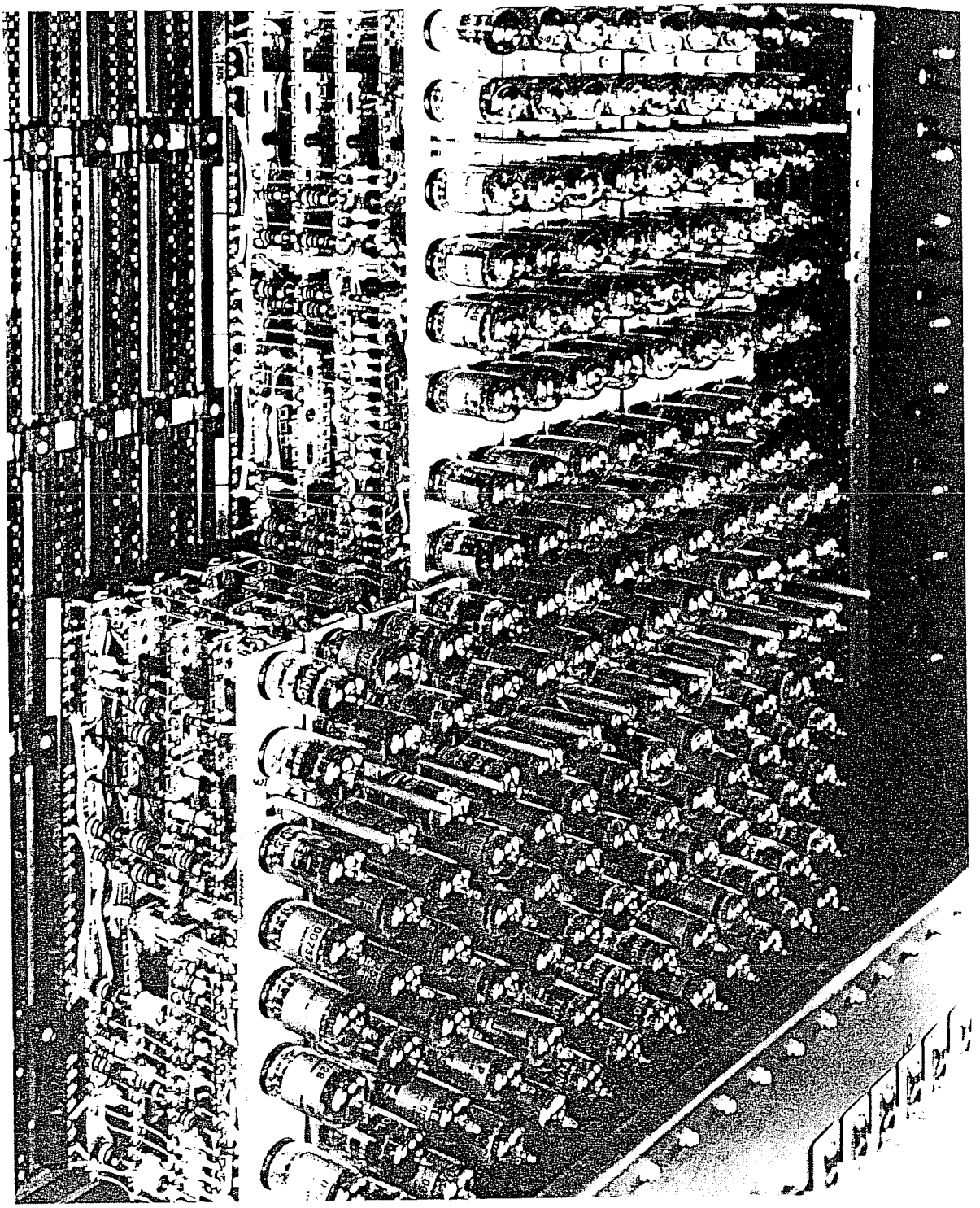


Figure 5.2
Electronic panel of the Defense Calculator, with eight-tube pluggable units

occurred in two separate motions. The eight-tube pluggable unit was almost 10 inches long, 5 inches high from base to tube deck, and a bit more than an inch wide; figure 5.2 shows a typical array of them in a production machine. The unit, the basic building block for IBM computers throughout the vacuum tube era, simplified manufacturing by isolating circuit assembly from framing and cabling. Its component density enhanced circuit speeds by allowing related circuits to be con-