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CASCODE AMPLIFIER CHARACTERISTICS

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July 27, 1955

## CASCODE AMPLIFIER CHARACTERISTICS

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In a pentode amplifier application it is frequently desirable to use two triode sections arranged in cascode. Approximate static characteristics, usually needed in the design calculations, can be found very quickly from the corresponding characteristics of the triode under consideration.

Figure 1 illustrates a circuit that might be used to determine the static characteristics experimentally. Given a value of the upper grid voltage,  $E_{c2}$ , one can determine a family of  $E_b - I_b$  curves with  $E_{c1}$ , the bias voltage, as a parameter. These will appear to be similar to pentode characteristics, but with some important differences.

Assume  $E_{c1}$  and  $E_{c2}$  fixed for the moment. As  $E_b$  is increased to sufficiently large values,  $E_{b1}$  will increase until it approaches  $E_{c2}$ , at which time it will level out to a value very near  $E_{c2}$  because of the clamping action of the upper triode.  $I_b$  will also level out to a saturation value  $I_b'$  corresponding to  $E_{b1} \cong E_{c2}$ . As  $E_b$  is reduced to sufficiently low values, the upper triode goes into grid conduction and the voltage  $E_{b2}$  is determined from the zero bias curve for the particular  $I_b$ .

Once  $E_{c2}$  is set, then the cascode characteristic corresponding to a particular  $E_{c1}$  can be derived by determining  $E_{b1}$  on the  $E_{c1}$  bias triode line, and  $E_{b2}$  on the zero bias triode line, both as a function of  $I_b$  up to the saturation level  $I_b'$ .

An example is given in Fig. 2 for the 6BC4.  $E_{c2}$  is given as 150 volts. For the particular curve shown in detail  $E_{c1} = -1$  volt.  $I_b' = 20.5$  ma is shown as the value of  $I_b$  when  $E_{b1} = E_{c2} = 150$  volts. The point "x" is obtained for  $I_b = 15$  ma.  $E_{b1}$  is defined by the triode curve to be 132 volts at this point. Since the upper triode is in grid conduction,  $E_{b2}$  from the zero bias curve is 93 volts.  $E_b = E_{b1} + E_{b2}$  then is shown on the point "x" as 225 volts. Other points obtained in the same manner are shown and a continuous line is drawn through these and folded over at the knee to meet the  $I_b'$  line. Other curves for the family  $E_{c2} = 150$  volts can be drawn but are not shown here.

Characteristics obtained in this manner are not precise but should be well within the limits of the manufacturer's tolerances on  $g_m$ , etc. The upper grid

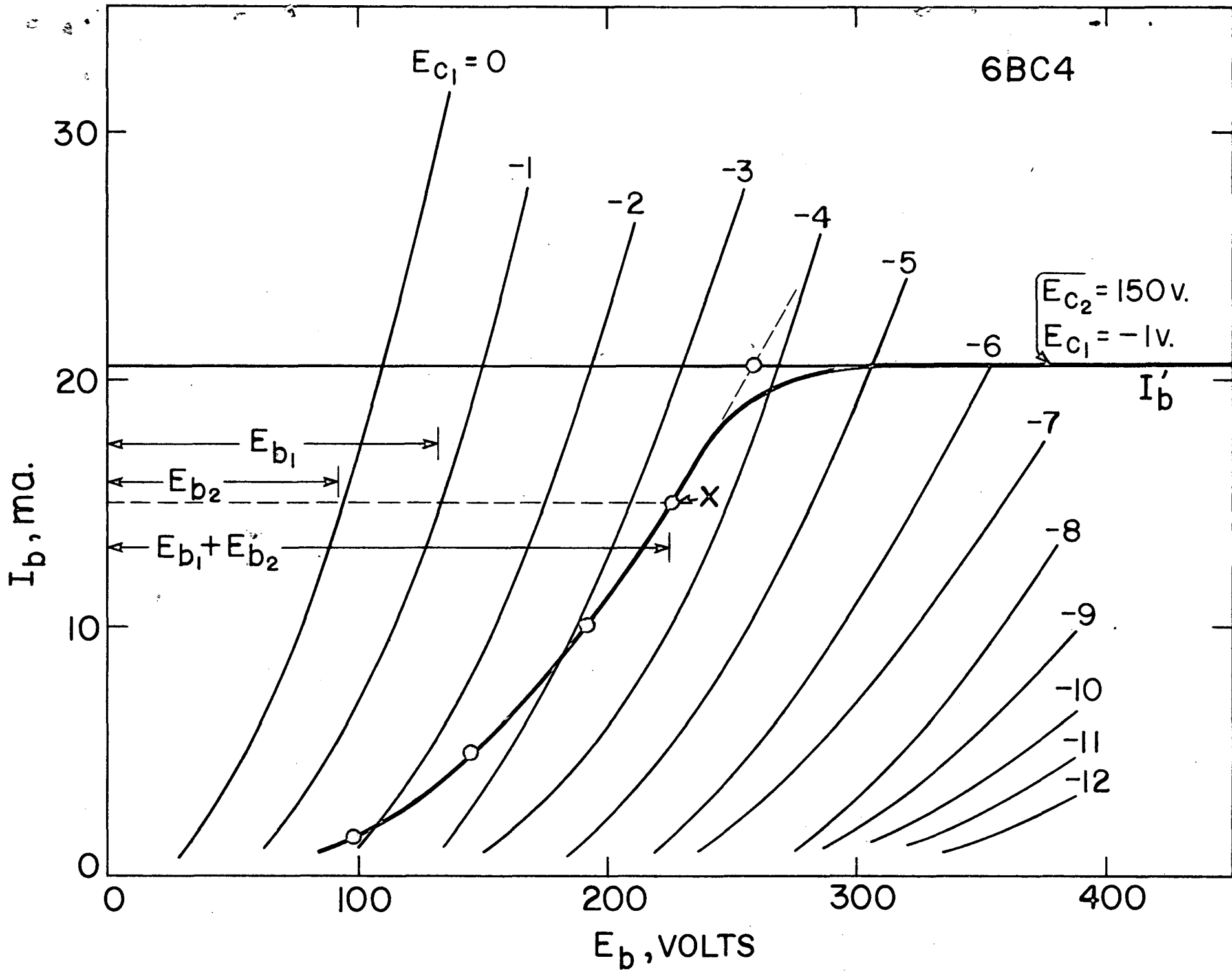


Fig 1

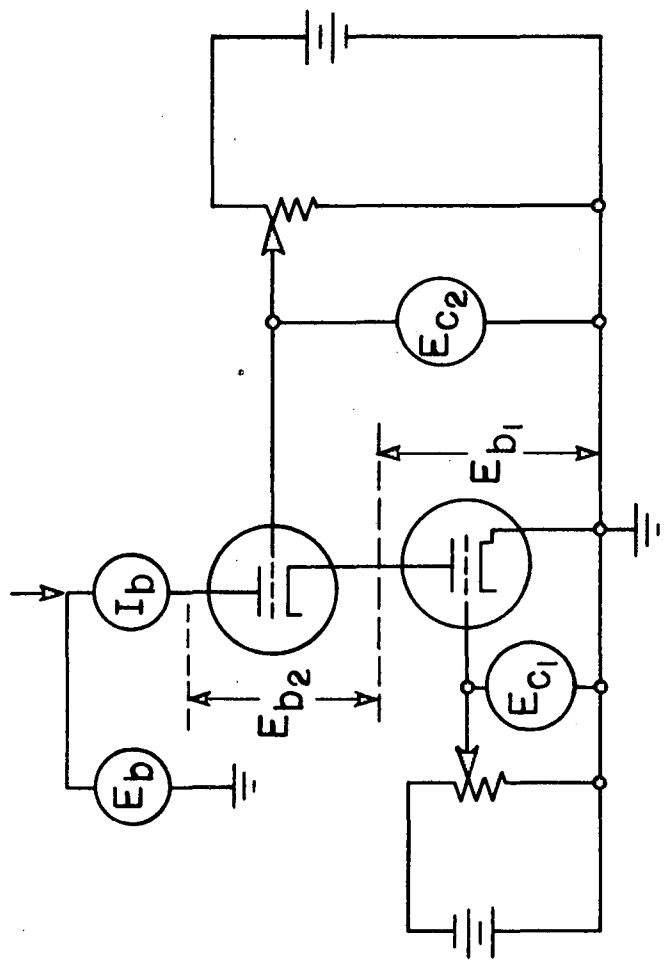


Fig 2

circuit may act as a plate load for the lower tube and tend to shift the lower part of the cascode curve in Fig. 2 to the left. In addition  $I_b$  should approach  $I_b'$  gradually -- more so with low- $\mu$  tubes.

Increasing  $E_{c2}$  has the effect of spreading out the cascode curves vertically and thus increasing the  $g_m$ ; however, the knee will be shifted to the right and higher plate-supply voltages are required to get into the "pentode" region.

The  $I_b'$  saturation lines are usually the ones of primary interest. These can be found quickly by the intersection of the  $E_b = E_{c2}$  line with the triode curves. The knee can be located approximately by assuming grid conduction at  $I_b'$  and marking off  $E_b = E_{b1} + E_{b2}$  as before. Determining one knee should be sufficient, as the others occur at about the same voltage.

This work was performed under the auspices of the U. S. Atomic Energy Commission.

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