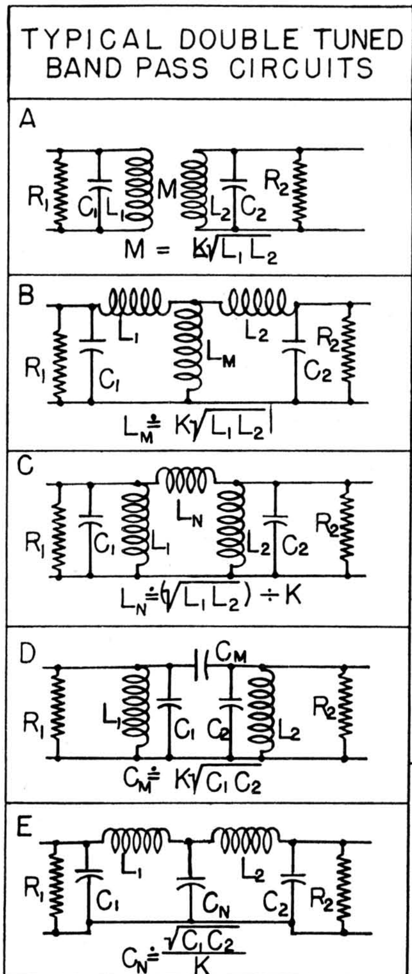
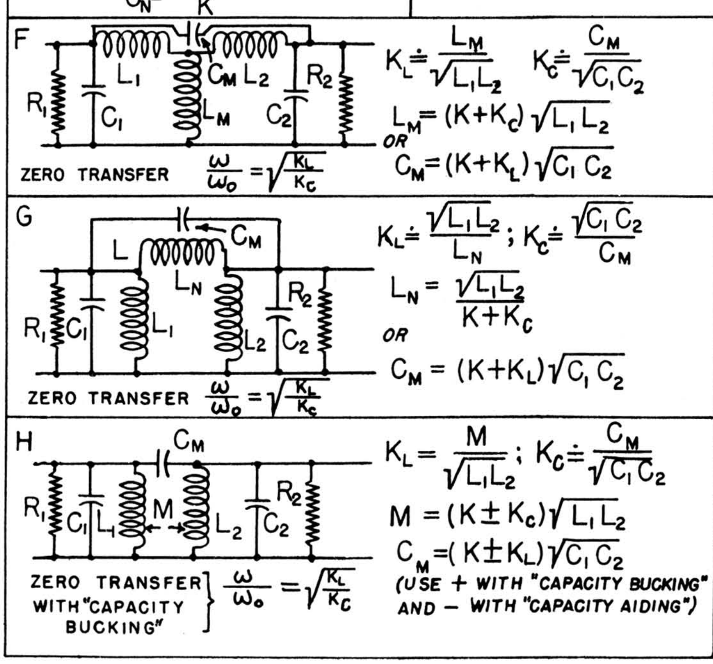
Instructions for Use of Federal Band Pass Nomographs A to C and I to III



IN ALL CIRCUITS A TO H, THESE RELATIONS HOLD:

$L_1 \doteq \frac{1}{\omega_0^2 C_1}$; $L_2 \doteq \frac{1}{\omega_0^2 C_2}$

$R_1 \doteq Q X_{OC_1}$; $R_2 \doteq Q X_{OC_2}$



The use of the bandpass-circuit nomographs is best explained by a few specific examples.

Example 1

Knowing that the gain per stage is approximately $Gain = G_M / 4\pi \Delta f_P \sqrt{C_1 C_2}$ it is decided that 5 stages are probably needed to obtain a certain desired gain. A ratio of peak gain to valley gain of 1.10 will be satisfactory. A bandwidth between peaks (Δf_P) of 2 megacycles is required; and to make th percentage bandwidth approximately 20% or less, a mid-frequency (f_0) of 30 Mc. is chosen.

What loading resistors should be used to give the proper Q in the two tuned circuits? What exact gain per stage will be obtained? What must the mutual impedance be to give the proper coefficient of coupling? What will the bandwidth be 6db down from the peaks? What will the bandwidth be 60 db down from the peaks?

Starting with Chart A we place a straight edge between point 5 on the "Number of Stages" column and point 1.10 on the "(V_P/V_V)" column. From the "$(Q/f_0/\Delta f_P)$" column we find that the Q of each resonant circuit must be

$$Q = .69\left(\frac{f_0}{\Delta f_P}\right)$$

and from this same column the exact gain per stage will be

$$Gain = .69\,\frac{G_M}{4\pi \Delta f_P \sqrt{C_1 C_2}}$$

Knowing the necessary Q and the reactances of the shunt capacities in the resonant circuits the necessary loading resistors is given simply by $R = QX_{oc}$.

From the "KQ" column of Chart A we see that the coefficient of coupling must be

$$K = \frac{1.22}{Q}.$$

In the type of circuit chosen (see list of possible types) the mutual reactance between the two resonant circuits is then found from the simple equation for the coefficient of coupling, as given with each type of circuit in the accompanying list.

To consider "skirt selectivity" we use Charts B & C. On Chart B we place a straight edge be-

EQUATIONS FOR DOUBLE TUNED-CASE

$$\sqrt{\frac{1}{2}\left[\frac{(V_p/V_v)^{1/N}}{\sqrt{(V_p/V_v)^{2/N}-1}}-1\right]} = M \qquad \text{(A)}$$

$$\frac{Q}{f_o/\Delta f_p} = \frac{1}{M} \qquad \text{(B)}$$

$$KQ = \sqrt{1+(1/M)^2} \qquad \text{(C)}$$

$$V_p/V_b = \left\{1+\left[\frac{(\Delta f_b/\Delta f_p)^2-1}{2M\sqrt{1+M^2}}\right]^2\right\}^{N/2} \qquad \text{(D)}$$

$$\Delta f_b/\Delta f_p = \sqrt{1+2M\sqrt{1+M^2}\sqrt{(V_p/V_b)^{2/N}-1}} \qquad \text{(E)}$$

$$\frac{\text{GAIN (per stage)}}{Gm/(4\Pi\Delta f_p\sqrt{C_1C_2})} = \frac{1}{M} \qquad \text{(F)}$$

$$\tan\theta_{\text{ per stage}} = \frac{\pm\left[1+2M^2-(\Delta f_b/\Delta f_p)^2\right]}{\pm\left[2M(\pm\Delta f_b/\Delta f_p)\right]} \qquad \text{(G)}$$

tween point 5 on the "Number of Stages" column, and 6db (or 2) on the "(V_ρ/V_β)" column. We read .56 on the middle or "Y" column. Now going to Chart C we place our straight edge between .69 on the "$(Q/fo/\Delta f\rho)$" column and .56 on "Y" column and read from the middle column that

$$\Delta f_{6db} = 1.95\ \Delta f\rho.$$

The bandwidth at the 60db down points is obtained in exactly the same way; i.e., on Chart B we place our straight edge between the point 5 on the "Number of Stages" column and 60db (or 1000) on the "(V_ρ/V_β)" column. We read 3.6 on the "Y" column. Going to Chart C we place our straight edge between point .69 on the "$(Q/fo/\Delta f\rho)$" column and 3.6 on the "Y" column. We read from the "$(\Delta f\beta/\Delta f\rho)$" column that

$$\Delta f_{\ 60db} = 4.4\ \Delta f\rho.$$

Any other points on the response curve are found in the same manner.

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Example 2

Knowing that the approximate gain per stage is *Gain* $= G_M/4\pi\Delta f\rho\ \sqrt{C_1C_2}$ it is decided that only 3 stages are needed to give a certain desired gain. It is necessary that the skirt selectivity be such that the bandwidth 60db down be only 5 times the bandwidth between peaks; i.e. $\Delta f_{60db}/\Delta f\rho = 5$. What must be the Q of each tuned circuit to obtain this skirt selectivity? What exact gain per stage will be obtained? What coefficient of coupling is required? What peak to valley ratio must be accepted in order to obtain this selectivity?

Starting with Chart B place a straight edge between point 3 in the "Number of Stages" column and point 60db on the "$(V\rho/V\beta)$" column and read 9.6 from the "Y" column. Going to Chart C we place our straight edge between point 5 on the "$(\Delta f\beta/\Delta f\rho)$" column and 9.6 on the "Y" column and read on the "$(Q/fo/\Delta f\rho)$" that the required Q is

$$Q = 1.1\ \frac{fo}{\Delta f\rho}.$$

Now going to Chart A we place our straight edge between point 3 on the "Number of Stages" column and 1.1 on the "$(Q/fo/\Delta f\rho)$" column and see that the exact gain will be

$$Gain = 1.1\ \frac{G_M}{4\pi\Delta f\rho\ \sqrt{C_1C_2}},$$

and from the "KQ" column the required coefficient of coupling is

$$K = \frac{1.48}{Q}.$$

From the "$(V\rho/Vv)$" column we find that the resulting peak to valley ratio will be 1.27.

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Example 3

As in the previous two examples an approximate estimate of gain per stage shows that 7 stages may be required. For a desired peak to valley ratio of 1.05 how much more gain can be obtained by the use of triple tuned circuits rather than double tuned circuits.

On Chart A we set our straight edge between point 7 on the "Number of Stages" column and 1.05 on the "$(V\rho/Vv)$" column and read from the "Gain" column that the exact gain per stage for the double tuned circuits is

$$Gain = .516\ \frac{G_M}{4\pi\Delta f\rho\ \sqrt{C_1C_2}}.$$

In Chart I we set our straight edge between 7 on the "Number of Stages" column and 1.05 on the "$(V\rho/Vv)$" column and read from the "Gain" column that the exact gain per stage with triple tuned circuits is

$$Gain = .788 \frac{G_M}{4\pi\Delta f\rho \sqrt{C_1 C_2}}.$$

Thus triple tuned circuits will give 1.53 times as much gain per stage and for seven cascaded stages we will get 19.6 times as much gain as with double tuned stages.

The required Q, coefficient of coupling K, and skirt selectivity, for the double tuned case are then found using Charts A, B and C. The triple-tuned values are obtained from Charts I, II, III.

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EQUATIONS FOR TRIPLE TUNED-CASE

$$\frac{1}{\sqrt{3}}\left[\left\{\frac{1+(V_P/V_V)^{1/N}}{\sqrt{(V_p/V_v)^{2/N}-1}}\right\}^{1/3} + \left\{\frac{1-(V_P/V_V)^{1/N}}{\sqrt{(V_P/V_V)^{2/N}-1}}\right\}^{1/3}\right] = P \quad (1)$$

$$\frac{Q}{fo/\Delta fp} = \frac{1}{P} \quad (2)$$

$$KQ = \sqrt{1+(1/P)^2} \quad (3)$$

$$V_P/V_b = \left[1 + \left\{\frac{(\Delta f_b/\Delta f_p)\left[(\Delta f_b/\Delta f_p)^2 - 1)\right]}{P\ (1+P^2)}\right\}^2\right]^{N/2} \quad (4)$$

$$\Delta f_b/\Delta f_p = \frac{1}{\sqrt[3]{2}}\left[\left(d+\sqrt{d^2-4/27}\right)^{1/3} + \left(d-\sqrt{d^2-4/27}\right)^{1/3}\right] \quad (5)$$

WHERE $d = P(1+P^2)\sqrt{(V_p/V_b)^{2/N}-1}$ (5A)

$$\frac{\text{GAIN (per stage)}}{Gm/(4\Pi\Delta f_p\sqrt{C_1\ C_2})} = \frac{1}{P} \quad (6)$$

$$\tan\theta_{\text{per stage}} = \frac{+(\pm\Delta f_b/\Delta f_p)\left[2P^2+1-(\Delta f_b/\Delta f_p)^2\right]}{-P\left[P^2+1-2(\Delta f_b/\Delta f_p)^2\right]} \quad (7)$$

Example 4

The nomographs may very conveniently be used for analysis of coupled circuits as well as for design or synthesis.

Thus, given the Q of two resonant circuits is 14 and the coefficient of coupling (K) between them is .16 and the resonant frequency is 15 Mc. What is the response curve?

The product of KQ is 2.24. Going to Chart A we set our straight edge between 1 on the "Number of Stages" column and 2.24 in the "KQ" column. From the "$(V\rho/Vv)$" column we see that $(V\rho/Vv) = 1.36$. From the "$(Q/fo/\Delta f\rho)$" column we see that the bandwidth between peaks will be

$$\Delta f\rho = 2\frac{fo}{Q} = 2\frac{15}{14} = 2.15\ Mc.$$

To find the width of the skirts at different points e.g. 10 times or 20db down, we go to Chart B, place our straight edge between 1 on the "Number of Stages" column and 20db on the "$(V\rho/V\beta)$" column and read 10 on the "Y" column. Going to Chart C we place our straight edge between 2 on the "$(Q/fo/\Delta f\rho)$" column and 10 on the "Y" column and see that

$$\Delta f_{20db} = 3.5\ \Delta f\rho$$

Any other points on the skirts are obtained in the same way.

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When a triple tuned band pass circuit is formed, the middle tuned circuit should be considered to be formed from two identical resonant circuits in parellel. The input resonant circuit is then coupled to one of the above resonant circuits and the output circuit is coupled to the other resonant circuit. The Q of the middle tuned circuit must be much higher than the Q required for the input and output resonant circuits as given by Charts I or III.

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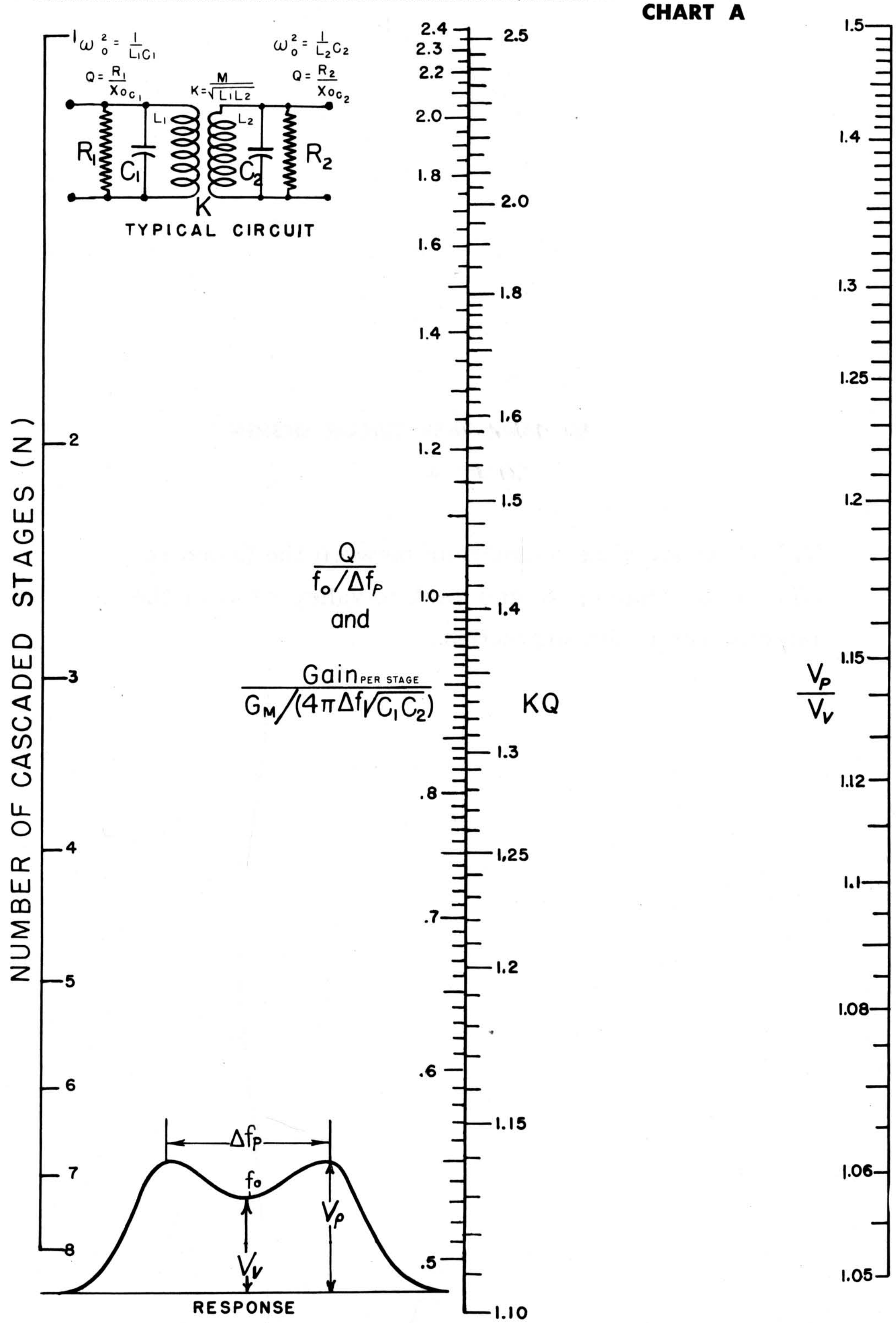
The equations from which these nomographs were calculated and the method of presentation were developed by Milton Dishal.

DOUBLE-TUNED BAND-PASS CIRCUIT DESIGN

CHART A



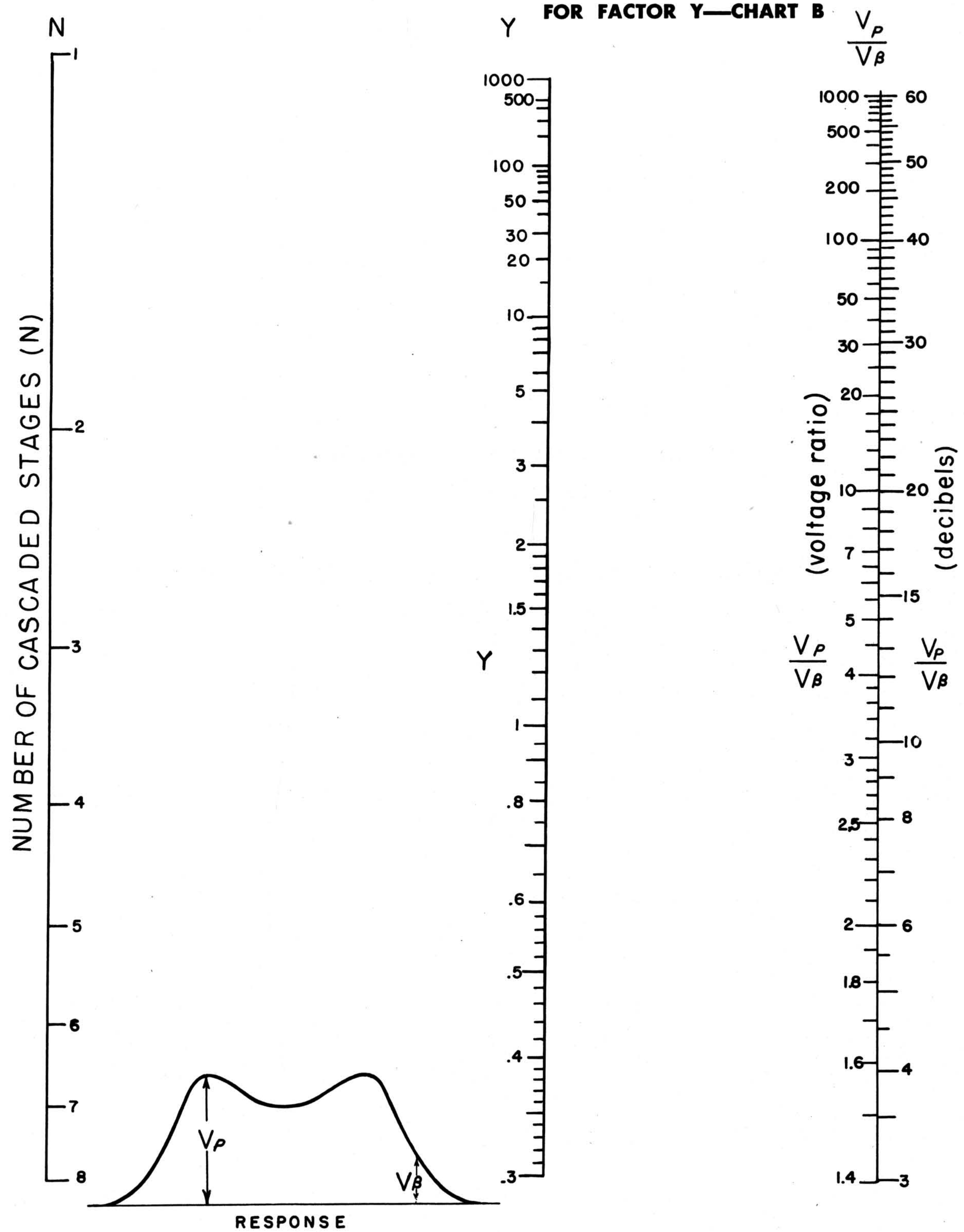
DOUBLE-TUNED BAND-PASS CIRCUIT DESIGN

CHART A

This chart gives the relationship between the Q and coefficient of coupling K and peak-to-valley ratio in the response curve. See instructions.

DOUBLE-TUNED BAND-PASS CIRCUIT DESIGN

FOR FACTOR Y—CHART B

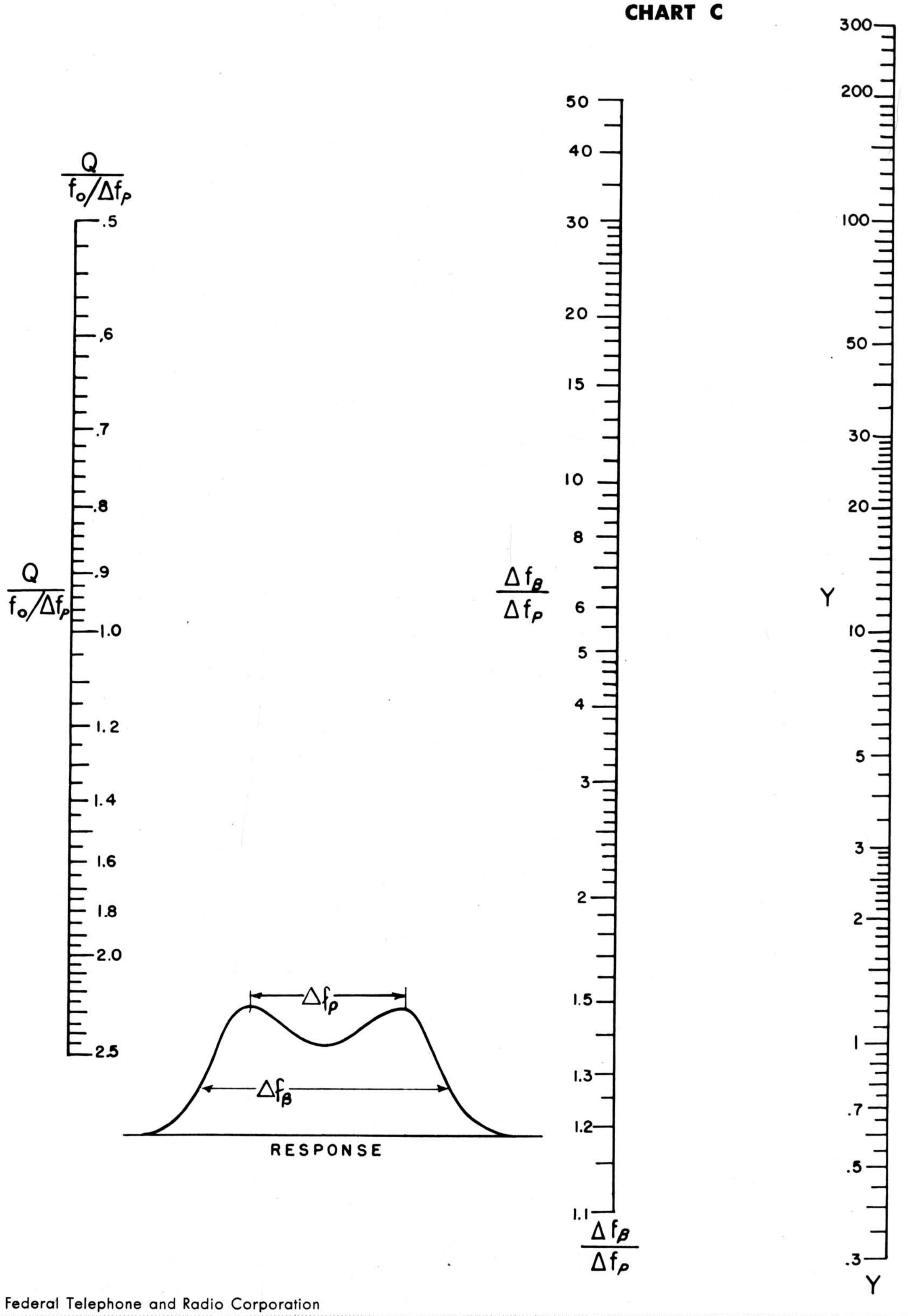


DOUBLE-TUNED BAND-PASS CIRCUIT DESIGN
FOR FACTOR Y—CHART B

This chart gives the factor Y which depends upon skirt response ratios. The factor Y is used in Chart C. See instructions.

DOUBLE-TUNED BAND-PASS CIRCUIT DESIGN

CHART C



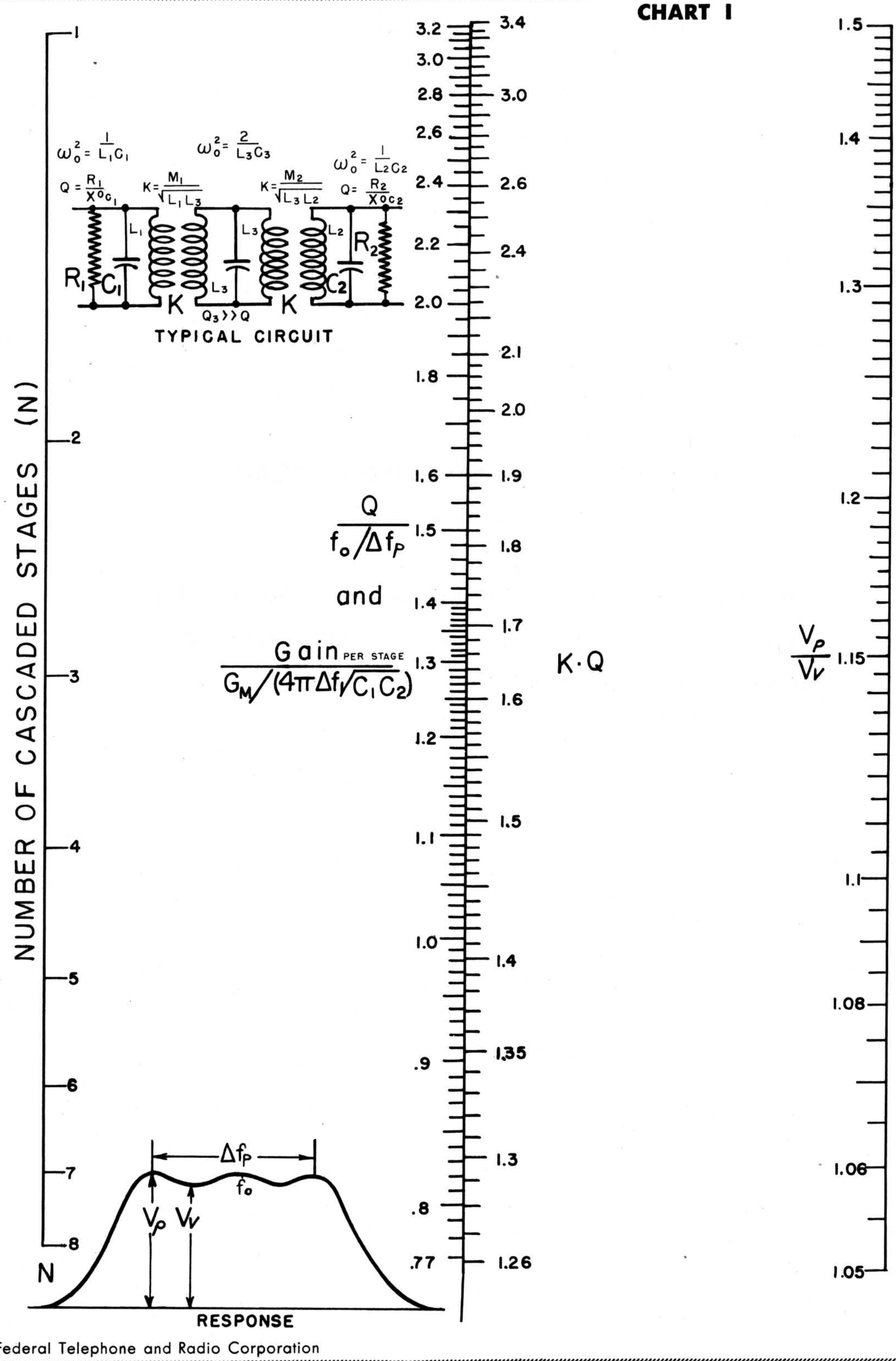
DOUBLE-TUNED BAND-PASS CIRCUIT DESIGN

CHART C

This chart gives the relationship between the circuit *Q's* and skirt selectivity using the factor *Y* from Chart B and *Q* from Chart A. See instructions.

TRIPLE-TUNED BAND-PASS CIRCUIT DESIGN

CHART I



TRIPLE-TUNED BAND-PASS CIRCUIT DESIGN

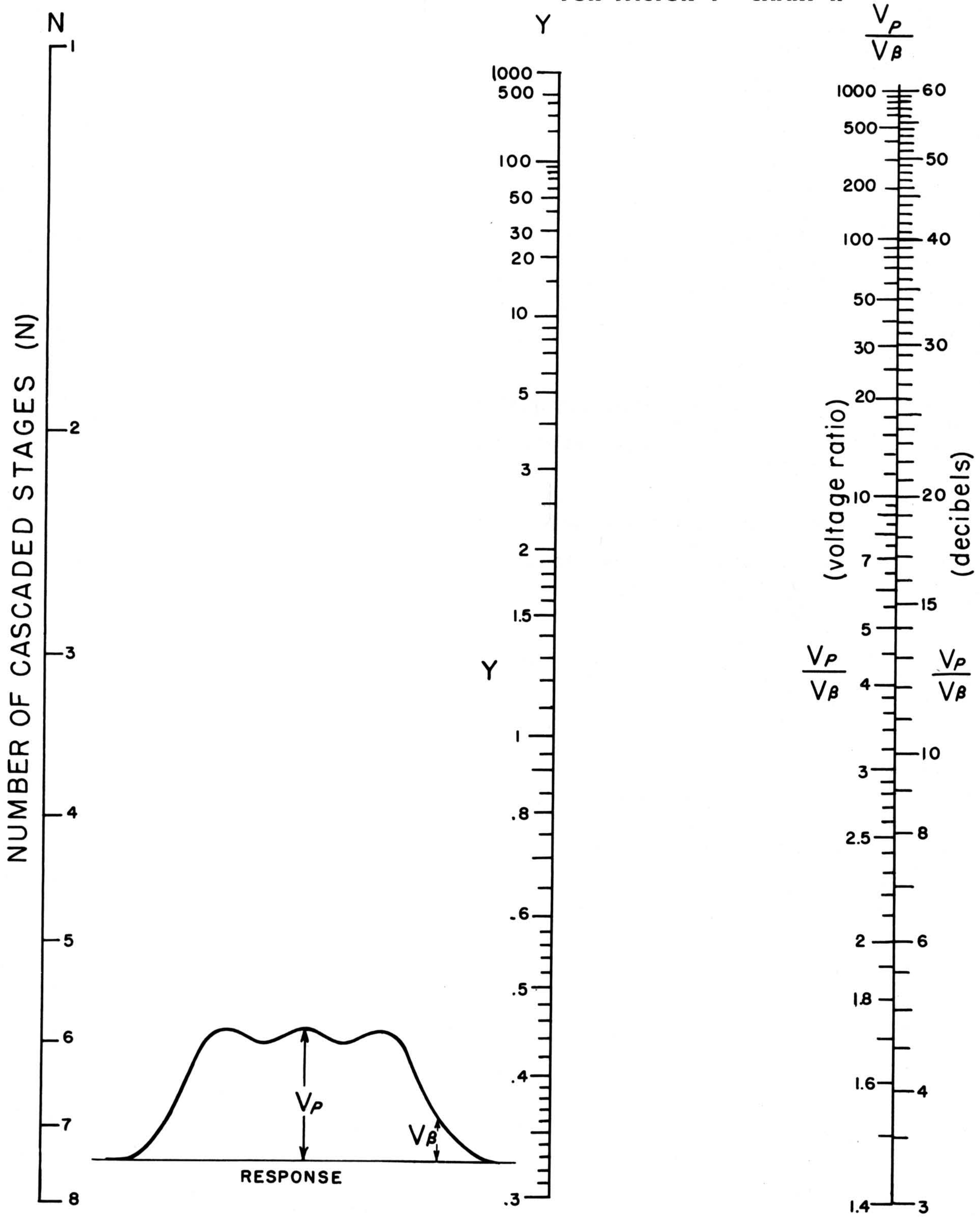
CHART I

This chart gives the relationship between the Q and coefficient of coupling K and peak-to-valley ratio of the response curve. See instructions.

Technical data

TRIPLE-TUNED BAND-PASS CIRCUIT DESIGN

FOR FACTOR Y—CHART II

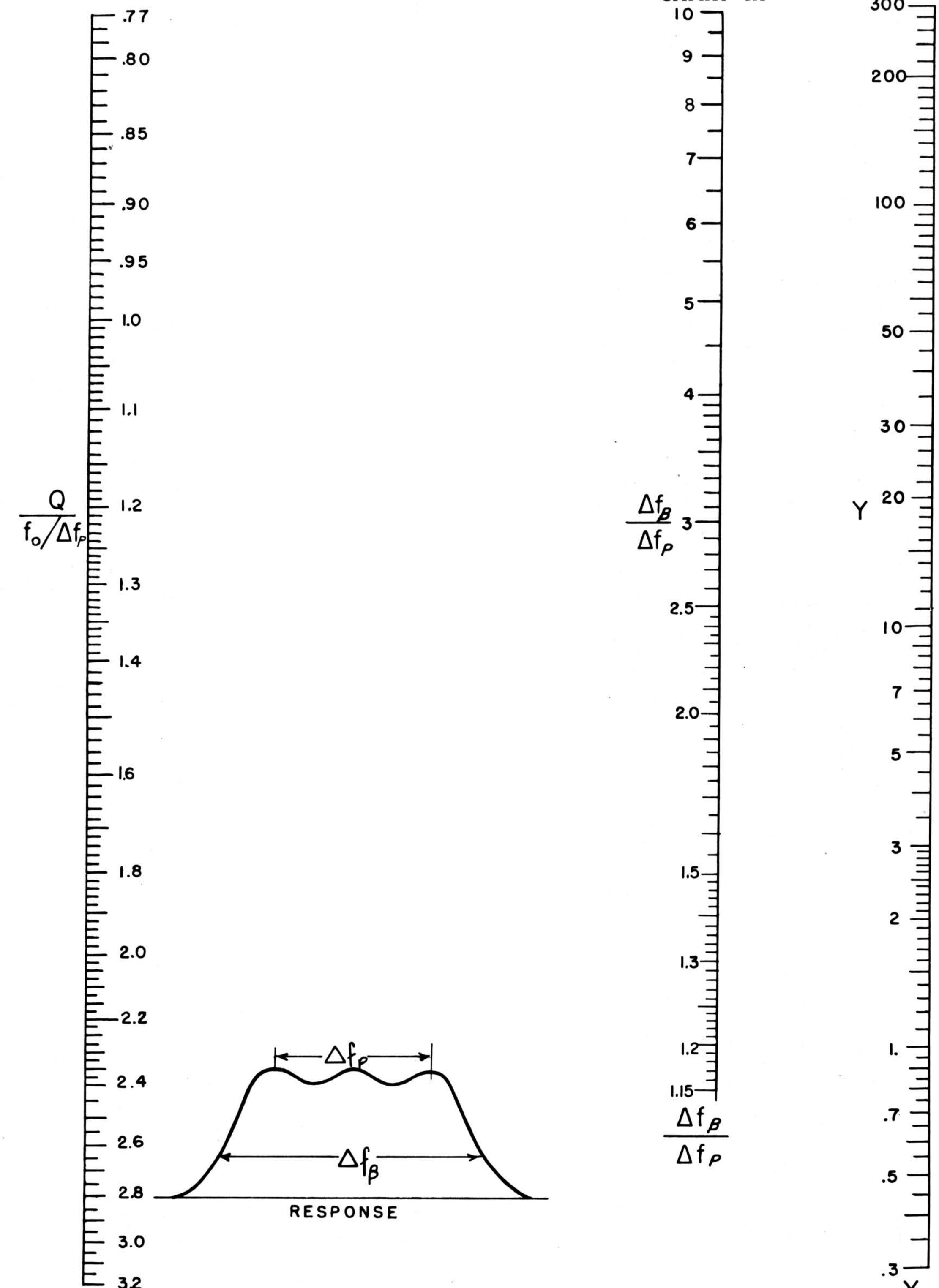


TRIPLE-TUNED BAND-PASS CIRCUIT DESIGN
FOR FACTOR Y—CHART II

This chart gives the factor Y which depends upon skirt response ratios. The factor Y is used in Chart III. See instructions.

TRIPLE-TUNED BAND-PASS CIRCUIT DESIGN

CHART III



TRIPLE-TUNED BAND-PASS CIRCUIT DESIGN

CHART III

This chart gives the relationship between the circuit *Q's* and skirt selectivities, using the factor *Y* from Chart II and *Q* from Chart I. See instructions.