

further. The time that would be spent reading further discussion can be spent more profitably in working out some examples with the aid of the calculator itself. However, here is an important thing to be aware of: When the feedback network contains reactances, which usually will be capacitors, the response calculated is that which appears at the output of the feedback network. Therefore it is necessary to subtract the response of the feedback network from the calculated response given by the mu-beta calculator to get the response for the over-all system. This is shown in the basic equation:

$$\text{gain} = 20 \log \frac{1}{\beta} + \text{mu-beta effect.}$$

Here is another use for the mu-beta calculator: It can be used for calculating the stability margin directly. As you

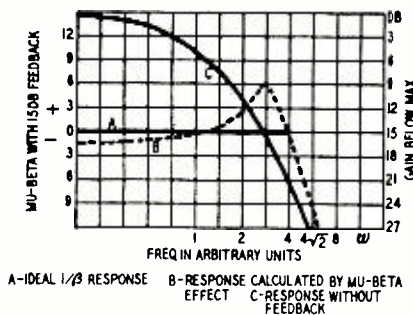


Fig. 5—Three design curves of amplifier.

may remember, we showed in Part VI that a quantity called the stability margin was a very useful measure for the safety of a design. This quantity is

$$\frac{K'}{K} = \frac{1}{1 + K\beta}$$

in our notation. The mu-beta effect, you will remember, is

$$\gamma = \frac{K\beta}{1 + K\beta} = \frac{1}{1 + \frac{1}{K\beta}}$$

If we have a value of, say, 6 db for $K\beta$, and we calculate the $\mu\beta$ -effect corresponding to -6 db, the quantity we ob-

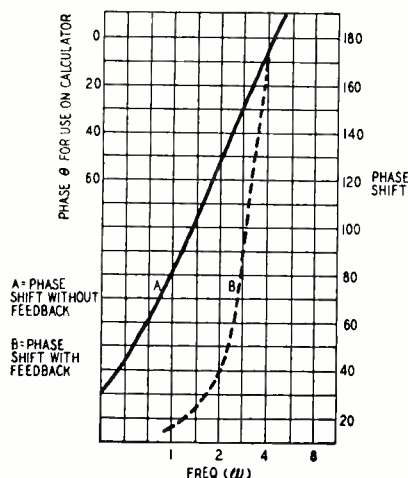


Fig. 6—Two curves showing phase shift.

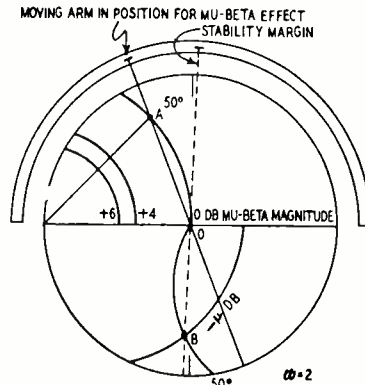


Fig. 7—The calculator solves a problem.

tain is the stability margin. Let us draw up a table from Figs. 5 and 6:

$\omega =$	1	1.4	2	2.8	4
$K\beta = \mu\beta$					
	+10	+7.5	+4.2	-1	-6.3 db
$\theta = 97^\circ$	75°	50°	26°	4°	
$\mu\beta$ effect					
	-0.8	+0.3	+2.3	+6.2	-0.5 db
Stability Margin					
	-10.8	-7.3	-1.8	+7.2	+5.8 db

The last line was calculated directly, taking the (-10 db, 97°), (-7.5 db, 75°) etc. points on the chart. This means that it is not necessary to pass through the response, mu-beta effect, over-all response system in order to check the stability margin. When the feedback path has a nonuniform response this can be very helpful, because all that need be done is to plot the two pairs of curves, for mu-beta and for beta, and then determine the stability directly.

There is a very attractive phrase which you can find in British patents: "Having now particularly described and ascertained the nature of the invention..." Well, we've done that, but just in case the explanation has not been sufficiently certain, Fig. 7 shows how the calculator is actually set to fish out the results at $\omega = 2$. The point marked A is at mu-beta = +4.2 db, mu-beta phase = 50°: the rotating arm OA has been turned until the edge passes through this point, and the mu-beta effect is read off at A on the scale printed on the arm. The phase of the mu-beta effect is read off on the circular scale. For the stability margin we hunt out point B, -4.2 db, 50°, and twist the arm to pass through this point. The stability margin is read off from the arm.

Wary readers may have noticed that almost everything I have discussed in this series of articles deals with the analysis of feedback circuits, and not the synthesis. We guess a circuit, and test it, on paper, to see if it will work. Nearly everything in the field of circuit design boils down to this in the end: The main differences appear in the methods of testing. At one extreme you wire up the circuit and pray; at the other extreme you test on paper in such a general way that you never come to a practical answer. These articles are aimed at a reasonable compromise. They

do provide all the information needed by the average professional designer, but at the same time I hope that they are not too forbiddingly mathematical for the man who wants to build just one amplifier, but wants to build it right. Anyway, you can always skip the mathematics.

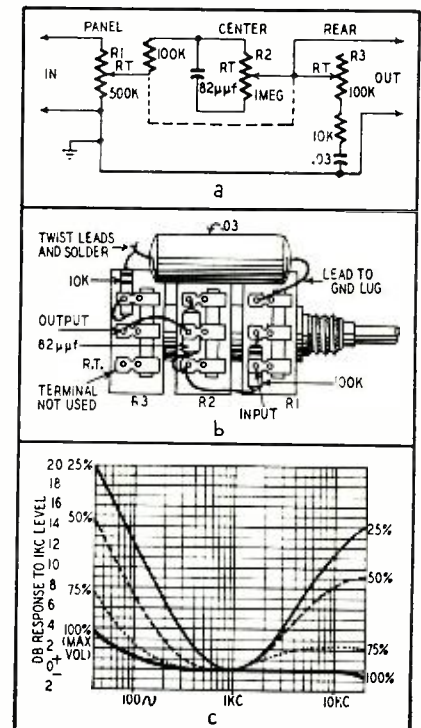
The important thing to learn here is: mu-beta simplifies design work.

(continued next month)

VARIABLE LOUDNESS CONTROL

Loudness controls are special volume controls which provide increasing amounts of bass and treble boost as the volume is reduced. This compensates for the variations in response of the human ear so the output of the amplifier will appear balanced at all volume levels. Tapped volume controls provide a limited amount of compensation. This is greatest when the arm of the control is resting on the tapped point. Step type controls require a large number of components. They are difficult to construct and require special care in shielding to prevent hum pickup and feedback.

A continuously variable loudness control requiring only seven inexpensive components is described in a release by I.R.C. The circuit of this control is shown at a and its physical construction is shown at b. R1, R2, and R3 are IRC controls type Q11-133, M13-137, and M13-128 respectively. The first is a standard type control and the others are multisections designed for making dual, triple, and quadruple controls. The curve c shows the increase in bass and treble boost as the control is turned toward the minimum-volume position.



This control has a 6-db insertion loss which must be made up elsewhere in the amplifier if full output is to be realized.