COMPUTER-DESIGNED AUDIO NETWORKS

This program eliminates the hard work in designing impedance-matching networks and attenuators for audio systems.

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■Ever since the early days of the telephone, attenuator networks have been used to control sound levels and to match impedances. Technicians, hobbyists, and experimenters who work with audio equipment and circuitry often find that a particular piece of equipment has an input (or output) impedance or line level that does not meet their requirements. In many of those instances, a commercially manufactured attenuator network is not readily available to solve the problem. Of course, you don't need a commercial network—you can put one together yourself.

Only four networks—the T, H, L, and U—will be considered. The T network consists of three resistors connected in the form of a "T," as shown in Fig. 1-a. It is an unbalanced attenuator. When used between circuits of unequal impedance, it is often called a taper pad. The H-type attenuator is a balanced T pad. It consists of 5 resistors connected in the form of an "H," as shown in Fig. 1-b.

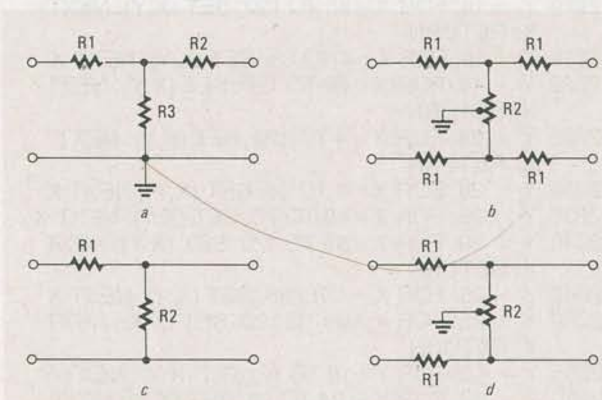

FIG. 1—THE FOUR ATTENUATOR TYPES that the program will help you design. Shown in *a* is a T attenuator, in *b* is an H-type, in *c* is an L-type, and in *d* is a U-type attenuator. Note that the tap on R2 (in *b* and *d*) is at the exact center of resistance.

An L-type attenuator, shown in Fig. 1-c, is perhaps the simplest form of attenuator, consisting of two resistive elements configured in the form of an "L." The L pad does not reflect the same impedance in both directions.

A U-type attenuator, shown in Fig. 1-d, is most often used matching a high impedance to a low impedance.

Before the era of personal computers or hand-held calculators, much time was spent using network formulas, dB charts, and possibly a slide rule to calculate the resistor values for one of those networks. Those calculations were time-consuming and tedious, especially for those not mathematically inclined.

The computer program shown in Table 1 will do all the lengthy calculations in seconds, after you choose one of the 4 networks, enter the line impedance, and the loss (in dB) desired (if applicable). It will then draw the circuit diagram showing the resistor values, the input and output impedances, and where the circuit may be grounded if necessary.

The program is written for the *TRS-80 Model III* with 16K, but it should be adaptable to other computers as well. Note that in the following program a bracket ([) indicates an exponent.

TABLE 1—AUDIO-NETWORK DESIGN

```
 5 CLS; PRINT
10 PRINT "DESIGN AN AUDIO LINE IMPEDANCE
   MATCHING NETWORK OR ATTENUATOR":
   PRINT: PRINT
15 PRINT " KIND", "Z IN/OUT",
   "CONFIGURATION", "SELECT ONE:":PRINT
20 PRINT " T", "EQUAL/TAPER",
   "UNBALANCED","1"
25 PRINT " H", "EQUAL/TAPER",
   "BALANCED","2"
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30 PRINT " L", "TAPER", "UNBALANCED", "3"
35 PRINT " U", "TAPER", "BALANCED","4"
40 PRINT
45 INPUT"ENTER NUMBER FOR CIRCUIT
   DESIRED";S
50 ON S GOTO 100, 200, 300, 400
70 PRINT "ERROR -- DO OVER": GOTO 45
100 CLS: PRINT: PRINT: PRINT " INPUT AND
    OUTPUT IMPEDANCES ARE EQUAL,
    SYMMETRICAL:....1"
105 PRINT: PRINT " INPUT AND OUTPUT
    IMPEDANCES ARE NOT EQUAL, TAPER:....2"
110 PRINT: PRINT: INPUT "ENTER NUMBER FOR
    CIRCUIT DESIRED" ;N
115 ON N GOTO 120, 150: PRINT "ERROR = DO
    OVER": GOTO 110
120 CLS: GOSUB 510: CLS
125 RA=INT (Z*( (K-1)/K+1))):
    RC=INT(Z+K)/(K[2-1))):A=Z: B=Z
130 RA=RA+1: IF S = 2 THEN 205:CLS
135 T$="T": B$="UNBALANCED":
    I$="SYMMETRICAL": U$="MATCH
    IMPEDANCE AND REDUCE POWER LEVEL.
140 GOSUB 1000: GOSUB 1020: GOSUB: 1055
145 GOSUB 2000: GOSUB 2025: GOSUB 2025:
    GOTO 3000
150 CLS:GOSUB 500:GOSUB 530:GOSUB
    525:CLS
155 KA=(K-1)/(K+1):KB=(K[2-1)/(2*K):
    RC=INT((A+B)/(2*KB))
160 RA=INT(((((A+B)*KA)+(A-B))/2)
165 RB=INT((((A+B)*KA)-(A-B))/2)
170 RC=RC+1:IF S = 2 THEN 250
175 T$="T": B$="UNBALANCED";I$="TAPER":
    U$=MATCH IMPEDANCE AND REDUCE
    POWER LEVEL"
180 GOSUB 1000:GOSUB 1025:GOSUB 1055
185 GOSUB 2000:GOSUB 2025:GOSUB 2055:
    GOTO 3000
200 GOTO 100
205 RA=INT (RA/2):RB=INT(RB/2)
218 CLS
215 T$="H": B$="BALANCED":
    I$="SYMMETRICAL":U$="MATCH
    IMPEDANCE AND REDUCE POWER LEVEL"
220 GOSUB 1000: GOSUB 1050
225 GOSUB 2000: GOSUB 2030: GOSUB 2055:
    GOTO 3000
250 RA=INT (RA/2): RB=INT(RB/2)
255 T$="H": B$="BALANCED":
    I$="TAPER":U$="MATCH UNEQUAL
    IMPEDANCES"
260 GOSUB 1000:GOSUB 1035:GOSUB1050
265 GOSUB 2000:GOSUB 2030:
    GOSUB 2055:GOTO 3000
300 CLS
305 GOSUB 500:GOSUB 530: DB=DB+1:
    GOSUB 525
310 RA=INT((A/SQR(A/B))*(((K*SQR(A/B))-1/K))
315 RC=INT((A/SQR(A/B))*(1/(K-SQR(A/B))))
320 T$="L":B$="UNBALANCED"; I$="TAPER":
    U$="MATCH UNEQUAL IMPEDANCE"
325 GOSUB 1000:GOSUB 1040:GOSUB 1055
330 GOSUB 2015:GOSUB 2025:GOSUB 2055:
    GOTO 3000
400 CLS
405 GOSUB 500: GOSUB 530: CLS:RO=B/A
410 RA=INT(A*((SQR(1-RO))/2))
415 RC=INT(A*(RO/SQR(1-RO))):RC=RC+1
420 T$="U": B$="BALANCED": I$= TAPER":
    U$="MATCH UNEQUAL IMPEDANCES"
425 GOSUB 1000:GOSUB 1045
430 GOSUB 2015:GOSUB 2045:GOSUB 2055:
    GOTO 3000
500 PRINT:PRINT:INPUT "ENTER LARGER OF
    TWO IMPEDANCES" ;A
505 INPUT "ENTER SMALLER OF TWO
    IMPEDANCES";B:RETURN
510 PRINT:PRINT INPUT"ENTER THE
    ATTENUATOR IMPEDANCE";Z
515 PRINT "ENTER THE REQUIRED LOSS IN DB"
520 INPUT"DB LOSS CAN BE 0.5 TO 30+ IN
    SOME CASES";DB
525 K=EXP((DB/20)/(LOG(2.71828)/LOG(10)))
    :RETURN
530 DB=CINT(ABS(20*(LOG(SQR(1/(A/B
    ((/(1+SQR(1-(1/(A/B)))))/LOG(10)))+1)
535 RETURN
1000 PRINT @ 83, "TYPE: "T$: PRINT @ 100,B$
1005 PRINT @ 164, "LOSS IN DB: "DB
1010 PRINT @ 147,I$
1015 PRINT @ 211, "USE: "U$:RETURN
1020 PRINT @ 338, RA: PRINT @ 355,RA: PRINT
     @ 450,A: PRINT @ 476,RC: PRINT
     @ 505,A:RETURN
1025 PRINT @ 338, RA: PRINT @ 355, RB: PRINT
     @ 450, A: PRINT @ 476, RC: PRINT @ 505,B:
     RETURN
1030 PRINT @ 338, RA: PRINT @ 355, RA: PRINT
     @ 450, A: PRINT @ 476, RC: PRINT @ 505, A;
     PRINT @ 594, RA: PRINT @ 611, RA:
     RETURN
1035 PRINT @ 338, RA: PRINT @ 355, RB: PRINT
     @ 450, A: PRINT @ 476, RC: PRINT @ 505, B:
     PRINT @ 594, RA: PRINT @ 611, RB:
     RETURN
1040 PRINT @ 338, RA: PRINT @ 450, A:PRINT @
     476, RC: PRINT @ 505, B: RETURN
1045 PRINT @ 338, RA: PRINT @ 450, A: PRINT @
     476, RC: PRINT @ 505, B: PRINT @ 594, RA:
     RETURN
1050 PRINT @ 770, "IF NECESSARY GROUND AT
     CENTER OF "RC" OHMS RESISTOR.":
     RETURN
1055 PRINT @ 770, IF NECESSARY LOWER LINE
     MAY BE GROUNDED": RETURN
2000 Y = 16: FOR X=4 TO 36: SET (X,Y): NEXT X
2005 Y = 16: FOR X=49 TO 70: SET (X,Y): NEXT X
2010 Y = 16: FOR X=85 TO 120: SET (X,Y): NEXT
     X: RETURN
2015 Y = 16: FOR X=4 TO 36: SET (X,Y): NEXT X
2020 Y = 16: FOR X=49 TO 120: SET (X,Y): NEXT
     X, RETURN
2025 Y = 28: FOR X=4 TO 120: SET (X,Y): NEXT
     X: RETURN
2030 Y = 28: FOR X=4 TO 36: SET (X,Y): NEXT X
2035 Y = 28: FOR X=49 TO 70: SET (X,Y): NEXT X
2040 Y = 28: FOR X=85 TO 120: SET (X,Y): NEXT
     X: RETURN
2045 Y = 28: FOR X=4 TO 36: SET (X,Y): NEXT X
2050 Y = 28: FOR X=49 TO 120: SET (X,Y): NEXT
     X: RETURN
2055 Y = 60: FOR Y=16 TO 19: SET (X,Y): NEXT Y
2060 Y = 60: FOR Y =24 TO 28: SET (X,Y): NEXT
     Y: RETURN
3000 PRINT: PRINT: INPUT "PRESS <ENTER> TO
     START NEW CALCULATION.";:GOTO 5
3010 END
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