An Audio Step Generator

This project takes the tedium out of making frequency-response tests on audio equipment

By Jack Cunkelman

Running a frequency-response check with an audio signal generator can be quite a chore. A signal generator being the kind of instrument it is, you spend a lot of time just adjusting level controls. The greater the number of points to be plotted in a test, the more time you spend on monitoring signal levels and making adjustments. The Audio Step Generator described here is an ideal way around this problem. It automatically selects a series of frequencies and maintains a constant output level, letting you concentrate on the frequency-response test instead of on the test conditions.

Using a combination of analog and digital techniques, the Audio Step Generator automatically steps through 10 frequencies of your choice while maintaining an output level that is constant within 0.5 dB over the entire 20-Hz to 20-kHz range. In addition, sine-wave signal distortion is good enough to suit the needs of most users who do not require laboratory precision.

About the Circuit

The Step Generator is built around function generator integrated circuit *IC1* in Fig. 1, selected for this application because of the ease with which the frequency can be changed. Ordinarily, function generator chips do not produce low-distortion sine waves. However, the XR2206 chosen for *IC1* here provides a 0.5% distortion figure, which is acceptable in all but critical applications. Potentiometers *R1* and *R2* are used to adjust distortion of *IC1* to a minimum.

While it is possible to generate a sweep frequency output from a function generator, the ability to determine the frequency at any given instant is lost by doing so. Hence, it was decided that 10 discrete frequencies that could be stepped through would be used. Capacitor *C1* and the resistor connected to pin 7 of *IC1*, which we will refer to as R_X but is actually identified in Fig. 1 as *R9* through *R18*, determine the frequency of oscillation from the formula $f_O = 1/(R_X \times C1)$, with f_O in Hz, R_X in ohms and *C1* in farads.

Though the value of either R_X or *C1* can be varied to change the frequency, it is easier to fix the value of the capacitor and vary that of the resistor in steps. The Table lists various frequency and resistor values needed to generate these frequencies. Trimmer potentiometers or fixed resistors can be used for R_X, depending on the frequency accuracy you require. A Mylar or polystyrene capacitor for *C1* will provide maximum stability. If you use a 5% tolerance capacitor, the frequencies will be more accurate when using fixed resistors.

When pin 9 of *IC1* is open, R_X determines the frequency of oscillation. Grounding pin 9 makes *R6* the frequency-determining element. This feature is used to provide a SET LEVEL position in the project to permit setting initial levels before starting a frequency run, using *S1* to switch this function on and off.

Various values for R_X are switched in with the *IC3, IC4* and *IC5* CMOS switches. The switches are turned off and on by divide-by-10 counter *IC2*. Two NAND gates in *IC6* are wired as an oscillator to drive counter *IC2*. This oscillator sets the rate at which the frequencies are switched. The pulse output rates of this oscillator are determined by the *R7/C5* time constant. Using an audio taper for potentiometer *R5* permits the rate adjustment to be spread out over the

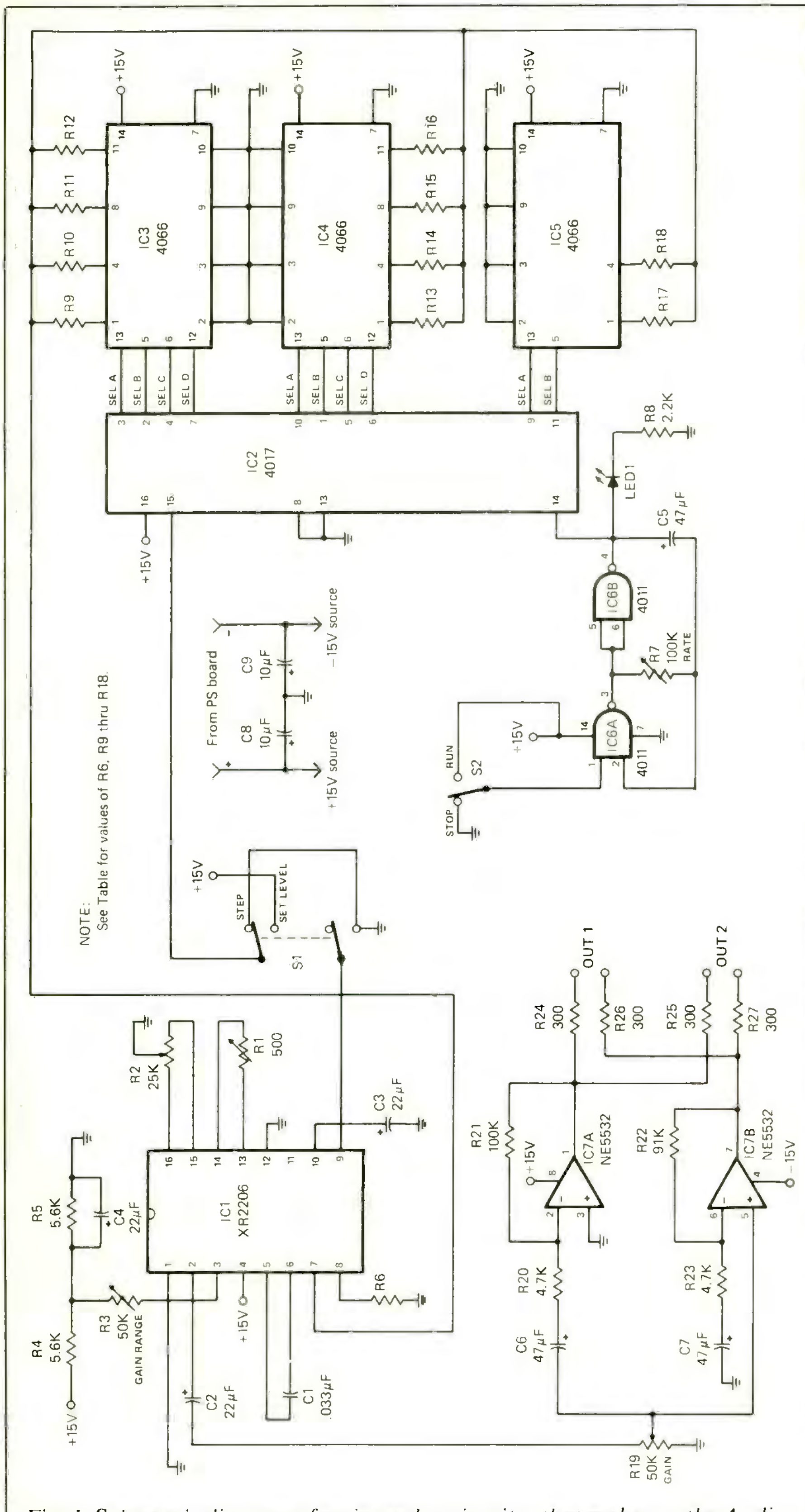

Fig. 1. Schematic diagram of main analog circuitry that makes up the Audio Step Generator. IC1 is a commonly available function generator IC chip.

PARTS LIST

Semiconductors

D1 thru D4—1N4005 rectifier diode
IC1—XR2206 function generator
IC2—4017 counter
IC3 thru IC5—4066 CMOS switch
IC6—4011 quad NAND gate
IC7—NE5532 dual op amp
IC8—7815 +15-volt regulator
IC9—7915 −15-volt regulator
LED1—Light-emitting diode

Capacitors

C1—0.033-μF, 5% Mylar
C2 thru C4—22-μF, 25-volt electrolytic
C5 thru C7—47-μF, 16-volt electrolytic
C8,C9—10-μF, 25-volt electrolytic
C10,C11—2200-μF, 25-volt electrolytic

Resistors (¼-watt, 10% tolerance)

R4,R5—5600 ohms
R6—See table
R8—2200 ohms
R9 thru R18—See table
R20,R23—4700 ohms
R21,R22—100,000 ohms
R24 thru R27—300 ohms
R1—500-ohm trimmer potentiometer
R2—25,000-ohm trimmer potentiometer
R3—50,000-ohm trimmer potentiometer
R7—100,000-ohm audio-taper potentiometer
R19—50,000-ohm audio-taper potentiometer

Miscellaneous

F1—¼-ampere slow-blow fuse
S1—Dpdt switch
S2,S3—Spst switch
T1—30-volt, 500-mA center-tapped transformer Printed-circuit board, perforated board and solder posts, or large solderless socket (see text); sockets for ICs; panel-mount, bayonet-type fuse holder for F1; suitable chassis box (LMB No. CR864 or similar); control knobs (2); output connectors; line cord with plug and strain relief; machine hardware; hookup wire; solder; etc.

entire range of the pot. When pin 1 of *IC6A* is high, the oscillator is enabled. Pulling pin 1 to ground disables oscillation. This is the RUN/STEP function. Its condition is determined by the setting of *S2*. When power is on, the frequencies are changed each time *LED1* goes from off to on.

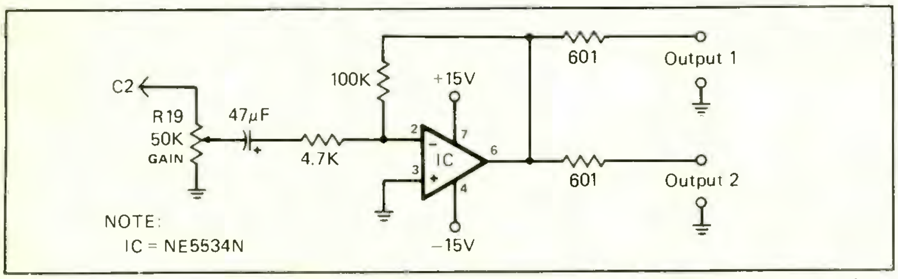

Fig. 2. This alternate output circuit provides outputs that properly match 600-ohm unbalanced inputs.

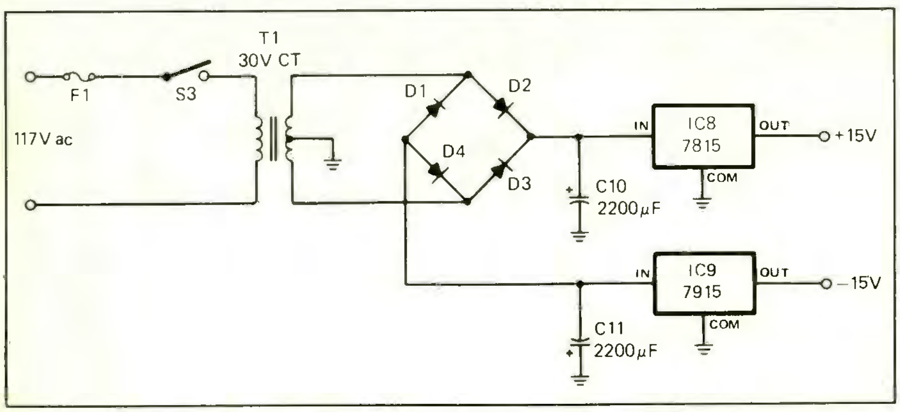

Fig. 3. This is the schematic diagram of the power supply used with the Step Generator's circuitry.

The output from this oscillator is fed into the clock input of counter *IC2*. The counter advances each time the clock pulse goes from ground to positive. As the counter advances, each of the 10 outputs is made positive, one at a time, in step fashion. The reset pin is normally at ground by setting *S1* to the STEP position. Throwing *S1* to the SET LEVEL position resets the counter to 0 and "sets" the function generator to its fixed frequency position. Thus, going from SET LEVEL to STEP always starts at the same spot.

The outputs of counter *IC2* drive the control terminals of analog switches *IC3, IC4* and *IC5*, which in turn switch in various values for R_X. When a control pin is made high, the switch is on. (The analog switches have an on resistance of approximately 100 ohms.)

Output buffer amplifier *IC7* contains a pair of high-performance operational amplifiers that provide balanced 600-ohm outputs. Inverting amplifier *IC7A*'s input and output are 180 degrees out-of-phase, while buffer *IC7B*'s input and output are in-phase with each other. Using one output from *IC7A* and one from *IC7B* yields a balanced output. Output impedance is fixed at 600 ohms by *R24* and *R26* for OUTPUT 1 and by *R25* and *R27* for OUTPUT 2. With two outputs available, you can check both channels of a stereo amplifier simultaneously.

In Fig. 2 is shown a scheme to derive two *un*balanced outputs. Only one amplifier is needed in this case. Output impedance is determined by the values of the resistors in series with the output. These values can be changed as needed.

As shown in Fig. 3, the power supply for the project is relatively simple. Its 30-volt center-tapped transformer feeds a four-diode bridge whose output is filtered by two capacitors and is regulated at +15 and −15 volts with separate IC regulators. (A 24-volt center-tapped transformer and 12-volt regulators could be used, but maximum output from the project would be less.)

Construction

There is nothing critical about construction. Just be sure to keep the ac line and power supply proper as far as possible from the analog circuits. Any reasonable method of wiring the project can be used—a printed-circuit board of your own design, perforated board and solder or Wire Wrap hardware or even a large solderless breadboarding socket.

It is a good idea to socket all ICs except the regulators. As you wire the project, referring to Figs. 1 and 3, be sure to observe proper orientations for the ICs and polarization of electrolytic capacitors and diodes.

Fig. 4 shows the Step Generator's analog cirlcuitry wired on a 4″ × 4″ perforated board with the aid of appropriate mounting/soldering hardware. The power supply section (Fig. 5) was assembled on a separate 4″ × 2″ perforated board. Because current drain is quite low, no heat sinks are required for the regulators.

The project fits nicely into an 8″ × 6″ × 4½″ chassis box. This size box assures ample front panel area for the controls, switches and LED, as well as enough interior space to insure isolation of the power supply from the main analog board.

Machine the chassis box as required. Drill holes for the controls, switches, output connectors and LED on the front panel, and the power supply board, power switch, power transformer, fuse holder and line cord on the rear panel. The analog board mounts on the floor of the box, as far forward as possible without interfering with the front-panel components.

Mount the power supply board on with 6-32 machine hardware and spacers. Mount the power trans-

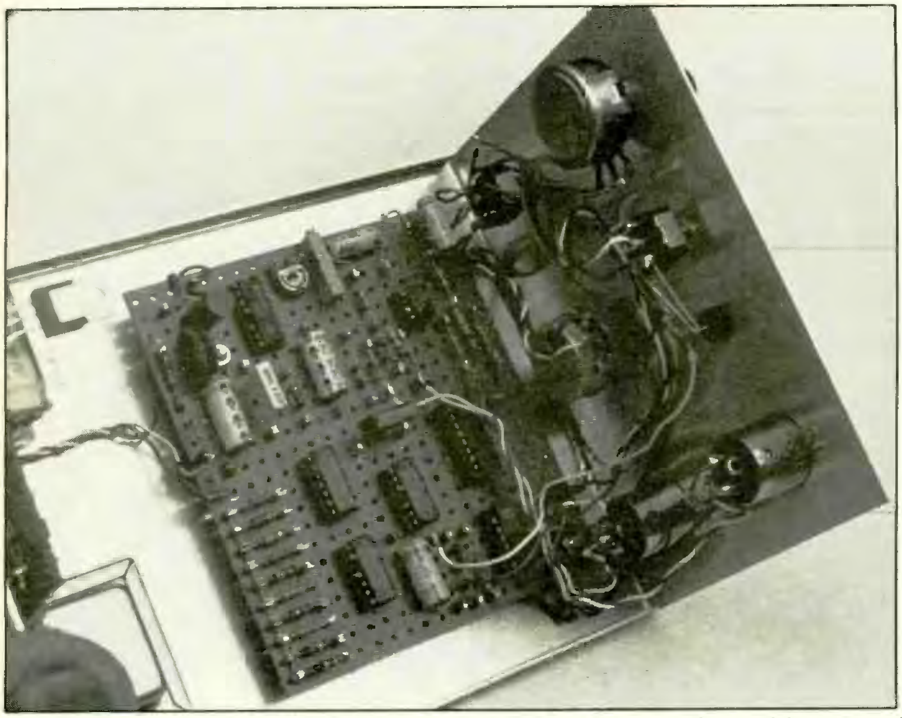

Fig. 4. This view shows analog circuit board layout on perforated board and front-panel component mounting details. ICs are in sockets.

Resistor Values			
Frequency (Hz)	**Value (ohms)**	**Frequency (Hz)**	**Value (ohms)**
20	1.515M	8k	3637
40	757.42k	10k	2880
80	378.64k	12k	2375
100	302.88k	14k	2014
400	75.607k	16k	1743
800	37.728k	17k	1632
1k	30.153k	18k	1533
2k	15.000k	19k	1444
4k	7425	20k	1365
6k	4900		

Resistor values for some typical frequencies. Select 10 frequencies that best suit your needs. The values shown in this table were selected for a 0.033-μF value for timing capacitor *C1*.

former and the fuse holder. Use a strain relief to secure the line cord in place about 4" from its free end inside the box. Alternatively, line the remaining hole with a rubber grommet and pass the line cord through into the box and tie a knot, leaving about 4" of wire inside the box.

Connect and solder one of the transformer's primary leads to one lug of the power switch and a short heavy-duty stranded hookup wire from the other lug of the power switch and one lug of the fuse holder. Connect and solder one line cord wire to the remaining lug of the fuse holder. Though Fig. 3 does not show it (the photo in Fig. 4 does), you can use the second pair of contacts of a dpdt switch to make and break the lower line in the transformer primary circuit simultaneous with the make/break action of the fused line. If you do, connect and solder the other line cord wire to one lug of the second switch section and the remaining transformer primary lead to the other lug. Otherwise, twist together the line cord wire and primary lead and screw onto the connection a wire nut.

Mount the front-panel components and the analog circuit board on the floor of the box. Referring to Figs. 1 and 4, carefully wire the controls, switches and LED into the circuit. When you are finished wiring the project, carefully go over all your wiring, particularly in the power supply, to make sure that everything is okay before you power the project.

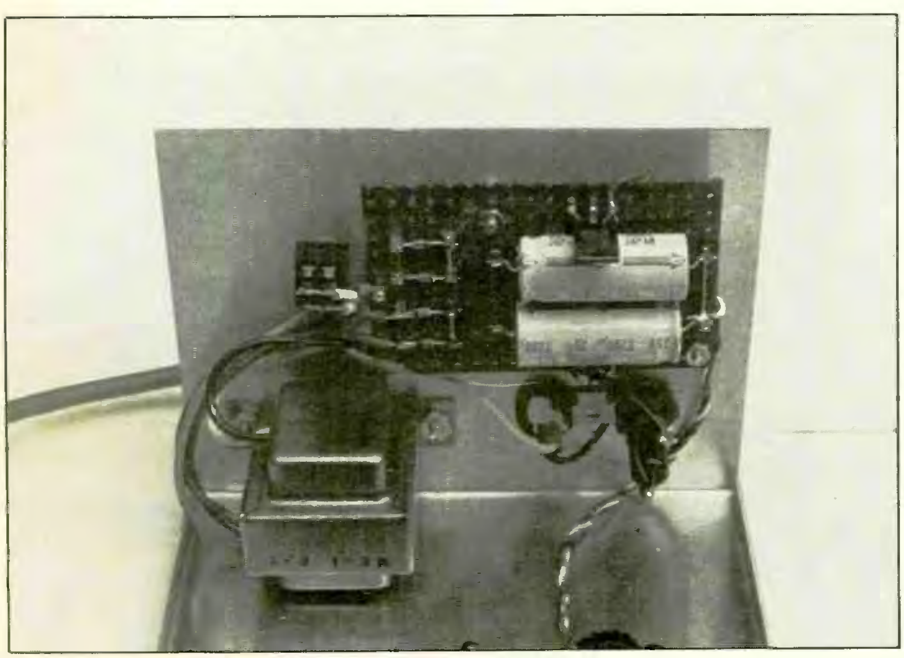

Fig. 5. Power supply board, transformer, fuse holder and power switch mount on rear panel. Secure the line cord as explained in the text.

Adjustment and Use

Set all controls to mid-rotation and

S1 to the SET LEVEL position. Connect an oscilloscope probe to the top of GAIN control *R19*. Plug in the Step Generator's line cord and turn on the power. While observing the oscilloscope display, adjust *R1* and *R2* for minimum distortion of the sine wave; *R1* adjusts for symmetry and *R2* adjusts for shape. You want a waveform with good rounding and symmetry. (If possible, use a distortion analyzer to adjust for minimum distortion. It should be possible to get the distortion down to 0.5% with trimmer potentiometers *R1* and *R2*.)

Move the scope's probe to one of the outputs of the buffer amplifier. Turn GAIN control *R19* fully clockwise and adjust *R3* until clipping is evident; then back off until clipping just disappears. This is the maximum output point. It should be about + 22 dBm with a + 15- and − 15-volt power supply.

Operation of the Audio Step Generator is relatively straightforward. With *S1* in the SET LEVEL position, adjust the output level of the Generator to the level the device under test normally sees at its input. Then set *S1* to STEP and use *R7* to set the RATE at which the generator steps through the frequencies. With STOP/RUN switch *S2*, you can stop the Generator at any frequency and then continue on. Whatever frequency is selected will be positioned between the highest and lowest frequencies to serve as a marker so that you can tell where the Generator is oscillating **ME**

Resistor Calculation

To calculate resistor values for a given frequency more accurately, you must obtain a more accurate value for timing capacitor *C1*. The following computer program will do this for you and then calculate the resistor values for any 10 frequencies you choose. For this procedure, you will need a good ohmmeter and a frequency counter (or oscilloscope). The program was written to run on an Apple II.

Your first objective is to accurately determine the value of *C1* as follows:

(1) Connect the frequency counter or oscilloscope to the Step Generator's input. If you are using a scope, set its sweep to external and apply a 60-Hz signal to the external input from a 6.3-volt filament transformer or other convenient signal source.

(2) Temporarily substitute a 250,000-ohm potentiometer for *R6* on the Step Generator's main board. Connect either outer lug of the pot to one of the resistor connections and the wiper lug to the other resistor connection.

(3) Set the Step Generator to its SET LEVEL mode and adjust the potentiometer for a reading of 240 Hz on the frequency counter. If you are using a scope, the displayed Lissajous pattern should resemble two connected figure 8s lying on their sides when the pot is properly adjusted.

(4) Making sure not to disturb the potentiometer's setting, disconnect it from the circuit and measure the resistance between its wiper and the selected lug. Make a note of your reading, since it will be used later by the computer program to calculate the value of timing capacitor *C1*.

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]LIST

10  HOME
20  REM  ** STEP GENERATOR
30  REM  ** RESISTOR CALCULATION
40  INPUT "DO YOU WANT TO CALCULA
     TE THE EXACT       CAPACITANC
     E VALUE OF C1 (Y OR N) ?";A$

45  PRINT
50  IF A$ = "Y" THEN 90
60  IF A$ = "N" THEN 70
65  GOTO 40
70  INPUT "ENTER THE VALUE OF C1
     (UF)";C
75 C = C * 1E - 6: PRINT
80  GOTO 130
85  PRINT
90  INPUT "INPUT RESISTANCE MEASU
     REMENT OF TEST POT (OHMS)";R

95  PRINT
100 C = 1 / (R * 240)
120  PRINT "EXACT VALUE OF CAPACI
     TOR C1 IS "C" UF "
125  PRINT
130  PRINT "INPUT THE 10 FREQUENC
     IES YOU WANT TO    CALCULATE
      RESISTOR VALUES FOR (HZ)"
140  FOR Z = 1 TO 10
145  PRINT Z;
150  INPUT F
160 R = 1 / (C * F)
170 F(Z) = F:R(Z) = R
180  NEXT Z
200  INPUT "DO YOU WANT PRINTER O
     UTPUT (Y OR N)";P$
210  IF P$ = "Y" THEN  PR# 1: GOTO
     240
220  IF P$ = "N" THEN 240
230  GOTO 200
240  HOME
250  PRINT  TAB( 5)"FREQUENCY"; TAB(
     20)"RESISTOR VALUE"
270  PRINT
280  FOR Z = 1 TO 10
290  PRINT Z;
300 R(Z) = R(Z) - 150
310  PRINT  TAB( 7)F(Z); TAB( 22)
      INT (R(Z)) / 1000"K OHMS"
320  NEXT Z
330  PRINT
340  PRINT  TAB( 10)"FOR C ="C *
     1E6"UF"
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