A TEST METHOD FOR MEASURING
CORONA INCEPTION VOLTAGE
FOR TRANSDUCER AUTOTRANSFORMERS

D.L. Diebel
and
A.C. Tims

Underwater Sound Reference Detachment
Naval Research Laboratory
P.O. Box 568337
Orlando, Florida 32856-8337
**Report Title:** A Test Method for Measuring Corona Inception Voltage for Transducer Autotransformers

**Authors:** Dean L. Diebel and A.C. Tims

**Performing Organization:**
NAVAL RESEARCH LABORATORY
UNDERWATER SOUND REFERENCE DETACHMENT
P.O. BOX 568337
ORLANDO, FL 32856-8337

**Sponsoring/monitoring Agency:**
NAVAL SEA SYSTEMS COMMAND
WASHINGTON, DC 20362-5101

**Abstract:**
An autotransformer corona inception test circuit has been developed and a prototype has been constructed and demonstrated. Circuit diagrams and component values are presented. Ancillary equipment for the test is identified and recommended, test procedures and precautions are presented, and measured corona inception voltage data as well as pictorial data are presented for autotransformers of different manufacture and type. Included is a computer program which is used to model and calculate values of test circuit filter components.

**Subject Terms:**
- Corona
- Transducers
- Autotransformer
- Reliability (electroacoustic)
Contents

INTRODUCTION................................................................. 1
BACKGROUND ........................................................................ 1
APPROACH AND OBJECTIVES............................................. 2
CIV TEST CIRCUIT DESCRIPTION........................................ 3
CIV TEST PROCEDURES........................................................ 10
CIV TEST PRECAUTIONS....................................................... 13
CIV TEST DATA.................................................................... 13
CONCLUSIONS....................................................................... 15
SUMMARY............................................................................... 16
ACKNOWLEDGMENTS............................................................. 16
REFERENCES.......................................................................... 16
APPENDIX - Ladder Computer Program for EMI Filter....................... 17
A TEST METHOD FOR MEASURING CORONA INCEPTION VOLTAGE
FOR TRANSDUCER AUTOTRANSFORMERS

INTRODUCTION

A small but significant percentage of failures in high-power fleet sonar transducers are due to breakdown of electrical insulating or dielectric materials. A physical phenomenon that contributes to these failures is corona which is a discharge of electricity caused by ionization of the surrounding medium when the voltage gradient exceeds a certain critical value. The frequency of discharge is above 75 kHz. At high operating voltages corona occurs before dielectric breakdown, but will, in time, deteriorate insulating materials and cause dielectric failure.

One of the components in a typical high-power transducer that is susceptible to corona is the autotransformer (tapped power inductor) which is used to augment tuning, transmit voltage response, and transmit impedance. These transformers usually operate at secondary voltages in the range of 1500 V, but may be as high as 5000 to 6000 V in some instances. A suitable corona test is valuable in determining if a particular transformer design or production transformer has corona at relatively low voltages. Such a situation may be indicative of poor terminal design, voids or air pockets in the coil coatings or potting compounds, and an indication of premature failure in the normal operating environment.

This report covers the development of a corona inception voltage (CIV) test that can be applied as a qualification, quality control, or quality assurance provision in a transducer autotransformer specification.

BACKGROUND

In 1987, General Electric (GE) and Raytheon were awarded production contracts to fabricate TR-317( ) sonar transducers according to a government developed Fabrication Specification Package (FSP). The FSP contains requirements that are deemed necessary for the composite transducer to achieve a 15-year service life. One such requirement was a corona specification for the autotransformer. As a part of the FSP development, certain critical assemblies of the transducer, which included the transformer, were procured by sample buys (in small quantities) to proof the FSP drawings. Because of limited financial resources in the years prior to the TR-317( ) production contract award, some of the sample buys were still in progress at the time of contract award.
During the transformer sample buy, a transformer contractor (Harder, Inc.) expressed concern about the validity of the corona requirements and the test method specified in the transformer drawings [1]. The concerns were: (1) the validity of a quantitative limit and measure of corona; and (2) the effectiveness of the specified filter circuit in attenuating the fundamental frequencies and passing the frequencies associated with corona. After consultation with the Naval Sea Systems Command (NAVSEA) it was determined that Harder's concerns were valid. These concerns led the TR-317( ) production contractors, with NAVSEA concurrence, to submit a Deviation/Waiver requesting modifications to the transformer drawing with respect to corona measurement, corona suppression, and abatement. In order to prevent delays in receiving First-Article transducers, the waiver (applicable to these transducers only) was allowed.

Since the waiver was allowed for First-Article transducers only, and at the beginning of production NAVSEA would again have to address the problem, NRL-USRD accepted the task of developing a technically defensible corona test for the TR-317 transformer that could be applied to the production transformers.

Several references are made in this report, to the TR-330A transducer (NAVSEA Drawing 53711-5517085), and TR-330A transformer corona data are presented. Corona requirements were not included in the original TR-330A FSP because the corona specifications for the TR-317( ) transformer were indefensible, and there were problems associated with corona testing the TR-317( ) transformer. The TR-317( ) FSP was used as a template for the TR-330A, thus the solution for the problem in the TR-317( ) also becomes the basis for a validated corona test for the TR-330A transformer.

**APPROACH AND OBJECTIVES**

The approach to the problem was to use the corona test circuit and specification in the TR-317( ) transformer drawing and make the necessary changes to provide a technically defensible test. That is, "defensible" in the sense that if a transformer failed to pass the test, the transformer would be questionable -- not the measurement, methodology, or test circuit.

The first step in the approach was to eliminate the quantitative test procedure and replace it with a qualitative test procedure. Therefore, instead of specifying a quantitative measure of corona current at some test voltage, the approach would be based on the qualitative detection of corona inception. That is, the goal was simply to be able to detect when corona first occurs, and measure the voltage at which it occurs.

The hardware for the test must be specified and tested to determine if corona can be detected reliably, repeatedly, and economically at the transformer assembly level.
The items needed to accomplish a CIV test, not including ancillary equipment, are:

1. A circuit to resonate with the autotransformer at the approximate center of the operating frequency range.

2. A high pass filter to attenuate the lower fundamental frequencies, yet allow the higher corona frequencies to be passed for detection.

3. A properly constructed Faraday shield to provide protection from outside electromagnetic interference which can mask the corona signal.

**CIV TEST CIRCUIT DESCRIPTION**

The corona test circuit and test procedure originally developed by the TR-317R transducer design team was inadequate for its intended purpose. Figure 1 depicts an improved CIV test circuit, including the ancillary test equipment, that has been developed from the original test circuit and validated. In Fig. 1, capacitor $C_A$, inductor $L$, and capacitor $C_B$ are the essential parts of the autotransformer resonant circuit: $C_A$ resonates with the transformer under test, $C_B$ isolates the EMI filter from the rest of the circuit to prevent loading, and $L$ enhances the corona detection by preventing the source from shunting the corona signal. $C_A$ is calculated from the formula for the resonance frequency of an ideal parallel LC circuit which is,

$$ f_r = \frac{1}{2\pi\sqrt{L_C A}} $$  \hspace{1cm} (1)

If, in Eq. (1), we define $L_T$ as the inductance of the transformer under test, and $f_r$ as the approximate center of the transformers operating frequency band, then

$$ C_A = \frac{1}{4\pi^2 f_r^2 L_T} $$  \hspace{1cm} (2)
Figure 2 is a schematic diagram of the EMI filter section of the circuit shown in Fig. 1 and depicts the three stage ladder, R-C, R-L, high-pass filter which passes the corona signal to an appropriate detector. The circuit component values shown in Fig. 2 were determined by using equations derived from the model of a three-stage, high pass, L section filter. The circuit values were verified on a computer program, developed by the Naval Ocean Systems Center (NOSC) for an L section filter. The computer program for the circuit is contained in the appendix.
Several different circuits were evaluated to determine the five most optimum values shown in Fig. 3, although all the circuits evaluated were, to some degree, acceptable in that the fundamental frequency would be attenuated while allowing the corona frequency to be passed through for detection. Circuit value set #1 was chosen because at no time did $E_{\text{out}}/E_{\text{in}}$ exceed 0 dB, and set #1 exhibited a steep cutoff slope. Set #2 also exhibited a steep cutoff slope, but exceeded 0 dB $E_{\text{out}}/E_{\text{in}}$. The other circuit values would allow attenuation of the fundamental frequency, but not to the same degree as set #1. The calculated values (along with actual tests) verified that the circuit would be acceptable for testing both TR-317( ) and TR-330 transformers with only a change in the value of capacitor $C_A$ shown in Fig. 1.
The quality of the components used in the circuit is very important to eliminate the possibility of corona in any other part of the circuit except the transformer under test. All capacitors are oil-filled polypropylene capacitors and have a dielectric dissipation factor of 0.001 (0.1%) or less.

The inductors for the CIV test circuit were designed and fabricated at NRL-USRD. Inductor L, in Fig. 1, consists of 18 turns of #25 polythermaleze insulated copper wire, pi wound on a three section bobbin. The bobbin assembly is placed into a Ferroxcube #2616 P 368 ferrite cup core, and the Q, measured on a RLC bridge, is 68. Inductors L1, L2, and L3 in Fig. 2 consist of 223 turns of #25 polythermaleze insulated copper wire in a Ferroxcube #3622 PA400 3B7 ferrite cup core; and the measured Q is approximately 270.

Figures 4a through 4f are photographs of the test circuit chassis and enclosure. Excluding the ancillary equipment, only the transformer under test is not within the shielded enclosure.

The Faraday shield for the circuit consists of the aluminum chassis bottom, the chassis faceplate, and the copper wire mesh attached by screws to the chassis as shown in Fig. 4c. Shielding the circuit could also be accomplished by enclosure in a metal box or cabinet instead of using a copper mesh. The mesh was used during the development phase to visually determine the existence of any arcing. The circuit components and wiring should be isolated from the enclosure to minimize any interaction between the return current path of the circuit and the grounded case shield which should not have any current flow. This condition is implied by the single point ground connection shown in Fig. 1.
The electrical connections between circuit components on the chassis are made with 15 kV dc rated, silicone insulated, 20 AWG stranded copper wire.

**Fig. 4a - Front view of faceplate.**

**Fig. 4b - Rear view shield mesh installed.**
Fig. 4c - Side view Faraday shield/chassis.

Fig. 4d - Top view mesh installed.
Fig. 4e - Top view internal components/mesh shield.

Fig. 4f - Rear view component mounting.
CIV TEST PROCEDURES

An oscilloscope with a measurement capability of dc to at least 20 MHz should be used. The output connector V1 is connected to the vertical input of the oscilloscope. The oscilloscope should be preset to a vertical input sensitivity of 2 V/division and a horizontal sweep time of 20 μs/division. The rest of the setup is done as shown in Fig. 1.

The hookup wire from the power amplifier output should be a single twisted pair. All other circuit connections are made with RG-58/U coaxial cable (which will withstand 2 kV) to further shield the circuit from EMI.

In evaluating test procedures, measurements were made with and without transformer shielding and the results indicated that a shield was not necessary for the transformers tested (TR-317 and TR-330A autotransformers). In extremely noisy environments, transformer shielding can easily be accomplished, if necessary, but all shielded ground connections to the circuit should be made at a single point on the chassis.

To make the CIV test:

1. Adjust the input voltage as read on the VM to the transformer to approximately 5 to 10V at the approximate resonant frequency \([fr, Eq.(1)]\) of the autotransformer under test. Then carefully adjust the frequency generator to the frequency that produces the maximum voltage on the voltmeter, or the maximum amplitude waveform on the oscilloscope.

2. After the frequency is adjusted to resonance, carefully increase the applied voltage as read on the VM until the corona inception "hash" is sporadically observed on the oscilloscope. Corona inception is evidenced by the sporadic high-frequency "hash" type oscillations on the oscilloscope waveform and by an increase in the voltmeter reading. Record the frequency and the voltage at which corona inception is observed.

3. Repeat the first two steps two more times to insure repeatability.

Figures 5 and 6 serve to illustrate how the corona "hash" appears on the oscilloscope waveform. Figure 5a shows the scope waveform for a TR-330A transformer under normal drive conditions and Fig. 5b under higher drive conditions that has produced corona. Note that a small amount of the drive frequency is evident in the oscilloscope display; but, as seen in the high-drive condition, Fig. 5b, is not detrimental to the observance of the corona "hash" in Fig. 5b. Figures 6a and 6b show the same drive conditions just described, respectively, for a TR-317 transformer; Fig. 6a shows a clean waveform; and Fig. 6b shows a waveform with high-frequency corona "hash." If desired, corona detection can be augmented if an AM radio receiver is available, placed near the transformer under test, and tuned to 550-560 kHz; sporadic noise (loud static) will be heard from the receiver at the same time that corona "hash" (as illustrated in Figs. 5b and 6b) appears on the oscilloscope waveform.
Fig. 5a - Output of the CIV test circuit for a TR-330A autotransformer under normal drive conditions.

Fig. 5b - Output of the CIV test circuit for a TR-330A autotransformer under high-drive conditions with corona "hash."
Fig. 6a - Output of the output of the CIV test circuit for a TR-317 autotransformer under normal drive conditions.

Fig. 6b - Output of the CIV test circuit for a TR-317 autotransformer under high-drive conditions with corona "hash."
CIV TEST PRECAUTIONS

The amplifier chosen for the CIV test must be adequate for the intended purpose. For the TR-317 transformer test circuit, shown in Fig. 1, the power amplifier should be an Instruments Inc. Model LDV 2-6, 10 kVA or an equivalent that will supply the current and voltages necessary for the test. For the TR-330A transformer, a McIntosh Model MG-2500, 1 kVA amplifier or equivalent is adequate. Since a high impedance output may make the test circuit susceptible to high-frequency noise pickup, one should use the minimum impedance setting on the amplifier compatible with providing the required test voltage across the transformer.

For the TR-317 corona test circuit, capacitor $C_A$ should be the value shown in Fig. 1. For the TR-330A transformer corona test, the value of $C_A$ should be 3000 pF.

It should be emphasized that corona occurs in the presence of high voltages; therefore, high voltage is required to make the test. The measurements should be made with care and respect for the operating conditions to prevent serious electrical shock to the operator.

CIV TEST DATA

The CIV test circuit and procedures previously described have been used to determine the CIV for several TR-317 and TR-330A production transformers and for experimental TR-330A toroidal autotransformers. The TR-317 group contains transformers salvaged from TR-317 autopsies, transformers from the TR-317R sample buy, and GE TR-317( ) production transformers -- the latter two made by Harder, Inc. and Chloride, respectively. The transformers are fabricated in a variety of ways; i.e., varnish coated but not potted, potted, etc., these conditions are noted with the measured data in Tables 1 and 2.

The TR-330A group contains transformers which are potted except for two experimental toroidal transformers which are unpotted. The unpotted transformers were included in the test to demonstrate the difference in CIV between unpotted and potted transformers.

Table 1 provides data from the CIV tests on the TR-317 transformers. The serial numbers shown in the table are the actual serial numbers shown on the transformers, except for those that have an A prefix (the A prefix indicates the serial number of the transducer from which the transformer was removed). The table indicates, in the column headed "Type," certain conditions and materials used in the fabrications of the transformer. Table 1a is corona test data for TR-317 transformers, some of which were salvaged from autopsies. Table 1b is test data for 6 GE TR-317( ) production transformers (Chloride). Table 1c shows the test data from 6 TR-317R Sample Buy (Harder) transformers. The frequency data shown in Table 1 is relative to the electrical resonance of the transducer in-water (peak of free-field voltage sensitivity). The table indicates three independent measurements on each transformer. Measurements were taken at approximately 1 minute intervals.
Table 1a - Corona Test Data for TR-317 Autotransformers.

<table>
<thead>
<tr>
<th>Ser #</th>
<th>CIV (Hz)</th>
<th>CIV (Hz)</th>
<th>CIV (Hz)</th>
<th>Type</th>
<th>CIV</th>
<th>Std</th>
</tr>
</thead>
<tbody>
<tr>
<td>013</td>
<td>2731</td>
<td>790</td>
<td>2522</td>
<td>858</td>
<td>2561</td>
<td>852</td>
</tr>
<tr>
<td>405</td>
<td>2915</td>
<td>586</td>
<td>2865</td>
<td>583</td>
<td>2596</td>
<td>597</td>
</tr>
<tr>
<td>H-1</td>
<td>3115</td>
<td>462</td>
<td>2557</td>
<td>499</td>
<td>2550</td>
<td>473</td>
</tr>
<tr>
<td>H-2</td>
<td>3007</td>
<td>518</td>
<td>2825</td>
<td>532</td>
<td>3110</td>
<td>519</td>
</tr>
<tr>
<td>H-3</td>
<td>2731</td>
<td>578</td>
<td>2899</td>
<td>613</td>
<td>2758</td>
<td>570</td>
</tr>
<tr>
<td>A31108</td>
<td>3372</td>
<td>587</td>
<td>3169</td>
<td>634</td>
<td>3125</td>
<td>604</td>
</tr>
<tr>
<td>A30433</td>
<td>2549</td>
<td>586</td>
<td>2778</td>
<td>605</td>
<td>2882</td>
<td>596</td>
</tr>
<tr>
<td>A22719</td>
<td>3196</td>
<td>596</td>
<td>2954</td>
<td>569</td>
<td>3020</td>
<td>572</td>
</tr>
<tr>
<td>A24394</td>
<td>2998</td>
<td>593</td>
<td>3142</td>
<td>579</td>
<td>3057</td>
<td>772</td>
</tr>
</tbody>
</table>

Table 1b - TR-317( ) Autotransformers from GE (made by Chloride).

<table>
<thead>
<tr>
<th>Ser #</th>
<th>CIV (Hz)</th>
<th>CIV (Hz)</th>
<th>CIV (Hz)</th>
<th>Type</th>
<th>CIV</th>
<th>Std</th>
</tr>
</thead>
<tbody>
<tr>
<td>037</td>
<td>2581</td>
<td>576</td>
<td>2564</td>
<td>577</td>
<td>2581</td>
<td>577</td>
</tr>
<tr>
<td>041</td>
<td>2522</td>
<td>570</td>
<td>2479</td>
<td>569</td>
<td>2526</td>
<td>569</td>
</tr>
<tr>
<td>054</td>
<td>3003</td>
<td>571</td>
<td>3100</td>
<td>568</td>
<td>3044</td>
<td>569</td>
</tr>
<tr>
<td>058</td>
<td>2670</td>
<td>568</td>
<td>2605</td>
<td>569</td>
<td>2500</td>
<td>568</td>
</tr>
<tr>
<td>060</td>
<td>2570</td>
<td>582</td>
<td>2500</td>
<td>582</td>
<td>2580</td>
<td>582</td>
</tr>
<tr>
<td>061</td>
<td>2700</td>
<td>579</td>
<td>2818</td>
<td>578</td>
<td>2703</td>
<td>579</td>
</tr>
</tbody>
</table>

* Hi Temp 221, Hi Temp Resins Inc.

Table 1c - TR-317R Sample Buy Autotransformers from Harder Inc.

<table>
<thead>
<tr>
<th>Ser #</th>
<th>CIV (Hz)</th>
<th>CIV (Hz)</th>
<th>CIV (Hz)</th>
<th>Type</th>
<th>CIV</th>
<th>Std</th>
</tr>
</thead>
<tbody>
<tr>
<td>037</td>
<td>2581</td>
<td>576</td>
<td>2564</td>
<td>577</td>
<td>2581</td>
<td>577</td>
</tr>
<tr>
<td>041</td>
<td>2522</td>
<td>570</td>
<td>2479</td>
<td>569</td>
<td>2526</td>
<td>569</td>
</tr>
<tr>
<td>054</td>
<td>3003</td>
<td>571</td>
<td>3100</td>
<td>568</td>
<td>3044</td>
<td>569</td>
</tr>
<tr>
<td>058</td>
<td>2670</td>
<td>568</td>
<td>2605</td>
<td>569</td>
<td>2500</td>
<td>568</td>
</tr>
<tr>
<td>060</td>
<td>2570</td>
<td>582</td>
<td>2500</td>
<td>582</td>
<td>2580</td>
<td>582</td>
</tr>
<tr>
<td>061</td>
<td>2700</td>
<td>579</td>
<td>2818</td>
<td>578</td>
<td>2703</td>
<td>579</td>
</tr>
</tbody>
</table>

14
Table 2 provides corona inception data for several TR-330A transformers. The test circuit shown in Fig. 1 was used to take the data with the following modifications: Capacitor CA was changed to 3000 pF and the power amplifier was a McIntosh Model 2500. The frequencies shown in Table 2 are, in this case, the actual resonance frequencies.

Table 2 - TR-330A Autotransformer Corona Test Data.

<table>
<thead>
<tr>
<th>Ser #</th>
<th>CIV (Hz)</th>
<th>CIV (Hz)</th>
<th>CIV (Hz)</th>
<th>Type</th>
<th>Mean</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1504</td>
<td>6925</td>
<td>1500</td>
<td>6922</td>
<td>1513</td>
<td>6922</td>
</tr>
<tr>
<td>2</td>
<td>1526</td>
<td>6944</td>
<td>1568</td>
<td>6948</td>
<td>1540</td>
<td>6950</td>
</tr>
<tr>
<td>3</td>
<td>1500</td>
<td>6942</td>
<td>1517</td>
<td>6945</td>
<td>1522</td>
<td>6942</td>
</tr>
<tr>
<td>194</td>
<td>1559</td>
<td>6583</td>
<td>1587</td>
<td>6582</td>
<td>1590</td>
<td>6582</td>
</tr>
<tr>
<td>587</td>
<td>1583</td>
<td>7152</td>
<td>1548</td>
<td>7148</td>
<td>1597</td>
<td>7150</td>
</tr>
<tr>
<td>617</td>
<td>1559</td>
<td>7088</td>
<td>1556</td>
<td>7087</td>
<td>1560</td>
<td>7086</td>
</tr>
<tr>
<td>MPP 1*</td>
<td>530</td>
<td>6543</td>
<td>600</td>
<td>6531</td>
<td>596</td>
<td>6534</td>
</tr>
<tr>
<td>MPP 2*</td>
<td>1659</td>
<td>6302</td>
<td>1644</td>
<td>6282</td>
<td>1652</td>
<td>6288</td>
</tr>
<tr>
<td>MPP 3*</td>
<td>545</td>
<td>6533</td>
<td>585</td>
<td>6526</td>
<td>562</td>
<td>6527</td>
</tr>
<tr>
<td>MPP 4*</td>
<td>1655</td>
<td>6235</td>
<td>1650</td>
<td>6234</td>
<td>1659</td>
<td>6235</td>
</tr>
</tbody>
</table>

* MPP 1 = Unpotted toroid 55251-W4 core.
* MPP 2 = Potted toroid 55251-W4 core.
* MPP 3 = Unpotted toroid 55248-A2 core.
* MPP 4 = Potted toroid 55248-A2 core.

MPP = Molypermalloy Powder core manufactured by Magnetics Inc.
Potting compound = Eccobond 45 black with 19M catalyst. Autotransformer was vacuum potted.

CONCLUSIONS

The data from both the TR-330A, TR-317( ), TR-317R, and the TR-317 autotransformer samples indicate that the TR-330A representatives have a smaller standard deviation than representatives from the TR-317 group. In particular, serial #H-1 of the TR-317 group, with a standard deviation of 324 V, presents an interesting problem. Operator error is the most probable cause of the first excessively high CIV reading for serial #H-1, as the last two readings are much closer to each other (within 7 V). Standard deviations were below 6% of the mean CIV recorded. For this type of measurement, the standard deviations are acceptable. An AM receiver was added to the rest of the auxiliary equipment to gather the TR-330A data where the standard deviations were less than 2% of the mean CIV. The AM receiver has the advantage of providing the operator with an audio reference which compliments the visual reference.
SUMMARY

An autotransformer corona test circuit has been developed and tested, ancillary equipment for the test has been identified and recommended, test procedures and precautions have been presented, and measured corona data are presented for autotransformers of different manufacture and type. As a result, recommendations have been made to NAVSEA to incorporate the test into appropriate drawing packages.

ACKNOWLEDGMENTS

The authors wish to express appreciation to Homer Ding of NOSC, San Diego, CA, for his work on the computer program and for his guidance, and to Leo Johnson, also of NOSC, for his guidance.

REFERENCES


Appendix

LADDER COMPUTER PROGRAM FOR EMI FILTER

Figure Al contains the circuit identifiers used to operate the computer program which follows. This program was used successfully on a Hewlett Packard 9000, model 200 computer using HP BASIC 5.0. Lines 80-120 in the program describe the initial procedure of loading the program.

Fig. A1 - Circuit identifiers.
DIEBEL and TIMS

LADDER PROGRAM VERSION 1.0, OCTOBER 1988

AUTHOR: HOMER DING
NAVAL OCEAN SYSTEMS CENTER
CODE 711, BLDG 132
SAN DIEGO, CA. 92152
(619) 553-1443

THIS PROGRAM WAS WRITTEN IN HP BASIC 4.0.
A COMPLEX EXTENSION FROM STRUCTURED SOFTWARE SYSTEMS
WAS ALSO USED.
THIS PROGRAM SHOULD WORK WITH HP BASIC 5.0 IF THE GET STATEMENT
IS USED TO PLACE THE ASCII FILE IN THE COMPUTER.

THIS PROGRAM WILL COMPUTE THE OUTPUT/INPUT VOLTAGE TRANSFER FUNCTION
OF A LADDER NETWORK.
 Nb = TOTAL NUMBER OF BRANCHES
 THE FIRST LETTER OF A BRANCH TYPE IS S, P, OR T
 S = SERIES BRANCH
 P = PARALLEL BRANCH
 T = IDEAL TRANSFORMER
 IF T THEN THERE ARE NO OTHER LETTERS WHICH DESCRIBES THE BRANCH TYPE
 Z = SERIES COMBINATION OF BRANCH COMPONENTS
 Y = PARALLEL COMBINATION OF BRANCH COMPONENTS
 C, L, AND R = TYPE OF BRANCH COMPONENTS

COM /Menu/ Menu$[20][80],Ch$[20][6],Mark0$[1],Mark1$[1],INTEGER N
ent,Nchr,Xtab,Ytab,Ch[20]
COM /N/ @Pathl,Netfile$[20],Cmnt$(2)[80],Br$(20)[63],INTEGER Nb,REAL R[20],L[20],C[20],Clk$[80]
COM /C/ REAL F,W,F1,F2,F5,S,Supsegs(6,4),INTEGER Nseg,Ns,Tns,Logflags
,Logflags(6),COMPLEX Eb[20],Ib[20],Imb[20],Yb[20],Anet[2,2]
COM /L/ LF$[1][1],Cr$[1][1],Ff$[3][1],Esc$[1][1],Portraits[6],Landscape$[6]
,Font$(4)[80],INTEGER Psc,Page,Npages,Fontnum
INTEGER Chose,M,K1,K2,I
REAL X,Y,G,B,Z,Mag,Ang
DIM S$[80],K$[2]
LOCAL 7
LF$=CHR$(10)
Cr$=CHR$(13)
Esc$=CHR$(27)
Ff$=Esc$&CHR$(7)&CHR$(12)
Portraits=Esc$"$100"
Portraits=Esc$"$110"
Font$(1)=Portraits$&Esc$"(10U"&Esc$"(s0p10.00h12.00v0s08"&Esc$&
&16D"
Font$(2)=Landscape$&Esc$"(10U"&Esc$"(s0p10.00h12.00v0s08"&Esc$&
&16D"
Font$(3)=Portrait$&Esc$"(10U"&Esc$"(s0p16.66h8.50v0s-3B"&Esc$&
&15.6667C"
Font$(4)=Landscape$&Esc$"(10U"&Esc$"(s0p16.66h8.50v0s-3B"&Esc$&
&15.6667C"
REPEAT

18
CALL Menu(1)
CALL Cls
SELECT ChS(1)
CASE "G"
    CALL Getnfile
CASE "E"
    CALL Entnet
CASE "S"
    CALL Recnfile
CASE "P"
    CALL Entint("PRINTER SELECT CODE(1=CRT, 2=THINKJET, 9=LASER JET)",Psc)
    Clk$(1,80]=FNClock$
    CALL Prtnet
    CASE "F"
    CALL Entswpsegs
    CASE "R"
    CALL Entint("PRINTER SELECT CODE(1=CRT, 2=THINKJET, 9=LASER JET)",Psc)
    Clk$(1,80]=FNClock$
    CALL Prttrat
    CASE "I"
    CALL Entint("PRINTER SELECT CODE(1=CRT, 2=THINKJET, 9=LASER JET)",Psc)
    Clk$(1,80]=FNClock$
    CALL Prtlev
    CASE "A"
    CALL Entint("PRINTER SELECT CODE(1=CRT, 2=THINKJET, 9=LASER JET)",Psc)
    Clk$(1,80]=FNClock$
    CALL Prtrnet
END SELECT
UNTIL Ch(I)=Nent
CALL C15
STOP

SUB Beep(OPTIONAL INTEGER Nbeep,Freq,REAL Secon,Secof)
    INTEGER I,F,N
    REAL S1,S0
    N=1
    F=2700
    S1=.03
    S0=.04
    IF NPAR>0 THEN N=Nbeep
    IF NPAR>1 THEN F=Freq
    IF NPAR>2 THEN S1=Secon
    IF NPAR>3 THEN S0=Secof
    FOR I=1 TO N
        BEEP F,S1
        WAIT S0
    NEXT I
SUBEND | Beep
SUB Fkeys(OPTIONAL INTEGER Keyon) !0=OFF, 1=ON
  INTEGER K
  K=1
  IF NPAR=1 THEN K=NOT Keyon
  CONTROL CRT,121;K
SUBEND ! Fkeys

SUB Curs(OPTIONAL INTEGER Col,Row,Curson)
  INTEGER C,R,S
  C=1
  R=19
  S=1 ! CURS ON
  IF NPAR>0 THEN C=Col
  IF NPAR>1 THEN R=Row
  IF NPAR>2 THEN S=Curson
  CONTROL CRT,0;C
  CONTROL CRT,1;R
  CONTROL CRT,10;S
SUBEND ! Curs

SUB C1s(OPTIONAL INTEGER Col,Row,Keyof)
  INTEGER C,R,K
  C=1
  R=19
  K=0
  IF NPAR>0 THEN C=Col
  IF NPAR>1 THEN R=Row
  IF NPAR>2 THEN K=Keyof
  OUTPUT CRT;CHR$(128);"K";
  CALL Fkeys(K)
  CALL Curs(C,R)
SUBEND ! C1s

DEF FNClock$
  RETURN UPC$(DATE$(TIMEDATE)."&TIME$(TIMEDATE))
FNEND ! FNClock$

SUB Continue
  INTEGER K1,K2
  DISP "TO CONTINUE HIT ANY KEY"
  CALL Kbscan(K1,K2)
  DISP
SUBEND ! Continue

DEF FNAtn2(X,Y,OPTIONAL INTEGER Posang) ! 4 QUADRANT ARC TANGENT
  INTEGER P
  DEG
  P=0
  IF NPAR=3 THEN P=Posang
  RETURN ARG(COMPLEX(X,Y))+(P<>0)*360
FNEND ! FNAtn2

SUB Rec2pol(Xr,Xi,Mag,Ang,OPTIONAL INTEGER Posang)
NRL MEMORANDUM REPORT 6559

1490 INTEGER P
1500 REAL M
1510 DEG
1520 P=0
1530 IF NPAR=5 THEN P=Posang
1540 M=ABS(CMPLX(Xr,Xi))
1550 Ang=FNAtn2(Xr,Xi,P)
1560 Mag=M
1570 SUBEND ! Rec2pl
1580 !
1590 SUB Pol2rec(Mag,Ang,Xr,Xi) !POLAR TO RECTANGULAR
1600 REAL Txr
1610 Txr=Mag*COS(Ang)
1620 Xi=Mag*SIN(Ang)
1630 Xr=Txr
1640 SUBEND ! Pol2rec
1650 !
1660 DEF FNDb(X)
1670 RETURN 20*LGT(X)
1680 FNEND ! FNDb
1690 !
1700 DEF FNAdb(X)
1710 RETURN 10^(.05*X)
1720 FNEND ! FNAdb
1730 !
1740 SUB Entstr(Prompt$.,Str$)
1750 DIM Temp$(80)
1760 DISP Prompt$&" = ";
1770 OUTPUT 2;Str$;
1780 OUTPUT KBD;CHR$(255);"H";
1790 LINPUT Temp$
1800 IF Temp$<>"" THEN Str$=Temp$
1810 PRINT Prompt$&" = ";Str$
1820 SUBEND ! EntSTR
1830 !
1840 SUB Entint(Prompt$.,INTEGER I,OPTIONAL INTEGER Noprt)
1850 DIM Temp$(80)
1860 INTEGER Prtflg
1870 Prtflg=1
1880 IF NPAR=3 THEN Prtflg=NOT Noprt
1890 DISP Prompt$&" = ";
1900 OUTPUT 2;VAL$(I);
1910 OUTPUT KBD;CHR$(255);"H";
1920 LINPUT Temp$
1930 IF Temp$<>"" THEN I=VAL(Temp$)
1940 IF Prtflg THEN PRINT Prompt$&" = ";I
1950 SUBEND ! Entint
1960 !
1970 SUB Entreal(Prompt$.,REAL U,OPTIONAL REAL Unitmult)
1980 REAL U
1990 DIM Temp$(80)
2000 U=1
2010 IF NPAR=3 THEN U=Unitmult
2020 DISP Prompt$&" = ";
2030  OUTPUT 2:VAL$(U/V);
2040  OUTPUT KBD:CHR$(255):"H";
2050  LINPUT Temp$
2060  IF Temp$<>"" THEN V=VAL(Temp$)*U
2070  PRINT Prompt$" = "V/U
2080  SUBEND ! Entreal
2090  !
2100  SUB Prtmenu(INTEGER Nmenu)
2110  COM /Menu/ Menu$:20](B0),Ch$:20](G1),Mark0$]1),Mark1$]1),INTEG
2120  R Nent,Nchr,Xtab,Ytab,Ch(20)
2130  PRINT IS CRT
2140  SELECT Nmenu
2150  CASE 1
2160  RESTORE Menu1
2170  CASE 2
2180  RESTORE Menu2
2190  CASE 3
2200  RESTORE Menu3
2210  END SELECT ! Nmenu
2220  CALL Cis
2230  ALPHA OFF
2240  READ MenuS(0)
2250  READ Nent
2260  READ Nchr
2270  Mxlen=0
2280  FOR I=1 TO Nent
2290    READ Menu$(I)
2300    Mxlen=MAX(Mxlen,LEN(Menu$(I)))
2310  NEXT I
2320  Xtab=INT(.5*(80-Mxlen)+1)
2330  Ytab=18-Nent
2340  PRINT TABXY(Xtab+Nchr+2,Ytab-1);Mark0$&Menu$(0)
2350  FOR I=1 TO Nent
2360    PRINT TABXY(Xtab,Ytab+I);Mark0$&Menu$(I)
2370  NEXT I
2380  SUBEXIT
2390  !
2400  Menu1:  DATA "LADDER NETWORK PROGRAM",9,1
2410  DATA G GET DATA FROM DISK
2420  DATA E ENTER NETWORK
2430  DATA S SAVE DATA TO DISK
2440  DATA P PRINT NETWORK
2450  DATA F ENTER FREQUENCY SWEEP
2460  DATA A PRINT A MATRIX
2470  DATA R PRINT I/O RATIOS
2480  DATA I PRINT INTERNAL LEVELS
2490  DATA Q QUIT
2500  !
2510  Menu2:  DATA MAIN PLOT MENU,9,1
2520  DATA I INITIALIZE FOR PLOTING
2530  DATA T ENTER TYPE OF PLOT
2540  DATA N ENTER NAMES FOR PLOT AND AXES
2550  DATA S ENTER SCALES
2560  DATA L ENTER LEGEND
SUBEND ! PrtMenu

SUB Kbscan(INTEGER K1,K2,OPTIONAL K$)

DIM Ch$(2)

K1=0

ON KBD GOSUB Kbintr

REPEAT

UNTIL K1<>0

OFF KBD

SUBEXIT

! 

SUBEND ! Kbscan

SUB Menu(INTEGER Nmenu)

COM /Menu/ Menu$(20)[80].Ch$(20)[6].Mark0$(1).Mark1$(1).INTEG

R Nent,Nchr,Xtab,Ytab,Ch(20)

INTEGER I,K1,K2,Width,Choose,Xtml

DIM K$(2)

Mark0$=CHR$(128)

Mark1$=CHR$(129)

CALL Prtmenu(Nmenu)

Choose=Ch(Nmenu)

Xtml=Xtab(1)

DISP "SELECT WITH ALPHA-NUMERIC OR UP-DOWN KEYS, THEN HIT RETU

RN"

REPEAT

Scan:

IF Choose<=1 THEN Choose=Nent

IF Choose>Nent THEN Choose=1

PRINT TABXY(Xtml,Ytab+Choose);Mark1$&" &Menu$(Choose)& ";

CALL Kbscan(K1,K2,K$)

PRINT TABXY(Xtml,Ytab+Choose);Mark0$&" &Menu$(Choose)& ";

IF K1<>255 THEN

GOSUB Search

ELSE

IF K2<>69 THEN Choose=Choose+(K2=86)-(K2=94)

END IF

UNTIL K1=255 AND K2=69

Ch(Nmenu)=Choose

Ch$(Nmenu)=Menu$(Choose)(1,Nchr)
DIEBEL and TIMS

3080 DISP
3090 SUBEXIT
3100 !
3110 Search: FOR I=1 TO Nent
3120 IF K$=Menu$(I)(1,1) THEN
3130 Chose=I
3140 I=Nent
3150 END IF
3160 NEXT I
3170 RETURN
3180 SUSENO!
3200!
3210 SUB Tboxon
3220 Lj$="CALL 25CE,I"&CHR$(13)
3230 OUTPUT 9i"QUIET ON"&CHR$(13);  
3240 OUTPUT 9i:Lj$;
3250 SUBEND ! Tboxon
3260!
3270 SUB Tboxoff
3280 Quit$=CHR$(27)&CHR$(127)&"DONE"&CHR$(13)&CHR$(13)
3290 OUTPUT 9i:Quit$;
3300 WAIT 1
3310 OUTPUT 9i"QUIET OFF"&CHR$(13);
3320 SUBEND ! Tboxoff
3330!
3340 SUB Preprint
3350 COM /Lj/ Lf$(1),Cr$(1),Ff$(3),Esc$(1),Portrait$(6),Landscape$(6),Font$(4)$(80),INTEGER Psc,Page,Npages,Fontnum
3360 PRINTER IS Psc
3370 IF Psc=9 THEN
3380 OUTPUT Psc;Esc$&CHR$(7)&"Q0;"! GO TO LASERJET SERIES II EMULATION
3390 WAIT 1.5
3400 OUTPUT Psc;Font$(Fontnum);
3410 OUTPUT Psc;Esc$&"&10L";! SET LEFT MARGIN 10 SPAACES
3420 OUTPUT Psc;Esc$&"&s0C";! SET LINE WRAP
3430 END IF
3440 SUBEND ! Preprint
3450!
3460 SUB Postprint
3470 COM /Lj/ Lf$(1),Cr$(1),Ff$(3),Esc$(1),Portrait$(6),Landscape$(6),Font$(4)$(80),INTEGER Psc,Page,Npages,Fontnum
3480 IF Psc=CRT THEN
3490 CALL Continue
3500 ELSE
3510 OUTPUT Psc;Ff$;
3520 END IF
3530 CALL Beep(S)
3540 SUBEND ! Postprint
3550!
3560 SUB List
3570 COM /Lj/ Lf$(1),Cr$(1),Ff$(3),Esc$(1),Portrait$(6),Landscape$(6),Font$(4)$(80),INTEGER Psc,Page,Npages,Fontnum

24
CALL Entint("PRINTER SELECT CODE(1=CRT, 2=THINKJET, 9=LASERJET ")",Psc)

File$="LADDER"
Page=0
Npages=0
Fontnum=3
CALL Preprint
CAT File$
CALL Postprint
CALL Continue
CALL Preprint
LIST #Psc
CALL Postprint
CALL Beep(5)

SUBEND ! Llist

SUB Record(OPTIONAL INTEGER A)
File$="LADDER"
IF NPAR>0 THEN
RE-SAVE File$&",.702,0".
DISP "**"&Files&"** PROGRAM RE-SAVED IN ASCII FORMAT";TAB(80)
ELSE
RE-STORE File$&",.1400"
DISP "**"&Files&"** PROGRAM RE-STORED IN INTERNAL FORMAT";TAB(80)
END IF
CALL Beep(5)
SUBEND ! Record

DEF FNExist(Name$)
INTEGER Existflg
Existflg=1
ON ERROR RECOVER Er
ASSIGN @P TO Name$
R: IF Existflg THEN ASSIGN @P TO *
OFF ERROR
RETURN Existflg

! FNEND ! FNExist

SUB Mknet
CREATE BOAT Netfile5,4
SUBEND ! Mknet

SUB Getnfile
INTEGER Fig

! SUB Getnfile
4070 \textbf{REPEAT}
4080 \textbf{CALL Entstr("NETWORK FILE NAME",Netfile$)}
4090 \textbf{Flg-FNExist(Netfile$)}
4100 \textbf{IF Flg=0 THEN}
4110 \textbf{BEEP}
4120 \textbf{PRINT '"";Netfile$"" DOESN'T EXIST, TRY AGAIN"}
4130 \textbf{END IF}
4140 \textbf{UNTIL Flg}
4150 \textbf{ASSIGN @Pathl TO Netfile$}
4160 \textbf{ENTER @Pathl;Cmnt$(*)|NbBr(*).R(*).C(*).L(*)}
4170 \textbf{ASSIGN @Pathl TO *}
4180 \textbf{SUBEND ! Getnfile}
4190 |
4200 \textbf{SUB Recnfile}
4210 \textbf{COM /N/ @Pathl;Netfile$[20],Cmnt$(2)[B0],Br$(20)[6],INTEGER Nb}
4220 \textbf{REAL R(20),L(20),C(20),Clk$(80)}
4230 \textbf{CALL Entstr("NETWORK FILE NAME",Netfile$)}
4240 \textbf{IF FNExist(Netfile$)=0 THEN CALL Mknet}
4250 \textbf{ASSIGN @Pathl TO Netfile$}
4260 \textbf{OUTPUT @Pathl;Cmnt$(*)|Nb,Br$(*)|R(*).C(*).L(*)}
4270 \textbf{ASSIGN @Pathl TO *}
4280 \textbf{SUBEND ! Recnfile}
4290 |
4300 \textbf{SUB Entnet}
4310 \textbf{COM /N/ @Pathl;Netfile$[20],Cmnt$(2)[B0],Br$(20)[6],INTEGER Nb}
4320 \textbf{REAL R(20),L(20),C(20),Clk$(80)}
4330 \textbf{INTEGER I}
4340 \textbf{DIM S$(40),T$(12)}
4350 \textbf{Format: IMAGE "BRANCH ",K,#}
4360 \textbf{CALL CIs}
4370 \textbf{CALL Entstr("REM 1",Cmnt$(1))}
4380 \textbf{CALL Entstr("REM 2",Cmnt$(2))}
4390 \textbf{CALL Entint("NUMBER OF BRANCHES",Nb)}
4400 \textbf{FOR I=1 TO Nb}
4410 \textbf{OUTPUT S$ USING Format:11}
4420 \textbf{T$=Br$(I)}
4430 \textbf{CALL Entstr(S$\&" TYPE",T$)}
4440 \textbf{Br$(I)=T$}
4450 \textbf{IF T$(I,1)="X" OR T$(I,1)="T" THEN CALL Entreal("TRANSFORMER TURNS RATIO (NS/NP)"),R(I))}
4460 \textbf{IF POS(T$,"R")<>0 THEN CALL Entreal(S$\&" R (KOHM)"),R(I),1.E+3)}
4470 \textbf{IF POS(T$,"C")<>0 THEN CALL Entreal(S$\&" C (nF)"),C(I),1.E-9)}
4480 \textbf{IF POS(T$,"L")<>0 THEN CALL Entreal(S$\&" L (mH)"),L(I),1.E-3)}
4490 \textbf{NEXT I}
4500 \textbf{SUBEND ! Entnet}
4510 |
4520 \textbf{SUB Seg2f(INTEGER S)}
4530 \textbf{COM /C/ REAL F,W,F1,F2,Fs,Swpsegs(6,4),INTEGER Nseg,Ns,Tns,Logflg,Logflags(6),COMPLEX Eb(20),Ib(20),Imb(20),Yb(20),Anet(2,2)}
4540 \textbf{F1=Swpsegs(S,1)}
4550 \textbf{F2=Swpsegs(S,2)}
NRL MEMORANDUM REPORT 6559

SUBF2seg(INTEGER S)

COM /C/ REAL F, W, F1, F2, Fs, Swpsegs(6, 4), INTEGER Nseg, Ns, Tsns, Log
flag, Logflags(6), COMPLEX Eb(20), Ib(20), Imb(20), Yb(20), Anet(2, 2)

Swpsegs(S, 1)=F1
Swpsegs(S, 2)=F2
Swpsegs(S, 3)=Fs
Swpsegs(S, 4)=Ns
Logflags(S)=Logflg

SUBEND ! F2seg

SUB Entswp($$)

COM /C/ REAL F, W, F1, F2, Fs, Swpsegs(6, 4), INTEGER Nseg, Ns, Tsns, Log
flag, Logflags(6), COMPLEX Eb(20), I b (20), Imb(20), Yb(20), Anet(2, 2)

CALL Entint($$&"SWEEP TYPE (0-LINEAR, 1=LOG)", Logflg)
CALL Entreal($$&"FIRST FREQUENCY (Hz)", F1)
CALL Entreal($$&"LAST FREQUENCY (Hz)", F2)
SELECT Logfig
CASE 0 ! LINEAR SWEEP
   CALL Entreal($$&"STEP FREQUENCY (Hz)", Fs)
   IF Fs=0 THEN
      CALL Entint($$&"NUMBER OF STEPS", Ns)
      Fs=(F2-F1)/(N-1)
   ELSE
      Ns=((F2-F1)/Fs)+1
   END IF
CASE 1 ! LOG SWEEP
   CALL Entreal($$&"NUMBER OF STEPS", Ns)
   Fs=(F2/F1)^(1/(Ns-1))
END SELECT
SUBEND ! Entswp

SUB Compimb(INTEGER Bi)

COM /N/ @PathI, Netfile$(20), Cmnt$(2)(80), Br$(20)(6), INTEGER Nb
, REAL R(20), L(20), C(20), C1k$(80)

COM /C/ REAL F, W, F1, F2, Fs, Swpsegs(6, 4), INTEGER Nseg, Ns, Tsns, Log
flag, Logflags(6), COMPLEX Eb(20), I b(20), Imb(20), Yb(20), Anet(2, 2)

INTEGER Ps, Pp, Py, Pz, Pr, P1, Pc
REAL Xr, Xi

Ps=POS(Br$(Bi), "S")
Pp=POS(Br$(Bi), "P")
Pz=POS(Br$(Bi), "Z")
Py=POS(Br$(Bi), "Y")
Pr=POS(Br$(Bi), "R")
P1=POS(Br$(Bi), "L")
Pc=POS(Br$(Bi), "C")
Xr=0
Xi=0
W=(PI+PI)*F
IF Pz<>0 THEN
IF Pr<>0 THEN Xr=R(Bi)

IF P1<>0 THEN Xi=Xi+w*L(Bi)
IF Pc<>0 THEN Xi=Xi-1/(w*C(Bi))

END IF

IF Py<>0 THEN
    Xi=Xi-Lj*w*B(Bi)
END IF

IF Pr<>0 THEN
    Xr=Xr-1/R(Bi)
END IF

IF P1<>0 THEN
    Xi=Xi+1/(w*L(Bi))
END IF

IF Pc<>0 THEN
    Xi=Xi+w*C(Bi)
END IF

Imb(Bi)=CMPLX(Xr,Xi)

IF (Ps<>0 AND Py<>0) OR (Pp<>0 AND Pz<>0) THEN Imb(Bi)=1/Imb(Bi)

SUBEND ! CompimbEDIT4530

SUB Cascade

COM /N/ @Path1,Netfile$(20),Cmnt$(2)[80],Br$(20)[6],INTEGER Nb,
REAL R(20),L(20),C(20),Clks[80]

COM /C/ REAL F,W,F1,F2,Fs,Segs(6,4),INTEGER Nseg,Ns,Tns,Log
flag,flags(6),COMPLEX Eb(20),Ib(20),Imb(20),Yb(20),Anet(2,2)

INTEGER I
Anet(1,1)=CMPLX(1,0)
Anet(1,2)=CMPLX(0,0)
Anet(2,1)=Anet(1,2)
Anet(2,2)=Anet(1,1)

FOR I=Nb TO 1 STEP -1
    CALL Compimb(I)
    SELECT Br$(I)[1,1]
    CASE "T","X"
        Anet(1,1)=Anet(1,1)/R(I)
        Anet(1,2)=Anet(1,2)/R(I)
    CASE "S"
        Anet(1,1)=Anet(1,1)+Imb(I)*Anet(2,1)
        Anet(1,2)=Anet(1,2)+Imb(I)*Anet(2,2)
    CASE "P"
        Anet(2,1)=Anet(2,1)+Imb(I)*Anet(1,1)
        Anet(2,2)=Anet(2,2)+Imb(I)*Anet(1,2)
    END SELECT
    NEXT I

SUBEND ! Cascade

SUB Compiby

COM /N/ @Path1,Netfile$(20),Cmnt$(2)[80],Br$(20)[6],INTEGER Nb,
REAL R(20),L(20),C(20),Clks[80]

COM /C/ REAL F,W,F1,F2,Fs,Segs(6,4),INTEGER Nseg,Ns,Tns,Log
flag,flags(6),COMPLEX Eb(20),Ib(20),Imb(20),Yb(20),Anet(2,2)

INTEGER I,Im1
Yb(Nb)=CMPLX(0,0)
Ib(Nb)=Yb(Nb)
Eb(Nb)=CMPLX(1,0)

FOR I=Nb TO 1 STEP -1
    Im1=I-1
    CALL Compimb(I)

SUBEND ! Compiby
SELECT BrS(I)[1,1]
CASE "T","X"
   Eb(Iml)=Eb(I)/R(I)
   Ib(Iml)=Ib(I)*R(I)
CASE "S"
   Eb(Iml)=Eb(I)+Ib(I)*Imb(I)
   Ib(Iml)=Ib(I)
CASE "P"
   Eb(Iml)=Eb(I)
   Ib(Iml)=Eb(I)*Imb(I)+Ib(I)
END SELECT

NEXT I
SUBEND ! Compeiy

SUB Prth

COM /N/ @Path1,Netfile$[20],Cmnt$[2][80],BrS(20)[6],INTEGER Nb
,REAL R(20),L(20),C(20),Clk$[80]
COM /Lj/ Lf$[1],Cr$[1],Fs$[3],Esc$(1],Portrait$[6],Landscape$[6],Font$(4)[80],INTEGER Psc,Page,Npages,Fontnum

IF Page>0 THEN
   IF Npages=0 THEN
      PRINT Clk$(1,51+10*(F>2)J&"PAGE "&VAL$(Page)
   ELSE
      PRINT Clk$(1,55+10*(F>2)J&"PAGE "&VAL$(Page)& OF "&VAL$(Npages)
   END IF

END IF

IF NOT (Cmnt$(1)[1,1]="" OR LEN(Cmnt$(1))=0) THEN PRINT Cmnt$(1)

IF NOT (Cmnt$(2)[1,1]="" OR LEN(Cmnt$(2))=0) THEN PRINT Cmnt$(2)

PRINT
SUBEND ! Prth

SUB Prtnet

COM /N/ @Path1,Netfile$[20],Cmnt$[2][80],BrS(20)[6],INTEGER Nb
,REAL R(20),L(20),C(20),Clk$[80]
COM /Lj/ Lf$[1],Cr$[1],Fs$[3],Esc$(1],Portrait$[6],Landscape$[6],Font$(4)[80],INTEGER Psc,Page,Npages,Fontnum

INTEGER I

Fmt1: IMAGE "BR TYPE R (KOHM) L (mH) C (nF) TURNS RATIO(S/P)"
Fmt2: IMAGE DD,3X,AAAAAA,\$,
Fmt3: IMAGE 6X,DDDDDD.DDDDD,\$,
Fmt4: IMAGE "",----------------",\$,
Fmt5: IMAGE 4X,DDDDDD.DDDDD,\$,
Fmt6: IMAGE 4X,"",----------------",\$,
Fmt7: IMAGE "PRINTING PAGE ",K," OF ",K

IF Psc=9 THEN
   Fontnum=3
ELSE
   Fontnum=0
END IF
CALL Preprint
CALL Prth

IF Psc<>CRT THEN OUTPUT CRT USING Fmt7;Page,Npages
PRINT USING Fmt1
FOR I=1 TO Nb
    PRINT USING Fmt2;Br$(I)
    IF POS(Br$(I),"R")<>0 THEN
        PRINT USING Fmt3;R(I)*1.E-3
    ELSE
        PRINT USING Fmt4
    END IF
    IF POS(Br$(I),"L")<>0 THEN
        PRINT USING Fmt3;L(I)*1.E+3
    ELSE
        PRINT USING Fmt4
    END IF
    IF POS(Br$(I),"C")<>0 THEN
        PRINT USING Fmt3;C(I)*1.E+9
    ELSE
        PRINT USING Fmt4
    END IF
    IF POS(Br$(I),"T")<>0 OR POS(Br$(I),"X")<>0 THEN
        PRINT USING Fmt5;R(I)
    ELSE
        PRINT USING Fmt6
    END IF
NEXT I
CALL Postprint
SUBEND I Prtnet
SUB Prtnet

CON /N/ @Path1,Netfile$[20],Cnt$(2)(80),Br$(20)[6],INTEGER Nb
,REAL R(20),L(20),C(20),Clk$(100]

CON /C/ REAL F,W,F1,F2,Fs,Swpsegs(6,4),INTEGER Nseg,Ns,Tns,Log
flg,Logflags(6),COMPLEX Eb(20),Ib(20),Imb(20),Yb(20),Anet(2,2)
COM /Lj/ Lf$(11),Cr$[11],Ff$[31],Esc$[11],Portraits$[6],Landscapes$ [6],Font$[4][80],INTEGER Psc,Page,Npages,Fontnum

INTEGER I,K,S,Md,Iml
REAL Zm, Za, Rm, Ra, Np
COMPLEX T

! Addition by Mitch Boiling to store data for plotting by PLOTTER
INTEGER Nbytes,Numrec
REAL Npts

,image "# FREQ(Hz) EOUT/EIN(dB) EOUT/EIN(DEG) ZINMAG(OMH) ZINANG(DEG)"

IMAGE DDD,5(2X,DDDDDDD.DDD)
IMAGE "PRINTING PAGE ",K," OF ",K

*** plot patch ***

Askplot: INPUT "Do you wish to create a PLOTTER file? (Y/N)",&Plots$
IF (Plot$="Y" OR Plot$="y") THEN
   Pflag=1
ELSE
   IF Plot$<"N" AND Plot$<"n" THEN Askplot
END IF

IF Psc=9 THEN
   Fontnum=3
ELSE
   Fontnum=0
END IF
CALL Preprint
Page=1
Np=Tns/(10+35*(Psc=2)+55*(Psc=9))
IF Np<1 THEN Np=1
Npages=INT(Np)
IF Np MOD Npages<>0 THEN Npages=Npages+1
K=1

*** plot patch ***

IF Pflag THEN
   Npts=0
   FOR I=1 TO Nseg
      CALL Seg2f(I)
      Npts=Npts+Ns
   NEXT I
   Nbytes=(INT((Npts*2*8)/256)+1)*256
   ASSIGN @Buffer TO BUFFER [Nbytes] FORMAT OFF
   Num_rec=INT((2*Npts+1)*8)/820
   IF ((2*Npts+1)*8) MOD 820<>0 THEN Num_rec=Num_rec+1
   INPUT "Enter the file name for the Plot: ", Pfile$
   CREATE BOAT Pfile$, Num_rec, 8200
   ASSIGN @Pathl TO Pfile$
   OUTPUT @Path_ INpts
   TRANSFER @Buffer TO @Path_1; COUNT (Npts*2*8), CONT
   END IF

***********
FOR S=1 TO Nseg
   CALL Seg2f(S)
   F=F1
   FOR I=1 TO Ns
      Im=I-1
      Md=K MOD (10+40*(Psc=2)+55*(Psc=9))
      IF Md=1 THEN
         CALL Prth
         IF Psc<>CRT THEN OUTPUT CRT USING Fmt3; Page, Npages
         PRINT USING Fmt1
         Page=Page+1
      END IF
   END IF
   CALL Compeiy
   T=Eb(0)/Ib(0)
   Rec2pol(REAL(T), IMAG(T), Zm, Za)
   T=Eb(Nb)/Eb(0)
DIEBEL and TIMS

6690 Rec2pol(REAL(T),IMAG(T),Rm,Ra)
6700 PRINT USING Fmt2;i,K,F,FN~b(Rm),Ra,1,E-3*Zm,Za
6701 !
6703 ! *** plotter patch ***
6704 IF Pflag THEN
6705 OUTPUT @Bufferi,F,FDNdb(Rm)
6707 END IF
6709 !
6710 ! ***********************
6711 IF Logflg THEN
6712 F=F+Fs
6713 ELSE
6714 F=F+F5
6715 END IF
6717 IF K MOD 5=0 THEN
6718 PRINT
6719 WAIT .S
6721 END IF
6723 IF Md=0 THEN
6724 IF Psc=CRT THEN
6725 CALL Continue
6726 ELSE
6727 OUTPUT Psc;Ffs;
6728 WAIT 1
6729 END IF
6731 END IF
6733 K=K+1
6735 NEXT I
6737 NEXT S
6739 !
6741 ! *** plotter patch ***
6743 CONTROL @Buffer,9:0
6744 WAIT FOR EOT @Path_!
6746 ASSIGN @Path_1 TO *
6747 ASSIGN @Buffer TO *
6749 !
6751 ! ***********************
6753 CALL Postprint
6755 SUBEND ! Prtranet
6757 !
6759 SUB Prtranet
6760 COM /N/ @Pathi,Netfile$(20),Cmnt$(2)(80),Br$(20)(6),INTEGER Nb,REAL R(20),L(20),C(20),Clk$(80)
6761 COM /C/ REAL F,W,F1,F2,Fs,Supseg$(6,4),INTEGER Nseg,Ns,Tns,Logflg,Logflags$(6),COMPLEX Eb(20),Ib(20),Imb(20),Yb(20),Anet(2,2)
6762 COM /L/ !f$(1),Cr$(1),Fs$(1),Esc$(1),Portrait$(6),Landscape$(6),Font$(4)(80),INTEGER Psc,Page,Npage5,Fntnum
6763 COM /D/ DIM S$(80)
6765 INTEGER I,Indx,S,Md,Iml,J,K
6767 REAL Xm,Xa,Xr,Xi,Np
6769 COMPLEX T
6770 Fnt1: IMAGE "F(Hz) = " ,2X,DDDDDD.DD," MAG ANG(DEF)
6772 REAL IMAG"
6774 Fnt2: IMAGE 14X,"A(" ,0,".,",0,".)",4(2X,SO.DDDDDDESZZ)
7040 Fmt3:  IMAGE "PRINTING PAGE ",K," OF ",K
7050 IF Psc=9 THEN
7060    Fontnum=3
7070 ELSE
7080    Fontnum=0
7090 END IF
7100 CALL Preprint
7110 Page=1
7120 Np=Tns/(3+8*(Psc=2)+12*(Psc=9))
7130 Npages=INT(Np)
7140 IF Np MOD Npages<>0 THEN Npages=Npages+1
7150 Indx=1
7160 FOR S=1 TO Nseg
    Seg2f(S)
    F=F1
7190 FOR I=1 TO Ns
    Md=Indx MOD (3+8*(Psc=2)+12*(Psc=9))
7210 IF Md=1 THEN
    CALL Prth
    IF Psc<>CRT THEN OUTPUT CRT USING Fmt3;Page,Npages
    Page=Page+1
7240 END IF
7250 CALL Cascade
7260 PRINT USING Fmt1;F
7270 FOR J=1 TO 2
7280 FOR K=1 TO 2
    Xr=REAL(Anet(J,K))
    Xi=IMAG(Anet(J,K))
    Rec2pol(Xr,Xi,Xm,Xa)
    PRINT USING Fmt2;J,K,Xm,Xa,Xr,Xi
7350 NEXT K
7350 NEXT J
7360 IF Logflg THEN
7370 F=F*Fs
7380 ELSE
7390 F=F+Fs
7400 END IF
7410 IF Md=0 THEN
7420 IF Psc=CRT THEN
    CALL Continue
7430 PRINT
7440 ELSE
    OUTPUT Psci;Ff$;
7460 END IF
7480 END IF
7490 Indx=Indx+1
7500 NEXT I
7510 NEXT S
7520 CALL Postprint
7530 SUBEND ! Prtnet
7540 !
7550 SUB Prtlev
7550 COM /N/ @Path1,Netfile$(20),Cmnt$(2)(80),Br$(20)(6),INTEGER Nb
7550 ,REAL R(20),L(20),C(20),C1k$(80)
DIEBEL and TIMS

7570 COM /C/ REAL F,W,F1,F2,Fs,Swpsegs(6,4),INTEGER Nseg,Ns,Tns,Log flg,Logflags(6),COMPLEX Eb(20),Ib(20),Imb(20),Yb(20),Anet(2,2)
7580 COM /Lj/ Lf$(1],Cr$(1],Ff$[3],EscSE1J,Portrait$6],Lald5CaqPe$
7590 INTEGER P5C,Page,Npages,Fontnum
7600 INTEGER Indx,I,J,S,MdIm1,Lpi,Ipp
7610 REAL Em,Ea,Im,Ia,Zm,Za,Np
7620 COMPLEX T
7630 Fmt1: IMAGE "FREQ (Hz) = ",K
7640 Fmt2: IMAGE " # BRANCH EMAG(V) EANG(DEG) IMAG(mA) IANG(DEG)
* IMAG(KOHM) ZANG(DEG)"
7650 Fmt3: IMAGE DD,2X,AAAAAA,2X,DDDDDD.DDD,2X,DDDD.DDD,2X,DDDDDDD.DDD,2X
,DDDDDD.DDD,2X,DDDDDD.DDD,2X,DDDDDO.DDD,2X,DDDDDO.DDD
7660 Fmt5: IMAGE "PRINTING PAGE ",K," OF ",K
7670 IF Psc=9 THEN
7680 Fontnum=3
7690 ELSE
7700 Fontnum=0
7710 END IF
7720 CALL Preprint
7730 Page=1
7740 Lpi=Nb+4
7750 Ipp=INT((14+42*(Psc=2)+64*(Psc=9))/Lpi)
7760 Np=Nts/Ipp
7770 Npages=INT(Np)
7780 IF Np MOD Npages<>0 THEN Npages=Npages+1
7790 Indx=1
7800 FOR S=1 TO Nseg
7810 CALL Seg2f(S)
7820 F=F1
7830 FOR I=1 TO Ns
7840 Md=(Indx MOD Ipp)+(Ipp-1)
7850 IF Md=1 THEN
7860 CALL Prth
7870 IF Psc<>CRT THEN OUTPUT CRT USING Fmt5;Page,Npages
7880 Page=Page+1
7890 END IF
7900 CALL Compeiy
7910 PRINT USING Fmt1;F
7920 PRINT USING Fmt2
7930 FOR J=0 TO Nb
7940 Rec2pol(REAL(Eb(J)),IMAG(Eb(J)),Em,Ea)
7950 Rec2pol(REAL(Ib(J)),IMAG(Ib(J)),Im,Ia)
7960 IF Ib(J)<>'CMPLX(0,0) THEN
7970 T=Eb(J)/Ib(J)
7980 Rec2pol(REAL(T),IMAG(T),Zm,Za)
7990 PRINT USING Fmt3;J,Br$(J),Em,Ea,1.E+3*Im,Ia,1.E-3*
8000 Zm,Za
8010 ELSE
8020 PRINT USING Fmt4;J,Br$(J),Em,Ea,1.E+3*Im,Ia
8030 END IF
8040 NEXT J
8050 IF Logflg THEN
8050 \quad F=F*Fs
8060 \quad ELSE
8070 \quad F=F+Fs
8080 \quad END IF
8090 \quad IF \textit{Ipp}=1 \text{ THEN } \textit{Md}=0
8100 \quad \text{ IF } \textit{Md}=0 \text{ THEN }
8110 \quad \text{ IF } \textit{Psc}=\text{CRT} \text{ THEN }
8120 \quad \text{ CALL Continue}
8130 \quad \text{ ELSE }
8140 \quad \text{ OUTPUT Psc;Ff$; }
8150 \quad \text{ END IF}
8160 \quad \text{ ELSE }
8170 \quad \text{ PRINT }
8180 \quad \text{ END IF }
8190 \quad \text{ Indx}=	ext{Indx+1}
8200 \quad \text{ NEXT I}
8210 \quad \text{ NEXT S}
8220 \quad \text{ CALL Postprint}
8230 \quad \text{ SUBEND ! Prtiev}
8240 \quad !
8250 \quad \text{ SUB Entswpsegs}
8260 \quad \text{ \texttt{COM /C/ REAL F,W,F1,F2,Fs,Swpsegs(6,4)}, INTEGER Nseg,Ns,Tns,Log$
8270 \quad \text{ flg,Logflags(6)}, \text{ COMPLEX Eb(20),Ib(20),Imb(20),Yb(20)}, \text{ Anet(2,2)}$
8280 \quad \text{ INTEGER S}
8290 \quad \text{ DIM S$\{80\}$}
8300 \quad \text{ Fmt1: } \text{ IMAGE "SEGMENT ",D,X,}$
8310 \quad \text{ Tns} = 0
8320 \quad \text{ CALL Entint("NUMBER OF SWEEP SEGMENTS",Nseg)}
8330 \quad \text{ FOR } S=1 \text{ TO Nseg}
8340 \quad \text{ CALL Seg2f(S)}
8350 \quad \text{ OUTPUT S$\#$ USING Fmt1;S}
8360 \quad \text{ CALL Entswp(S$\#$)}
8370 \quad \text{ Tns=Tns+Ns}
8380 \quad \text{ CALL F2seg(S)}
8390 \quad \text{ NEXT S}
8400 \quad \text{ SUBEND ! Entswpsegs
8410 \quad !