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ELCA - An Electronic Linear Circuit Analysis Program

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Approved for issue by

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1. INTRODUCTION

This program has been written with the express purpose of encouraging industrial concerns engaged upon design work to experiment in-house with an electronic design package. It is written in such a form that it can be readily implemented upon most computers that have a Fortran IV compiler. Since core size is often a limiting factor in preventing a successful implementation this package has been made available in a number of sizes, with varying capabilities.

Some engineers who will use the program will wish to become more familiar with the techniques employed. It has been assumed that such people will not always be aware of the details of algorithms generally employed in this field. Consequently the maths used is the simplest approach to generating the nodal solution of magnitude and phase against a base of frequency for general linear active and passive circuits.

For those users who wish to limit themselves to simply using the program to evaluate circuit performance the input format has been made highly user orientated. It also forms the general data base approach adopted by the ASPACE organisation in order that a large variety of electronic analysis packages may be used with a common user input format. A number of diagnostics have been employed with two aims in mind:-

(a) To indicate to the user just where his mistakes are.

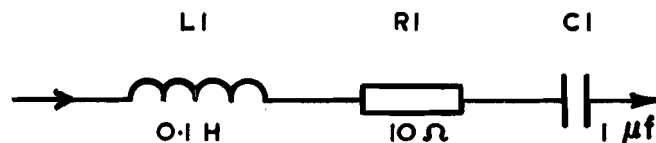
(b) To try to ensure that no matter how badly the input data are presented, the program will handle all the faults without causing the computer to end its attempts at reading by an unintentional stop. Doubtless a number of users will succeed in foiling this aim!

2. PREPARING CIRCUIT DATA

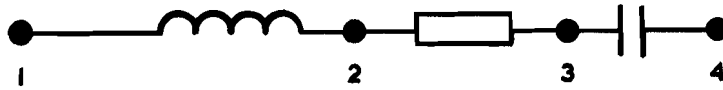
The first examples will consider only passive networks. These will be made up of resistors, inductors and capacitors in the units of ohms, henries and farads. Of course a circuit need not contain all three items but can be any desired assembly of them. The starting point to preparing the data for computer analysis is the normal electronic circuit diagram.

2.1 Example of a series tuned circuit

As a first example a series tuned circuit is given.

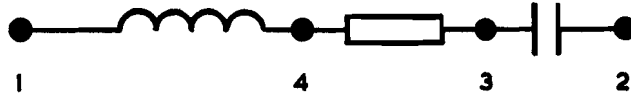


As is common practice the circuit components are numbered, named and valued. The only additional work required is to put in the node numbers. That is to number the interconnection points of the circuit.

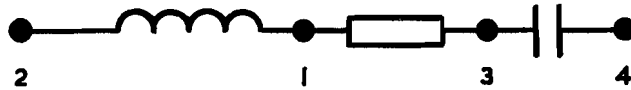


In the example these go from 1 to 4 but can be placed in any order.

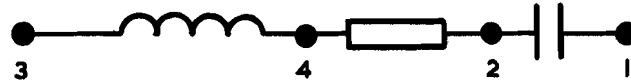
LIKE THIS



OR THIS



OR THIS



Node numbers not only define the circuit position of an element but also indicate the direction of current flow. In ELCA positive current flow is assumed to be from the first stated node to the second stated node. It may also be defined as the first stated node being positive with respect to the second. If errors are made in numbering the node signs will be reversed and 180° phase errors will appear in the printout. If feedback is employed then particular care must be taken with node numbering. In numbering any circuit, somewhere, there must be a sequential order of the nodal numbers. The common (earth) node must always be 0.

2.2 Coding R, L and C

To describe the example, as far as it has gone, to the computer requires the introduction of some coding rules. For the general case of passive components it is:-

Component name, interconnection points, value.

For the general resistive branch

Rname, node 'a', node 'b', value in ohms.

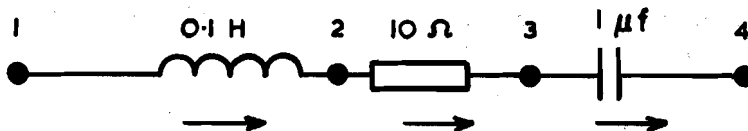
For the general inductive branch

Lname, node 'a', node 'b', value in henries.

For the general capacitive branch

Cname, node 'a', node 'b', value in farads.

Applying these rules to the given example provides the following code:-



R1, 2, 3, 10

RA, 3, 2, 10.0

C1, 3, 4, .000001 or

LA, 2, 1, 0.1

L1, 1, 2, .1

CA, 4, 3, 1.E-6*

From this example it will be seen that the component order, disposition on the page, name, and values with or without decimal points are of no consequence. However, the following points are vital:-

- (a) The name must not exceed 4 letters, numbers or a mixture of both.
- (b) The left to right coding sequence must be in the correct order.
- (c) Commas must be placed between each piece of information.
- (d) Nothing must follow the last piece of information.

2.3 E notation

The use of the E notation is merely a shorthand method recognised by the computer as meaning that the following figure is an exponent value raising the preceding figures by that power of ten. From the example

$$C1, 3, 4, 1.E-6 \quad \text{then} \quad 1.E-6 = 1.0 \times 10^{-6}.$$

Examples of the correct use of the E notation:-

$$1.E3 = 1.0E3 = 1E3 = 10E2 = 100.0E1 = 1000$$

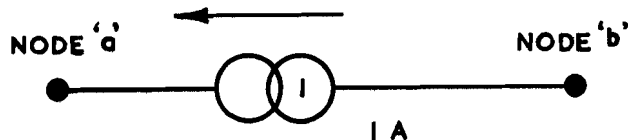
$$5.5E-1 = 0.55$$

Note: The exponent value must be integer incorrect use is 1.E3.0 or 10E2.0

*See section 2.3.

2.4 Coding driving sources

In an ac analysis program the driving sources are considered as sinusoidal and in ELCA both current and voltage generators may be selected. The current source is the ideal current generator with infinite impedance. The branch representation is



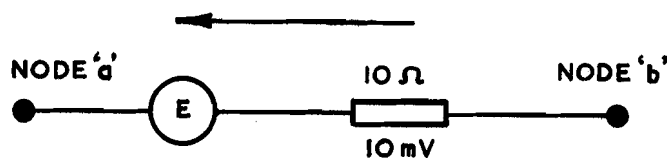
and it is coded

component name, interconnection points, value.

For the general case this is

SAname, node 'a', node 'b', value in amps.

The voltage source must contain a series source resistor and the branch representation is



and it is coded

component name, interconnection points, value, source resistor.

For the general case this is

SVname, node 'a', node 'b', value in volts, resistor in ohms.

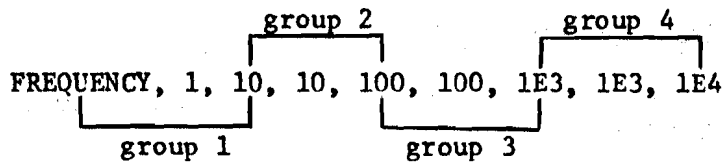
2.5 Coding the frequency of the driving source

A circuit may be investigated at any frequency or over a range of frequencies in ascending order. The maximum number of frequency points permissible in any one run is fifty. If this number is exceeded a warning is printed out and the circuit is analysed over the first fifty frequency steps.

The coding is

FREQUENCY, value or values in Hz.

The assumption is made that the first value is zero but in an ac analysis this step is ignored from the point of view of calculation and print-out. A specific example follows giving a series of groups with log spacing, but note that in any decade the steps will be linear.



Each set of frequencies is taken as a group of three. In the above example these are:-

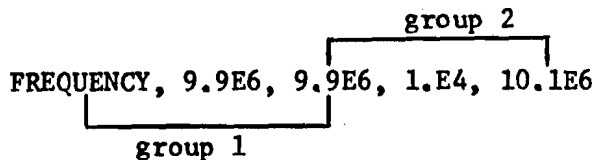
From 0 Hz to 10 Hz in steps of 1 Hz = group 1.

From 10 Hz to 100 Hz in steps of 10 Hz = group 2.

From 100 Hz to 1 kHz in steps of 100 Hz = group 3.

From 1 kHz to 10 kHz in steps of 1 kHz = group 4.

The next example gives a large initial step followed by a detailed investigation.

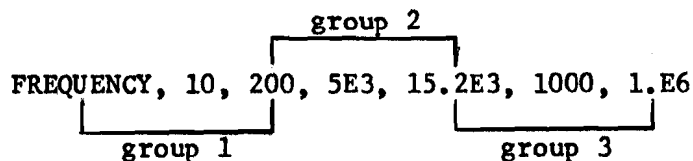


In the above example the grouping is:-

From 0 Hz to 9.9 MHz in steps of 9.9 MHz = group 1.

From 9.9 MHz to 10.1 MHz in steps of 10.0 kHz = group 2.

The final example shows an investigation at both ends of a frequency band with large steps in the anticipated pass-band.



It will be seen that the user has not bothered to evaluate the exact final frequency knowing that the program will stop after fifty frequency steps have been taken. The resulting groups are:-

From 0 Hz to 200 Hz in steps of 10 Hz = group 1 = 20 steps.

From 200 Hz to 15.2 kHz in steps of 5 kHz = group 2 = 3 steps.

From 15.2 kHz to 42.2 kHz in steps of 1 kHz = group 3 = 27 steps.

2.6 Coding to obtain print-out of results

The print out is in tabular form using a fixed format and providing information.

	<u>Plotting Code</u>
Log gain in decibels between any two points in the circuit	DBS
Linear gain in volts between any two points in the circuit	VØLTS
Phase shift in degrees between any two points in the circuit	PHASE
The real component of the nodal voltage at the selected output	RCØMP
The imaginary component of the nodal voltage at the selected output	ICØMP
The magnitude of the nodal voltage at the selected output	ABS

All this information is provided against the frequency base as selected in the detail of section 2.5.

The coding is

PRINT, ref. node, output nodes not exceeding forty in nos.

For the general case this is

PRINT, Ref. Node, node 'a', node 'b', node 'n'

For a specific case this is

PRINT, 1, 3, 10

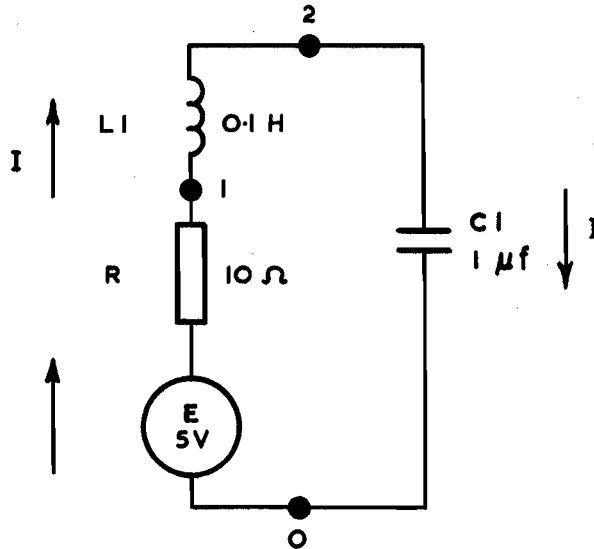
This would provide information as shown above for nodes 3 and 10 referenced to node 1.

Note 1: All nodes are referenced to the common line. Therefore it means that the magnitude between Node 3 and Common is referenced to Node 1 and Common. From this it will be seen that it is not appropriate to reference Node 0.

Note 2: It should be remembered that the voltage gain expressed in decibels is only correct when the reference node and output node have the same loading conditions.

3. A WORKED EXAMPLE OF PASSIVE CIRCUIT ANALYSIS

The information provided up to this point is sufficient to enable the user to analyse passive circuits. The example will be that already considered in section 2.2, but with a driving source added.



For results of above circuit see appendix A.

3.1 Comments

It is often desirable to include a written description of the circuit being analysed; or comments may be required describing the purpose of the tests. This is accomplished in ELCA by enclosing any information requiring print-out between ~~dollar~~ signs. An example is

(This is a comment for print-out only. *)*

ELCA also uses this for a heading to each sheet of output data but if more than one comment is used it will print the last comment as a heading.

3.2 Execution

The computer has to be informed when the circuit description is completed and analysis should commence. So when all the coding has been completed it must be finalised with the command

EXECUTE

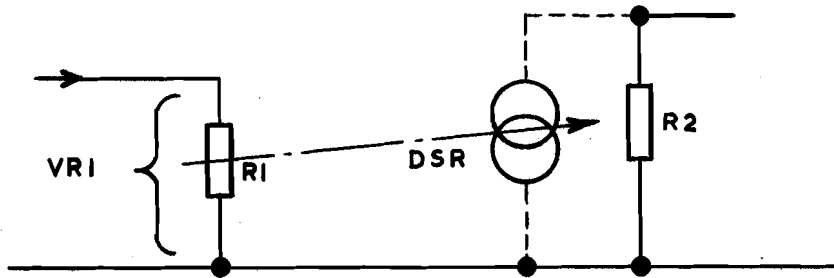
Note: A PRINT statement must be included in the original data set otherwise the analysis will not be executed.

3.3 Producing the coding form

The circuit data must now be produced on punched cards and the form with the above example coded upon it is shown in figure 1. The punch operator will produce the cards directly from this form. Each line of code will result in one punched card.

4. DEPENDENT SOURCES

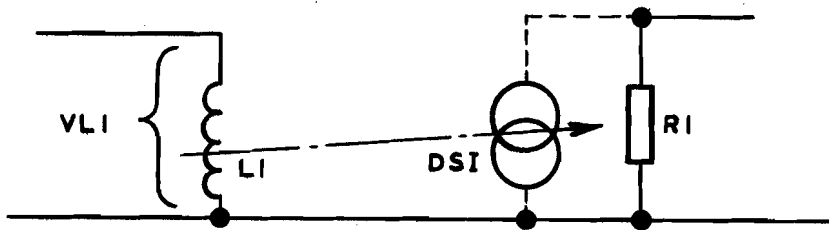
Circuit elements that have inputs associated with other elements elsewhere in the circuit are usually termed "dependent sources". The following shows a simple example:-



The dependent current source is DSR which is dependent upon the current flowing in the resistor R1 or alternatively the voltage developed across that branch, ie, VRI. This dependency commonly known as the transconductance, or gm, of the device is measured as A/V in ELCA. It can be shown that

$$g_m = \frac{\beta}{R_1}, \text{ where } \beta \text{ is equal to the gain of the device.}$$

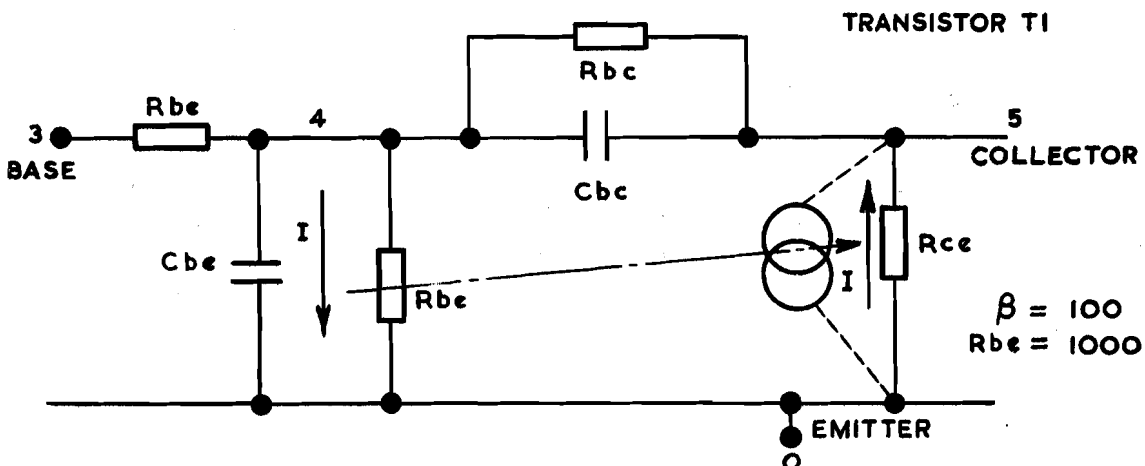
If the controlling branch is reactive,



the dependent source is designated DSI, otherwise the use is identical to the real dependent source, DSR.

4.1 Describing a transistor

If the library facility is not used a transistor may be described using the dependent source technique. The following example shows its use in the hybrid-pi model:-



4.2 Coding dependent sources

As shown in the above examples there are two forms of coding dependent sources according to the type of driving branch. However, both have the same common form:-

component name, nodes of driven branch, nodes of driving branch, gm. If the driving branch is resistive then the general case is DSRname, node 'a', node 'b', node 'x', node 'y', gm in A/V.

In the specific case as used in the hybrid-pye model above it is

DSRT1, 0, 5, 4, 0, 0.1

The gm value is as calculated above, ie, if beta = 100

if Rbe = 1000,

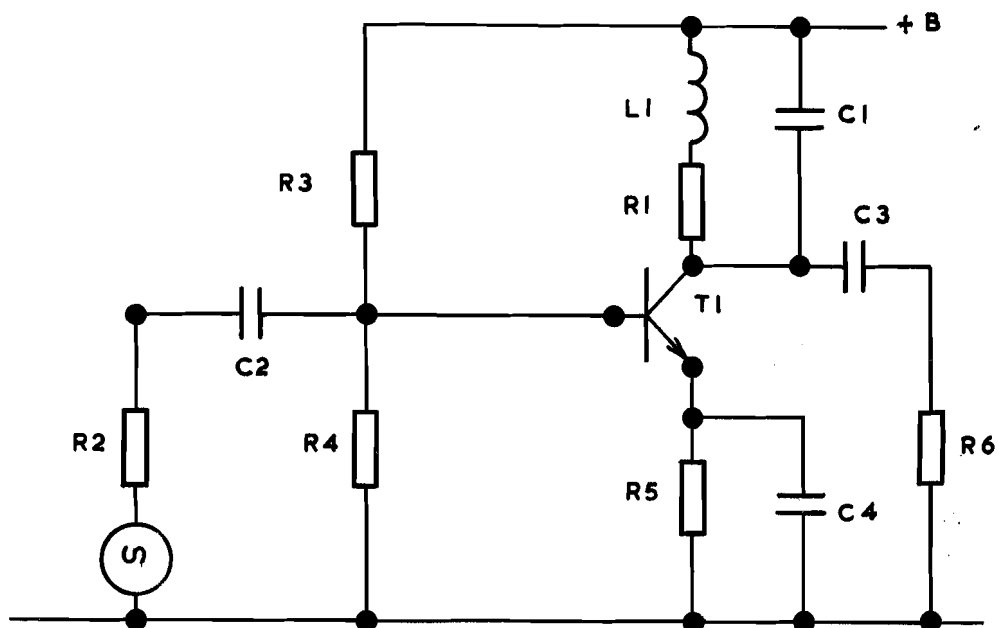
then gm = beta/Rbe = 100/1000 = 0.1.

4.3 Dependent source branch

In each of the above examples a branch component is shown in parallel with the dependent source. This is essential to complete the matrix operations within the program. If not actually a real circuit member then a dummy value, such as 1.E8 must be introduced.

5. A WORKED EXAMPLE OF ACTIVE CIRCUIT ANALYSIS

The example worked in section 3 will now be enlarged to act as a passive network within a circuit containing active elements. The whole forms a low frequency amplifier. Note that the capacitor elements of the transistor model have been omitted because it is a lf application.



R1	10 Ω	C1	1 μ F	T1	Beta 100
R2	600 Ω	C2	25 μ F		Rbe 500
R3	7.5 k Ω	C3	30 μ F		
R4	1.2 k Ω	C4	100 μ F		
R5	300 Ω				
R6	12 k Ω	L1	0.1 H		

Figure 2 shows the equivalent circuit and appendix B shows ELCA print-out.

6. SENSITIVITY ANALYSIS

A circuit may be subjected to a sensitivity analysis for a given parameter at a selected single frequency. This analysis will automatically alter each component by $\pm 10\%$. The resultant print list provides the parameter change against circuit change. Any parameter changes exceeding 1% are also indicated in histogram form. For an example of a sensitivity analysis print-out see appendix C.

6.1 Coding for sensitivity analysis

For the general case this is

SENSITIVITY, ref. node, output node, parameter, frequency in Hz. The parameters which may be investigated singularly are exactly as shown for the print listing in section 2.6. If more than one parameter is to be investigate this is carried out as a modification. The details for the modifications are as given in section 8.

The following examples give specific cases of sensitivity analysis. If the input node of an amplifier was 1 and the output node was 14 and a sensitivity analysis for gain in decibels was required at 50 Hz and 50 kHz the following applies:-

SENSITIVITY, 1, 14, DBS, 50

EXECUTE

SENSITIVITY, 1, 14, DBS, 50.E3

A study of the phase sensitivity across nodes 4 and 7 within the same circuit is made:-

SENSITIVITY, 4, 7, PHASE, 50.E3

If this option is utilised and modifications are required please note section 8.3.

7. PRINTER-PLOTTER CAPABILITY

The output of the circuit analysis may be presented in a graphical format using the on-line printer. This will produce a coarse plot because the grid containing the graphical information is limited by the number of characters that the ordinary page will accept. Normally this will be approximately 40 or 50 vertically \times 120 horizontally.

The general format required to obtain a plotted output is `PLØT`, frequency base, numbers of plots, parameters.

The frequency base can be either logarithmic - `LØG`
or linear - `LINEAR`

The number of plots is limited between 1 and 10. This will be the number of plots taken from the print list in sequential order. For example if the print list statement was

```
PRINT, 1, 4, 6, 7, 8
```

and the plot statement was

```
PLØT, LINEAR, 3, DBS
```

three plots of logarithmic gain at nodes 4, 6 and 7 referenced to node 1 would be obtained against a linear base of frequency.

The parameters are limited to six in any one plot statement. These are the same as given in section 2.6. An example using all six is given:-

```
PLØT, LØG, 2, VØLTS, DBS, PHASE, RØMP, IØMP, ABS
```

The order of the six parameters may be as required. It should be noted that if the full capability of this statement is used it will result in sixty graphs being plotted!

8. CIRCUIT MODIFICATION

Any circuit may be modified in terms of the circuit values, driving functions, or output functions. Circuit topology may not be modified. Changes always follow an `EXECUTE` statement.

The modification to the original circuit values is carried out.

For the general case this is

*Original component name, new value or values.

The following generalises for the various components:-

*Rname, new value in ohms

*Lname, new value in henries

*Cname, new value in farads

*SAname, new value in amps

*SVname, new value in volts, new value in ohms

*DSRname, new value of gm

*DSIname, new value of gm

To modify the statements PRINT, FREQUENCY, PLOT, or SENSITIVITY the statement is repeated in full following an EXECUTE statement. The * sign must not be used. It is not essential to make either of the last two statements in the original listing before the first execution. For example an overall frequency print-out may be required but only plots of say the hf roll-off. This could be obtained by omitting the PLOT statement in the original list and then introducing it after the first execution with a different frequency listing.

It is essential to repeat the PRINT and FREQUENCY statements in any modified runs following the use of the SENSITIVITY option.

9. LOSSLESS TRANSMISSION LINES

In an ac linear analysis it is sometimes a requirement to use transmission lines within the network. These have been included in ELCA as "black boxes" which equate to balanced, lossless lines.

9.1 Coding for a lossless line

For the general case this is

component name, interconnection points, line length, velocity ratio, surge impedance.

where
XLname, nodes 'a', 'b', 'c', 'd', value 1, value 2, value 3

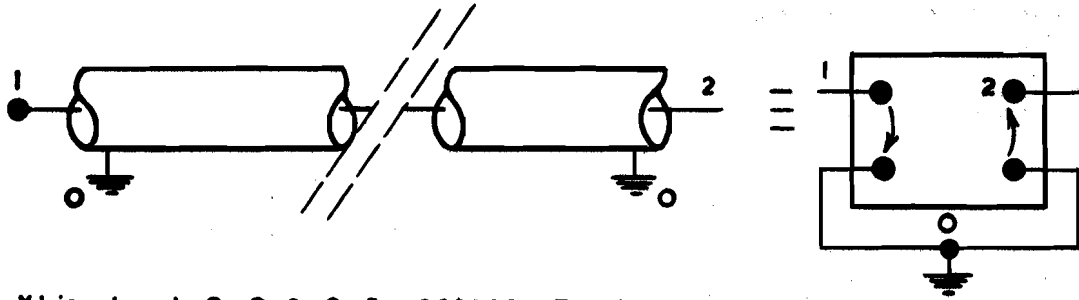
line length is in wavelengths

velocity ration is $\frac{\text{velocity in the line}}{\text{velocity in free space}}$

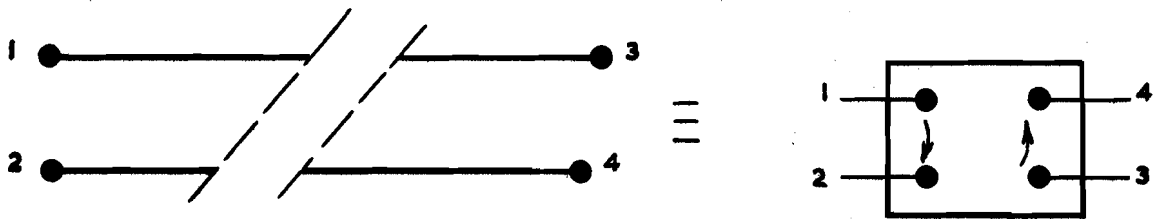
surge impedance is in ohms.

9.2 Examples of a balanced and unbalanced line

For a specific examples the following shows balanced and un-balanced lines.



XLine 1, 1, 0, 0.2, 0.5, .333333, 72.6



XLbal, 1, 2, 4, 3, 0.8, .42, 80

For an example see appendix D.

APPENDIX A

A WORKED EXAMPLE OF PASSIVE CIRCUIT ANALYSIS

```

START
$ A WORKED EXAMPLE OF PASSIVE CIRCUIT ANALYSIS. $
SV1,0,1,5,10
L1,1,2,0.1
C1,2,2,1E-6
PRINT,1,2
FREQUENCY,425,425,5,575
EXECUTE
    
```

\$ A WORKED EXAMPLE OF PASSIVE CIRCUIT ANALYSIS. \$

DATE 12/02/70

FREQUENCY (HZ)	NODE	GAIN(DBS) (REFERENCE INPUT AT NODE	GAIN(VOLTS) 1)	PHASE SHIFT ()	NODAL VOLTAGE REAL COMP.	NODAL VOLTAGE IMAG COMP.	NODAL VOLTAGE MAGNITUDE.
4.2500000E+02	2	1.084E+01	3.485E+00	.000E 00	-1.728E+01	1.608E+00	1.735E+01
4.3000000E+02	2	1.137E+01	3.703E+00	.000E 00	-1.833E+01	1.834E+00	1.842E+01
4.3500000E+02	2	1.194E+01	3.953E+00	.000E 00	-1.954E+01	2.111E+00	1.965E+01
4.4000000E+02	2	1.255E+01	4.243E+00	.000E 00	-2.093E+01	2.454E+00	2.107E+01
4.4500000E+02	2	1.322E+01	4.582E+00	.000E 00	-2.254E+01	2.888E+00	2.273E+01
4.5000000E+02	2	1.396E+01	4.986E+00	.000E 00	-2.444E+01	3.446E+00	2.469E+01
4.5500000E+02	2	1.477E+01	5.474E+00	.000E 00	-2.671E+01	4.180E+00	2.704E+01
4.6000000E+02	2	1.567E+01	6.074E+00	.000E 00	-2.946E+01	5.172E+00	2.991E+01
4.6500000E+02	2	1.669E+01	6.832E+00	.000E 00	-3.285E+01	6.557E+00	3.350E+01
4.7000000E+02	2	1.786E+01	7.817E+00	.000E 00	-3.711E+01	8.567E+00	3.808E+01
4.7500000E+02	2	1.923E+01	9.152E+00	.000E 00	-4.258E+01	1.163E+01	4.414E+01
4.8000000E+02	2	2.087E+01	1.106E+01	.000E 00	-4.976E+01	1.660E+01	5.246E+01
4.8500000E+02	2	2.293E+01	1.401E+01	.000E 00	-5.926E+01	2.530E+01	6.443E+01
4.9000000E+02	2	2.566E+01	1.919E+01	9.095E-13	-7.112E+01	4.201E+01	8.259E+01
4.9500000E+02	2	2.971E+01	3.060E+01	9.095E-13	-8.028E+01	7.641E+01	1.108E+02
4.9900000E+02	2	3.769E+01	7.669E+01	4.547E-13	-5.635E+01	1.358E+02	1.470E+02
5.0500000E+02	2	4.335E+01	1.471E+02	1.800E+02	3.228E+01	1.507E+02	1.541E+02
5.1000000E+02	2	3.143E+01	3.727E+01	1.800E+02	7.680E+01	9.172E+01	1.196E+02
5.1500000E+02	2	2.655E+01	2.125E+01	1.800E+02	7.214E+01	4.959E+01	8.754E+01
5.2000000E+02	2	2.341E+01	1.482E+01	1.800E+02	6.002E+01	2.905E+01	6.668E+01
5.2500000E+02	2	2.110E+01	1.135E+01	1.800E+02	4.977E+01	1.863E+01	5.314E+01
5.3000000E+02	2	1.926E+01	9.179E+00	1.800E+02	4.197E+01	1.283E+01	4.389E+01
5.3500000E+02	2	1.772E+01	7.694E+00	1.800E+02	3.606E+01	9.326E+00	3.724E+01
5.4000000E+02	2	1.641E+01	6.614E+00	1.800E+02	3.149E+01	7.066E+00	3.227E+01
5.4500000E+02	2	1.526E+01	5.793E+00	1.800E+02	2.787E+01	5.529E+00	2.841E+01
5.5000000E+02	2	1.423E+01	5.149E+00	1.800E+02	2.495E+01	4.440E+00	2.535E+01
5.5500000E+02	2	1.331E+01	4.629E+00	1.800E+02	2.256E+01	3.641E+00	2.285E+01
5.6000000E+02	2	1.247E+01	4.201E+00	1.800E+02	2.056E+01	3.038E+00	2.078E+01
5.6500000E+02	2	1.169E+01	3.842E+00	1.800E+02	1.886E+01	2.573E+00	1.904E+01
5.7000000E+02	2	1.097E+01	3.538E+00	1.800E+02	1.741E+01	2.206E+00	1.755E+01
5.7500000E+02	2	1.031E+01	3.276E+00	1.800E+02	1.615E+01	1.912E+00	1.627E+01

APPENDIX B

A LF AMPLIFIER AS DETAILED IN SECTION 5

```

START
$ L.F AMPLIFIER AS DETAILED IN PARA. 5. $
SV1,0,1,1E-3,600
R1,5,6,10
R3,2,0,1.5E3
R4,2,0,1.2E3
R5,4,0,300
R6,7,0,12E3
C1,5,0,1E-6
C2,1,2,25E-6
C3,5,7,30E-6
C4,4,0,100E-6
L1,6,0,1
$ THE *** ENCLOSE THE HYBRID-PI TRANSISTOR MODEL DATA. $
$ ***** $
RBB,2,3,50
RBE,3,4,1E3
RBC,3,5,1E6
RCE,4,5,0.1E6
DSR1,4,5,3,4,.1
$ NOTE.- THE CAPACITORS CBE AND CBC ARE OMITTED BECAUSE IT IS AN $
$ L.F REQUIREMENT. $
$ ***** $
$ ACTIVE CIRCUIT ANALYSIS. $
PRINT,1,7
PLOT,LINEAR,1,DBS,PHASE
FREQUENCY,425,425,5,575
EXECUTE
    
```

\$ ACTIVE CIRCUIT ANALYSIS.

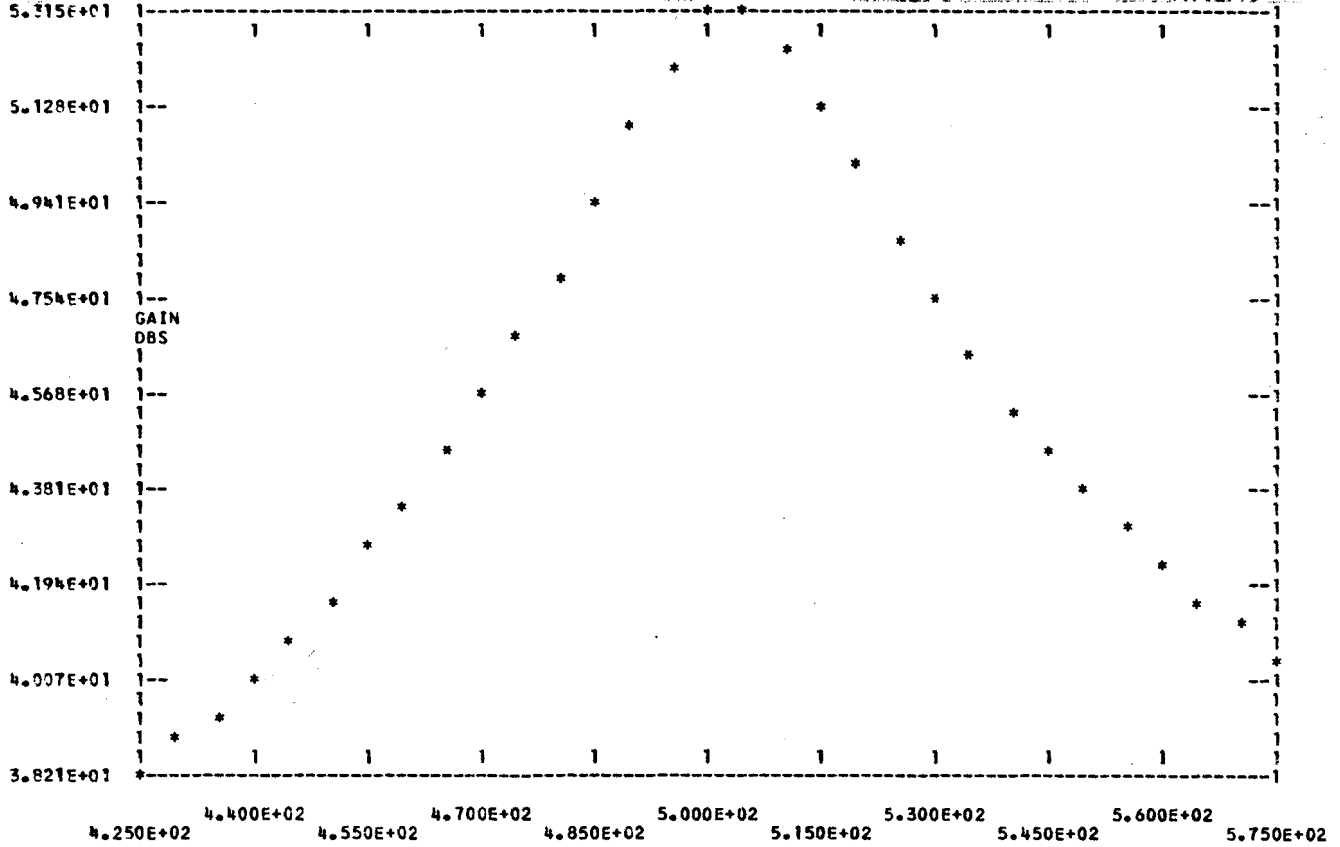
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DATE 16/02/70

FREQUENCY (HZ)	NODE	GAIN(DBS) (REFERENCE INPUT AT NODE)	GAIN(VOLTS)	PHASE SHIFT (1)	NODAL VOLTAGE REAL COMP.	NODAL VOLTAGE IMAG COMP.	NODAL VOLTAGE MAGNITUDE.
4.25000000E+02	7	3.821E+01	8.133E+01	8.125E+01	-1.162E-03	3.902E-02	3.903E-02
4.30000000E+02	7	3.882E+01	8.734E+01	8.221E+01	-5.110E-04	4.187E-02	4.187E-02
4.35000000E+02	7	3.948E+01	9.416E+01	8.328E+01	3.327E-04	4.509E-02	4.509E-02
4.40000000E+02	7	4.017E+01	1.020E+02	8.448E+01	1.435E-03	4.875E-02	4.877E-02
4.45000000E+02	7	4.091E+01	1.110E+02	8.583E+01	2.889E-03	5.293E-02	5.301E-02
4.50000000E+02	7	4.169E+01	1.215E+02	8.738E+01	4.830E-03	5.773E-02	5.793E-02
4.55000000E+02	7	4.254E+01	1.339E+02	8.918E+01	7.458E-03	6.329E-02	6.372E-02
4.60000000E+02	7	4.345E+01	1.488E+02	9.132E+01	1.107E-02	6.973E-02	7.060E-02
4.65000000E+02	7	4.444E+01	1.667E+02	9.389E+01	1.613E-02	7.719E-02	7.886E-02
4.70000000E+02	7	4.552E+01	1.888E+02	9.707E+01	2.334E-02	8.577E-02	8.888E-02
4.75000000E+02	7	4.670E+01	2.163E+02	1.011E+02	3.380E-02	9.535E-02	1.012E-01
4.80000000E+02	7	4.799E+01	2.508E+02	1.063E+02	4.919E-02	1.053E-01	1.162E-01
4.85000000E+02	7	4.937E+01	2.941E+02	1.132E+02	7.173E-02	1.137E-01	1.344E-01
4.90000000E+02	7	5.079E+01	3.465E+02	1.226E+02	1.034E-01	1.159E-01	1.553E-01
4.95000000E+02	7	5.211E+01	4.030E+02	1.354E+02	1.426E-01	1.034E-01	1.762E-01
5.00000000E+02	7	5.300E+01	4.469E+02	1.516E+02	1.781E-01	6.825E-02	1.908E-01
5.05000000E+02	7	5.315E+01	4.544E+02	1.698E+02	1.915E-01	1.604E-02	1.922E-01
5.10000000E+02	7	5.249E+01	4.214E+02	1.733E+02	1.771E-01	-3.214E-02	1.800E-01
5.15000000E+02	7	5.134E+01	3.691E+02	1.598E+02	1.482E-01	-6.207E-02	1.607E-01
5.20000000E+02	7	5.003E+01	3.173E+02	1.498E+02	1.188E-01	-7.524E-02	1.407E-01
5.25000000E+02	7	4.873E+01	2.733E+02	1.424E+02	9.468E-02	-7.841E-02	1.229E-01
5.30000000E+02	7	4.753E+01	2.378E+02	1.369E+02	7.621E-02	-7.673E-02	1.081E-01
5.35000000E+02	7	4.643E+01	2.096E+02	1.327E+02	6.235E-02	-7.305E-02	9.604E-02
5.40000000E+02	7	4.543E+01	1.869E+02	1.294E+02	5.189E-02	-6.872E-02	8.611E-02
5.45000000E+02	7	4.453E+01	1.684E+02	1.267E+02	4.390E-02	-6.439E-02	7.793E-02
5.50000000E+02	7	4.370E+01	1.531E+02	1.246E+02	3.768E-02	-6.030E-02	7.110E-02
5.55000000E+02	7	4.295E+01	1.404E+02	1.228E+02	3.277E-02	-5.655E-02	6.535E-02
5.60000000E+02	7	4.226E+01	1.297E+02	1.212E+02	2.882E-02	-5.315E-02	6.046E-02
5.65000000E+02	7	4.162E+01	1.204E+02	1.199E+02	2.560E-02	-5.008E-02	5.624E-02
5.70000000E+02	7	4.102E+01	1.125E+02	1.187E+02	2.293E-02	-4.732E-02	5.259E-02
5.75000000E+02	7	4.047E+01	1.055E+02	1.177E+02	2.070E-02	-4.484E-02	4.939E-02

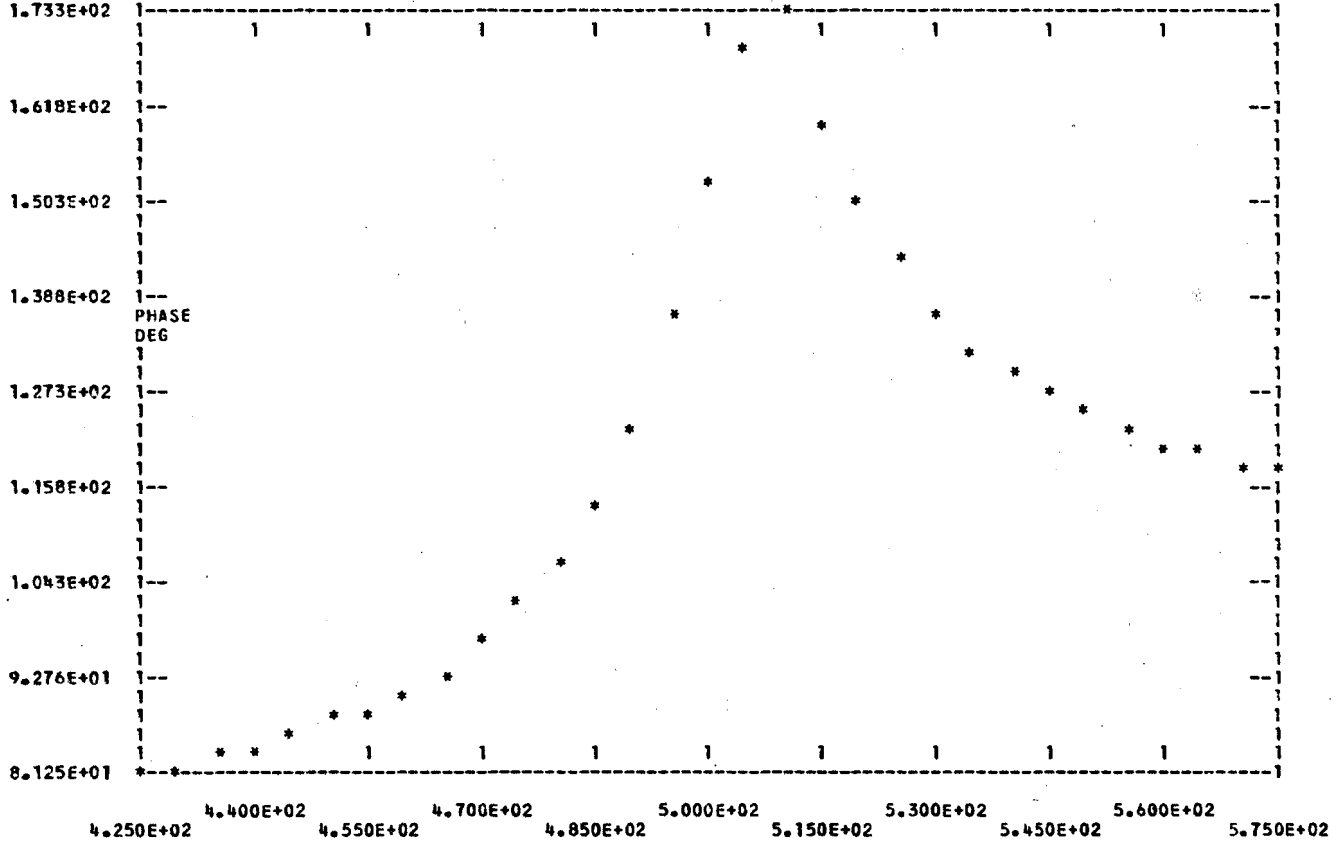
REF.= 1 OUTPUT= 7 \$ ACTIVE CIRCUIT ANALYSIS.

16/02/70



REF.= 1 OUTPUT= 7 \$ ACTIVE CIRCUIT ANALYSIS.

16/02/70



APPENDIX C

A SENSITIVITY ANALYSIS OF THE LF AMPLIFIER

A SENSITIVITY ANALYSIS OF THE LF AMP . OF PARA 5.

SENSITIVITY ANALYSIS FOR INCREASED COMPONENT VALUES
 FREQUENCY = 5.033000E+02 HZ REF. = 4.569E+02 V GAIN

ITEM	NAME	VALUE		OUTPUT V GAIN	PERCENTAGE DIFF.
		ORIGINAL	MODIFIED		
1	RS25	6.000E+02	6.600E+02	4.569E+02	-3.105E-11
2	R1	1.000E+01	1.100E+01	4.350E+02	-4.797E+00*****
3	R3	7.500E+03	8.250E+03	4.569E+02	4.348E-04
4	R4	1.200E+03	1.320E+03	4.569E+02	2.679E-03
5	R5	3.000E+02	3.300E+02	4.570E+02	2.455E-02
6	R6	1.200E+04	1.320E+04	4.751E+02	3.974E+00*****
7	RBB	5.000E+01	5.500E+01	4.540E+02	-6.417E-01*
8	RBE	1.000E+03	1.100E+03	4.588E+02	4.264E-01
9	RBC	1.000E+06	1.100E+06	4.581E+02	2.618E-01
10	RCE	1.000E+05	1.100E+05	4.588E+02	4.236E-01
11	C1	1.000E-06	1.100E-06	2.392E+02	-4.766E+01*****
12	C2	2.500E-05	2.750E-05	4.571E+02	4.808E-02
13	C3	3.000E-05	3.300E-05	4.569E+02	1.083E-04
14	C4	1.000E-04	1.100E-04	4.602E+02	7.278E-01*
15	L1	1.000E-01	9.091E-02	2.391E+02	-4.767E+01*****
16	DSR1	1.000E-01	1.100E-01	4.973E+02	8.846E+00*****

A SENSITIVITY ANALYSIS OF THE LF AMP . OF PARA 5.

SENSITIVITY ANALYSIS FOR DECREASED COMPONENT VALUES
 FREQUENCY = 5.033000E+02 HZ REF. = 4.569E+02 V GAIN

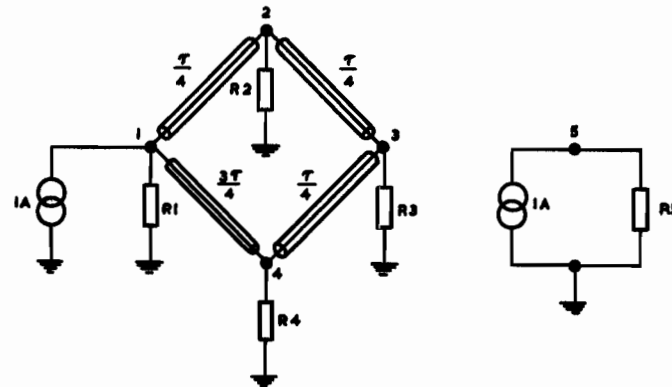
ITEM	NAME	VALUE		OUTPUT V GAIN	PERCENTAGE DIFF.
		ORIGINAL	MODIFIED		
1	RS25	6.000E+02	5.400E+02	4.569E+02	-1.007E-10
2	R1	1.000E+01	9.000E+00	4.811E+02	5.308E+00*****
3	R3	7.500E+03	6.750E+03	4.569E+02	-5.346E-04
4	R4	1.200E+03	1.080E+03	4.569E+02	-3.398E-03
5	R5	3.000E+02	2.700E+02	4.568E+02	-2.997E-02
6	R6	1.200E+04	1.080E+04	4.365E+02	-4.463E+00*****
7	RBB	5.000E+01	4.500E+01	4.599E+02	6.497E-01*
8	RBE	1.000E+03	9.000E+02	4.545E+02	-5.162E-01*
9	RBC	1.000E+06	9.000E+05	4.554E+02	-3.182E-01
10	RCE	1.000E+05	9.000E+04	4.545E+02	-5.131E-01*
11	C1	1.000E-06	9.000E-07	2.461E+02	-4.613E+01*****
12	C2	2.500E-05	2.250E-05	4.566E+02	-5.961E-02
13	C3	3.000E-05	2.700E-05	4.569E+02	-1.326E-04
14	C4	1.000E-04	9.000E-05	4.525E+02	-9.534E-01*
15	L1	1.000E-01	1.111E-01	2.459E+02	-4.619E+01*****
16	DSR1	1.000E-01	9.000E-02	4.153E+02	-9.095E+00*****

APPENDIX D

AN EXAMPLE OF THE USE OF LOSSLESS LINES AS DESCRIBED IN SECTION 9

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START
1 THIS IS AN EXAMPLE OF THE USE OF LOSSLESS LINES AS DESCRIBED IN
1 PARAGRAPH 9. THE EXAMPLE IS THAT OF A RAT-RACE COUPLER ANALYSED
1 OVER A FREQUENCY SWING OF PLUS AND MINUS 20 PERCENT ABOUT 100MHZ.
S A1,1,C,1
R1,1,C,50
R2,2,C,50
R3,3,C,50
R4,4,C,50
XL1,1,C,0.2,.025,.333333,7C.7105
XL2,1,C,0.3,.025,.333333,7C.7105
XL3,1,C,0.4,.025,.333333,7C.7105
XL4,1,C,0.4,.075,.333333,7C.7105
1 THE *** ENCLOSE THE REFERENCE SOURCE . THIS DOES NOT EFFECT THE
1 CIRCUIT PERFORMANCE.
1 *****
SAREF,5,C,1
REF,5,C,25
1 *****
FREQUENCY,80E7,60E7,1E7,120E7
PRINT,5,3,1,2,4
PLC1,LINEAR,1,CBS
1 THE ANALYSIS OF A RAT-RACE COUPLER.
EXECUTE
    
```



THE ANALYSIS OF A RAT-RACE COUPLER.

DATE

FREQUENCY (HZ)	NODE	GAIN(DBS)	GAIN(VOLTS) (REFERENCE INPLT AT NODE 5)	PHASE SHIFT	NODAL VOLTAGE REAL COMP.	NODAL VOLTAGE IMAG COMP.	NODAL VOLTAGE MAGNITUDE.
8.0000000E+08	3	-1.704E+C1	1.406E-01	2.979E+02	1.645E+00	-3.107E+00	3.515E+00
	1	-3.845E-C1	9.567E-01	7.071E+00	2.374E+01	2.944E+00	2.392E+01
	2	-4.167E+00	6.190E-01	1.300E+02	-9.946E+00	1.185E+01	1.547E+01
	4	-2.361E+C0	7.620E-01	3.226E+02	-1.514E+01	-1.156E+01	1.905E+01
8.1000000E+08	3	-1.770E+C1	1.303E-01	2.962E+02	1.436E+00	-2.923E+00	3.257E+00
	1	-3.284E-C1	9.629E-01	6.723E+00	2.391E+01	2.618E+00	2.407E+01
	2	-4.022E+C0	6.294E-01	1.278E+02	-9.653E+00	1.242E+01	1.573E+01
	4	-2.424E+C0	7.565E-01	3.198E+02	1.445E+01	-1.220E+01	1.891E+01
8.2000000E+08	3	-1.838E+C1	1.206E-01	2.945E+02	1.250E+00	-2.743E+00	3.014E+00
	1	-2.785E-C1	9.684E-01	6.359E+00	2.406E+01	2.682E+00	2.421E+01
	2	-3.692E+C0	6.388E-01	1.257E+02	-9.322E+00	1.297E+01	1.597E+01
	4	-2.484E+C0	7.513E-01	3.170E+02	1.374E+01	-1.280E+01	1.878E+01
8.3000000E+08	3	-1.906E+C1	1.114E-01	2.929E+02	1.083E+00	-2.566E+00	2.785E+00
	1	-2.346E-C1	9.734E-01	5.984E+00	2.420E+01	2.537E+00	2.433E+01
	2	-3.776E+C0	6.474E-01	1.236E+02	-8.957E+00	1.348E+01	1.619E+01
	4	-2.541E+C0	7.464E-01	3.143E+02	1.303E+01	-1.336E+01	1.866E+01
8.4000000E+08	3	-1.977E+C1	1.027E-01	2.914E+02	9.352E-01	-2.392E+00	2.568E+00
	1	-1.961E-C1	9.777E-01	5.603E+00	2.433E+01	2.386E+00	2.444E+01
	2	-3.672E+C0	6.553E-01	1.215E+02	-8.560E+00	1.397E+01	1.638E+01
	4	-2.595E+C0	7.418E-01	3.116E+02	1.230E+01	-1.388E+01	1.854E+01
8.5000000E+08	3	-2.049E+C1	9.452E-02	2.899E+02	8.027E-01	-2.222E+00	2.363E+00
	1	-1.626E-C1	9.815E-01	5.219E+00	2.443E+01	2.232E+00	2.454E+01
	2	-3.578E+C0	6.624E-01	1.194E+02	-8.136E+00	1.442E+01	1.656E+01
	4	-2.645E+C0	7.375E-01	3.689E+02	1.157E+01	-1.436E+01	1.844E+01
8.6000000E+08	3	-2.124E+C1	8.670E-02	2.884E+02	6.844E-01	-2.057E+00	2.167E+00
	1	-1.336E-C1	9.847E-01	4.836E+00	2.453E+01	2.075E+00	2.462E+01
	2	-3.494E+C0	6.688E-01	1.174E+02	-7.687E+00	1.485E+01	1.672E+01
	4	-2.693E+C0	7.335E-01	3.062E+02	1.082E+01	-1.480E+01	1.834E+01
8.7000000E+08	3	-2.202E+C1	7.923E-02	2.870E+02	5.789E-01	-1.894E+00	1.981E+00
	1	-1.088E-C1	9.876E-01	4.455E+00	2.461E+01	1.918E+00	2.469E+01
	2	-3.419E+C0	6.746E-01	1.153E+02	-7.217E+00	1.524E+01	1.686E+01
	4	-2.737E+C0	7.297E-01	3.035E+02	1.008E+01	-1.521E+01	1.824E+01
8.8000000E+08	3	-2.284E+C1	7.209E-02	2.856E+02	4.848E-01	-1.736E+00	1.802E+00
	1	-8.758E-C2	9.900E-01	4.078E+00	2.469E+01	1.760E+00	2.475E+01
	2	-3.352E+C0	6.798E-01	1.133E+02	-6.727E+00	1.561E+01	1.730E+01
	4	-2.777E+C0	7.263E-01	3.009E+02	9.320E+00	-1.524E+01	1.816E+01
8.9000000E+08	3	-2.371E+C1	6.522E-02	2.842E+02	4.012E-01	-1.580E+00	1.636E+00
	1	-6.963E-C2	9.920E-01	3.707E+00	2.475E+01	1.603E+00	2.480E+01
	2	-3.293E+C0	6.845E-01	1.113E+02	-6.220E+00	1.594E+01	1.711E+01
	4	-2.815E+C0	7.232E-01	2.983E+02	8.560E+00	-1.593E+01	1.808E+01

§ THE ANALYSIS OF A RAT-RACE COUPLER.

FREQUENCY (Hz)	NODE	GAIN(DBS) (REFERENCE INPUT AT NODE 5)	GAIN(VOLTS)	PHASE SHIFT (5)	DATE		
					NODAL VOLTAGE REAL COMP.	NODAL VOLTAGE IMAG COMP.	NODAL VOLTAGE MAGNITUDE.
9.00000000E+00	3	-2.464E+C1	5.859E-02	2.829E+02	3.271E-01	-1.428E+00	1.465E+00
	1	-5.455E-C2	9.937E-01	3.342E+00	2.480E+01	1.448E+00	2.484E+01
	2	-3.240E+C0	6.886E-01	1.093E+02	-5.698E+00	1.625E+01	1.722E+01
	4	-2.845E+C0	7.204E-01	2.956E+02	7.795E+00	-1.624E+01	1.801E+01
9.10000000E+00	3	-2.565E+C1	5.218E-02	2.816E+02	2.618E-01	-1.278E+00	1.305E+00
	1	-4.199E-C2	9.952E-01	2.983E+00	2.485E+01	1.295E+00	2.488E+01
	2	-3.194E+C0	6.923E-01	1.074E+02	-5.162E+00	1.652E+01	1.731E+01
	4	-2.880E+C0	7.178E-01	2.930E+02	7.026E+00	-1.651E+01	1.795E+01
9.20000000E+00	3	-2.675E+C1	4.596E-02	2.803E+02	2.047E-01	-1.131E+00	1.149E+00
	1	-3.162E-C2	9.964E-01	2.631E+00	2.488E+01	1.143E+00	2.491E+01
	2	-3.154E+C0	6.955E-01	1.054E+02	-4.616E+00	1.676E+01	1.739E+01
	4	-2.907E+C0	7.156E-01	2.905E+02	6.253E+00	-1.676E+01	1.789E+01
9.30000000E+00	3	-2.756E+C1	3.989E-02	2.790E+02	1.553E-01	-9.850E-01	9.972E-01
	1	-2.316E-C2	9.973E-01	2.286E+00	2.491E+01	9.944E-01	2.493E+01
	2	-3.119E+C0	6.983E-01	1.034E+02	-4.059E+00	1.698E+01	1.746E+01
	4	-2.931E+C0	7.136E-01	2.879E+02	5.478E+00	-1.698E+01	1.789E+01
9.40000000E+00	3	-2.938E+C1	3.395E-02	2.777E+02	1.133E-01	-8.412E-01	8.488E-01
	1	-1.635E-C2	9.981E-01	1.946E+00	2.494E+01	8.475E-01	2.495E+01
	2	-3.089E+C0	7.007E-01	1.015E+02	-3.494E+00	1.717E+01	1.752E+01
	4	-2.952E+C0	7.118E-01	2.853E+02	4.700E+00	-1.716E+01	1.780E+01
9.50000000E+00	3	-3.102E+C1	2.813E-02	2.764E+02	7.817E-02	-6.989E-01	7.033E-01
	1	-1.097E-C2	9.987E-01	1.613E+00	2.496E+01	7.027E-01	2.497E+01
	2	-3.065E+C0	7.027E-01	9.958E+01	-2.922E+00	1.732E+01	1.757E+01
	4	-2.970E+C0	7.104E-01	2.828E+02	3.920E+00	-1.732E+01	1.776E+01
9.60000000E+00	3	-3.300E+C1	2.240E-02	2.751E+02	4.978E-02	-5.578E-01	5.600E-01
	1	-6.619E-C3	9.992E-01	1.284E+00	2.497E+01	5.598E-01	2.498E+01
	2	-3.045E+C0	7.043E-01	9.765E+01	-2.344E+00	1.745E+01	1.761E+01
	4	-2.985E+C0	7.092E-01	2.802E+02	3.138E+00	-1.745E+01	1.773E+01
9.70000000E+00	3	-3.553E+C1	1.674E-02	2.738E+02	2.789E-02	-4.175E-01	4.184E-01
	1	-3.755E-C3	9.996E-01	9.594E-01	2.499E+01	4.184E-01	2.499E+01
	2	-3.030E+C0	7.055E-01	9.573E+01	-1.762E+00	1.755E+01	1.764E+01
	4	-2.956E+C0	7.083E-01	2.776E+02	2.355E+00	-1.755E+01	1.771E+01
9.80000000E+00	3	-3.907E+C1	1.113E-02	2.725E+02	1.236E-02	-2.783E-01	2.782E-01
	1	-1.652E-C3	9.998E-01	6.378E-01	2.499E+01	2.782E-01	2.500E+01
	2	-3.019E+C0	7.064E-01	9.382E+01	-1.177E+00	1.762E+01	1.766E+01
	4	-3.004E+C0	7.076E-01	2.751E+02	1.570E+00	-1.762E+01	1.769E+01
9.90000000E+00	3	-4.510E+C1	5.556E-03	2.713E+02	3.085E-03	-1.389E-01	1.389E-01
	1	-4.251E-C4	1.000E-00	3.183E-01	2.500E+01	3.89E-01	2.500E+01
	2	-3.012E+C0	7.069E-01	9.191E+01	-5.888E-01	1.766E+01	1.767E+01
	4	-3.009E+C0	7.072E-01	2.725E+02	7.853E-01	-1.766E+01	1.768E+01

§ THE ANALYSIS OF A RAT-RACE COUPLER.

FREQUENCY (Hz)	NODE	GAIN(DBS) (REFERENCE INPUT AT NODE 5)	GAIN(VOLTS)	PHASE SHIFT (5)	DATE		
					NODAL VOLTAGE REAL COMP.	NODAL VOLTAGE IMAG COMP.	NODAL VOLTAGE MAGNITUDE.
1.00000000E+09	3	-1.251E+C2	5.554E-07	9.000E+01	3.087E-11	1.388E-05	1.388E-05
	1	-2.188E-C5	1.000E-00	3.600E+02	2.500E+01	-1.388E-05	2.500E+01
	2	-3.010E+C0	7.071E-01	9.000E+01	5.891E-05	1.768E+01	1.768E+01
	4	-3.010E+C0	7.071E-01	2.700E+02	-7.854E-05	-1.768E+01	1.768E+01
1.01000000E+09	3	-4.510E+C1	5.557E-03	8.873E-01	3.087E-03	1.389E-01	1.389E-01
	1	-4.252E-C4	1.000E-00	3.597E+02	2.500E+01	-1.389E-01	2.500E+01
	2	-3.012E+C0	7.069E-01	8.809E+01	5.889E-01	1.766E+01	1.767E+01
	4	-3.009E+C0	7.072E-01	2.675E+02	-7.854E-01	-1.766E+01	1.768E+01
1.02000000E+09	3	-3.907E+C1	1.113E-02	8.745E+01	1.236E-02	-2.780E-01	2.783E-01
	1	-1.652E-C3	9.998E-01	3.594E+02	2.499E+01	-2.783E-01	2.500E+01
	2	-3.019E+C0	7.064E-01	8.618E+01	1.177E+00	1.762E+01	1.766E+01
	4	-3.004E+C0	7.076E-01	2.649E+02	-1.570E+00	-1.762E+01	1.769E+01
1.03000000E+09	3	-3.553E+C1	1.674E-02	8.618E+01	2.790E-02	4.175E-01	4.185E-01
	1	-3.755E-C3	9.996E-01	3.590E+02	2.499E+01	-4.184E-01	2.499E+01
	2	-3.030E+C0	7.055E-01	8.427E+01	1.762E+00	1.755E+01	1.764E+01
	4	-2.996E+C0	7.083E-01	2.624E+02	-2.355E+00	-1.755E+01	1.771E+01
1.04000000E+09	3	-3.300E+C1	2.240E-02	8.490E+01	4.978E-02	-5.578E-01	5.600E-01
	1	-6.620E-C3	9.992E-01	3.587E+02	2.497E+01	-5.598E-01	2.498E+01
	2	-3.045E+C0	7.043E-01	8.235E+01	2.345E+00	1.745E+01	1.761E+01
	4	-2.985E+C0	7.092E-01	2.598E+02	-3.138E+00	-1.745E+01	1.773E+01
1.05000000E+09	3	-3.102E+C1	2.813E-02	8.362E+01	7.817E-02	6.989E-01	7.033E-01
	1	-1.097E-C2	9.987E-01	3.584E+02	2.496E+01	-7.028E-01	2.497E+01
	2	-3.065E+C0	7.027E-01	8.042E+01	2.922E+00	1.732E+01	1.757E+01
	4	-2.970E+C0	7.104E-01	2.572E+02	-3.920E+00	-1.732E+01	1.776E+01
1.06000000E+09	3	-2.938E+C1	3.395E-02	8.233E+01	1.133E-01	8.413E-01	8.489E-01
	1	-1.635E-C2	9.981E-01	3.581E+02	2.494E+01	-8.476E-01	2.495E+01
	2	-3.089E+C0	7.007E-01	7.849E+01	3.494E+00	1.717E+01	1.752E+01
	4	-2.952E+C0	7.118E-01	2.547E+02	-4.700E+00	-1.716E+01	1.780E+01
1.07000000E+09	3	-2.756E+C1	3.989E-02	8.104E+01	1.553E-01	9.851E-01	9.972E-01
	1	-2.316E-C2	9.973E-01	3.577E+02	2.491E+01	-9.944E-01	2.493E+01
	2	-3.119E+C0	6.983E-01	7.655E+01	4.059E+00	1.698E+01	1.746E+01
	4	-2.931E+C0	7.136E-01	2.521E+02	-5.478E+00	-1.698E+01	1.789E+01
1.08000000E+09	3	-2.675E+C1	4.596E-02	7.974E+01	2.047E-01	1.131E+00	1.149E+00
	1	-3.162E-C2	9.964E-01	3.574E+02	2.488E+01	-1.144E+00	2.491E+01
	2	-3.154E+C0	6.955E-01	7.461E+01	4.616E+00	1.676E+01	1.739E+01
	4	-2.907E+C0	7.156E-01	2.495E+02	-6.253E+00	-1.676E+01	1.789E+01
1.09000000E+09	3	-2.565E+C1	5.218E-02	7.842E+01	2.618E-01	-1.278E-01	1.305E+00
	1	-4.199E-C2	9.952E-01	3.570E+02	2.485E+01	-1.295E+00	2.488E+01
	2	-3.194E+C0	6.923E-01	7.265E+01	5.163E+00	1.652E+01	1.731E+01
	4	-2.880E+C0	7.178E-01	2.470E+02	-7.026E+00	-1.651E+01	1.795E+01

\$ THE ANALYSIS OF A RAT-RACE COUPLER.

\$ DATE + +

FREQUENCY (Hz)	NODE	GAIN (DBS)	GAIN (VOLTS)	PHASE SHIFT	NCNAL VOLTAGE REAL COMP.	NCNAL VOLTAGE IMAG COMP.	NCNAL VOLTAGE MAGNITUDE.
		(REFERENCE INPLT AT NCDE 5)					
1.10000000E+09	3	-2.464E+C1	5.860E-02	7.710E+01	3.271E-01	1.428E+00	1.465E+00
	1	-2.456E+C2	9.937E-01	3.567E+02	2.480E+01	-1.448E+00	2.484E+01
	2	-2.240E+CC	6.886E-01	7.067E+01	5.698E+00	1.625E+01	1.722E+01
	4	-2.649E+CC	7.204E-01	2.444E+02	-7.795E+00	-1.624E+01	1.801E+01
1.11000000E+09	3	-2.371E+C1	6.522E-02	7.576E+01	4.012E-01	1.580E+00	1.631E+00
	1	-6.964E+C2	9.920E-01	3.563E+02	2.475E+01	-1.603E+00	2.480E+01
	2	-2.293E+CC	6.845E-01	6.869E+01	6.220E+00	1.594E+01	1.711E+01
	4	-2.815E+CC	7.232E-01	2.417E+02	-8.560E+00	-1.593E+01	1.808E+01
1.12000000E+09	3	-2.284E+C1	7.209E-02	7.439E+01	4.848E-01	1.736E+00	1.802E+00
	1	-8.759E+C2	9.900E-01	3.559E+02	2.469E+01	-1.760E+00	2.475E+01
	2	-3.352E+CC	6.798E-01	6.668E+01	6.727E+00	1.561E+01	1.700E+01
	4	-2.777E+CC	7.263E-01	2.391E+02	-9.320E+00	-1.558E+01	1.816E+01
1.13000000E+09	3	-2.202E+C1	7.924E-02	7.301E+01	5.789E-01	1.894E+00	1.981E+00
	1	-1.068E+C1	9.876E-01	3.555E+02	2.461E+01	-1.918E+00	2.469E+01
	2	-3.419E+CC	6.746E-01	6.466E+01	7.217E+00	1.524E+01	1.686E+01
	4	-2.737E+CC	7.297E-01	2.365E+02	-1.008E+01	-1.521E+01	1.824E+01
1.14000000E+09	3	-2.124E+C1	8.670E-02	7.159E+01	6.845E-01	2.057E+00	2.167E+00
	1	-1.337E+C1	9.847E-01	3.552E+02	2.453E+01	-2.075E+00	2.462E+01
	2	-2.494E+CC	6.688E-01	6.263E+01	7.687E+00	1.485E+01	1.672E+01
	4	-2.693E+CC	7.335E-01	2.338E+02	-1.082E+01	-1.480E+01	1.834E+01
1.15000000E+09	3	-2.049E+C1	9.452E-02	7.014E+01	8.027E-01	2.222E+00	2.363E+00
	1	-1.626E+C1	9.815E-01	3.548E+02	2.443E+01	-2.232E+00	2.454E+01
	2	-3.576E+CC	6.624E-01	6.057E+01	8.136E+00	1.442E+01	1.656E+01
	4	-2.645E+CC	7.375E-01	2.311E+02	-1.157E+01	-1.443E+01	1.844E+01
1.16000000E+09	3	-1.977E+C1	1.027E-01	6.865E+01	9.352E-01	2.392E+00	2.568E+00
	1	-1.961E+C1	9.777E-01	3.544E+02	2.433E+01	-2.386E+00	2.444E+01
	2	-3.672E+CC	6.553E-01	5.850E+01	8.560E+00	1.397E+01	1.638E+01
	4	-2.595E+CC	7.418E-01	2.284E+02	-1.230E+01	-1.388E+01	1.854E+01
1.17000000E+09	3	-1.906E+C1	1.114E-01	6.711E+01	1.083E+00	2.566E+00	2.785E+00
	1	-2.346E+C1	9.734E-01	3.540E+02	2.420E+01	-2.537E+00	2.433E+01
	2	-3.776E+CC	6.474E-01	5.640E+01	8.957E+00	1.348E+01	1.619E+01
	4	-2.541E+CC	7.464E-01	2.257E+02	-1.303E+01	-1.336E+01	1.866E+01
1.18000000E+09	3	-1.838E+C1	1.206E-01	6.551E+01	1.250E+00	2.743E+00	3.114E+00
	1	-2.785E+C1	9.684E-01	3.536E+02	2.406E+01	-2.682E+00	2.421E+01
	2	-3.892E+CC	6.388E-01	5.429E+01	9.322E+00	1.297E+01	1.597E+01
	4	-2.484E+CC	7.513E-01	2.230E+02	-1.374E+01	-1.280E+01	1.878E+01
1.19000000E+09	3	-1.770E+C1	1.303E-01	6.384E+01	1.436E+00	2.924E+00	3.257E+00
	1	-3.284E+C1	9.629E-01	3.533E+02	2.391E+01	-2.818E+00	2.407E+01
	2	-4.022E+CC	6.294E-01	5.215E+01	9.653E+00	1.242E+01	1.573E+01
	4	-2.424E+CC	7.565E-01	2.202E+02	-1.445E+01	-1.220E+01	1.891E+01

\$ THE ANALYSIS OF A RAT-RACE COUPLER.

\$ DATE + +

FREQUENCY (Hz)	NODE	GAIN (DBS)	GAIN (VOLTS)	PHASE SHIFT	NCNAL VOLTAGE REAL COMP.	NCNAL VOLTAGE IMAG COMP.	NCNAL VOLTAGE MAGNITUDE.
		(REFERENCE INPUT AT NCDE 5)					
1.20000000E+09	3	-1.734E+C1	1.406E-01	6.210E+01	1.645E+00	3.107E+00	3.515E+00
	1	-2.845E+C1	9.567E-01	3.529E+02	2.374E+01	-2.944E+00	2.392E+01
	2	-4.167E+CC	6.190E-01	5.000E+01	9.946E+00	1.185E+01	1.547E+01
	4	-2.361E+CC	7.620E-01	2.174E+02	-1.514E+01	-1.156E+01	1.905E+01

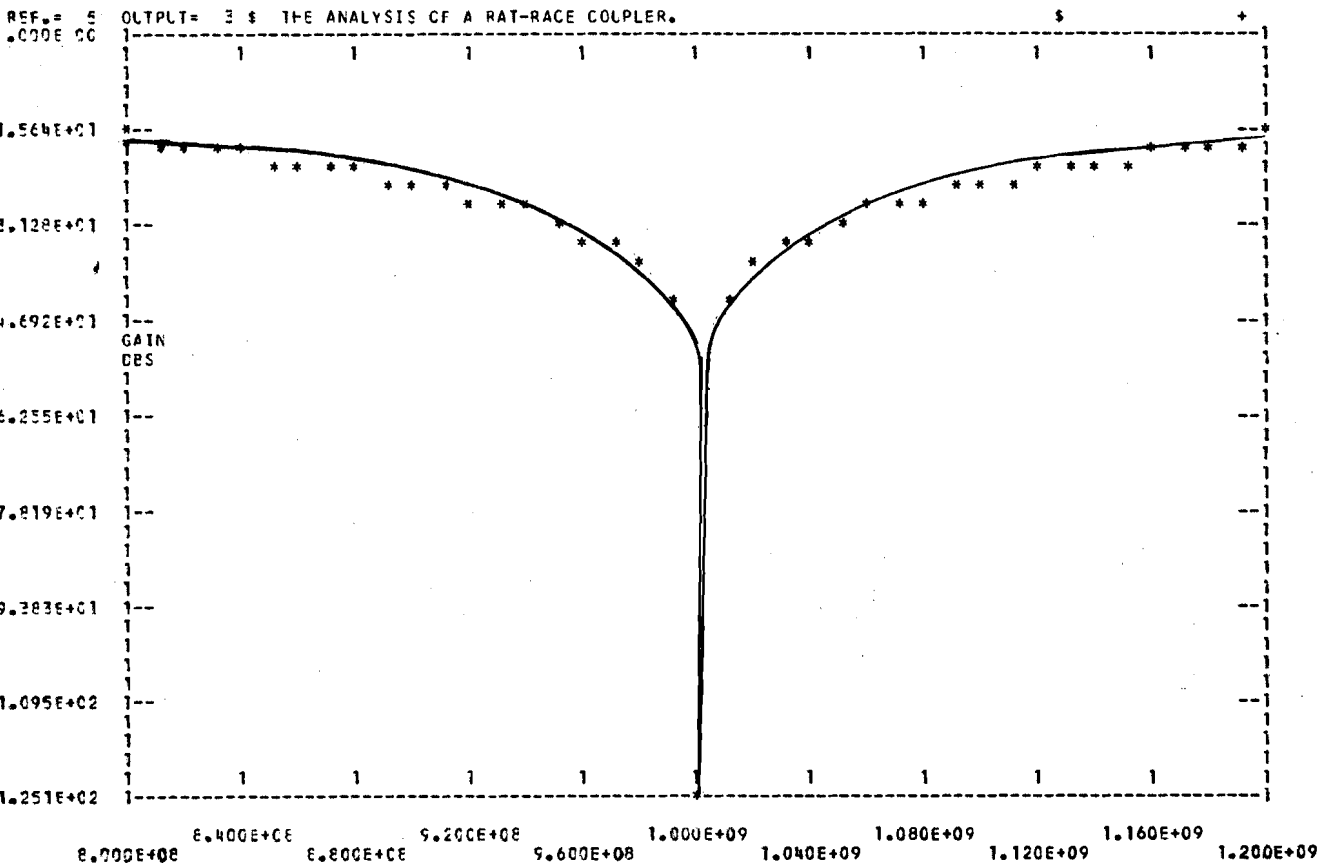
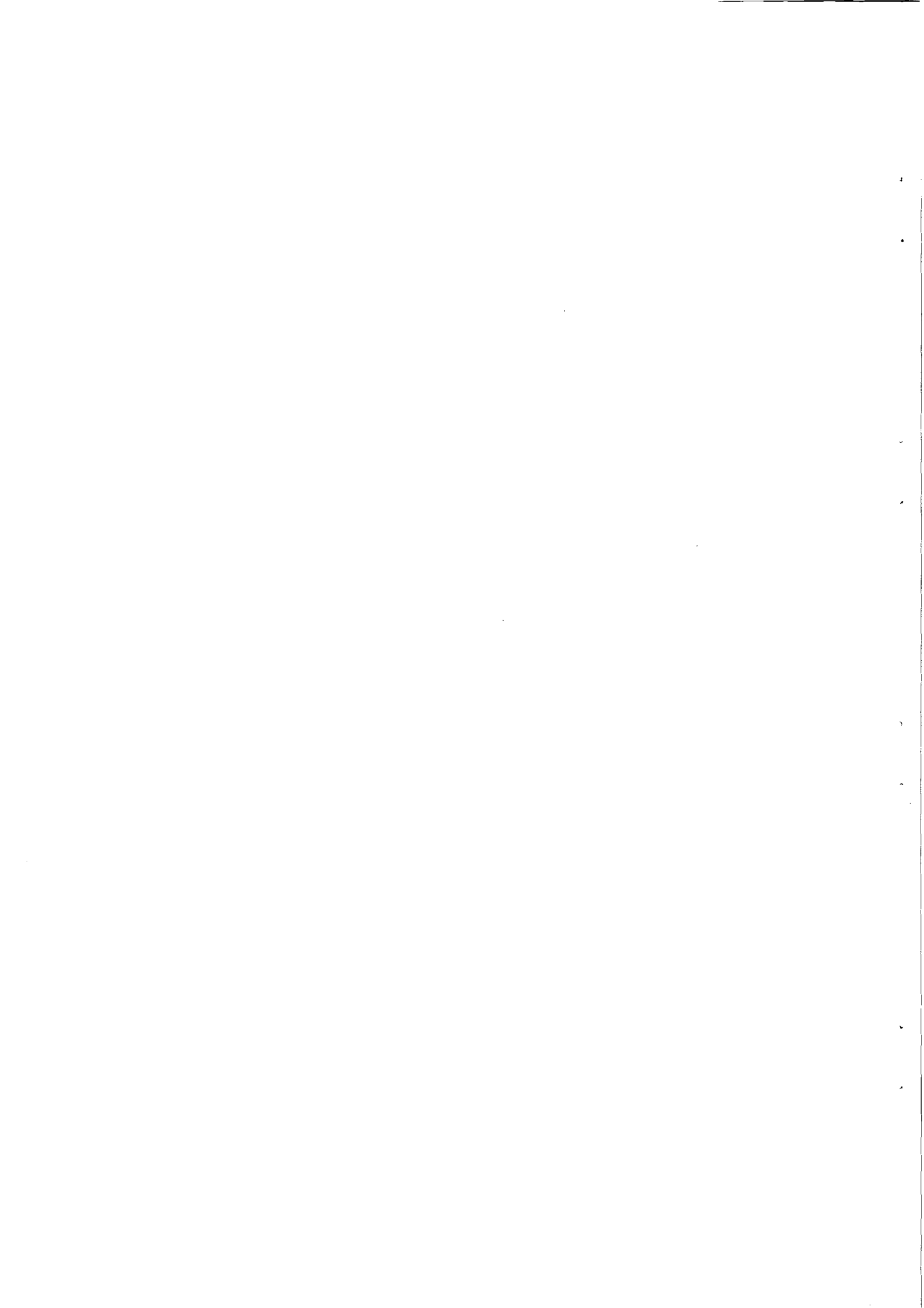


FIGURE 1

S. S. C. M. COMPUTING BUREAU		AUTHOR: J. HOGGS		GROUP: ENG	BLDG: DN	PAGE: 1 of 1	
FORTRAN CODING FORM		PROGRAM TITLE: TUNED COT		DATE: 1 - 1 - 70			
C	STATEMENT No.	FORTRAN STATEMENT					LABEL
1	2	\$ A WORKED EXAMPLE OF PASSIVE CIRCUIT ANALYSIS. \$					72 73
5	6	SV1 , 0 , 1 , 5 , 10					
		11 , 1 , 2 , 0.1					
		C1 , 2 , 0 , 1E-6					
		PRINT , 1 , 2					
		FREQUENCY , 425 , 425 , 5 , 575					
		EXCITE					
		END OF JOB					



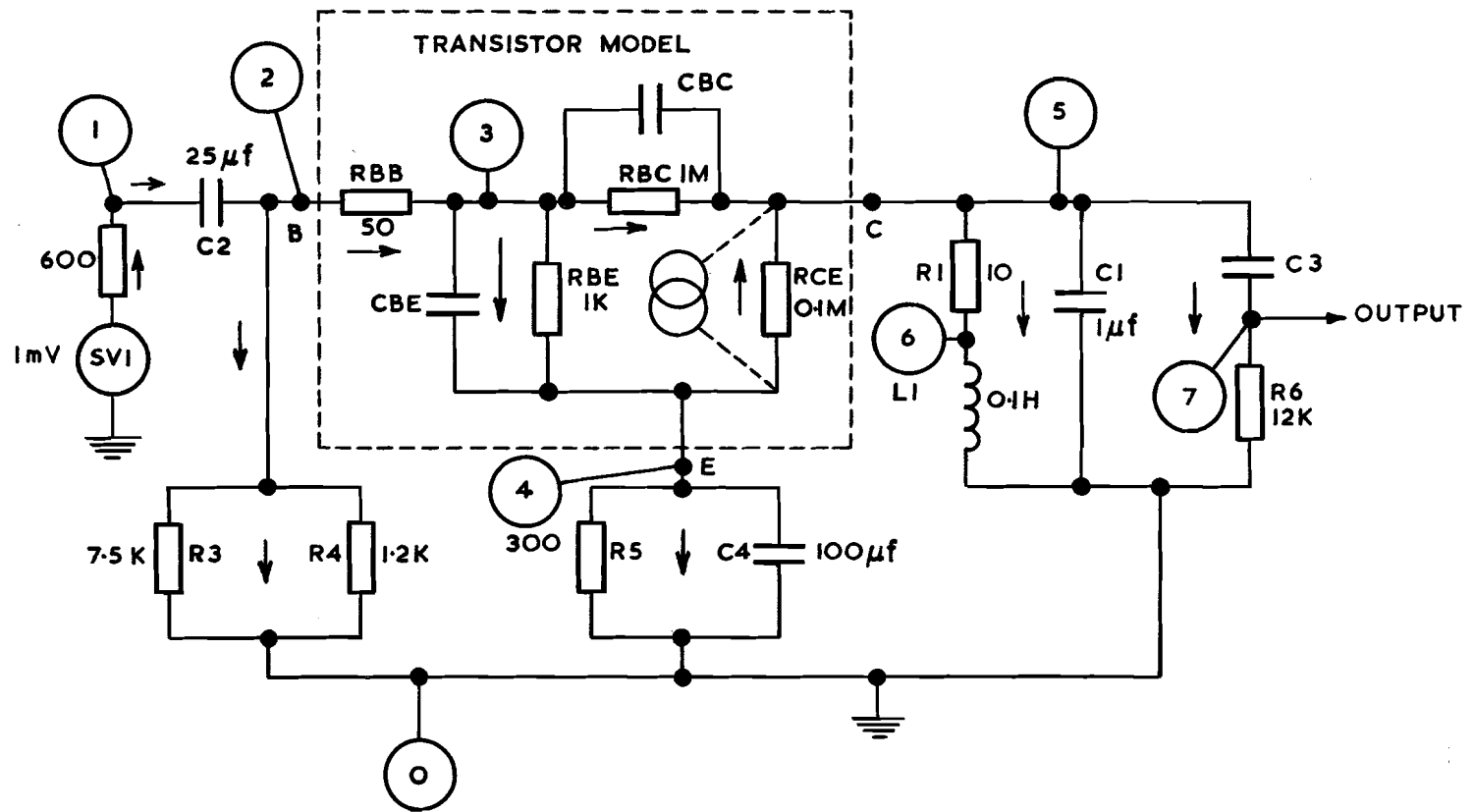


FIGURE 2. EQUIVALENT CCT OF LF AMPLIFIER

