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MIMP

Motorolas Impedance Matching Program

The Smith diagram is an important aid in the design of matching circuits. Mimp software makes it possible to design matching circuits for amplifiers in a relatively simple and clear manner, with the assistance of the electronic form of the Smith diagram.

1.

Introduction

For many radio amateurs, the use of the so-called Smith diagram in the design of matching circuits is a closed book. However, it makes it possible to design matching circuits for four-wire networks in a very clear manner, since it gives a graphic representation of the influence which the individual components of the four-wire network have.

If you are designing matching circuits by hand, as well as having the Smith diagram, a pair of compasses, a ruler and a pencil, you will also always have to carry out a few secondary calculations and standardisations / de-standardisations, using a pocket calculator, to obtain the component values for the desired frequency range. The MIMP freeware program (Motorolas Impedance Matching Program) is there for just this application, and can be downloaded, for example, from [1].

With the MIMP program, matching circuits for amplifiers can be designed in a clear manner, with the help of the Smith diagram, without knowing in detail how the Smith diagram works. You merely need to know that the centre point of the Smith diagram is the target point of the transformation curve.

The secondary calculations, standardisations and de-standardisations, and the graphical representation of the transformation curve on the Smith diagram are carried out by the PC. With a few mouse clicks, you can alter component values and track their effect on the matching immediately on the screen.

2.

Hardware Pre-Conditions

MIMP is a purely DOS program. It was developed in 1990 and does not make any great demands on the PC.

All you need is an IBM-compatible PC, an 80286 processor or better with a VGA graphics card, a 640 kbyte operational memory and a two-button mouse. The program also runs in the DOS window of Windows 95.

3.

Installation

The compressed Mimpzip.exe program, which can be downloaded on demand, needs only 120 kB. It should be copied into a sub-directory previously set up by hand and unpacked by running the program, which is self extracting.

The following files are then unpacked:

- Mimp.exe, the executable program
- Devfile.asc, an ASCII file with the names of transistors, the impedance data of which are stored in the file
- devfile.bin
- Helvb.fon, a Microsoft C font.

Then come the batch processing files:

- readme.bat for printing out the text file
- readme.txt, the batch processing file
- printme.bat for printing out the text file
- readme.txt, mimp.doc, the MS Word for Windows version 6 file of the readme.txt text file.

All the files take up a space of 273 kB on the hard disc. The text files can be deleted if required.

4.

Operation

The program is started in DOS mode by entering the command Mimp. It can also be started from Windows 95, if the program is correspondingly integrated, under Start, Settings, Task strip in the Start add menu.

The user operates the MIMP program via 3 screens:

a) Screen for entering frequencies and impedances of transistor to be matched

b) Screen for entering components with which matching is to take place

c) Screen with Smith diagram on which transformation curve is entered

A mouse is recommended as a simple way of altering the data entered. However, there are keyboard commands which correspond to most mouse functions.

The three screens can be reached one after the other by pressing the ESC key, or by activating the right-hand mouse key.

4.1 Impedance screen

The program starts when the impedance screen is called up; see Fig. 1. It is divided into 4 sections:

1) Frequency table

2) Load impedance table

3) Source impedance table

4) Numerical keyboard, which can be activated by using the mouse cursor and left-clicking the mouse

First the number of frequencies must be indicated for which the source impedance and load impedance are entered. A maximum of eleven frequencies can be entered.

Next, the load impedances are entered in series form (real component + imaginary component). To enter the numerical values, use either the keyboard or

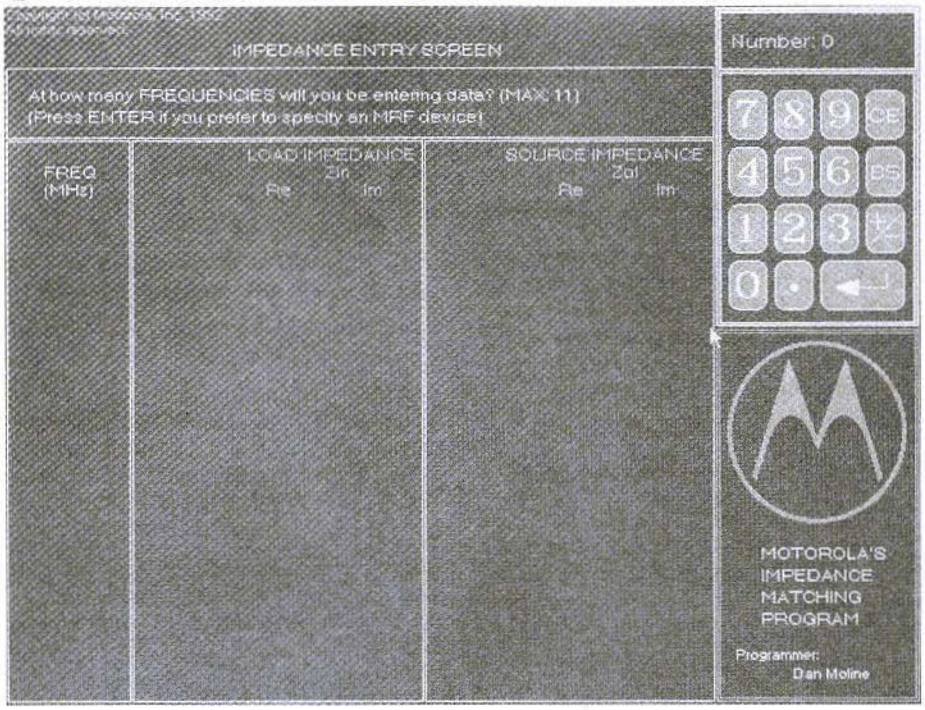

Fig. 1: Opening screen

the screen keyboard at the top right-hand corner of the screen, with the mouse cursor and the left-hand mouse key.

The program automatically calculates the equivalent parallel circuit, and represents these values in the line below in each case.

When all the impedances have been entered, the source impedance for each frequency must be entered. In most cases, it is desired to match the transistor to 50 real (50 + j0). In this case, the value can be entered by pressing the Return key (or by right-clicking the mouse).

If a standard Motorola transistor is to be used, press the Return key and select the corresponding square in which the initial letters of the transistor to be selected appears (MRF, 2N, JO, TP). Enter the corresponding numbers of the types, using the keyboard or the mouse cursor in the right-hand top corner of the screen keyboard. You must also specify whether you wish to select the input impedance or the output impedance.

A list of the transistors available can not be obtained directly. Nor can the data for additional transistors be added. The author extracted the type names from the Devfile.asc file. They are listed in Table 1. Unfortunately, since then Motorola has ceased to manufacture a number of the transistors listed in this table.

Motorola uses the conjugate complex impedance in series form for the impedances of the its transistor, specified at maximum power. Data sheets from other manufacturers may be based on

Table 1: List of transistor impedance data available in MMIP

2N5642	JO4036	MRF134	MRF392	MRF752	TP301
2N5643	JO4045	MRF136	MRF393	MRF754	TP302
2N5944		MRF137	MRF406	MRF837	TP303
2N5945		MRF138	MRF410	MRF838	TP304
2N5946		MRF140	MRF421	MRF839	TP2031
2N6080		MRF141	MRF422	MRF840	TP2032
2N6081		MRF148	MRF426	MRF841	TP2033
2N6082		MRF150	MRF427	MRF841F	TP2034
2N6083		MRF151	MRF428	MRF843	TP2037
2N6084		MRF154	MRF429	MRF843F	TP2180
2N6439		MRF161	MRF430	MRF844	TP2304
2N6985		MRF162	MRF433	MRF846	TP2314
2N6986		MRF163	MRF448	MRF847	TP2317
		MRF171	MRF449	MRF873	TP2330
		MRF172	MRF450	MRF890	TP2335
		MRF174	MRF454	MRF891	TP2502
		MRF221	MRF455	MRF892	TP2503
		MRF224	MRF458	MRF894	TP3004
		MRF226	MRF460	MRF898	TP3005
		MRF227	MRF464	MRF1000	TP3009
		MRF229	MRF466	MRF1002	TP3010
		MRF232	MRF475	MRF1004	TP3012
		MRF233	MRF476	MRF1008	TP3015
		MRF234	MRF477	MRF1015	TP3019
		MRF237	MRF479	MRF1035	TP3021
		MRF240	MRF485	MRF1090	TP3030
		MRF247	MRF486	MRF1150	TP3031
		MRF260	MRF492	MRF1250	TP3040
		MRF261	MRF497	MRF1325	TP3060
		MRF262	MRF553	MRF1946	TP3061
		MRF264	MRF555	MRF2001	TP3062
		MRF314	MRF557	MRF2001M	TP5002
		MRF315	MRF559	MRF2003	TP5040
		MRF316	MRF607	MRF2003M	TP9386
		MRF317	MRF630	MRF2005	TPM405
		MRF321	MRF641	MRF2005M	TPV5055B
		MRF323	MRF644	MRF2010	TPV6080B
		MRF325	MRF646	MRF2010M	
		MRF326	MRF648	MRF2016	
		MRF327	MRF650	MRF2628	
		MRF329	MRF658	MRF4070	
		MRF338	MRF652	MRF5174	
		MRF340	MRF653	MRF5175	
		MRF342	MRF654	MRF10005	
		MRF344	MRF660	MRF10030	
		MRF390	MRF750		

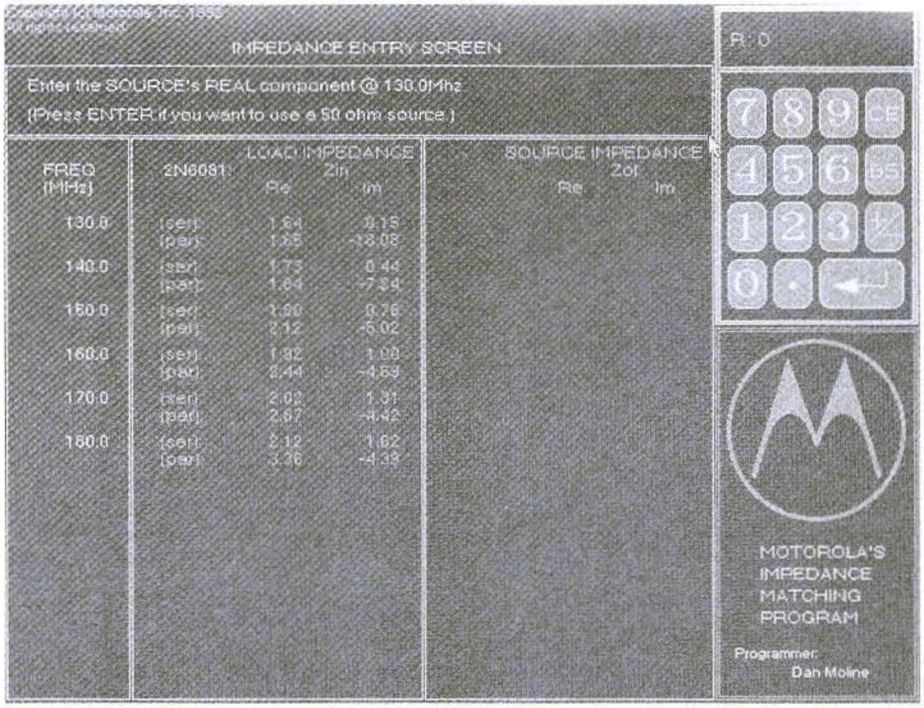

Fig. 2: Data from 2N6081 (input impedance) can be read in from the file available in the program

other pre-conditions, so it may be necessary to undertake a parallel-series conversion of the individual impedances. It must also be determined whether the impedance is indicated in complex form and already conjugate. If necessary, reverse the sign in front of the imaginary component to make sure the conjugate complex value is entered correctly.

When all the data has been entered, press the Return key on the keyboard or right-click the mouse to go to the next screen.

In Fig. 2, the input impedances of 2N6081 have been selected. These values are to be transformed to 50Ω.

4.2 Circuit input screen

This screen consists of three parts:

1) Component library

2) Numerical keyboard for entering component values using mouse cursor

3) Identification areas with selected components for impedance transformation

Fig. 3 shows this screen. Since most high-frequency power transistors are

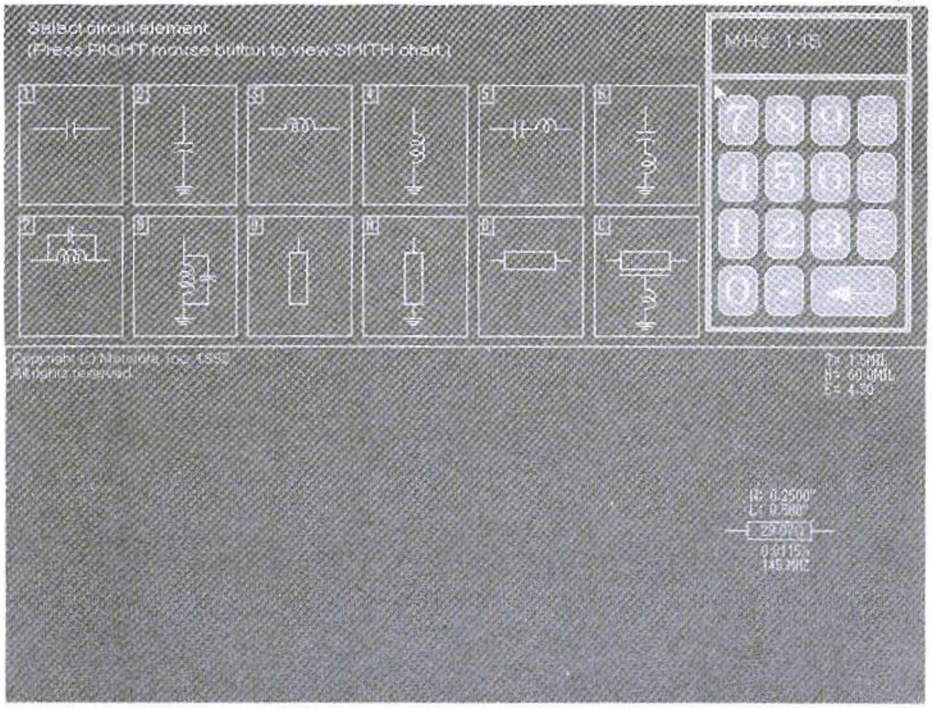

Fig. 3: The first component has been selected (microstrip)

supplied with wide terminal lugs, these connections can be brought in by entering a microstrip for the impedance transformation. In this case, the transistor connection are simulated using a 12.5 mm. (500 mil) long and 6.35 mm (250 mil). wide microstrip section. The terminal lug can be easily soldered onto this microstrip. This line section simultaneously forms the first transformation element of the circuit.

The component library contains sixteen components; an ideal capacitor wired in series or in parallel (component with a connection to earth), an ideal inductance, a series resonant circuit or capacitor with feed inductance, a parallel resonant circuit or coil with internal capacitance, a stub open at the end (microstrip with open end) and microstrips.

A component is selected by positioning the mouse cursor on the corresponding field and left-clicking the mouse, or by using the keyboard to press the number or letter specified in the corresponding field of the component in the top left-hand corner. The component values are then entered; capacities in pF, inductances in nH. If the user wishes to enter the corresponding reactive impedance, first press Return and then enter this value in Ohms at a specified frequency in MHz.

A microstrip is defined by its characteristic impedance (in Ohms) and its electrical length (in fractions of the wavelength). The electrical length must be specified at a frequency (in MHz).

Microstrips can also be entered through their mechanical dimensions, such as width, length and thickness of the

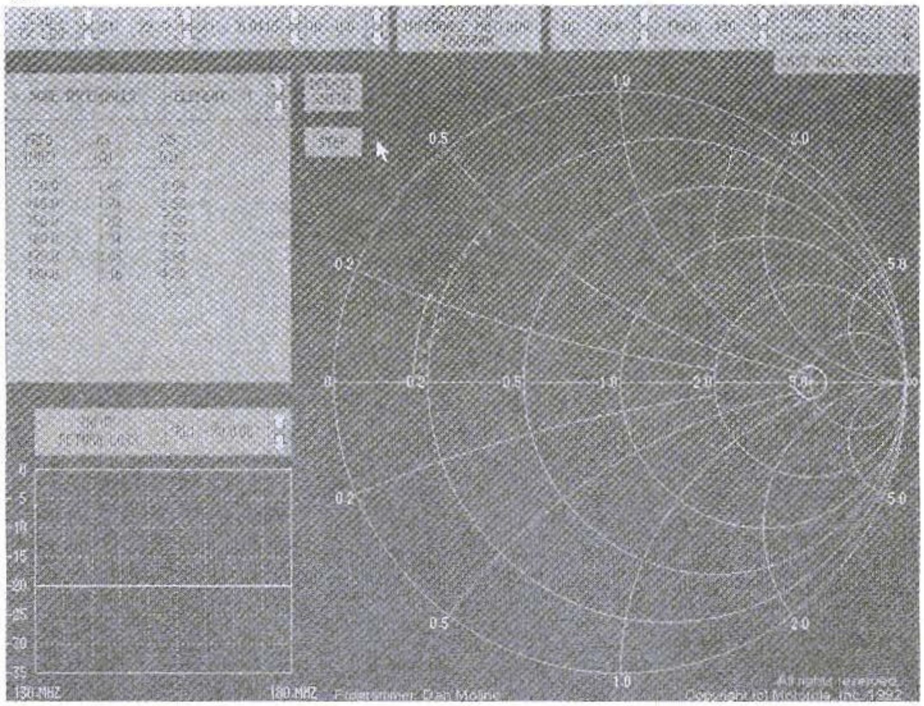

Fig. 4: Transformation path of first element (microstrip) The system impedance is still 10Ω !

dielectric, thickness of the conductor, or dielectric constant of circuit board material used. Dimensions must be entered in mil (= 0.0254 mm.). For conversion, the entry in mm. should be divided by the factor 0.0254 to obtain the entry in mil.. The thickness of a circuit board of 1.5 mm. corresponds to 60 mil., the thickness of the copper layer of 35 μm. corresponds to 1.6 mil, a 6.35 mm. wide microline is entered as 250 mil..

The component in box C displays one special feature. It is a real capacitor with feed inductance, which is connected to earth, and the hot end of which lies on a microstrip. In most CAD programs, it is assumed that a chip capacitor has no electrical width; i.e., it occupies an individual point in the circuit.

However, at high frequencies this simplification leads to errors, in particular at low impedances. Since a chip capacitor is usually mounted on a microstrip, its final width can cause a phase displacement, which is not negligible. A 100 mil. (= 2.54 mm.) wide capacitor has an electrical wavelength of 0.02 at a frequency of 1 GHz if it is mounted on a substrate with aluminium oxide. This error can be reduced by modelling a capacitor with the replacement circuit described in box C. Once this type has been selected, the capacity and a possible feed inductance must then be entered. Next, the characteristic impedance of the microstrip to which the hot end of the capacitor is soldered is entered. Finally, the length of the capacitor is entered in fractions of the wavelength which the capacitor uses. MIMP uses this to calculate the effect of the two influences.

Once the circuit has been entered, the user can move on to displaying the Smith diagram by pressing the ESC key or by right-clicking on the mouse. However, if no component is selected and you try to go to the next screen by pressing Return, the program crashes.

Selected elements can be removed by activating the back-space key, which first deletes the most recently selected component. If all components have been deleted, the program switches to the previous screen.

4.3 Smith diagram display screen

The screen (Fig. 4) is divided into four fields:

1) Smith diagram

2) Menu field

3) Field displaying node impedances

4) Diagram for scalar representation of return loss at individual input of transformation network

The Smith diagram graphically represents the impedances which, starting from the load impedance of the transistors, have been transformed by each of the series or parallel components in the previous second screen. The individual impedance values are indicated by small crosses. To distinguish between the impedance values at the various frequencies, the crosses for each frequency are represented by a separate colour. If several series or parallel components have been used, the resulting impedances are combined and displayed as one element.

The first time the third screen is called up, the following settings are active:

The impedance values on the lowest frequency are connected.

The conjugate complex source impedance is represented by a yellow cross in a circle, which indicates impedances which amount to a return loss of 20 dB. (This conjugate complex source impedance is the desired impedance, converted through the transformation network.)

The Smith diagram is standardised at 10Ω.

The constant quality (Q) circuits are set to 0.

The impedance is represented for the last nodes.

The value of the first element can be altered in the menu field via the mouse cursor.

With the menu field, the user can:

1. Select the various components and alter their values;

2. Set the constant operating quality circuit over the range from 0.0 to 99.99 in steps of 0.1;

3. Standardise the Smith diagram to impedances between 0.1Ω and 999.9Ω ;

4. Select the frequency for which the node impedances should be represented;

5. Connect / not connect the impedance values for a selected frequency;

6. Switch the component connections (nodes) on and off;

7. Represent the impedance values of the last node alone;

8. Switch over between continuous and stepped component value change (Continuous means that the component value continues changing as long as you left-click on the mouse);

9. Change input return loss circuit from 0 to 99.9 dB;

10. Select node, the impedance of which is to be displayed;

11. Update display on Smith diagram.

To the right of some menu items, two arrows are displayed, pointing up or down. The corresponding value can be altered with their help by using the mouse cursor. The decimal point which is to be changed is underlined in red. This is selected by the mouse cursor and can be moved to the left or right by left-clicking on the mouse.

The number of the component, the value of which is to be changed, can be specified with the arrows in the first menu field.

The component values can also be changed using the keyboard. The commands can be found in the operating instructions. However, this is nowhere near as user-friendly as using the mouse. Since nowadays every PC is normally operated by a mouse, we need not go into the description of the keyboard commands.

If the Smith diagram becomes confused due to multiple component changes, press the Update Smith key to display the transformation path of the previous change. All earlier intermediate solutions are deleted.

According to the operating instructions, you should press p or P to obtain a print-out. This function can not be confirmed by the author.

In the table in the top left-hand corner, the impedance transformed at the start for the individual component is displayed, starting from the load (input or output of transistor to be matched). If the transformation network consists of several components, the impedance of all components is combined.

The return loss diagram displays (by indicating the return loss in dB) how well the transformed impedance matches the desired source impedance. The pre-set return loss value of 20 dB corresponds to a VSWR of approximately 1.2 and is sufficient in most cases.

To leave the program, use the keyboard command Ctrl-X.

5.

On Balance

The MIMP program can be used to design matching circuits for transistor amplifiers in a very clear manner. One of the things the author likes about this program is that the component values can be changed using a mouse. Thus, you can begin with an estimated value and then arrive at the desired result by changing the values. The effect of the changes is shown immediately in the Smith diagram. You can play around a bit and test the effects of various components on the impedance transformation.

Unfortunately, no circuits can be saved. Nor can the transformation circuit and the Smith diagram be printed directly from the program. Moreover, the on-line help normally available for Windows programs is missing. However, since operating with the mouse is very simple, no new commands need to be learned, not even the keyboard command for terminating the program.

6.

Literature

[1]
p.html

Calculations for microstrips are carried out using the formulae in [2].