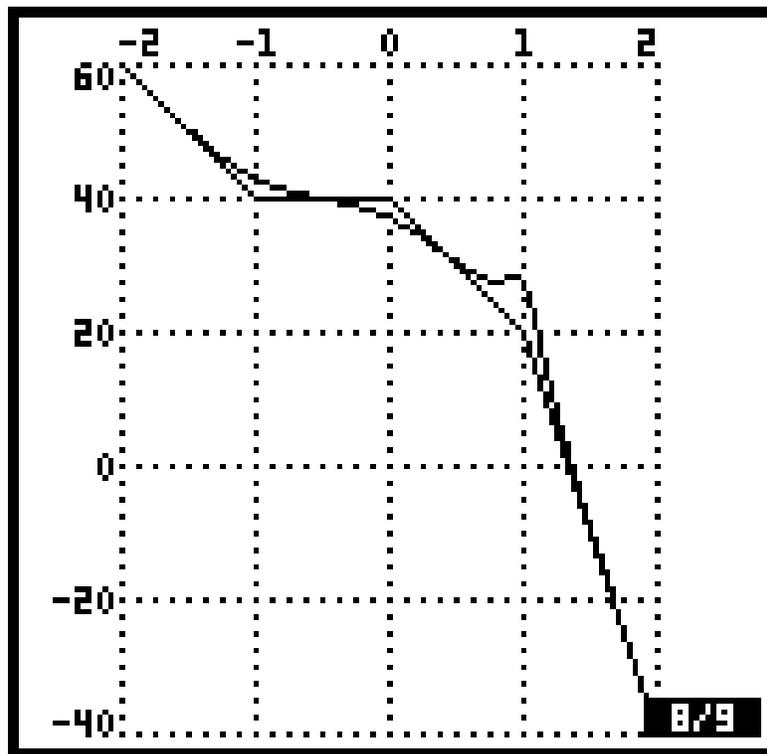


# BODE

## v 2.31 sg



by Thomas Reitmayr



## Table of Contents

1. Introduction	1
1.1. Notice	1
1.2. Parts of this Version	1
1.3. System Requirements	1
1.4. Installation	1
2. BODE.LIB	2
2.1. General Description	2
2.2. Format of Input	2
2.3. Restrictions to Input	3
2.4. The Menu	4
2.5. Analysis of an Exemplary Function	4
2.5.1. Input	4
2.5.2. Program Execution	5
2.5.3. Result: Presentation of the Function	5
2.5.4. Result: Marginal Values	5
2.5.5. Result: Documentation of Zeros and Poles	6
2.5.6. Result: Gain Characteristic	7
2.5.7. Result: Phase Characteristic	8
2.6. Known Weaknesses of the Program	9
3. Usage of LISTER	10
4. Deinstallation of the Programs	10
5. Appendix	11
5.1. Version History of BODE	11
5.2. Where to Get Further Information?	12



## 1. Introduction

### 1.1. Notice

The programs BODE.LIB, BODEE.LIB, BODEGX.LIB, BODEGXE.LIB, and LISTER.LIB as well as its documentations are provided "as are", and are subjected to change without notice. The author makes no warranty of any kind with regard to the software or documentation, including, but not limited to, the implied warranties of merchantability and fitness for a particular purpose. The author shall not be liable for any error or for incidental or consequential damages in connection with the furnishing, performance, or use of this software and documentation.

The programs are copyrighted by the author. Others may freely reproduce and distribute this material. Sale of this material is prohibited without prior written permission of the author.

### 1.2. Parts of this Version

This package contains a program for analyzing transfer functions of linear time-invariant systems and drawing the corresponding bode-diagram. There is also an auxiliary program (LISTER) included as freeware to display the results of BODE. This program can be used in connection with the bode-analyzer or independently in own applications.

### 1.3. System Requirements

A HP48 S(X)/G(X) with at least 25 KB free memory. Therefore it is not recommended to run the programs on a HP48 calculator equipped only with the basic memory size of 32 KB. A converted version for the HP49 is available thanks to Alain Robillard.

### 1.4. Installation

- a) Delete all installed versions of BODE and LISTER on your calculator.
- b) Download the files BODE.LIB and LISTER.LIB into your HP48 (e.g. using KERMIT on your PC or from another HP48)
- c) Recall the contents of the menu entry "BODE.LIB" to the stack and purge this entry. Then store the library into a (not merged!) port (e.g. use the command "0 STO" for port 0)
- d) Carry out point c for LISTER.LIB too.
- e) Turn your calculator off and on again.

In case of correct installation of BODE, it reports version number, author, and copyright in a short message each time performing a warm-start (e.g. through ON-C).

## 2. BODE.LIB

### 2.1. General Description

- Detailed analysis of all zeros and poles of the given transfer function.
- Construction of the multiplied and the factored form of the transfer function.
- Graphical output of a linear approximation and the smooth characteristic of gain and phase.
- Axes of graphs labeled in powers of ten (frequency  $\varpi$ ), decibel (gain) and radians (phase).
- Arbitrary dimension of the analysis protocol through organization in text pages and scrollable graphical pages.
- Comfortable and flexible input format.
- High execution speed, depending on the function to be analyzed, between 25 and 30 seconds (SX) or 15 and 20 seconds (GX)
- Preservation of the last calculated data, which can be recalled at any time.
- Special menu entry for multiplying and factoring a polynomial.

### 2.2. Format of Input

Before starting an analysis of a transfer function, this one has to be available to the program in a suitable format:

- A single constant is entered as simple number.
- The basis of the following points is the expression of a fully multiplied polynomial

$$P(s) = a_n s^n + a_{n-1} s^{n-1} + \dots + a_2 s^2 + a_1 s + a_0$$

which is done by specifying the coefficients  $a_i$ . These are provided to the program in the following manner:

$$\{a_n \ a_{n-1} \ \dots \ a_2 \ a_1 \ a_0\}$$

i.e. the coefficients are expressed as list with the highest order coefficient **first**.

Important: Coefficients  $a_i = 0$  must not be left out!

Example:  $s^4 + 5s^3 + 104s^2 + 100s \longrightarrow \{151041000\}$

- If a polynomial is provided in partially factored form, the separate polynomials can be entered without being multiplied first.

$$P(s) = (a_n s^n + a_{n-1} s^{n-1} + \dots + a_1 s + a_0)(b_m s^m + \dots + b_1 s + b_0)$$

is to be entered as  $\{\{a_n \ a_{n-1} \ \dots \ a_1 \ a_0\}\{b_m \ b_{m-1} \ \dots \ b_1 \ b_0\}\}$

Example:  $s(s^2 + 4s + 100)(s + 1) \longrightarrow \{\{1\ 0\}\{1\ 4\ 100\}\{1\ 1\}\}$

- Due to further simplification constant factors can be inserted at any place within the first brace-level.

$C_1 \cdot P(s) \cdot C_2 \cdot Q(s)$  can be entered as  
 $\{C_1 \text{coeff}_{P(s)} C_2 \text{coeff}_{Q(s)}\}$  or  $\{C_1 \cdot C_2 \langle \text{coeff}_{P(s)} \text{coeff}_{Q(s)} \rangle\}$

Example:

$5(2s + 4) \longrightarrow \{5\ 2\ \{1\ 2\}\} \hat{=} \{5\{1\ 2\}\ 2\} \hat{=} \{10\{1\ 2\}\}$

After the different forms for specifying a polynomial are known, the required input of arbitrary transfer functions is shown. In case of linear time-invariant systems, the function to be analyzed exists as fraction of two polynomials:

$$G(s) = \frac{a_n s^n + a_{n-1} s^{n-1} + \dots + a_2 s^2 + a_1 s + a_0}{s^m + b_{m-1} s^{m-1} + \dots + b_2 s^2 + b_1 s + b_0}$$

According to the rules mentioned above the numerator is typed in first and then the denominator. Thus the topmost stack-levels look like this:

#2: { numerator }  
 #1: { denominator }

***That's it!***

Now just select the menu of the BODE-library and execute BODE (see chapter 2.4).

### 2.3. Restrictions to Input

At the beginning of program execution the entered data are checked, whereby the following situations are recognized as inadmissible and terminate the program with an error message:

- There is no or only one polynomial on the stack.
- At least one polynomial is repugnant to the rules described above.
- A constant factor is zero.
- A polynomial only consists of coefficients equal to zero.
- A number is not real but complex.
- The transfer function represents a pure integrator or differentiator. These do not have any singularity at a point different to zero, which is necessary to dimension the graphs.

## 2.4. The Menu

To start one of the programs of BODE, the menu of the library must be selected. The bottom line of the display shows like that:

```
BODE BSHO BCLEAR ABOUT FACTO CROOT
```

The different items of the menu can be described as follows:

- **BODE:** Actually starts the analysis of a transfer function; the format of the necessary parameters is described in the above sections.
- **BSHOW:** Shows the result of the last analysis.
- **BCLEAR:** Clears the last analysis protocol. Thus between 1 and 4 KByte are released depending on the complexity of the previous function.
- **ABOUTBOD:** Shows the name of the program, version, author, and copyright; only for information.
- **FACTOR:** Multiplies and factors polynomials. The parameter is **one** polynomial formatted in the usual way, which is multiplied by the program if necessary and then factored in two steps. These three results are prepared graphically and displayed.
- **CROOT:** Calculates all roots of a polynomial, i.e. complex roots are possible too. The calculated values are collected to a list object. This menu entry will be interesting especially for S(X)-owners, because in G(X) versions there already exists a similar command named PROOT.

## 2.5. Analysis of an Exemplary Function

In the following sections the result of an analysis is commented. The transfer function used is

$$G(s) = \frac{1000(10s + 1)}{s(s + 1)(s^2 + 4s + 100)}$$

### 2.5.1. Input

After input the stack display looks like this:

```
{ HOME }          04.02.95   19:00:00
-----
3:
2:   { 1000 { 10 1 } }
1:   { { 1 0 } { 1 1 } {
        1 4 100 } }
```

```
BODE BSHO BCLEAR ABOUT FACTO CROOT
```

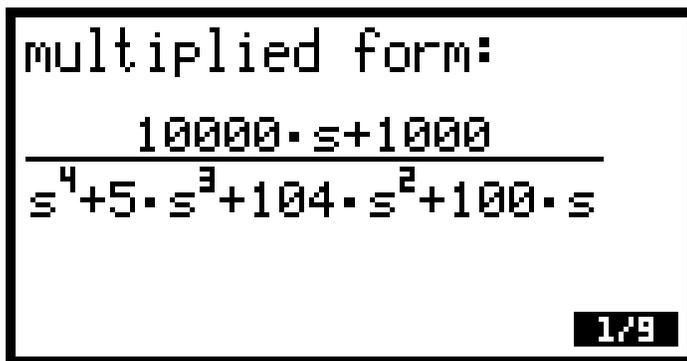
This picture already shows the BODE menu. The program is invoked by pressing key [A].

### 2.5.2. Program Execution

After about one second, in which the correctness of the parameters is checked, the display is turned off to reduce execution time by about 11 %. The progress of calculation can be watched though the blinking symbols (annunciators) on the upper edge of the display. During this state the program can be terminated by pressing the ON-key, the data calculated up to there can be recalled with BSHOW, as usual. In that case an additional last page in the protocol indicates the incomplete analysis.

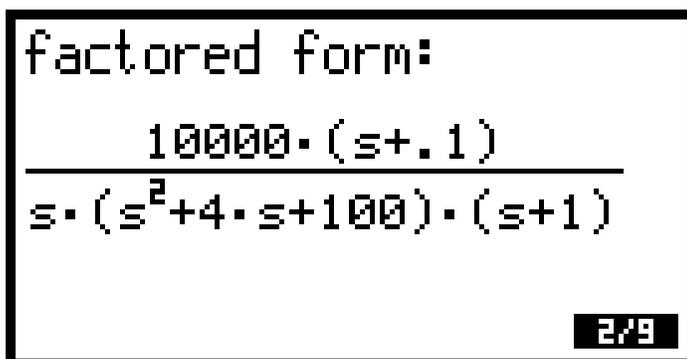
### 2.5.3. Result: Presentation of the Function

The first page in the analysis protocol shows the multiplied form of the given transfer function.


$$\text{multiplied form:}$$
$$\frac{10000 \cdot s + 1000}{s^4 + 5 \cdot s^3 + 104 \cdot s^2 + 100 \cdot s}$$

1/9

On the following page the factored form is presented. 2nd degree terms with complex roots will not be factored any more, because that is not necessary for the analysis.


$$\text{factored form:}$$
$$\frac{10000 \cdot (s + .1)}{s \cdot (s^2 + 4 \cdot s + 100) \cdot (s + 1)}$$

2/9

### 2.5.4. Result: Marginal Values

The third page shows the frequency area important for analysis and plotting of the transfer function. The calculation is done according to the rule that at least one decade should be plotted

beyond the frequency of the outermost poles or zeros. Furthermore an asymptotical approximation for the function at  $s \rightarrow 0$  is displayed.

```

frequency scale
  from 10^-2 s^-1
  to   10^2 s^-1

asyp. G0(s→0)=k*s^r:
  k = 10
  r = -1
  
```

3/9

The following page presents the marginal values of the left edge of the specified area ( $10^{-2} \text{ s}^{-1}$  in our example).

```

values on left edge:
  gain: 60 dB
  gradient: -20 dB/dec
  phase: -π/2
  
```

4/9

### 2.5.5. Result: Documentation of Zeros and Poles

The pages are sorted in a way that zeros are shown first and then poles.

The description of zeros is done in the same manner as of poles, therefore all following statements apply to both kinds of roots.

Below the **kind of root** (zero of pole) the radian frequency  $\nu$  (or  $\omega$ ) of that point is given (" $\nu = \text{xx.xx s}^{-1}$ ").

Then in case of **2nd degree terms** a notice is shown and additionally the mathematical expression of that term. In case of **real roots** only the multiplicity of that point is returned (1-fold, ...).

"**Δgradient**" gives the gradient's additive change in the gain characteristic in decibel/decade. For the reason of the special kind of transfer function only multiples of 20 dB/dec. are possible.

Analogous "**Δphase**" shows the additive change in the approximation of the phase characteristic in radians. There are only multiples of  $\pi/2$  allowed.

The last line in the page provides the **deviation of the approximations to the real characteristics** at the current point. When using this value it has to be kept in mind, that it is valid only if the function has this single root and not two or three. But in practice it is a good approximation if there are no roots in the immediate neighborhood of the examined point.

Here are the three pictures of our analysis:

```
ZERO:
v = .1 s-1
1-fold
Δgradient +20 dB/dec
Δphase +π/2
deviation +3.0103 dB
5/9
```

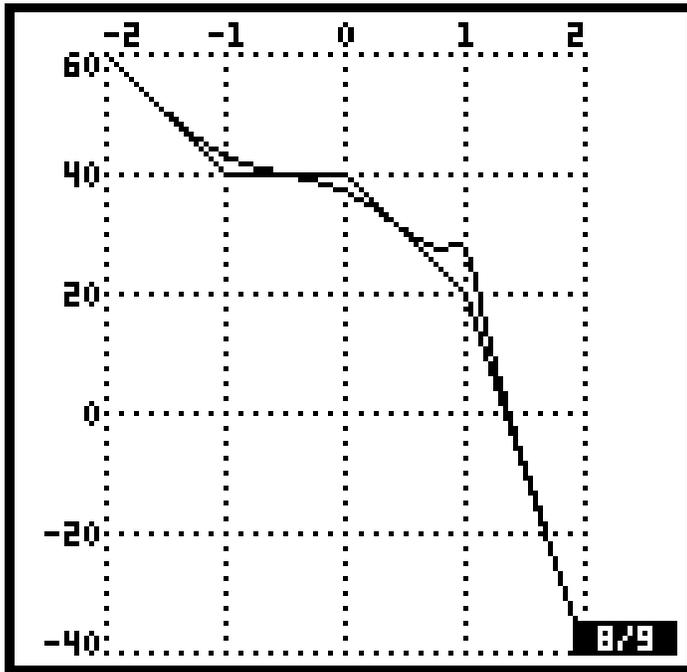
```
POLE:
v = 1 s-1
1-fold
Δgradient -20 dB/dec
Δphase -π/2
deviation -3.0103 dB
6/9
```

```
POLE:
v = 10 s-1
square term
s2+4*s+100
Δgradient -40 dB/dec
Δphase -π
deviation +7.9588 dB
7/9
```

### 2.5.6. Result: Gain Characteristic

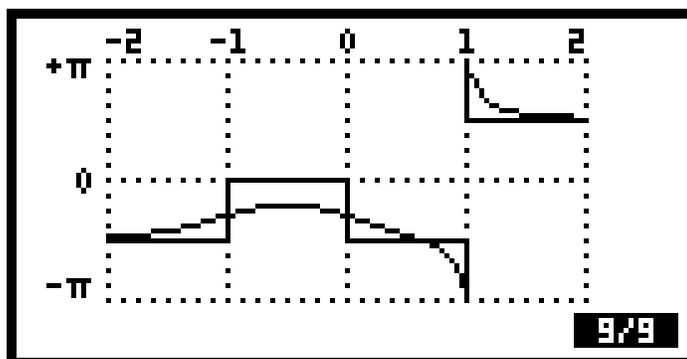
In the graph of the gain characteristic the abscissa is labeled in powers of ten and the ordinate in decibel. Approximation and smooth curve are plotted on top of each other, but they are distinguishable clearly. In order to show pictures which exceed the boundaries of the calculator's

display, the graph can be scrolled with the arrow keys (see below). The size of the graphs is limited only by the amount of free memory.



### 2.5.7. Result: Phase Characteristic

Most of the things said above are valid here, too. The ordinate is labeled in radians. It has to be noted that the deviation between the approximated and the real characteristic is quite large because an approximation of order zero is used.



## 2.6. Known Weaknesses of the Program

This program is not perfect too, therefore there is a list of weaknesses which should not cause severe problems in general.

- Roots with a multiplicity of more than 2 lead to **inaccuracy** in calculating the roots. The analysis of the different points can show wrong results (e.g. square term instead of 2-fold), but generally the characteristics are not affected.
- In general it has to be considered that the protocol shows **rounded** values, i.e. { 1 .00001 } appears as s+0 on the first page!
- Equal terms in numerator and denominator are **not reduced**. At that point the phase characteristic shows a (useless) vertical line.

### 3. Usage of LISTER

The BODE program needs an auxiliary program named LISTER to display the analysis protocol, the following table shows its simple operation.

function key	action
÷ (divide)	jump to first page
+ (plus)	jump to last page
× (multipliy)	one page up
− (minus)	one page down
arrow keys	scroll graph
shift-right + arrow keys	jump to top, bottom, left or right edge of the graph
F (menu key)	toggle display of page numbers
<b>OFF</b>	turn off the calculator (no program termination!)

Every other key or key combination terminates LISTER.

### 4. Deinstallation of the Programs

If you want to remove the programs from your calculator (eg. to install an updated version), follow these steps:

- a) Type in  
for BODE to be removed:    : x : 1228  
for LISTER to be removed:   : x : 1230  
(x has to be replace by the specific port number!)
- b) Press ENTER again to double the previous line
- c) Execute DETACH
- d) Execute PURGE

It is recommended to run BCLEAR before removing the BODE-library to delete the protocol of the last analysis. Otherwise these data reside in memory and can not be deleted until BODE is installed again!

## 5. Appendix

### 5.1. Version History of BODE

#### **v2.31sg - april 1995:**

- + moved all language dependent strings into string-table
- + created parallel English version BODEE.LIB and BODEGXE.LIB

#### **v2.30sg - february 1995:**

- + improved error handling
- + added my own graphic packers PKGROB/UPKGROB
- + documentation written (this here!)

#### **v2.20sg - december 1994:**

- + created G(x)-version v2.20g
- + routine for displaying polynomials expanded to complex numbers
- + factorizer made available through "FACTOR"
- + rooter made available through "CROOT"

#### **v2.17s - november 1994:**

- + now pre-factored polynomials can be entered too

#### **v2.13s - november 1994:**

- PGROB/UPGROB removed because of bugs (graphic stored uncompressed now)

#### **v2.10s - october 1994:**

- + complex routines for calculating the characteristic replaced by real number algorithm (→ faster)
- + included graphic packer/unpacker PGROB/UPGROB by Erik Bryntse.
- + average execution time 25 - 30 seconds (SX)!
- removed some bugs in displaying the polynomials on page 1/2

#### **v2.00s - september 1994:**

- + translated into system-RPL and stored as library
- + LCD turns off for higher speed (about 11 %)
- + average execution time 45 - 50 seconds (SX)!
- auxiliary program POLY removed

#### **v1.20sg - may 1994:**

- + included factored form of function into protocol
- + parallel version v1.20g for G(X)-series

**v1.00s - april 1994:**

- + program written in user-RPL and stored as directory
- + complete analysis of zeros and poles
- + characteristic of gain and phase plotted
- + POLY v3.2 by Wayne Scott used for finding roots
- + average execution time 4 - 5 minutes (SX)

**5.2. Where to Get Further Information?**

If you have any suggestions or questions feel free to contact me at:

Email: [treitmayr@yahoo.com](mailto:treitmayr@yahoo.com)

WWW: <http://www.devbase.at/hp48/>