

# **Frodo**

Christian Bauer

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**COLLABORATORS**

	<i>TITLE :</i> Frodo		
<i>ACTION</i>	<i>NAME</i>	<i>DATE</i>	<i>SIGNATURE</i>
WRITTEN BY	Christian Bauer	January 18, 2023	

**REVISION HISTORY**

NUMBER	DATE	DESCRIPTION	NAME

# Contents

<b>1 Frodo</b>	<b>1</b>
1.1 Frodo Manual . . . . .	1
1.2 What's new? . . . . .	2
1.3 Overview . . . . .	2
1.4 Installation . . . . .	3
1.5 Start/quit . . . . .	4
1.6 Settings . . . . .	5
1.7 Keyboard layout . . . . .	7
1.8 File access . . . . .	8
1.9 Printers . . . . .	8
1.10 The SID card . . . . .	9
1.11 The IEC cable . . . . .	9
1.12 Sample programs . . . . .	10
1.13 Technical info . . . . .	10
1.14 A note on speed . . . . .	11
1.15 The source . . . . .	12
1.16 Copyright and distribution . . . . .	13
1.17 Bug reports . . . . .	13
1.18 Credits . . . . .	14
1.19 The author . . . . .	14
1.20 History . . . . .	15
1.21 The future . . . . .	16

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# Chapter 1

## Frodo

### 1.1 Frodo Manual

Frodo

Version 1.5

What's new?

A Commodore 64 emulator  
for Commodore-Amiga computers

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Freely distributable

Overview

Why another C64 emulator?

Installation

How to install Frodo

Start/quit

There and back again

Settings

You only have to configure...

Keyboard layout

Where the hell is the "any" key?

File access

A 64 with hard disk

Printers

Using C64 printers

The SID card

Do you want the real sound?

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The IEC cable  
How to connect a 1541 to the Amiga

Sample programs  
The included demo programs

Tecnical info  
Revealing the secrets

A note on speed  
Why is it so slow?

The source  
Use the source, Luke.

Copyright  
Legal mush

Bug reports  
Got some problems?

Credits  
The author wishes to thank...

The author  
Programmer's address

History  
Revision history of Frodo

The future  
What's on my to-do list

## 1.2 What's new?

The most important changes to version 1.4:

- A severe bug in the joystick routines has been corrected that could lock up the whole emulation
- The "Merlin" graphics card is now supported

Details are given in the  
revision history

.

## 1.3 Overview

"Those days, the Third Age of Middle-earth,  
are now long past, and the shape of all lands

---

has been changed."

Frodo is a multitasking C64 emulator for the Commodore Amiga and the world's first C64 emulator not bearing a "64" in its name. :-)  
(No, it has absolutely nothing to do with frodo.hiof.no, that's a pure coincidence.)

Frodo was especially developed to reproduce the graphics of games and demos better than the existing emulators for the Amiga. Therefore Frodo needs much more computing power than other emulators. Even using a 25MHz 68040 with a graphics card gives only slightly more than half of the 64's original speed. But on the other hand, Frodo can display raster effects correctly that only result in a flickering mess under "A64".

An Amiga with (at least) OS2.1, a 68020 processor and 1MB RAM is required. Frodo can use the built-in Amiga graphic capabilities as well as access EGS/CyBERgraphics graphics cards, the "Picasso" and the "Merlin" directly to vastly improve performance. So the recommended configuration is an A4000/040 with a Zorro-III graphics card. It is possible to run it on an A1200, but you won't have any fun with it. There is, however, a special monochrome mode that has no color but is a lot faster than the full emulation.

The program is not a 100% emulation (is there such?), the main missing things are:

- Only line-by-line raster effects possible
- Neither Amiga printers nor RS232 usable
- No support for .d64 files
- No built-in machine language monitor/debugger
- No emulation of a REU (RAM expansion unit)

But the next version is coming real soon now... :-)

## 1.4 Installation

The archive contains the following files:

README	- Short description
Frodo	- Main program
Frodo.info	- Its icon
Frodo.guide	- The german version of this manual
Frodo.guide.info	- Its icon
Frodo_E.guide	- This manual
Frodo_E.guide.info	- Its icon
Frodo Prefs	- Preferences file
Frodo Prefs.info	- Its icon
FrodoSIDCard.lha	- Archive with information on the SID card
Basic ROM.info	- Icon for Basic ROM
Kernal ROM.info	- Icon for Kernal ROM
Char ROM.info	- Icon for Character ROM
Catalogs/#?	- Language files
64prgs/#?	- Some sample programs
src/#?	- Source

All you have to do is to unpack the archive somewhere onto your hard

---

disk. The files in "Catalogs" don't need to be copied to LOCALE:, they can stay where they are. Frodo doesn't need any assigns, but copies of the original C64 ROMs are required. For legal reasons these are not included in the archive and you have to get them elsewhere.

Frodo looks for three ROM files named "Basic ROM", "Kernal ROM" and "Char ROM" in the same directory Frodo is in. If you already have ROM files for "A64 V2.0" (not the \*.data files, these are not the real ROMs), you can simply rename them and use them with Frodo. Otherwise, they can be read from a real C64 by means of the following program:

```
10 OPEN 1,8,2,"BASIC ROM,S,W"
20 FOR X=40960 TO 49151:PRINT#1,CHR$(PEEK(X));:NEXT
30 CLOSE 1
40 OPEN 1,8,2,"KERNAL ROM,S,W"
50 FOR X=57344 TO 65535:PRINT#1,CHR$(PEEK(X));:NEXT
60 CLOSE 1
70 POKE 56334,0:POKE 1,51
80 FOR X=16384 TO 20479:POKE X,PEEK(X+36864):NEXT
90 POKE 1,55:POKE 56334,1
100 OPEN 1,8,2,"CHAR ROM,S,W"
110 FOR X=16384 TO 20479:PRINT#1,CHR$(PEEK(X));:NEXT
120 CLOSE 1
```

Unfortunately, Frodo has no function to get these files saved on a C64 disk to the Amiga, but you can transfer them via a null-modem cable or using A64 or any of the 1541-to-Amiga transfer utilities. (Frodo can indeed access C64 disk drives, but to start Frodo you must already have the ROMs %-).

There is, however, a way to get the ROMs via a mailserver. Write to "duck@pembvax1.pembroke.edu" with subject "MAILSERV" and "send roms.zip" in the body of the mail. You'll receive a uuencoded .zip archive containing a lot of commodore ROMs. The ones needed for Frodo are in the directory "64": "basic", "kernal.3" and "charset". Simply rename them and copy them into Frodo's directory.

For sound emulation, Frodo uses the "6581sid.library" which is part of A64 V3.0 and likewise not included. The demo version of A64 on the Aminet contains this library so you can get it from there.

## 1.5 Start/quit

After a double cklick on the icon, the window for the emulation settings appears.

The actual emulation is started by a click on "OK". Then, at first a black screen should appear followed by the C64 startup message after a short moment.

Clicking the right mouse button will quit the emulator at any time.

---



## 1.6 Settings

The settings window appears directly after starting Frodo, or by pressing F9 in the running emulation.

"Cycles per line (CPU)" and "Cycles per bad line (CPU)" control the relation of graphics speed and processor speed. The higher the values, the faster the emulated CPU, but the slower the graphics refresh speed. If a program is showing flickering lines or graphical flaws you should try to slightly alter both values.

With "Cycles per line (CIA)" you can control the speed of the CIA timers. Entering a higher value increases the frequency of cursor blinking and key repeat. Some programs don't run correctly with the default value (e.g. "Ballblazer" which needs a value of 65).

The settings for the three "Cycles" coming closest to an original PAL C64 are (63,23,63).

Under "Every (n)th frame" you can select if Frodo should skip frames when displaying the C64 graphics. The normal setting is "1", that is, every frame (every simulated raster beam sweep) is recalculated. If you change this to "2", for example, then only every second frame is calculated, immensely speeding up the display, though some raster effects may look a bit jerky. The setting for an A4000/040 without graphics card that gives the original C64's speed in most cases is "5".

"Joystick on Port 1/2" relates to the Amiga ports. Normally, you will want to have port 1 switched off if you have your mouse connected there. With "Swap joysticks" you can swap the assignment of the Amiga ports to the C64 ports without having to plug out and in your joysticks. E.g. if a C64 game is using a joystick on port 1 you can simply activate "Swap joysticks" and use a joystick in port 2 to play the game.

With "Use SID card" you specify if the sound emulation should be done over the

SID card

or using the "6581sid.library" (i.e. over the Amiga sound channels). If you don't have a SID card, you should leave this gadget switched off to prevent illegal memory accesses.

The keyboard layout normally matches that of a german keyboard (Y and Z swapped). With "American keyboard" you can prevent the swapping (preferable, if you are not using a german keyboard).

The gadget "Sprite collisions" determines if collisions between sprites and between sprites and graphics should be detected. Turning off collisions will make you invincible in some games (sadly, your enemies are likely to become invincible, too :-/).

With the setting "Fast Reset" you can disable the memory test on C64 reset. On the Amiga, the memory test is not necessary and the reset procedure (F10) becomes much faster when it is disabled.

---

The setting "Screen type" determines the way Frodo controls the graphics. The choices are "Amiga" (for using the built-in Amiga graphics), "EGS" (for EGS graphics cards), "Picasso" (for the Picasso graphics card), "CyBERgraphics" (for CyBERgraphics cards), "Merlin" (for the Merlin graphics card) and "Amiga Mono", a particularly fast monochrome mode without sprite collisions (useful for "Elite", for example). After choosing the screen type, you have to select an appropriate resolution using "Screen mode". The display on graphics cards is faster than the Amiga graphics (besides monochrome mode), but CyBERgraphics is a bit slower than EGS and Picasso. These settings can not be altered in the middle of the running emulation.

Next to "Drive 8" to "Drive 11" you give the paths of directories (relative to the directory Frodo is in) that are used for the simulation of disk drives 8, 9, 10 and 11 (see file access ). Clicking on the symbols to the right of the string gadgets will open a requester to select the directory more user friendly.

The four checkmark gadgets under "IEC" control whether the belonging disk drive is to be accessed over the IEC cable as real C64 devices.

If you have, for example, a real 1541 with drive number 8 connected to your Amiga, you have to activate the "IEC" checkmark for drive 8 to use the 1541 (instead of the simulated one).

When the symbol "Use IEC for other devices" is active, Frodo uses the IEC cable also for device numbers 4 to 7 and 12 to 15. So, if you have connected a

C64 printer with device number 4, you should click on this gadget to use the printer. If this gadget is not activated, all device numbers except 8 to 11 give a "device not present error".

With "'/' -> '\' in file names" you control whether the '/' in C64 filenames will be translated to '\' and vice versa. The '/' character is used to access subdirectories on the Amiga, but as the C64 doesn't have subdirectories, it's a valid part of a C64 file name. This is a problem if a program wants to create a file with '/' in it as AmigaDOS would interpret the part before the '/' as a directory name and, finding no such directory, would return an error and the open would fail. Now simply activate this gadget and all '/'s will transparently be translated into '\', so in directory listings the '/' will still appear. If you turn off this gadget, you can of course use the '/' to access files in Amiga subdirectories from the C64.

By clicking "Save" the settings are saved on disk to be reloaded next time you start Frodo. "OK" will start the actual emulation (resp. return to it) and "Cancel" will discard your changes to the settings and quit Frodo (resp. discard the changes and return to the emulation).

---

## 1.7 Keyboard layout

The keyboard layout closely resembles that of a C64, but the "Y" and "Z" keys are normally swapped (german keyboard layout). This can be prevented by clicking on "American keyboard" in the settings window.

The individual rows of the keyboard are mapped as follows (american keyboard, those with other keyboards may want to have a look at the german manual for the mapping of the two extra keys to the left of the Return key and the right of the left Shift key):

Option "American keyboard" off:

```
<- 1 2 3 4 5 6 7 8 9 0 + - £      [ ] / *
    Q W E R T Z U I O P @ *      -
    A S D F G H J K L : ;        <Joy> +
    Y X C V B N M , . /
```

Option "American keyboard" on:

```
<- 1 2 3 4 5 6 7 8 9 0 + - £      [ ] ^ =
    Q W E R T Y U I O P @ *      -
    A S D F G H J K L : ;        <Joy> +
    Z X C V B N M , . /
```

In addition, the following keys are used:

```
Esc      - RUN/STOP
<-      - INS/DEL
Del      - CLR/HOME
Help     - RESTORE
Return  - RETURN
Enter   - RETURN
Amiga   - C=
Alt     - C=
F1-F8   - F1-F8
F9      - Opens the settings window
F10     - Resets the C64
```

So the famous key combination RUN/STOP-RESTORE corresponds to ESC-Help on the Amiga keyboard. But you don't have to thrash the Help key the same way as the RESTORE key on the original C64. :-)

The cursor (arrow) keys can be used as on the Amiga. I.e. "cursor up" corresponds to "Shift-cursor down" on the C64. The same applies to the function keys F2, F4, F6 and F8.

The numerical keypad is emulating a joystick in port 2 (with "Swap joysticks" one in port 1):

```
  7      8      9
      ^
      |
  4      5      6
<-- Feuer -->
      |
```

```

      v
1     2     3

0
Feuer

```

## 1.8 File access

Frodo can simulate 1541 drives with the drive numbers 8, 9, 10 and ↔  
11  
in Amiga directories as well as access real C64 drives by means of an

IEC cable

. So you can store your C64 programs on your Amiga's hard disk and LOAD and SAVE them as usual from Frodo. The paths to the directories of the simulated drives are given in the settings window under "Laufwerk 8" to "Laufwerk 11".

You can even load the directory with LOAD"\$",8. All files marked as executable are displayed as "PRG", all the others as "SEQ". The file type "DIR" marks an Amiga subdirectory. To get into it you have to open the settings window and change the path for the drive, as the operating system of the C64 doesn't know about subdirectories. Though, it is possible to use a "/" in the C64 file name to access these subdirectories (e.g. LOAD"GAMES/ELITE",8), unless the '/' translation setting is turned on.

For the opening of files, the file types "PRG" and "SEQ" and the access modes "R", "W" and "A" are supported. Wildcards (\*,?) can be used, but you have to remember that files in Amiga directories have no specific order and the result of LOAD"\*",8 is rather random. Files are always overwritten even if they are not opened with "@:". Floppy commands, relative files and direct block access are not implemented, you can however read the error channel.

For connecting real C64 drives you need a special cable to hook them to your Amiga. Then you have to activate the symbol "IEC" for the corresponding drive number in the settings, so Frodo will know that this drive number belongs to a device on the IEC cable. Drives connected this way can be used like from the C64, but speed loaders are most probably not working.

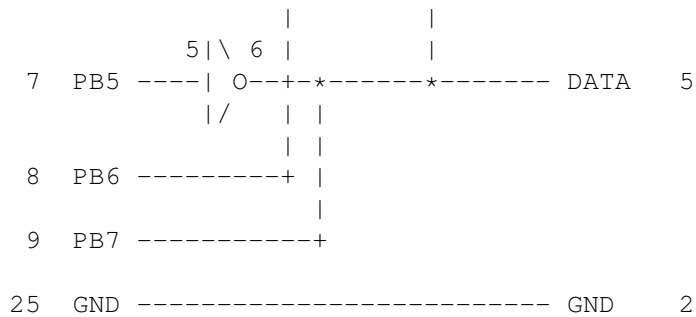
## 1.9 Printers

Frodo can't use Amiga printers, but you can connect a C64 IEC ↔  
printer  
using the

IEC cable

that is accessed as usual under the C64. You have to activate the gadget "IEC für andere Geräte verwenden" in the





The 7406 (a 74LS05 will do as well) must be connected to +5V and GND of course. The trained technician will notice that this is the same circuit found inside the real C64.

[Important note: If you plan to build and connect such a cable, please remember that you do it on your own risk. I will not take any responsibility if there is blue smoke coming out from the back of your computer!]

## 1.12 Sample programs

The directory "64prgs" contains some little sample programs to show the capabilities (and weaknesses) of Frodo. They are all loaded with `LOAD"<name>",8` and started with `SYS49152`. To do so, you have to type '64prgs' in the settings for "Laufwerk 8" so Frodo will find the programs.

If you like, you can try these programs on other emulators or on a real C64.

A short description of each program:

```

3fff      : Opens the top and bottom border and displays swinging
           letters ("Zyklen pro Zeile (CPU)" should be set to 60
           for this one)
colorbars: Flickering colors
dycp      : Scrolling with different Y character position
fld       : Demonstrates the FLD effect (flexible line distance)
stretch   : One thing Frodo is not (yet) able to emulate: variably
           expanded sprites
tech-tech: Horizontal scrolling with large amplitude (use joystick
           in port 2 to control)
text26    : Displays (nearly) 26 lines of text
monitor   : A simple machine language monitor

```

## 1.13 Technical info

"Known?" said Gandalf.

"I have known much that only the Wise know, Frodo."

In contrast to A64 that is biased towards the Amiga hardware, Frodo tries to exactly imitate C64 hardware features. Now the 64's hardware

(esp. the graphics chip "VIC") has a rather simple design resulting in many of the internal processes coming to the "outside". So there are lots of "undocumented features" you can do effects with the designers never dared to dream about.

Frodo uses a line-by-line emulation, i.e. the function of the VIC and the processor (6510) are emulated for one raster line of the C64 screen at times. In practice, Frodo runs VIC and 6510 alternately for 63 simulated cycles each (corresponding to one raster line). At first, it emulates the processor for 63 cycles, then switches over to the VIC that paints one pixel row to the screen, then again 63 cycles processor, and so on... With the exception of monochrome mode, all graphics is internally calculated for a chunky mode display. The Amiga mode uses a chunky->planar conversion to display the chunky pixels on screen.

Even though this is a heavy simplification of the processes in a real C64, it lets you perfectly emulate many graphical effects possible on the 64, e.g. FLD, FLI, DYCP, hyperscreen and many more. But this method has one big disadvantage: Changes made to VIC registers by the processor in the middle of a raster line will only take effect at the start of the next line. E.g. you can't change the border color in the middle of a line, the color change takes place in the next line. Therefore, very sophisticated techniques depending on the exact position of a register change can't be emulated. For instance, it is no problem to open the top and bottom border, but opening the left and right border is impossible (and therefore not implemented in the emulation).

The next step above line-by-line emulation would be to resolve VIC and 6510 into single cycles. The processes in the VIC and the 6510 for each cycle are quite well known, so there is no theoretical problem in the realization. The only real problem is speed. You would have to switch between VIC and 6510 after every cycle, instead of after 63 cycles as Frodo does in the moment. This would mean abandoning the register-based 6510 emulation, as the overhead for storing and retrieving the complete register set for every switch would be too high.

The present opcode dispatch model would have to be replaced by some kind of "cycle continuation pointer" pointing to the subroutine for the next cycle of the current opcode (or should the opcode dispatch table be extended by 8 entries for each opcode for the single cycles?). As a first estimation, the speed would go down by a factor of 3-4, so before the availability of faster Amigas there is no hope for cycle based emulation. Though you could emulate effects like AFLI and the VC and sprite counter confusions of the VIC precisely.

## 1.14 A note on speed

Ok, the emulation is very slow, but why is this so?  
Some little calculations:

The overscanned display area of the C64 is 411\$ \times \$284 pixels, 368\$ \times \$272 ←  
of  
which are displayed by Frodo, giving a total of 100096 pixels. In

chunky mode each pixel needs one byte, so at a frame rate of 50Hz we'd have to transfer 5MB/s into the display memory. The bandwidth of the Zorro III bus on an A4000/040 is 6.6MB/s...

Considering that the emulator moreover has to read the graphics from somewhere and has to emulate the processor and I/O "by the way", you'll discover that there are theoretical limits for the speed of the emulation. By using Amiga bitplane graphics the amount of data could be halved, but the gain is largely absorbed by the lower chip RAM bandwidth (4.5MB/s) and the more complicated processing required.

So what can be done about it? The most obvious idea would be to remove the chunky->planar conversion and to have the VIC write directly into the Amiga bitplanes using optimized routines. The monochrome mode is the first step in this direction, but at full color emulation the results were disappointing, even when using the blitter asynchronously. They were nevertheless not that disappointing that I would have abandoned this idea completely.

The chunky mode routines don't look very efficient at the first glance, but I have not yet succeeded to make them significantly faster. I have tried to replace the pixel color conversions by table lookups, but this even got slower.

So, if the graphics can't be made faster, how about the processor emulation? I have also thought about this and tentatively replaced the opcode jump table model by a model with opcode routines of 256 bytes each which are called directly using the opcode value as index. But although this model allows fetching the second instruction byte without additional overhead, it was slower than the current emulation that seems to be using the cache more efficiently. CPU transcription is impossible because of the intensive use of self-modifying code on the C64.

In my opinion, accuracy is more important than speed, so removing features out of the emulation would be out of the question.

## 1.15 The source

For those confused by the numbers: A small description of all modules:

1541.asm	- File access and IEC routines
6510.asm	- The processor
6526.asm	- The CIAs (in/output, keyboard, timers)
6569.asm	- The VIC (graphics)
6569mono.i	- Routines for monochrome graphics
6581.asm	- The SID (sound)
c2p4.asm	- Chunky->planar conversion
ExpTable.bin	- Included by 6569mono.i
FrodoPrefs.#?	- GadToolsBox user interface of settings window
Frodo_rev.#?	- Version information
Main.asm	- The main module
Strings.#?	- For localization, created by CatComp
Boopsi.o	- An object file from GadToolsBox to be linked in



The calls for assembling and linking are:

```
PhxAss Main.asm INCPATH Include: OPT !
PhxAss 6510.asm INCPATH Include: OPT !
PhxAss 6569.asm INCPATH Include: OPT !
PhxAss 6526.asm INCPATH Include: OPT !
PhxAss 6581.asm INCPATH Include: OPT !
PhxAss 1541.asm INCPATH Include: OPT !
PhxAss FrodoPrefs.s INCPATH Include: OPT !
PhxAss c2p4.asm INCPATH Include: OPT !
PhxLnk Lib:RXstartup.obj Main.o 6510.o 6569.o c2p4.o 6526.o 6581.o
1541.o FrodoPrefs.o Boopsi.o Lib:small.lib TO Frodo
```

Note that PhxAss V4.0 or later must be used for assembling.

## 1.16 Copyright and distribution

The program "Frodo", this manual and the source code may be freely distributed as long as they remain unchanged (archiving and packing is allowed) and all files are included. You must not make any profit by selling Frodo, especially the price of a disk containing Frodo may not exceed US\$ 5,- (or equivalent amounts in other currencies). Please feel free to distribute Frodo over bulletin board systems and networks and as part of shareware/freeware CD-ROMs.

Anyone using this program agrees to incur the risk of using it for himself. In no way can the author be held responsible for any damage directly or indirectly caused by the use or misuse of this manual and/or the program.

The rights on the source code remain at the author. It may not - not even in parts - used for commercial purposes without explicit written permission by the author. Permission to use it for non-commercial purposes is hereby granted as long as my copyright notice remains in the program. You are not allowed to use the source to create and distribute a modified version of Frodo.

The user interface of the program was designed with GadToolsBox  
© Copyright 1991-1993 Jaba Development.

Parts of the program are © Copyright 1992-1993 Jaba Development.

## 1.17 Bug reports

If you find a bug or a misfeature in Frodo, or have an idea how to make some things better, then please drop me a note so I'll be able to improve Frodo in the future. My address can be found  
here  
.

I don't think the emulation can be made much faster without changing the concept but I'll be happy to find someone showing me how to do it.

---

Besides, I'm looking for translations of Frodo.catalog in other languages. An elvish version would be especially welcome. :-)

## 1.18 Credits

The following persons deserve special thanks from me as they made a significant contribution to the development of Frodo:

- Frank Wille <frank@phoenix.owl.de>, whose PhxAss was used for developing Frodo
- Jaba Development, whose GadToolsBox developed Frodo's user interface
- Peter McGavin <peterm@maths.grace.cri.nz>, who wrote the chunky-to-planar conversion
- Andreas Boose <a.boose@ldb.han.de> and Marko Mäkelä <marko.makela@hut.fi>, who provided me with precious information on the VIC and on the C64 in general
- Markus Winklbauer <sysop@ng-box.wwbnet.de>, for the docs for the Picasso card
- Lord Prayer for the docs for the Merlin card
- Teemu Suikki <Teemu.Suikki@lut.fi> for the idea of skipping frames
- Pawel Soltysinski <polonus@felix.univ.szczecin.pl> and Pawel Hernik <spi-ph@srv1.tu.kielce.pl> for the polish catalog files
- Giovanni Gentile <gentile@dsi.unimi.it> for the italian catalog files
- Marcus Comstedt <marcus@amicus.rydnet.lysator.liu.se> for the swedish catalog files
- Jarkko Lindblad <lindblad@cc.helsinki.fi> for the finnish catalog files
- Claus Østergaard <dos@dator.dk> for the danish catalog files
- Kjell Irgens <kjelli@stud.cd.uit.no> for the norwegian catalog files
- J.R.R.Tolkien for the suggestion for the name of the emulator
- All the people who have sent me suggestions and comments

## 1.19 The author

My address is:

Christian Bauer  
Langenastr. 65  
56070 Koblenz  
Germany

EMail:

bauec002@goofy.zdv.uni-mainz.de (More reliable but polled  
cbauer@mzdmza.zdv.uni-mainz.de less frequently)  
cebix@ng-box.wwbnet.de (Polled daily, but slower connection)

Questions, criticism, suggestions and  
bug reports  
are always  
welcome. EMail is preferred.

---

Frodo is not a shareware program, but I won't reject any gifts. :-)

## 1.20 History

This emulator started as a player routine for C64 music (therefore the SID card) until I saw A64 V3.0 and was so disappointed of it that I began to write a "real" C64 emulator (around christmas 1994).

V0.4 05.Jan.1995

- First released version

V0.5 10.Jan.1995

- Starting Frodo on a 68000 correctly gave a requester but then the computer crashed. I told you this only works on 68020+ :-)
- Removed two enforcer hits in the memory configuration routine
- Sprite cycles are now calculated correctly
- Switching off a sprite in the middle of its display blanked it immediately. Now it is drawn completely.
- Graphics speed for EGS/Picasso improved by means of a line buffer (20% faster), other small optimizations to the graphics
- VIC interrupt flag is now cleared on every write access to \$d019 (a hack for RMW commands doing two write accesses)
- CIA timers B are now capable of counting underflows of timer A (for "Ballblazer" :-)
- PLP and RTI clear the break flag
- Completely new 1541 emulation, 4 drives
- CPU cycle counter heavily optimized (again 25% gain in speed)

V1.0 25.Jan.1995

- PHP now sets the break flag on stack
  - HandleRESET erroneously set the I flag (don't trust a data sheet, even if it's from the manufacturer...)
  - A RESET will set the VIC bank to 0
  - All illegal opcodes implemented
  - New algorithm for the VIC's VC that is more close to the real VIC
  - The VBlank routines now jump back to Periodic6569 as there was a non-existent -1st line
  - TOD clocks implemented
  - ECM+BMM, ECM+MCM and ECM+BMM+MCM now correctly display a black screen
  - Access to SID card is now disable-able (!? :-)
  - Some bugs in 1541 emulation corrected
  - Use of IEC devices over an adaptor cable is now possible
  - Selecting the directories for the 1541 emulation can now be done with a directory requester
  - Turning off the screen using bit 4 of \$D011 is working
  - Setting for "raster frequency" removed
  - Interrupt handling completely rewritten
  - Some internal optimizations
  - During a reset, the CBM80 signature is now only overwritten if it is present
  - Frodo now works on non-AGA machines
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- Sprite-sprite collisions implemented
- Swapping of Y and Z keys is now a settings item

V1.1 was an internal test version with bitplane graphics  
(removed again in V1.2)

V1.2 09.Feb.1995

- Average graphics speed is now higher, especially in multicolor and bitmap modes
- New, very fast monochrome mode
- Sprite routines are more efficient. No processor time is wasted when all sprites are off.
- Sound emulation with 6581sid.library when SID card is disabled
- Minimal screen resolution is now 384 $\times$ 272
- Sprite collisions can be turned off
- 1541 emulation now handles sequential files and access modes and ignores drive numbers and the '@'
- Frodo is now multilingual by means of "locale.library"
- Overscan resolutions can now be used
- Modes like PAL:Lowres are now selectable under OS2.x
- Option to translate '/' in file names to '\ ' and vice versa
- Joysticks are now only polled in the VIC vertical blank routine
- Amiga graphics routines now also use double buffering
- Option to accelerate the memory test on reset

V1.3 22.Feb.1995

- Bug in Closel541 corrected (could crash on quit)
- CyBERgraphics support
- 1541 emulation now handles wildcards
- Option to skip frames implemented

V1.3a 04.Mar.1995

- Corrected a bug with opening the prefs window with F9 on the Picasso card

V1.4 05.May.1995

- Pause6510 and Resume6510 now use signals
- Keyboard routines improved, the option "American keyboard" will now map "=" and "^" to the numerical keypad
- Sprite routines completely rewritten, sprite graphics priorities and collisions are now taken into account
- Branches over \$ffff/\$0000 work
- Joystick emulation with numerical keypad
- Polish and italian catalog files

V1.4a 12.Mai.1995

- Bug in joystick routines corrected
- Danish, finnish and swedish catalog files

V1.5 06.Jun.1995

- Merlin graphics card support
- Norwegian catalog files

## 1.21 The future

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These are some of the things on planned for the next versions:

- Faster graphics on Amiga chips (theory is ready, but the code needs to be heavily optimized to compare with the current method)
  - A built-in machine language monitor that pops up by hotkey
  - Possibilities to save and restore the state of the emulation (memory and register snapshot)
  - Direct access to .d64 files (is this urgent?)
  - Sound emulation using "PlaySID"
  - Usage of Amiga printers and modems (rather unlikely, as Frodo has not been written to run PrintShop on it :-)
  - Cycle based emulation. I have ideas for that and hopefully the speed won't go down as drastically as I expected at first. This would of course be switchable or there would be two versions of the emulator.
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