

LisaEm User's Guide

v1.2.0



by Ray Arachelian

LisaEm User's Guide

The World's First Fully Functional Lisa Emulator™

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<http://lisaem.sunder.net>

About LisaEm

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LisaEm emulates Apple Computer's Lisa 2/5 computer.

LisaEm is the world's first Lisa emulator project, started in late 1997, and it is the first to be able to emulate enough of the Lisa hardware accurately enough so as to be run the Lisa Office 7/7. While other emulators for the Lisa exist now, they do so because of the efforts of this project.

LisaEm attempts not just to emulate the Lisa computer, but also provide as much of the experience of using an actual Lisa and several of its peripherals.

LisaEm currently runs on the win32, OS X, and Linux platforms. It should run on any platform where wxWidgets 2.8 will compile, possibly requiring some modifications.

LisaEm is built around James Ponder's Generator CPU core, which has been heavily modified to fully support Lisa's memory management unit.

Historical Note:

The Apple Lisa was a machine of historical importance. Its design, while based on the Xerox Alto, signifies the beginning of ubiquitous user friendly computing. The Lisa was a revolutionary computer in many ways, itself building upon, and extending the ideas invented at Xerox PARC.

While many believe that the Macintosh signifies the start of the user friendly computer revolution, despite the infamous 1984 SuperBowl commercial, the Mac is actually the Lisa's descendant, and includes software that was both built on and also used on the Lisa. Macintosh computers include QuickDraw in their ROMs which was first designed on the Lisa. Building software for the Mac required a Lisa due to the limitations of the original Mac.

The introduction of the Lisa also sparked the creation of Microsoft's Windows environment, and modern user friendly computing, and the office suite.

Due to its limited run, and the destruction of many machines for tax benefits, actual Lisa computers and parts tend to be rare to find in good working condition, and are expensive.

While component level parts are mostly available, there are many components that are no longer available and cannot be replaced, except from other Lisas. (i.e. the COPS421 microcontroller, the CRT, etc.)

Because of this realization, and the Lisa's historical significance, I felt the need to build an emulator for this machine to allow it to continue past the point where no actual Lisa's will still function.

This emulator was designed to both be open source and to use only open source components, in order to ensure that it will be both available, and maintainable on future machines. It was also built to be portable, so that it handle various types of host machines, whether they run on big or little endian CPU's.

As various platforms evolve, no one can predict which will survive and which will go extinct. With this in mind, I've chosen the wxWidgets framework as it allows me to write code for multiple platforms, and easily port to others as they are available.

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LisaEm uses the libdc42 library, which was created for, and is a part of this project. libdc42 provides support for Disk Copy 4.2 disk images as well as DART disk images.

The routines for the LZH compression compatibility in libdc42 which provide DART support are additionally subject to the following restrictions:

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Requirements

Requirements

Host CPU and memory:

LisaEm needs a fairly fast machine. It provides decent performance on machines such as a Intel PIII-750MHz with ample free memory. It is able to emulate a 5MHz Lisa on a 500MHz G4 with 512MB of memory on Mac OS X 10.3.9.

LisaEm makes extensive use of memory as part of its operation in order to speed up its operations. Its footprint has been noted to rise above 64MB on some environments depending on the options used.

In particular, the virtual ImageWriter/ADMP printers tend to be memory hungry. It is highly recommended to only configure a single printer. Each virtual printer requires at least 4MB as a frame buffer, however, once the page is ready to printed or save, its requirements will temporarily rise to 12MB.

Lisa Software and ROMs:

To use the emulator, you will optionally need an operating system such as Lisa Office System or MacWorks. (At this time the Xenix Operating System does not yet run.)

Optionally, if you have a copy of the Lisa Boot ROM and/or the Dual Parallel ROM, you can configure LisaEm to use them. If you do not have ROMs, the emulator will still work without them.

You will need to make disk images of the Lisa Operating System disks using the Disk Copy 4.2 or DART programs as the emulator cannot read the original diskettes. This is because only classic 68k and early PowerPC Maci machines with GCR capable drives are able to read the 400K floppies used by the Lisa.

Disk Images made from Disk Copy versions greater than 4.2 will not work. Disk Images converted from DART to Disk Copy 4.2 by use of any program other than LisaFSH-Tool will not work on real Lisa hardware, nor, LisaEm.

Software tools will eventually be provided to allow ROM extraction. Please read and follow the documentation that comes with them.

NOTE: If your ROM version is 3A, you will only be able to run the MacWorks environment as your Lisa has the screen modification kit for square pixels. Using the 3A ROM with LisaEm will also disable the raw, anti-aliased, anti-aliased with gray replacement display modes.

If your ROM is version 3A, but you wish to run Lisa Office System, do not configure a ROM in the preferences, and one will be simulated for you, without the screen modification.

Downloading and building LisaEm

Downloading Binary and Source Versions:

LisaEm is available for download from <http://lisaem.sunder.net/downloads.html>

Pre-Compiled versions of LisaEm are available for Mac OS X (intel and PPC), win32, and Ubuntu Linux. Note that due to the variation between Linux distributions, it is recommended to compile your own version for your system from source.

Some Linux distributions may provide precompiled packages and binaries for their distribution. If these are available, and you prefer to use them, use your distro's preferred installation method (i.e. apt-get install or rpm -ihv and so forth.)

If LisaEm is not provided for your platform in binary form, you can compile your own version, provided you have proper development environment/software including wxWidgets 2.8, the GNU C compiler toolchain, the bash shell, the netpbm package, and other standard open source tools available on most open source systems.

Compiling LisaEm for your system:

Prerequisites:

On Unix, BSD, and Macintosh systems:

You'll need to download, compile, and install wxWidgets 2.8.4 from <http://www.wxwidgets.org> and the netpbm package for your system.

NOTE: For Macintosh, you'll need to edit wxWidgets as follows before compiling wxWidgets or the graphics display by LisaEm may not work properly. For versions 1.0.0 and later of LisaEm, this is no longer required, but may cause performance issues on some machines.

in your wxWidgets directory, edit the file include/wx/mac/carbon/chkconf.h

```
change the line with '#define wxMAC_USE_CORE_GRAPHICS 1'
to                  '#define wxMAC_USE_CORE_GRAPHICS 0'
```

(Many thanks to Brian Foley for finding this!)

On Microsoft Windows systems:

You'll need to install both Cygwin and the wxDev-Cpp 6.10-2 environment. Download wxDev-CPP 6.10-2 from <http://wxdsgn.sourceforge.net/> and install it in [c:\wxDev-Cpp](#). Do NOT allow the installer to install it underneath the [C:\Program Files](#) directory. The space between "Program" and "Files" will cause issues that cannot be easily resolved with the build script.

wxDev-Cpp was chosen since it contains both wxWidgets and the MINGW gcc/g++ compiler toolchain, however, Cygwin and its netpbm package are required for the build script.

The Cygwin environment can be downloaded from <http://cygwin.com>. When you install Cygwin, be sure to enable the netpbm graphical tools. The bash shell should be installed by default, but you should check to make sure that it is enabled.

Building LisaEm:

From your OS's shell or terminal program (use cygwin on win32), run the following commands:

```
bzip2 -cd lisaem-1.2.0 | tar xvf -      # Extract the archive
cd lisaem-1.2.0                        # enter the directory
./build.sh clean build                 # build the software
sudo ./build.sh install                # optionally install it.
```

On win32, remove the sudo command. Just issue `./build.sh install` by itself.

Additional options can be found by running `./build.sh --help`.

On Mac OS X systems, the `--with-rawbitmap` option is automatically enabled. On other platforms, it is disabled, as the rawbitmap options causes win32 to crash, and Linux to display a black screen.

On Windows, the install command will install LisaEm to <C:\Program Files\Sunder.NET\LisaEm>

On Unix Systems, except for OS X, it will install the binaries to `/usr/local/bin`, and resources to `/usr/local/share/LisaEm`.

On Mac OS X, it will install the binary to `/Applications/LisaEm.app`, which will not be a universal binary. If you wish to build a universal binary, you'll have to repeat the build process on the alternate architecture, and use the `lipo` command to merge the binaries together. The `lisafsh-tool` and `lisadiskinfo` command line tools will be installed to `/usr/local/bin`.

The `--with-rawbitmap` option enables the use of the undocumented `rawbmp.h` `wxWidgets` interface. This allows very fast access to the individual RGB colors in a `wxBitmap`, so it allows for fast display refreshes. When this option isn't available (any platform other than OS X for the current version), an alternate method is used.

The alternate method uses a `wxImage`, and the `SetRGB` method to achieve what `rawbmp.h` does, with a small slowdown induced by the conversion of the `wxImage` to a `wxBitmap` since `wxImages` cannot be directly Blitted to the display. This is the display method used on Linux, and Windows currently.

Extra debugging options are provided on OS X and Linux via the use of the `--with-debug` and `--with-tracelog` options. When used together, these enable a new menu option called Trace Log. This option is a boolean, that is when enabled, it logs every executed opcode as well as any I/O, and memory accesses including MMU translations, and I/O timer events (IRQ's). Trace logs generate very large logs at the rate of megabytes for every second of runtime.

This option is intended to help the reverse engineering of operating systems running on the Lisa, and also the debugging of the emulator. It is not intended for end users, and will not be discussed further in this document.

Compatibility

Compatibility

If you are unfamiliar with the Apple Lisa computer, reading the LisaFAQ is highly recommended. see: <http://lisafaq.sunder.net> as it also contains pointers to other Lisa information such as operation manuals and guides.

The following software has been reported to work under various versions of the emulator:

- Lisa Office System 3.x
- Lisa Pascal Workshop 3.x
- MacWorks XL
- MacWorks Plus
- LisaTest (video timing test fails, the VIA tests pass internally, but lock up LisaTest.)
- LisaMonitor

The focus of this project is to provide emulation for the Lisa Office System, so the other environments may not be fully functional. This may vary from release to release.

NOTE: *The current versions of LisaEm has bugs preventing the use of MacWorks! The 2007.01.28 Preview version of LisaEm is the only one that works with MacWorks!*

The following hardware is emulated by the emulator:

- Display
- Keyboard
- Mouse
- Sound
- VIA
- Parallel Ports (including the dual parallel card.)
- Serial Ports
- Profile hard drives (5M, 10M under LOS/LPW, other sizes under MacWorks.)
- ImageWriter I printer (serial port connection)
- Apple Dot Matrix Printer (ImageWriter on a parallel port connection)

The following software **does not** (yet) work under the emulator:

- Microsoft/SCO Xenix 3.0

The following Lisa hardware **is not** emulated by LisaEm, and will likely not be supported in the future due to lack of technical documentation and access to actual hardware for reverse engineering:

- Inkjet/Laser printers
- SCSI/Priam hard drives
- Quad port serial card
- Priam hard drive

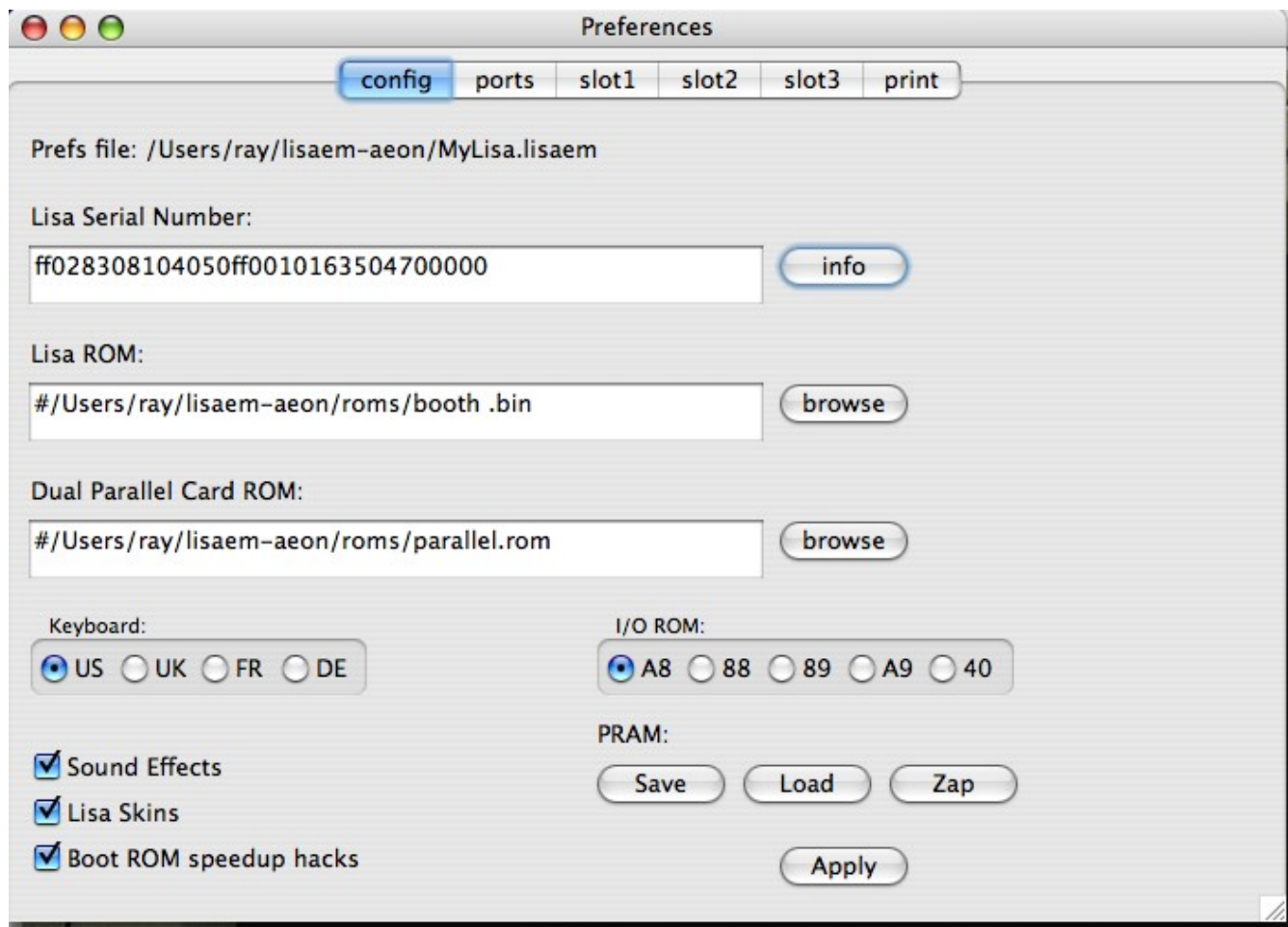
Configuring LisaEm

Configuring LisaEm

The screenshots in this documentation come from the Mac OS X version. Your display may vary from these. The screenshots come from various different versions of LisaEm, and because of this, the coloring will vary slightly.

If you have a copy of the Lisa Boot ROM that you wish to use, tell the emulator where to find it. To do this, open the Preferences dialog box which can be found under the File Menu, except on Mac OS X, where it can be found under the LisaEm menu.

The Preferences Dialog box:



The **Preferences** dialog box allows you to configure the emulator's settings.

Once you are happy with your changes, press the **Apply** button which will save them and dismiss the Preferences dialog. If you close the window, your changes will not be saved. Note that your changes will take effect the next time you power on the emulator.

The Lisa Boot ROM

With version 1.2.0 and later, Lisa Boot ROMs are **not** required. The emulator will work without a boot ROM. If you happen to have a proper boot ROM, you should use it, except if it happens to be the 3A ROM and you wish to run something other than MacWorks. In that case, you should run LisaEm **ROMless**.

The emulator can support several formats for the Lisa boot ROM. If you have extracted the ROMs from your Lisa's CPU board and read them in with a ROM dumper, you should save them as booth.lo and booth.hi. The naming of these files are important if you're using the split ROM. These are labeled 341-0175-H and 341-0176-H for the H version of the ROM.

The Lisa's ROM are split into odd/even bytes which the emulator will stitch together into a single file for you in the same location as the booth.hi or booth.lo files and change its preferences to point to the merged ROM file.

The emulator will run the same checksum routine that the Power On Self Test (POST) uses to check the ROM. Should it notice a problem with the checksum it will alert you and offer the option to continue anyway.

NOTE: Corrupted, or improperly merged ROM files **will** cause the emulator to crash. The same is true of defective software run under MacWorks or other environments; should LisaEm attempt to execute opcode sequences that are not handled by the Generator core, LisaEm may unexpectedly quit.

The Lisa Boot ROM has a diagnostic mode called Service Mode which can be reached by attempting to boot from a non-existent drive, and then sending Command-S. You can use the **Key** menu to send this command and enter this mode. (This is unavailable when ROMless.)

If you are an expert on your host machine's operating system, you can directly edit the path in the text field under the Lisa ROM entry in the **Preferences** dialog box under the **config** tab, otherwise you should click on the **browse** button and use the file picker to select the ROM file.

NOTE: both the ROMs and operating systems used on the Lisa are copyrighted and subject to license restrictions. Please use only the ROMs and operating systems which are licensed for your own Lisas.

Please do not ask me to provide copies of the ROMs or other Lisa software. I prefer not to break Apple's copyright.

If you do not own a Lisa, and wish to legally obtain a copy of the ROM, you'll need to either own a real Lisa, or buy a Lisa CPU board and extract the ROM yourself.

If you need Lisa Office System, you'll sometimes find eBay sellers offering an Apple CD titled "**Service Source**" which contains legal disk images of the Lisa Office System in DART format.

At various times, you may find actual Lisa Office System diskettes available for sale, which may or may not work due to the age of the actual media.

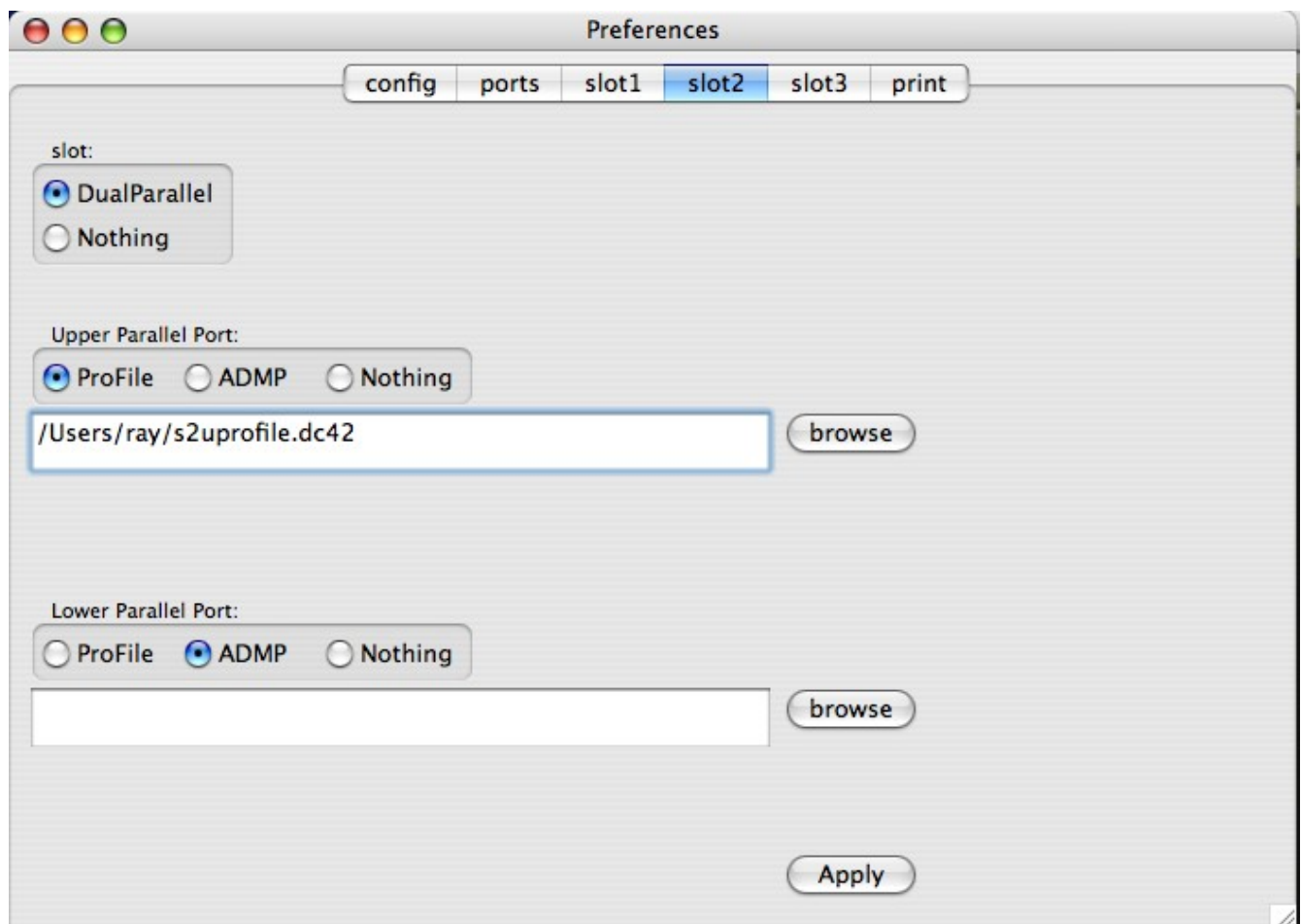
The Dual Parallel Card ROM

One of the more popular expansion cards for the Lisa was the Dual Parallel Card. This card allowed Lisa users to expand the Lisa's storage by adding extra ProFile hard drives and also allowed connections to the Apple Dot Matrix Printer.

If you have this card on your Lisa and dumped its ROM, point the emulator at its ROM file. (You do not actually need this ROM to make use of the dual parallel card emulation.)

If you are an expert user of your host operating system, you can directly type the file path to the Dual Parallel Card ROM file into the text field, otherwise press the **browse** button to use your operating system's file picker and select the ROM file.

The tab for slot 2 shows an enabled dual parallel port card with a ProFile hard drive attached to the upper port and an ADMP printer on the lower port:



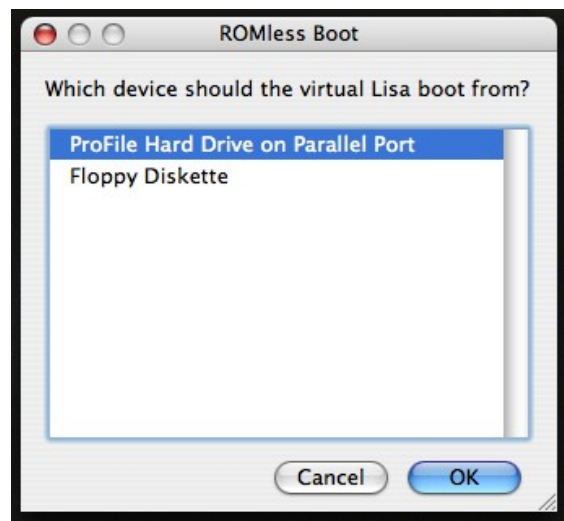
Running ROMless

As of version 1.2.0, LisaEm no longer requires the Lisa Boot ROM in order to start an operating system, such as the Lisa Office System. If you do not have a proper boot ROM file, simply leave the **Lisa ROM** field underneath the **config** tab of Preferences empty.

If you use a file that cannot be found, or have no access to as a boot ROM, LisaEm will run ROMless, and present the ROMless Boot dialog below.

If you pick an invalid or corrupted file, LisaEm may crash if you attempt to power it on!

When you attempt to power on the virtual Lisa, you'll see the following dialog box:



You can now boot from the Floppy drive, or the ProFile hard drive on the Parallel Port.

Booting from a floppy image:

If you've selected the floppy drive, and a floppy has been inserted into the Floppy drive before attempting to power on the virtual Lisa, LisaEm will boot from it. Otherwise, a dialog box will appear asking for a floppy disk image to boot from. You will of course only be able to boot from valid bootable Lisa disk images such as the [Lisa Office System 1](#) diskette.

Booting from the ProFile hard drive:

You will be able to boot from a Profile if the virtual Lisa has been configured, and has the **Parallel Port** under the **ports** tab of **Preferences** set to **Profile**, and the Profile disk image it points to has a valid OS installed.

Booting from Profile drives attached to expansion port slots is not possible when running ROMless. To do that, you would need both the Lisa Boot ROM and the Dual Parallel ROM.

Danger: Do not mix the **ROMless** and **ROMed** modes with existing Lisa Operating Systems. This may lead to troubling issues such as the 10738 OS error. Install LOS ROMless if you want to run ROMless. To be safe, always keep backups of all your disk and Profile images.

The Dual Parallel Card in ROMless Mode

Note that you cannot boot from Profile drives attached to expansion port slots when running ROMless. To do that, you would need both the Lisa Boot ROM and the Dual Parallel ROM.

Even if you have the Lisa Boot ROM, if you do not have an actual Dual Parallel Card ROM, LisaEm will not allow you to boot from ProFile drive images attached to virtual dual parallel boards on expansion slots. If you need to boot from such ProFile images, you'll need both the Lisa Boot ROM and a dump of the Dual Parallel Card ROM.

With LisaEm 1.2.0 and later, the Dual Parallel Card ROM is simulated internally by the emulator. Since there's no actual boot code for this, real Lisa Boot ROMs are prevented from seeing any configured dual parallel port cards as bootable, so their icons will not show up.

However, once an Operating System, such as Lisa Office System is booted up, LisaEm will allow that Operating system to see the configured dual parallel port cards. You will still need to tell Lisa Office System which expansion port slots have dual parallel cards, and what devices are attached to those before using them.

Notes on Dual Parallel Cards and Lisa Office System

Whether you run **ROMless** or **ROMed**, LOS (Lisa Office System) and LPW (Lisa Pascal Workshop) are very sensitive to configuration changes. These operating systems are by no means “plug and play.” If you make too many changes simultaneously, you'll find that they will no longer boot and return an error such as 10737 or 10738.

Before adding any new blank ProFile hard drives to LisaEm, you should make good backups of your existing ProFile drives and PRAM, incase you find yourself unable to boot. If this happens and you don't have backups, you'll have to reinstall the OS!

The **Lisa Owner's Guide** (page D39 for the **Lisa 1 Owner's Guide**, Page 79 for the **Lisa 2 Owner's Guide**) and the **Lisa Office System Guide for 3.1** (page 177) mentions the proper procedure for adding new drives. In terms of LisaEm, this means that you would enable one of the expansion slots to with a Dual Parallel Port card, most preferably the lower port on slot 2, and configure the port for a ProFile drive, then create an appropriately sized Profile disk image.

Note: only the 5MB and 10MB sizes are recognized by Lisa Office System and Workshop. If you pick any other size, LOS/LPW will only see the first 5MB of the drive!

While LisaEm will support upto 7 ProFile hard drives in a virtual Lisa, limitations in LOS and LPW will prevent you from using that many. Indeed, if you try, you may find yourself unable to boot your virtual Lisa at all, and receive error 10737 or 10378!

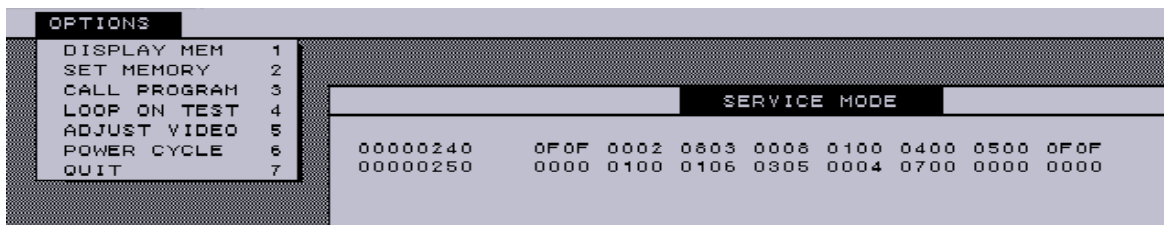
Once you've configured LisaEm, start up Lisa Office System, and open the Preferences icon. Select the expansion slot that you've attached the new ProFile to, and select ProFile. You'll probably be asked to restart Lisa Office System before the new ProFile disk will be recognized. A quick way to do this is to select the **Apple-Power** item from the **key** menu, which will bring up the **Environments Window**. You can then reboot Lisa Office System, which should not see the new drive, and you'll be able to initialize it as a new hard drive.

The Lisa Serial Number:

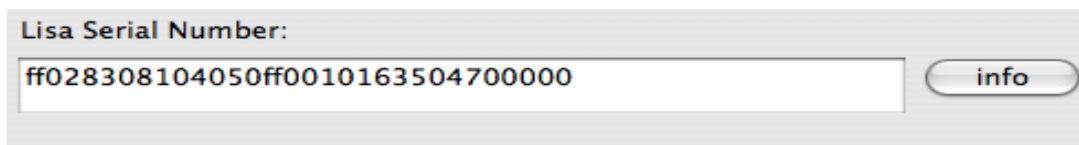
To properly make use of existing Lisa Office System disks in the emulator, you'll have to use the same serial number on LisaEm as on your real Lisa, otherwise the Lisa tools will fail to install. LisaEm will offer you the option of deserializing both Office System installation disks and Tool disks, if you do not wish to go through this task.

On your real Lisa, enter **Service Mode** by attempting to boot off a non existent drive, such as a powered off profile, or from the floppy drive without an actual disk in the drive, then press the Apple-S key.

Next, click on the 1 in the Options menu, or press 1 on the keyboard. You'll be asked for address, enter 240. You'll be asked for count, enter 20. You'll see something similar to the display below:



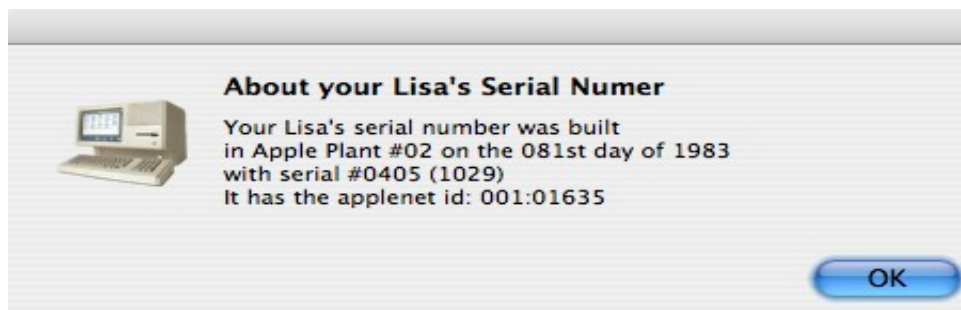
Copy the hex numbers above from the service mode hex dump display into the **Lisa Serial Number** field under the **config** tab of **Preferences**, omitting every alternate zero starting with the first one. This is your Lisa's serial number. Please double check this number as your Lisa Office Software will not work if it doesn't match.



For example, the leading 0f0f 0002 becomes ff02 in the serial number, the next two numbers 0803 0008 becomes 8308, 0100 0400 becomes 1040, 0500 0f0f becomes 50ff, and so on.

In the above example, the actual Serial Number for this Lisa is 0405, and this is be used to serialize LOS installation diskettes as well as the Office System Tools (i.e. LisaWrite.)

The other numbers contain information about when the Lisa was built, the AppleNet ID number, and various checksums and sync bytes. Pressing the **info** button will reveal the details stored in the serial number:



See David T. Craig's *Lisa Tool Deserialization* papers for further details.

The I/O ROM version:

The Lisa emulator does not actually use the I/O ROM itself, all it needs is the ROM version to report it to the running operating system.

The I/O ROM version most commonly used in the Lisa 2/5 is A8. Version 88 is for the Lisa 2/10. The emulator does not support Widget drives, so you should stick to A8. Versions 88, 89, A9 are meant to be used with Xenix to fool it into using the right sized drive. Version 40 is used for the Lisa 1, however the emulator does not emulate enough of a Lisa 1 to be useful yet.

The Keyboard Language:

The Lisa automatically detects the type of keyboard attached and switches its language based on this selection. The emulator provides this as an option for US English, British English, French or German. Other languages may have existed, if you happen to know the keyboard IDs for them, please contact me and I'll add them to the emulator. The emulator itself has not been internationalized. If you wish to help in this task, please contact me.

The Extra options:

Sound Effects: Enables playback of sound effects such as the power switch clicks, floppy insertion, eject, motor, and the power off click.

Skins: Enables or disables the Lisa skin. This provides for animations of power on, power off, floppies being inserted or ejected at the cost of a larger memory footprint. It is intended for machines with lots of memory and large displays. Same as the item in the **Display** menu.

Boot ROM speedup hacks: this option enables patches (also known as cheats in the emulator world) that speed up the Boot ROM. Specifically they disable the long memory tests, checksums and other tests to provide a quicker startup. If you have the Dual Parallel port ROM, this option will skip the lengthy Power On Self test for this card. This is not applicable when running in **ROMless** mode.

The PRAM:

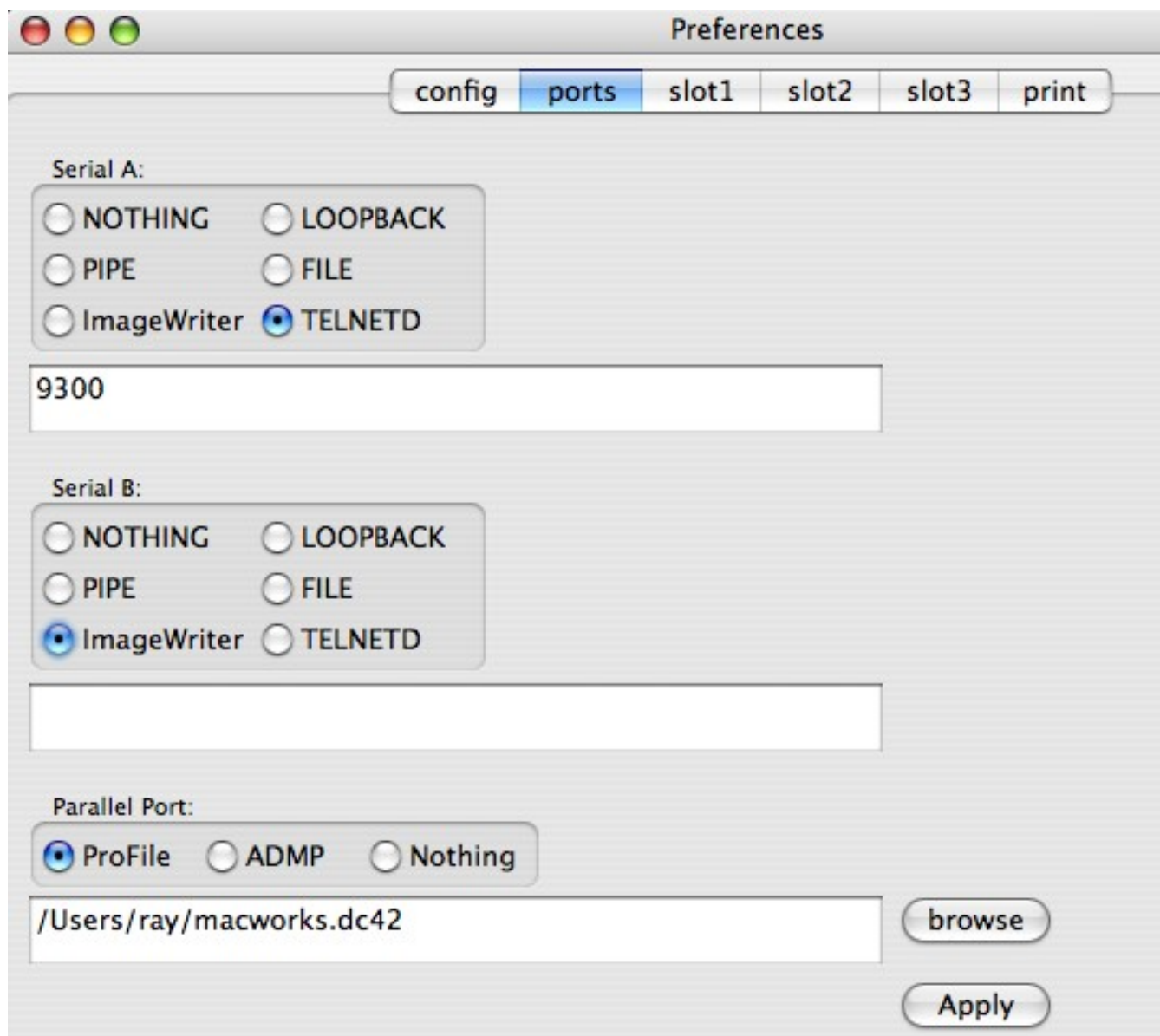
The Parameter RAM is a battery backed up configuration memory on a real Lisa. this is stored in the LisaEm Preferences. Sometimes it is necessary to Zap the PRAM to fix a problem. These options let you save, load, or Zap the PRAM. These options should be used as a last resort (except the **Save** which you should do often as a form of backup.)

Save: Saves the PRAM to a file. Do this often to keep backups of the PRAM.

Load: Loads the PRAM settings from a previously saved file, erasing the current settings, and replacing them with those stored in a backup.

Zap: Zeroes out the PRAM allow the Lisa Boot ROM and whatever Operating System is installed on the Lisa to restore it from its own configuration, or to the defaults.

The ports tab:



The image shows a Mac OS X Preferences window titled "Preferences". At the top, there is a tab bar with six tabs: "config", "ports", "slot1", "slot2", "slot3", and "print". The "ports" tab is currently selected and highlighted in blue.

Under the "ports" tab, there are three main sections:

- Serial A:** This section contains a group box with six radio button options: "NOTHING", "LOOPBACK", "PIPE", "FILE", "ImageWriter", and "TELNETD". The "TELNETD" option is selected. Below this group box is a text field containing the number "9300".
- Serial B:** This section contains a similar group box with the same six radio button options. The "ImageWriter" option is selected. Below this group box is an empty text field.
- Parallel Port:** This section contains a group box with three radio button options: "ProFile", "ADMP", and "Nothing". The "ProFile" option is selected. Below this group box is a text field containing the path "/Users/ray/macworks.dc42". To the right of this text field are two buttons: "browse" and "Apply".

Serial Ports:

The ports tab allows you to configure LisaEm's connections. At the top are serial ports A, and B. These can be connected to nothing, a loopback plug, an OS pipe, a file, an ImageWriter printer, or on some systems (linux, or OS X) can run a telnet daemon.

The loopback plug connects both serial ports together. If you select this plug on either port, both will be connected.

For file, the file will be connected to either an actual file, which will be read, or to a device, such as /dev/ttya.

Pipe is used to run an external program using the unix popen() call.

If you select the telnetd, provide a port number to listen to. For example 9300. The Lisa emulator will then listen on 127.0.0.1:9300. You can then telnet to this port from another terminal window on the same machine and communicate with LisaTerm or ZTerm for example.

Note: misconfigured Pipe, Telnet, and File modes may cause LisaEm to crash!

The Imagewriter option allows you to connect a printer to one of the serial ports, using the settings from the printer tab.

The Parallel Port:

The Parallel Port is mainly used to attach a ProFile hard drive. It can also be used to attach an ADMP printer, however, it is preferable to attach an ImageWriter to a serial port if you do not have a dual parallel card ROM, otherwise to one of the ports on the dual parallel card.

You should select the Profile option, then click on the **browse** button to save the location for a profile drive, or to select an existing profile drive image.

The first time you power on the emulator you will be asked for the size of the profile drive to create. A 10M image is optimal.

Notes:

The Profile hard drive format used by LisaEm is the same format as the **Disk Copy 4.2**, but with an interleave of 5 to match what Lisa Office System uses. You will not be able to do anything with the virtual ProFile disk images in the actual Disk Copy program. These are only useful to LisaEm and the LisaFSH-Tool.

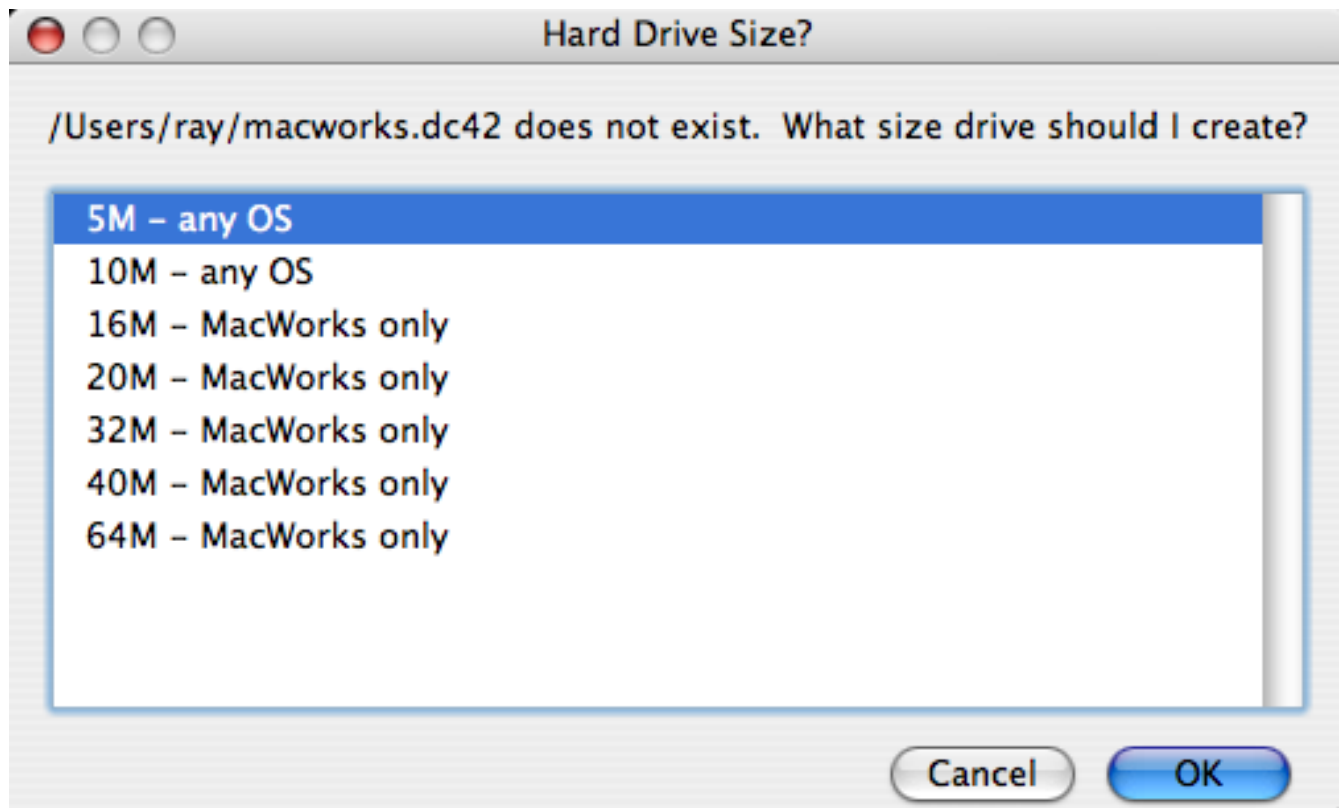
I reused the floppy drive code because it was a convenient storage format for disk images and it can also be used with lisafsh-tool.

Profile hard drive creation:

The first time you power on the emulator, if a specified virtual profile disk image file does not exist, you will be asked what size drive to create. Note that only the 5MB and 10MB Profiles will work with the Lisa Office System.

If you use any other size, only the first 5MB will be used, wasting the rest of the space.

Xenix, which is even more finicky, only supports 5MB and 10MB Profiles, but decides on their size based on the I/O ROM version! (Xenix doesn't currently run in LisaEm.)



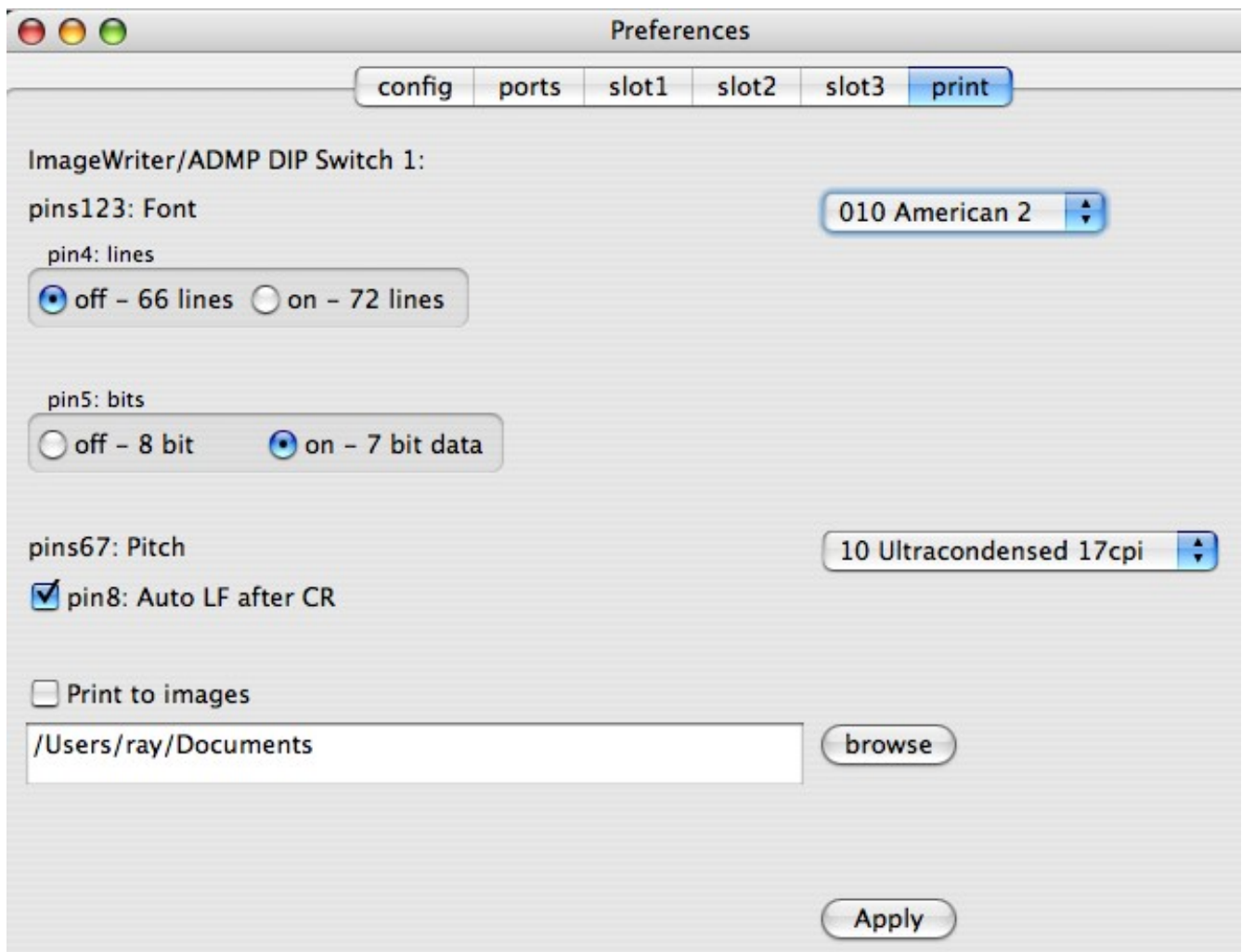
The newly created drive will not be bootable as no Lisa Operating System has been installed on it yet. Should you attempt to boot from it, the Lisa ROM will throw error #84, or #85:



You will need to install a Lisa compatible operating system such as Lisa Office System 3.1 on the newly created virtual Profile drive before you'll be able to boot from it.

The print tab:

The **print** tab in the Preferences dialog box allows you to set the ImageWriter/ADMP's DIP switches. The defaults for the Lisa are automatically selected:



The Print to Images check box allows you to redirect printouts to image files. Depending on how wxWidgets or the availability of image libraries in your operating system these may be saved as PNG's, TIF's or BMP's. The text field allows you to chose a directory to save the printouts in. The **browse button** will allow you to select this directory. If the check box isn't selected, printouts will go to the host OS's printing system.

Printing is page oriented, so it is difficult for the emulator to tell apart one print job from another.

This may cause several printed documents to be batched together. For most systems this will be just fine, however if you are printing to a file on your host OS such as PostScript or PDF, you may have issues.

Because of this, there is a **Flush Printer jobs** menu item under the File menu. Use this option between print jobs to separate them.

Running the emulator for the first time

Once you have properly configured the emulator's preferences, you should press the **Apply** button to save your preferences. The Preferences dialog box will then be dismissed. If you forget this step, or wish to discard the changes you've just made, and close the Preferences window using the X button, you will lose your changes.

When you are ready, you can power on the virtual Lisa. There are several ways to do this.

You can use the **File** menu's **Run** command, or the **key** menu's **Power** command.

If you are running with the skins enabled, you can actually press the **power button** located underneath the floppy drive. If your display isn't large enough, you will have to scroll down and to the right of the Lisa photo to see it.

The Lisa will then power on, and if your ROM file is good, it will go through the self tests. If the ROM file is bad, it may cause the emulator to crash. If you're running **ROMless** you'll be asked what device to boot from.

You may see a hard drive error 84 or 85 since you are running with a blank profile hard drive. This is normal. If you get this error, boot from a valid Lisa Installation floppy.

Inserting a micro-diskette:

In Lisa speak, 3.5" 400K SS/DS floppies were called 'micro-diskettes'. The emulator uses virtual disk images of these, preferably in the Disk Copy 4.2 format.

If you wish to install the Lisa Office System, you should now insert the disk called "*Lisa Office System 1/5*" into the virtual floppy drive. You can do this using the File menu's Insert diskette command. Continue following the instructions in the Installing Lisa Office System chapter.

If you are running with skins, you can simply click on the floppy drive.

A file picker dialog box will appear allowing you to browse to the Disk Copy 4.2 or DART image file.

Note that DART images will take longer to open. This is because they will be converted to Disk Copy 4.2 format since that is the emulator's preferred disk image format. Consequently you shouldn't place disk images on read only media such as CDROM's DVD-ROM's or file servers where you only have remote access.

DART image support is experimental and might not always work. It has worked with the disk images we have tried, both the fast RLE and the higher LZH compressed versions, but there are no guarantees that it will work with every image.

Always use Disk Copy 4.2 to image Lisa diskettes. Using newer versions of Disk Copy will result in non-functional disk images as vital data called tags will be stripped off!

see: http://lisafaq.sunder.net/lisafaq-hw-media-floppy_dc42.html

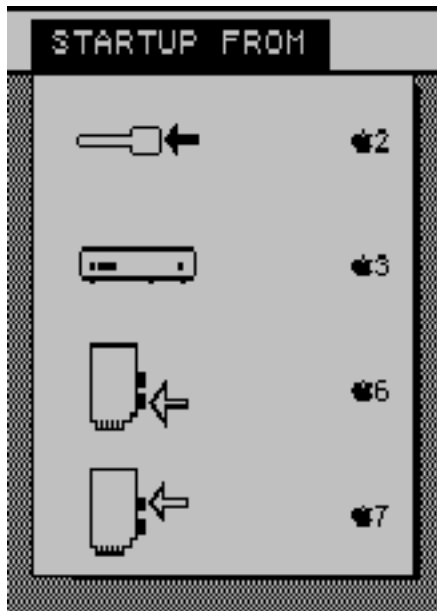
Tags were not used very often by Macintosh software so their use is deprecated, however the Lisa requires them in order to know that floppies are bootable.

Lisa Office System uses tags to allow repairs to be made using a program called the scavenger. You can invoke this by booting from the Lisa Office System 1 Installer disk, or by using the Repair command under the Housekeeping menu of Lisa Office System.

Installing the Lisa Office System

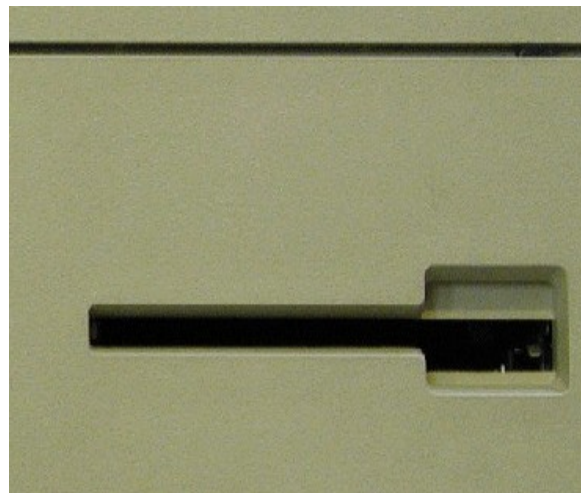
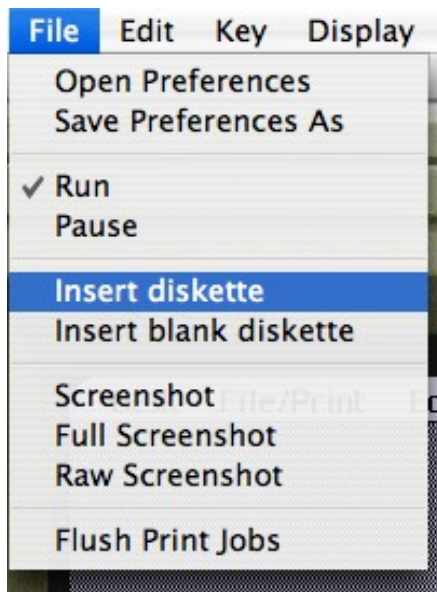
Installing the Lisa Office System:

Once the Lisa self tests are done, you'll see the boot menu:

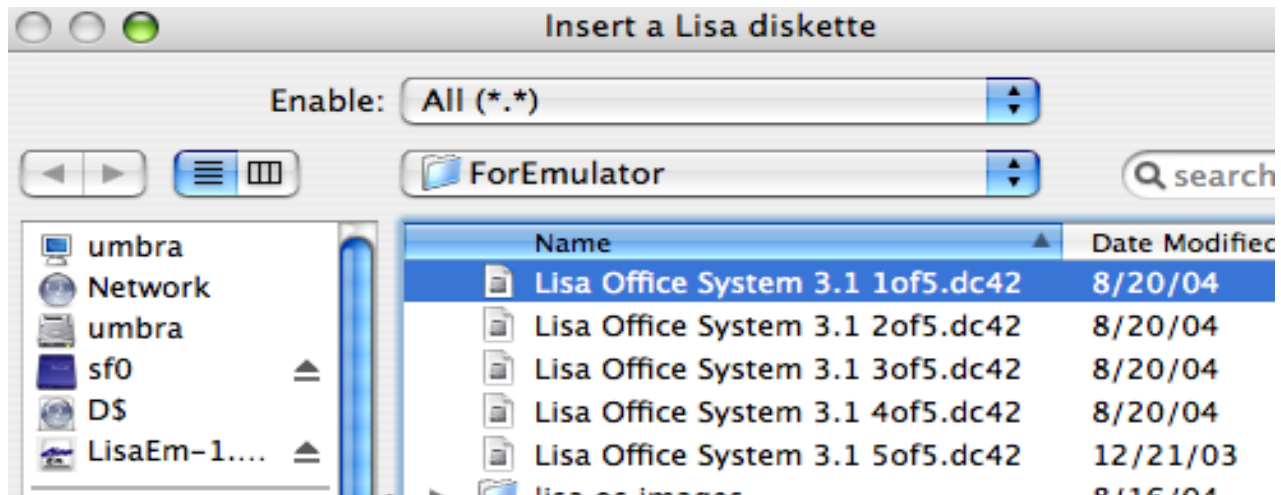


(If you're running **ROMless**, you'll see the **ROMless Boot** dialog instead. Pick the **Floppy Diskette** option, and you'll be prompted for a Floppy Disk Image to boot from.)

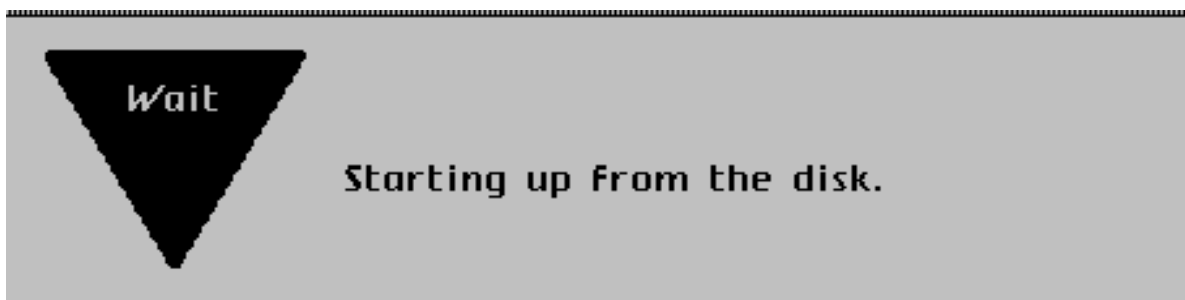
Insert the microdiskette labeled Lisa Office System 1, by using the **File** menu item named **Insert Diskette**. Alternatively, if you have **skins** enabled, click on the picture of the floppy drive.



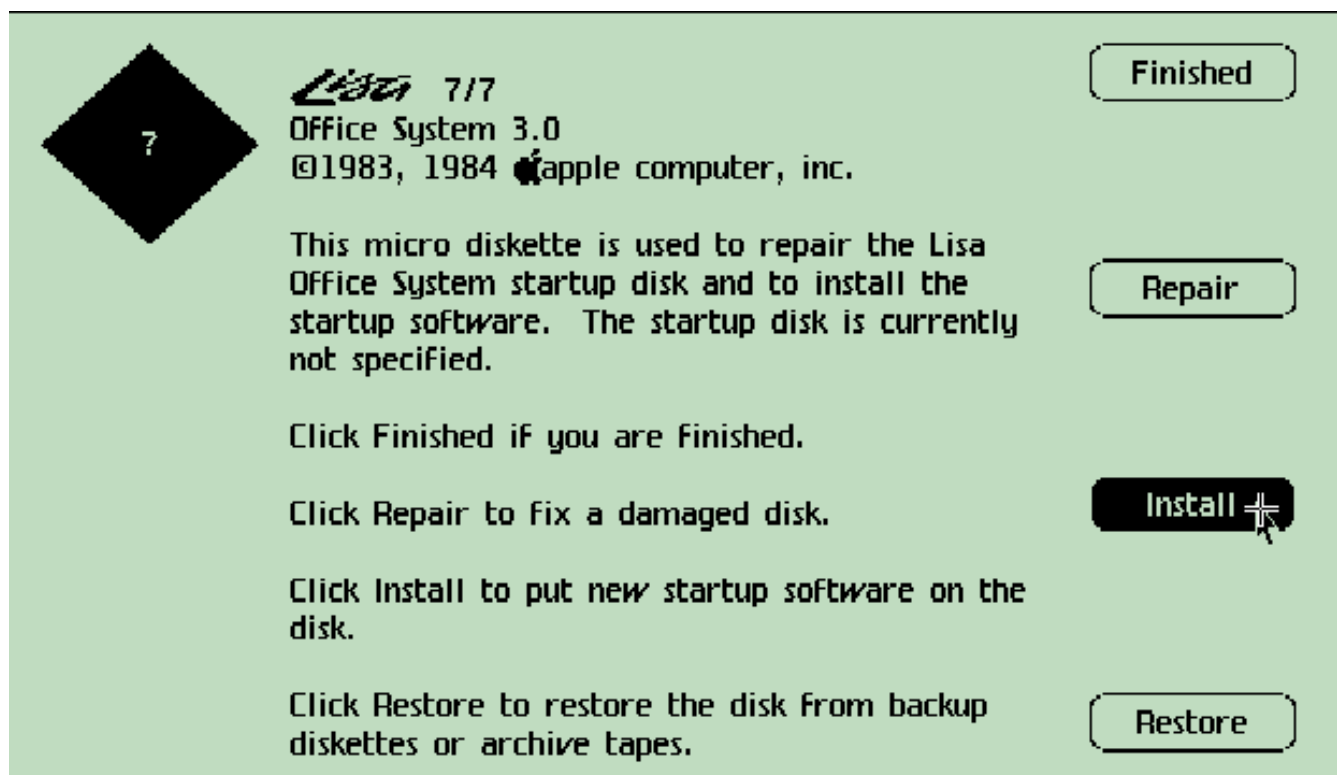
You may need to pull down the **Enable** menu to select **All**, **Disk Copy 4.2**, or **DART** depending on the type and name of the disk images you have. On some host OS's, such as Linux with GTK and some versions of OS X, you may have to click on a triangle button to get the dialog box to fully open.



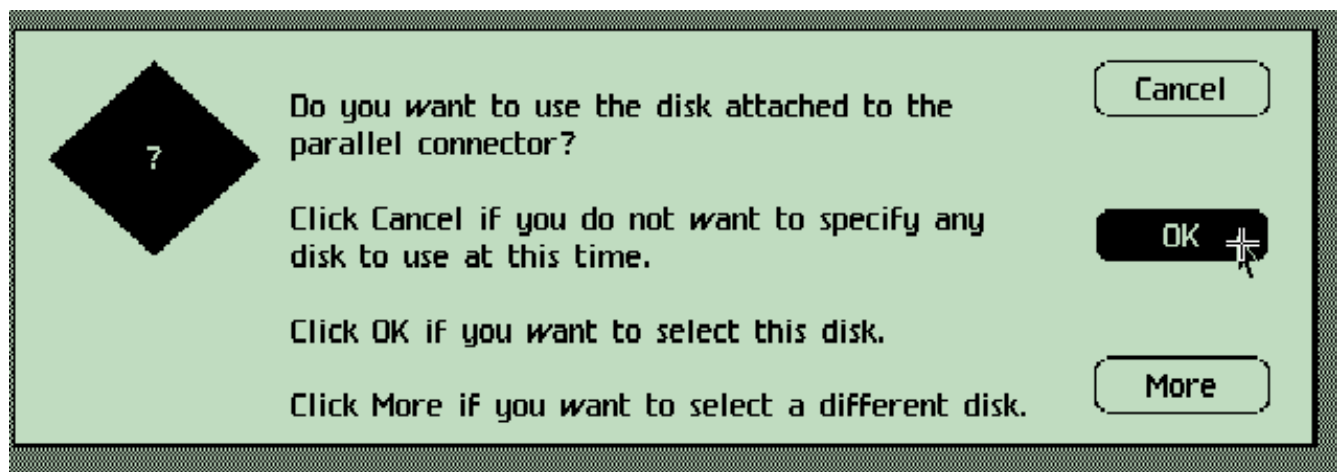
Select the Lisa Office System 1 of 5 disk image from the file picker dialog box.



The LOS installation disk will now boot. In a few seconds you'll see the LOS splash screen.

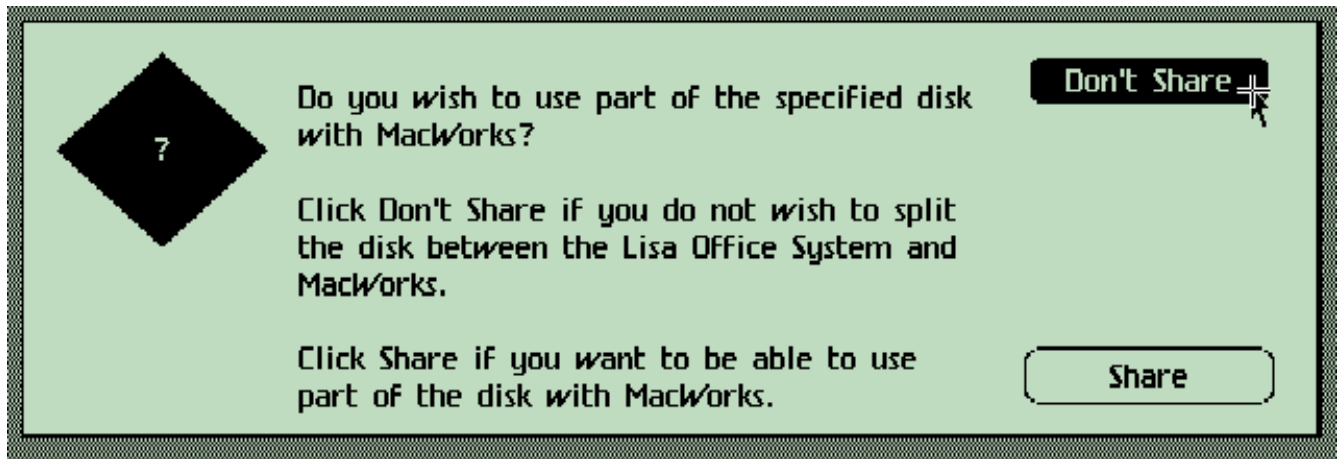


Once the Lisa Office System installer has loaded, you'll see the installation menu as depicted above. Press the **Install** button at this screen to start the installation process.



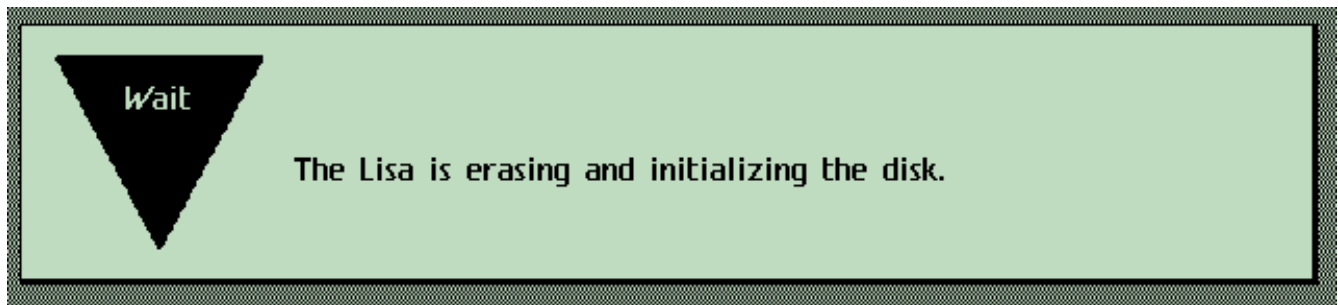
The Installer will now search for a ProFile hard drive to install The Lisa Office System onto. Ideally this should be the profile attached to the parallel port.

Press the **OK** button to allow the installer to use this Profile.

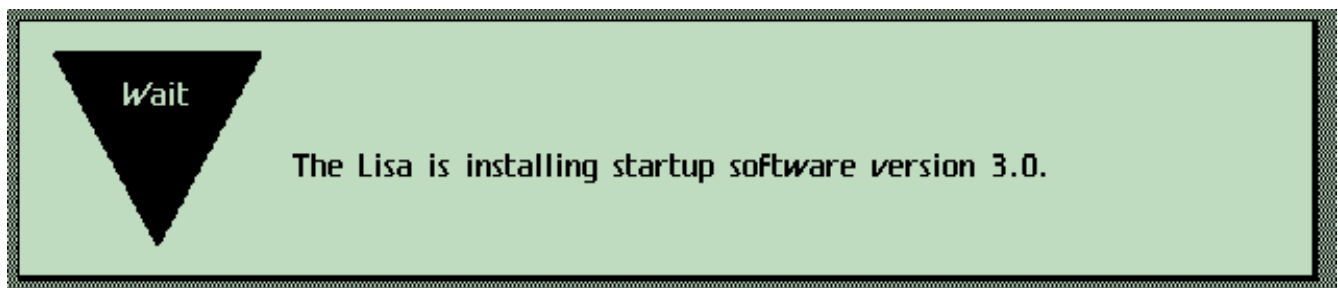


Click on the **Don't Share** button. If you would like to also use MacWorks, or another environment, you should create another Preferences file with its own profile drive instead.

Sharing the drive results in limited space, which will cause space issues on a 5MB profile, preventing Lisa Office System from functioning when all of the tools are installed.



The installer will now erase the profile. If you had used a Profile disk image which had previous data, you would be asked to confirm if you are sure that you wish to erase the disk.

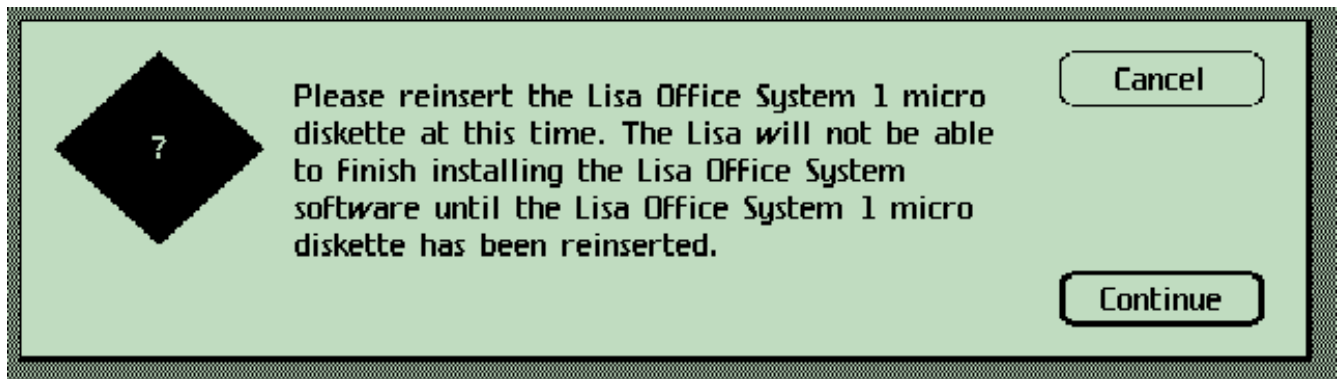


After a few minutes, the Lisa Installer will begin to copy itself to the ProFile hard drive.

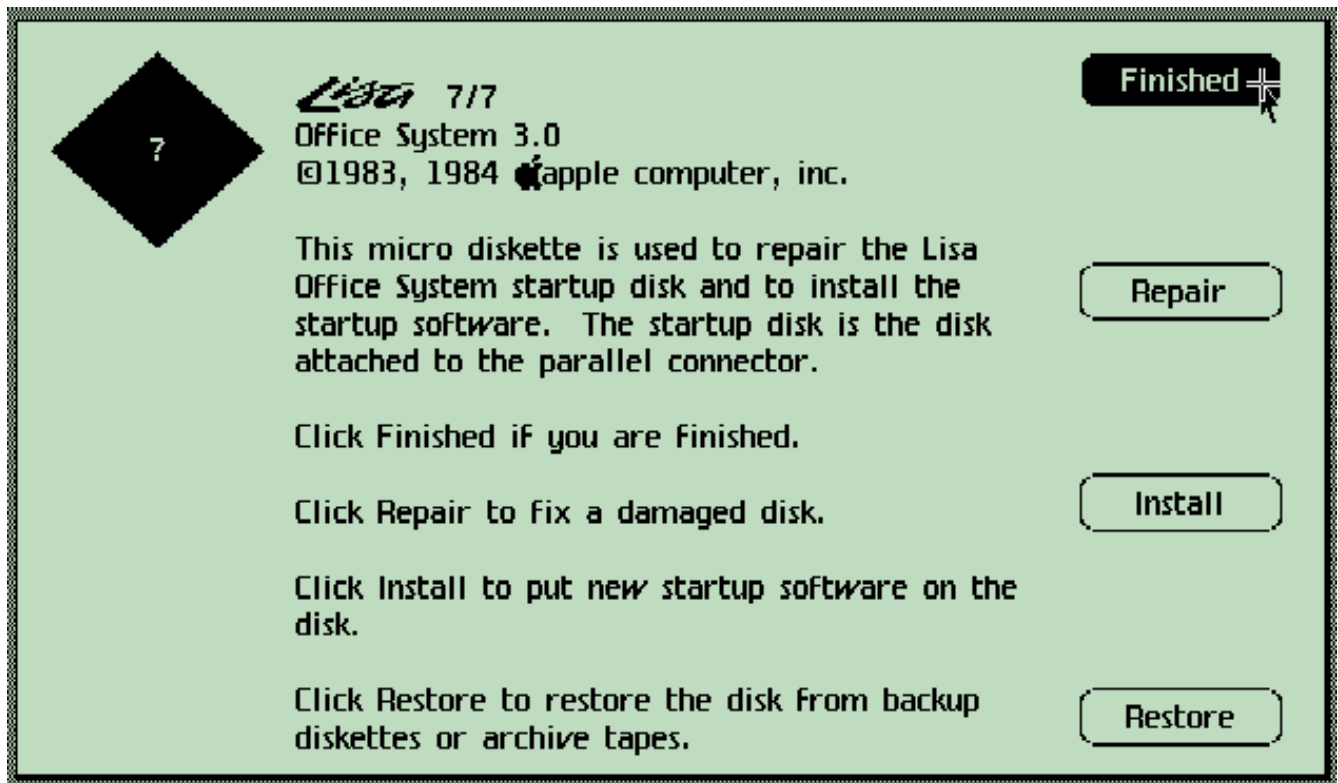


Once the disk is copied, the installer will then eject Lisa Office System 1/5 and ask for the next disk, disk 2. You do not have to press the **Continue** button as the installer will recognize that a floppy has been inserted and will be able to tell if it is the disk it wanted.

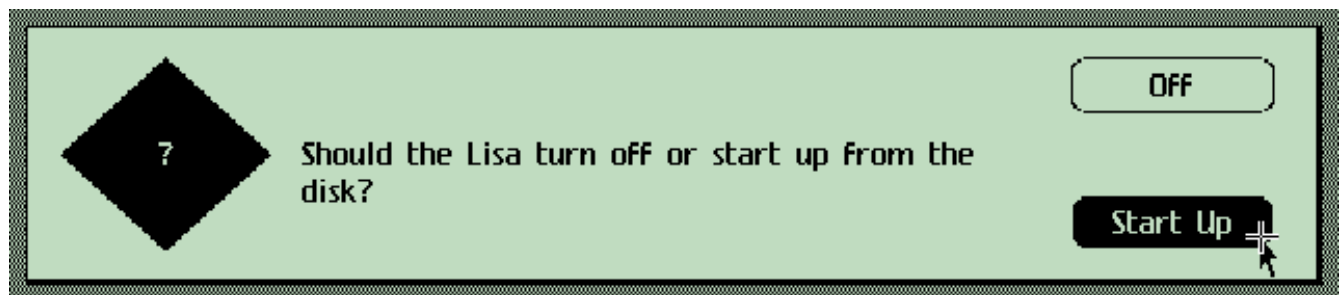
You'll repeat this process until LOS is fully installed.



At the end of the installation process, it will ask for the first disk again. You must insert the same disk image you first booted from in order to complete the install. If you are given an option to deserialize Disk 1, say **No** at this time as this may cause the installation to fail.



You'll soon be returned to the main menu. Since you're done installing, click on the **Finished** button.



Select **Start Up** in order to boot from the freshly installed Lisa Office System on the profile.



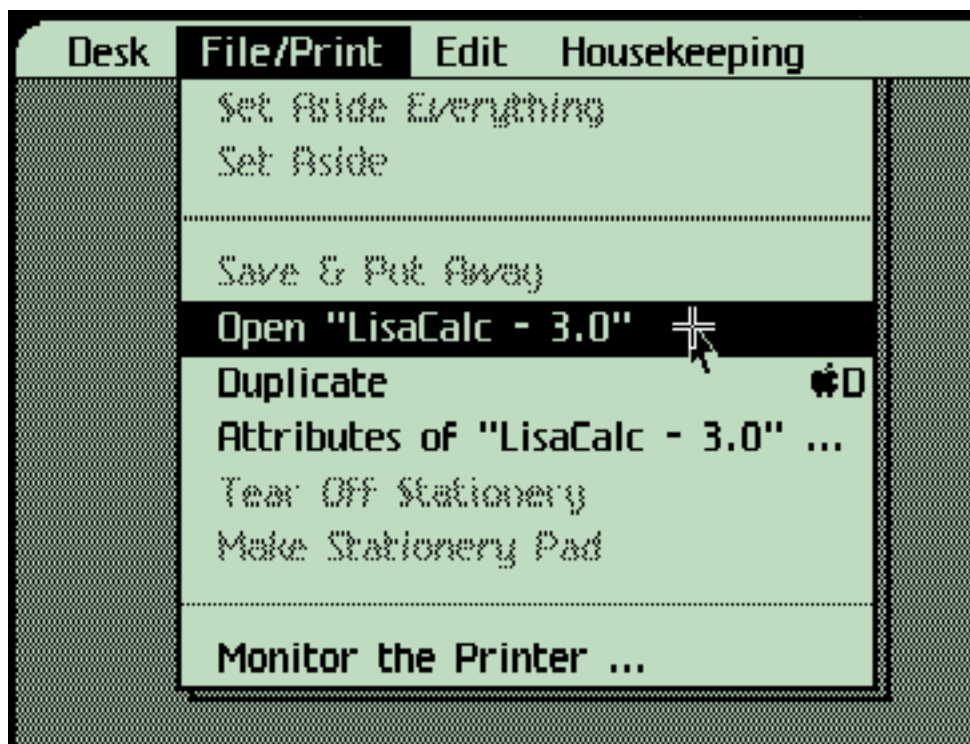
Lisa Office System has now been installed. If you are returned to the Power On boot menu, click on the Profile icon. Lisa Office System will then boot.

Instaling the Lisa Office System Applications (also known as tools):

Once you see the Office System Desktop, you'll want to install some of the applications, which in Lisa speak are known as tools.



Next, insert one of the tool (Application) diskettes such as LisaCalc. It's icon will show on the Lisa desktop.

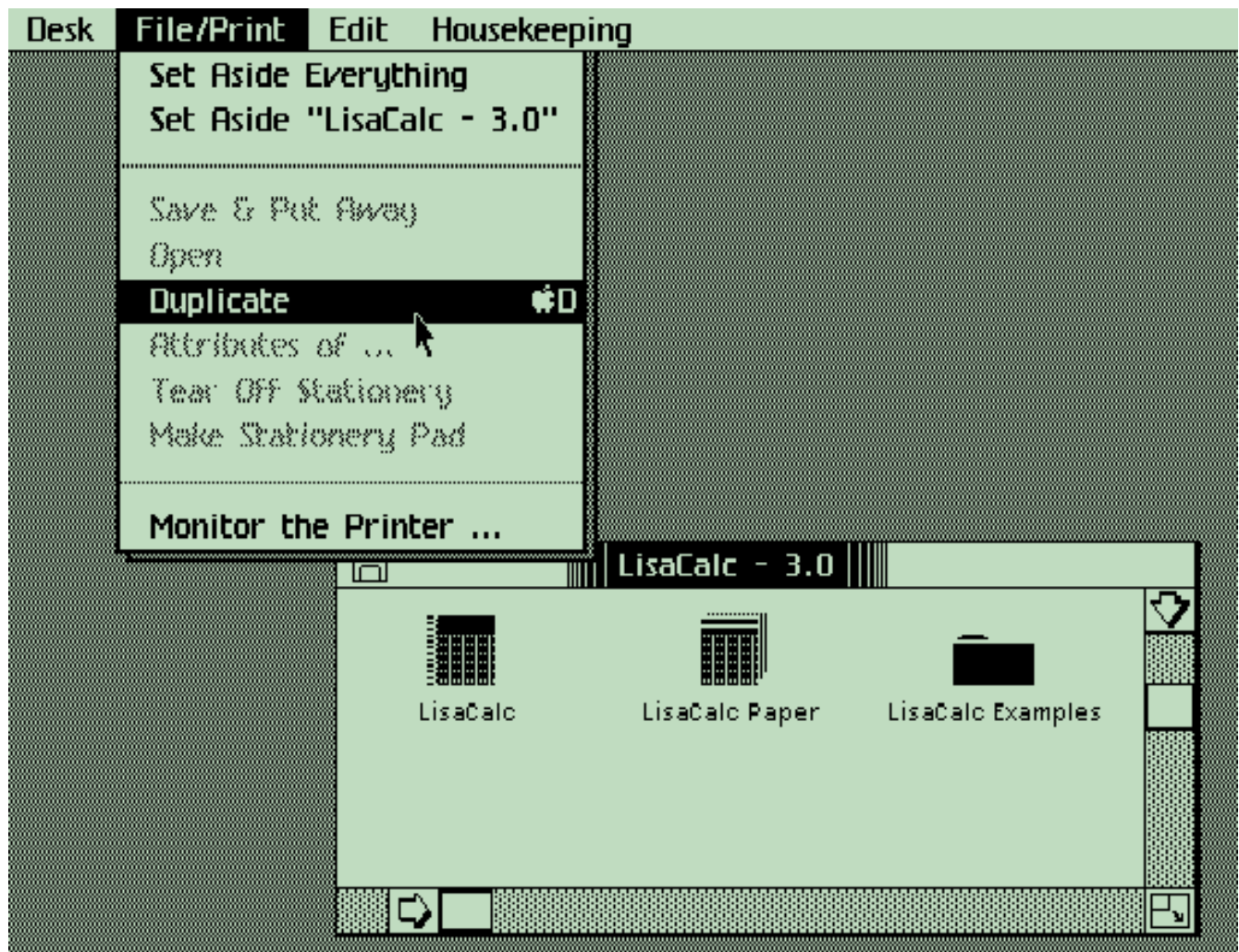


The disk will show up on the Lisa Office System desktop. Double click on it to open it, or use the **File/Print** menu **Open** option (inside the virtual Lisa)



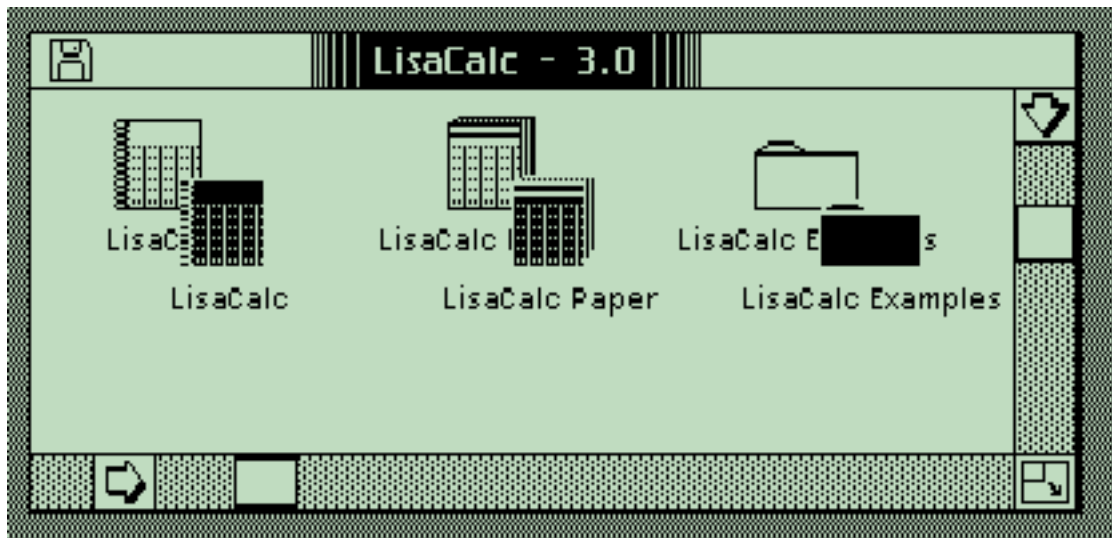
With the Lisa Calc window open, pull down the Edit menu and select the "Select all Icons" item. (Alternatively, you could use the mouse to drag a square around the icons.)

This will highlight, the icons so that you can duplicate them to the virtual hard drive.

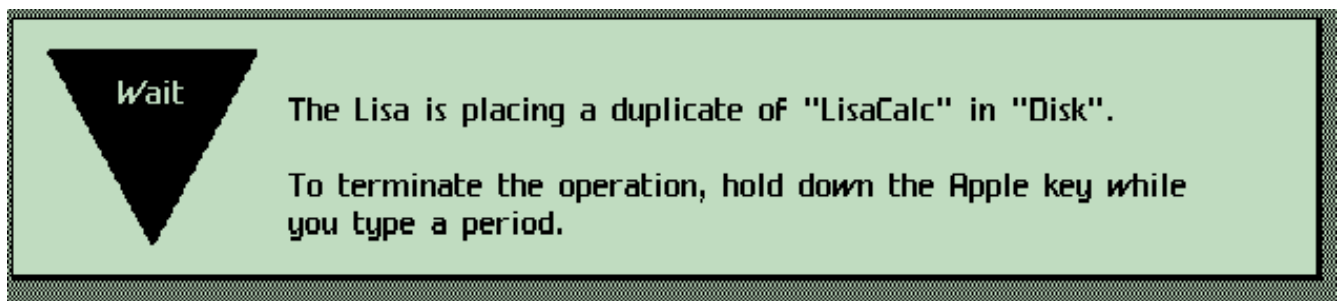


Do not drag the icons to the hard drive, as this will move them – that is erase them from the floppy once they're copied to the profile hard drive.

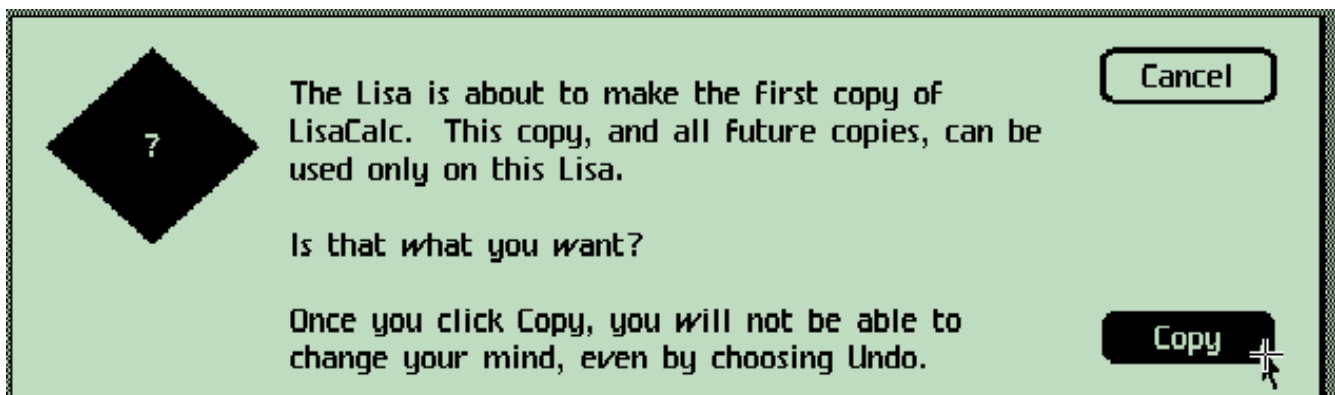
Instead, once the files are highlighted, pull down the **File/Print** menu and select the **Duplicate** item. The selected icons will form “blinking shadows” underneath them.



Drag these blinking “shadows” to the hard drive window or its icon, to start copying them.



The Lisa desktop will now copy the files.

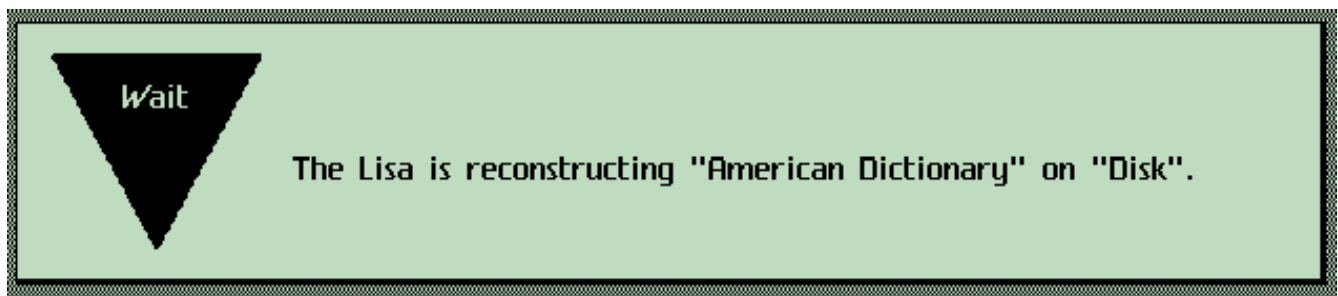


Note that Lisa tools are serialized: the first time they are used, the Lisa's serial number is written on them to prevent them from being installed on any other Lisa. You should have backup disk images made if you are using original Lisa disks before continuing.

You'll be asked if this is what you want. Press **Copy** to allow the tool to be installed. The Lisa will write its serial number to the tool and copy it to the profile hard drive. Note that next time you insert this floppy LisaEm will offer the option to deserialize the tool. :-)



Once the copy completes, you can eject the LisaCalc disk by pulling down the **Housekeeping** menu and selecting the **Eject Micro Diskette** option. Repeat the installation process with the remaining Lisa tools (applications.)



Note that LisaWrite's dictionary file is actually split across onto the second disk and lives on both disks. Don't try to copy it along with the other files, instead once LisaWrite and the examples are copied across, duplicate just the dictionary. You'll see this dialog box during the duplication.



Once the first portion of the dictionary is copied, the diskette will eject, and you'll be prompted to insert the second diskette.

Once the copy is completed, you can eject the diskette.

NOTE: Be sure to press the **power** key before quitting the emulator so that you do not corrupt the file system on the virtual profile hard drive. You can do this by using the **Power** option under the **Key** menu, or if you have skins turned on, by clicking on the power button, which is located underneath the diskette drive, next to the keyboard jack. (Scroll the display downwards and to the right if your host machine's monitor cannot show the entire skin.)

Congratulations, you've successfully installed the Lisa Office System and Tools!

You can now party, like it's 1983. :-)

Installing the MacWorks XL Environment

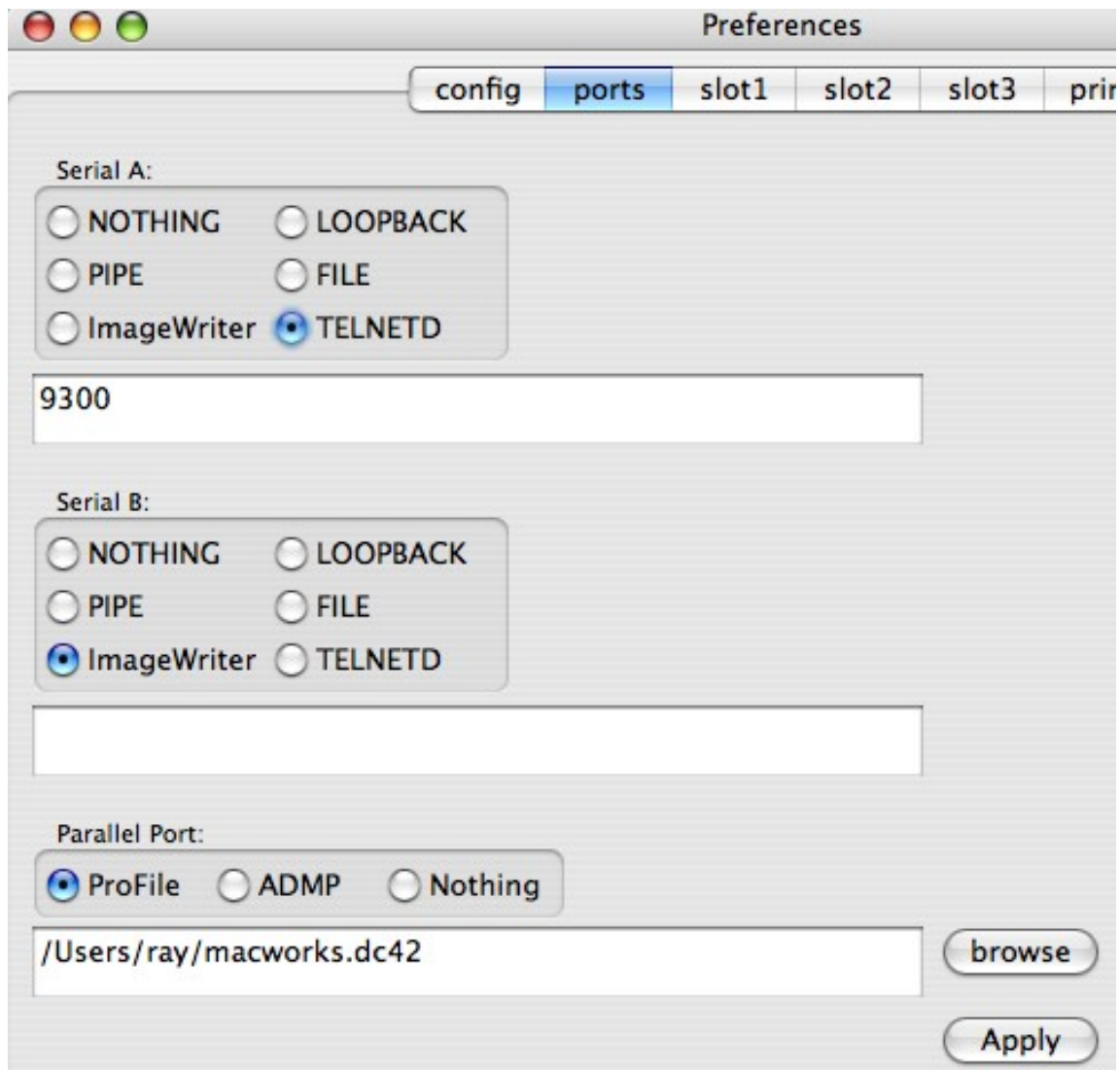
NOTE: The current version of LisaEm has bugs preventing the use of MacWorks! Presently, the 2007.01.28 Preview version of LisaEm is the only one that works with MacWorks!

MacWorks, MacWorks XL, MacWorks Plus aren't real emulators, but rather they are closer to a virtualization program that allow the Lisa to run early Mac OS software.

MacWorks consists of two diskettes. A boot diskette containing MacWorks itself named **MacWorks Boot**, and a copy of the Macintosh System named **MacWorks System**.

The first thing to do if you've already installed the Lisa Office System is to save your preferences with a new name. If you've already configured the Preferences for Lisa Office System, Save the current settings as "Lisa Office System.lisaem" so that you can return back to Lisa Office System later.

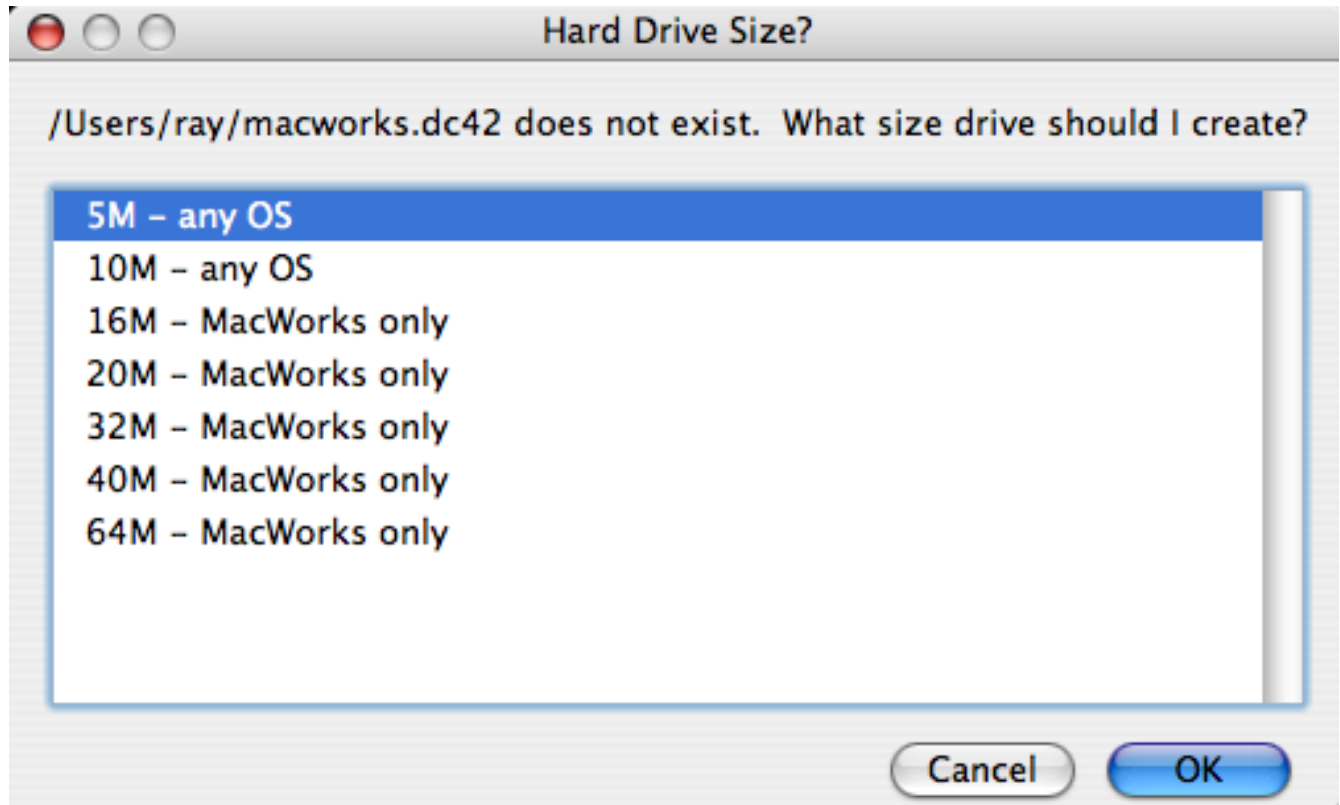
Next, save the preferences once more as "MacWorks.lisaem"



Then go back to the Preferences dialog box, click on the ports tab and change the profile drive file name. Once the name is changed, press **Apply**. You're now ready to install MacWorks.

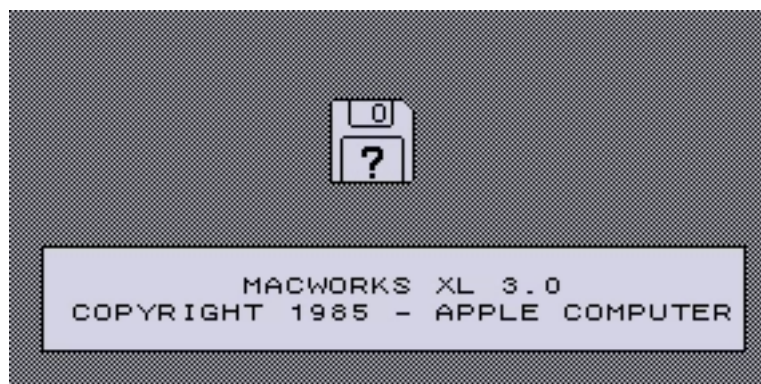
MacWorks is best viewed in the "Raw" display mode, since it will provide the square pixels needed by MacWorks. If you would like to experience the non-square pixels that the Lisa had without the screen modification kit, leave the Display setting to AntiAliased.

Once you power on the virtual Lisa, you will be prompted for the size of the profile drive you wish to create since this is a new drive. With MacWorks, you can chose any of the sizes presented.

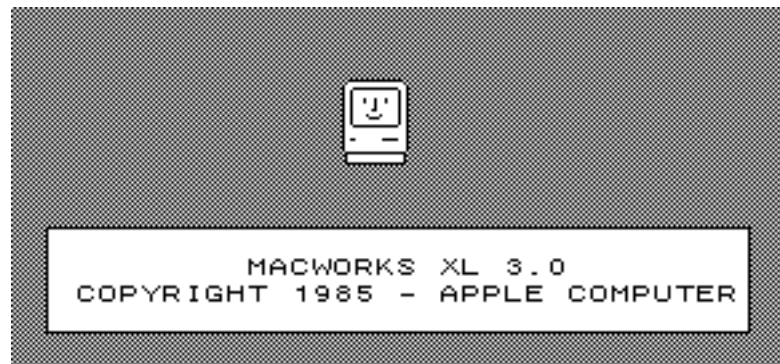


Once the Power On Self Test completes, you may see an error 84 because it is still a blank hard drive. Insert the disk image named "MacWorks XL" and boot from the Floppy drive.

In a few seconds, the display will clear, the floppy will be ejected and you'll see this:



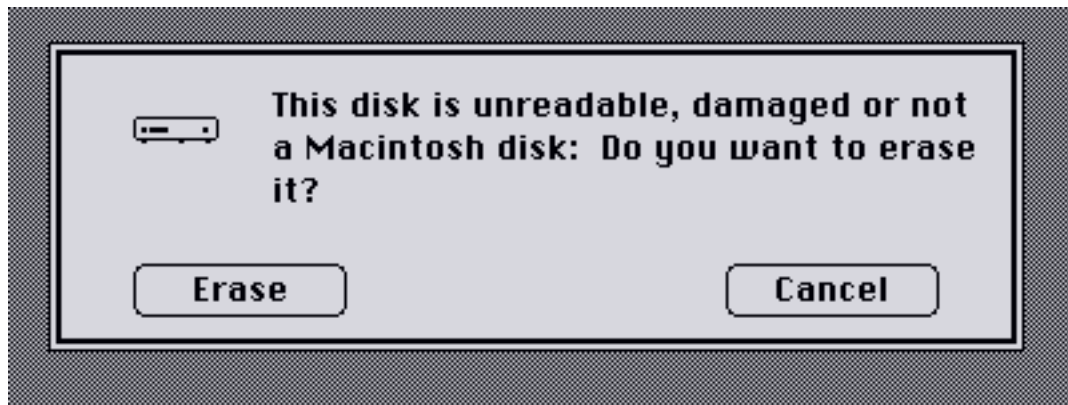
Insert the diskette image named "MacWorks System." This contains the Macintosh operating system.



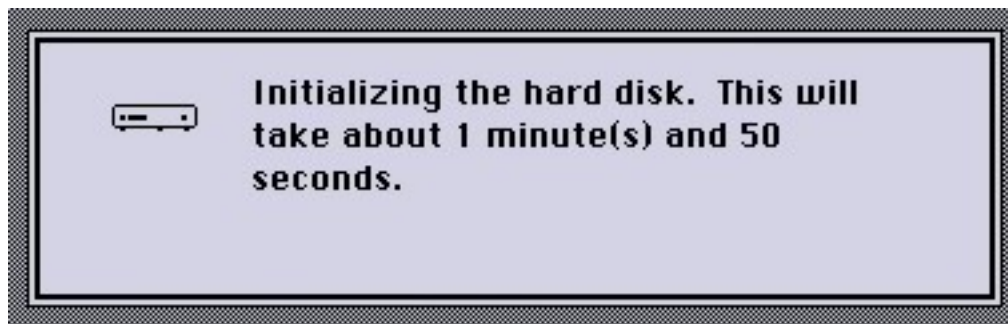
You'll see the usual Happy Mac icon, followed by the MacWorks splash screen



Once it boots up, open up the MacWorks System Disk and run the application titled Hard Disk Install. Either double click on the icon, or use the **File** menu's **Open** item to launch it.



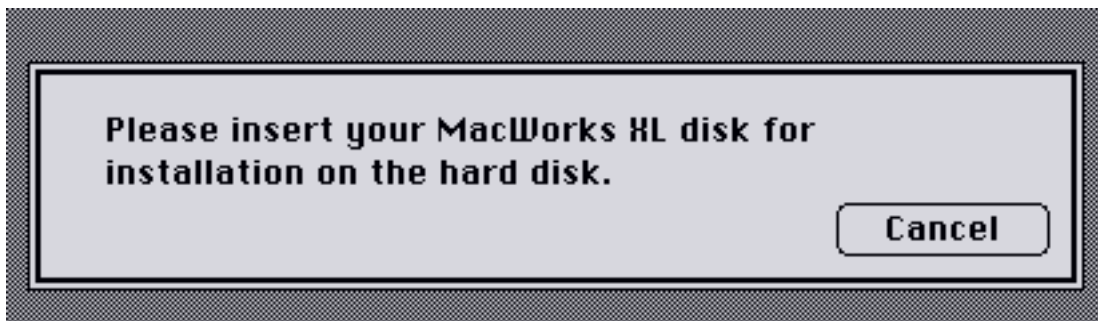
Since this is a fresh hard drive, HD Install will say its not readable. Click on the Erase button. If you have Lisa Office System or Pascal Workshop installed, you'll be asked if you'd like to share this disk instead.



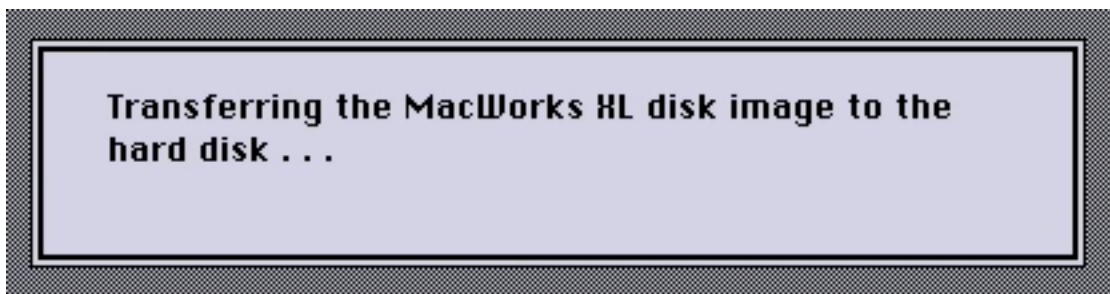
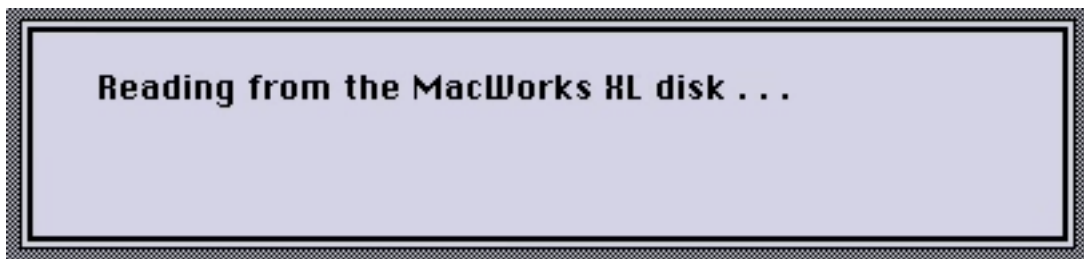
HD Install is now formatting the virtual Profile hard drive for MacWorks, by erasing all the sectors on it, and installing the MFS file system.



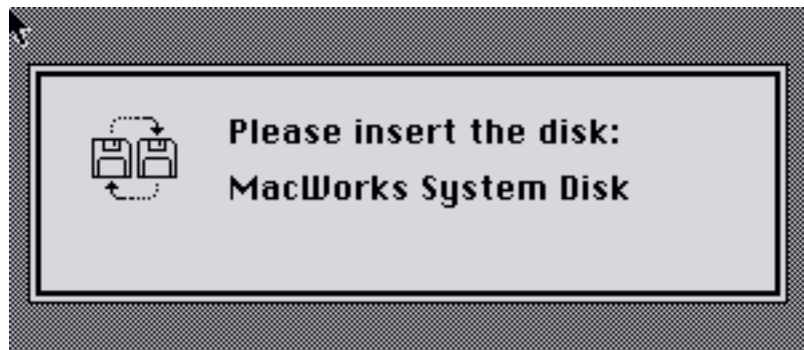
When it is done erasing the disk, it will display the above dialog box. Press Ok to continue.



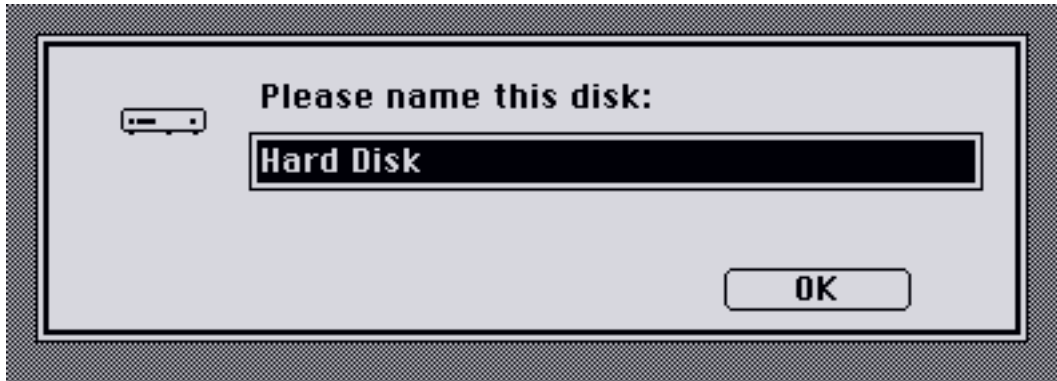
Next, Insert the MacWorks XL diskette when prompted.



HD Install is now copying the MacWorks software to your profile hard drive.



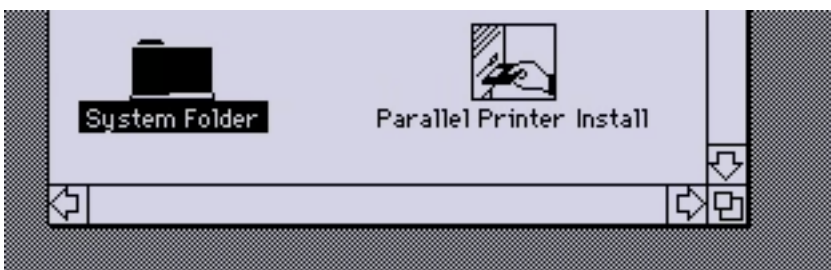
After the copy completes, the MacWorks XL disk will be ejected, and you'll then be prompted to re-insert the System diskette.



Next, name your profile hard drive. This is the name that will show up on the Desktop.



IMPORTANT: The install is complete, but you must copy the system folder to the hard drive, otherwise attempting to boot from it will cause a Sad Mac error, from which you'll not be able to recover except by throwing away the Profile hard drive image and starting over!



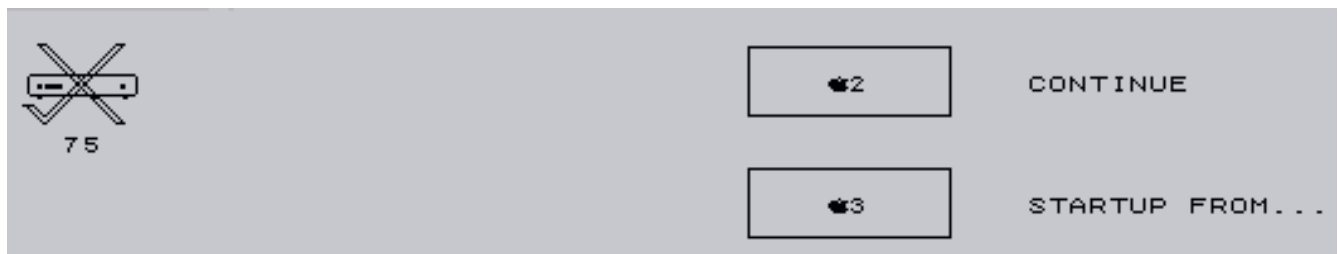
Use the mouse to drag System folder icon to the Profile hard drive. This will copy the System Folder to the hard drive, preventing the Sad Mac error!



The Finder is now copying the System Folder to the Profile hard drive.

Once it's done copying, you can use the **Special** menu item **Shutdown** to power off your virtual Lisa.

Whenever you want to boot up MacWorks, you'll still need to first boot from the MacWorks XL boot floppy, however, once loaded it will see that the ProFile has MacWorks installed and it will boot Mac OS from it from that point.



If you attempt to boot from the Profile directly, you'll get error #75.

Congratulations, MacWorks is now installed.

Managing Multiple LisaEm Preferences files

Managing multiple preferences files

The emulator allows you to manage multiple preferences files, each one representing a separate virtual Lisa. You can have a Lisa with the Lisa Office System, another with MacWorks, another with the Lisa Pascal Workshop and so on.

You should save the current preferences with a descriptive name indicating what was installed on the Lisa. i.e. "Lisa Office System.lisaem", "Lisa Pascal Workshop.lisaem", or "MacWorks XL 3.0.lisaem"

Then, when, you are ready to create a new virtual Lisa, save the preferences with a new name indicating the new configuration, and then change that configuration using the Preferences menu item.

Click Apply in the Preferences window to save your settings. You may then start installing the new environment

When you wish to switch configurations, use the **File** menu **Open Preferences** item to load a new preferences file. The settings will take effect when you power on the virtual Lisa.

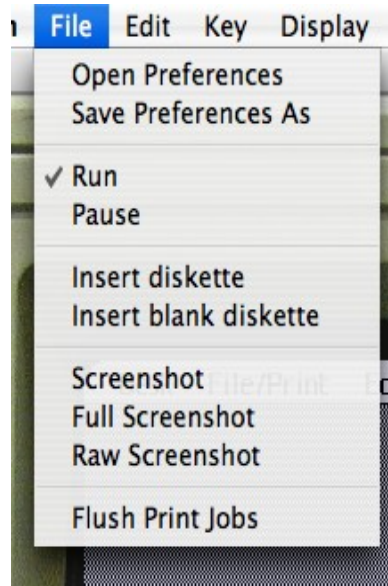
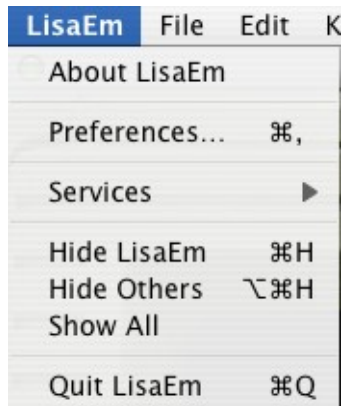
If you are switching between preference files, you should only do so while the virtual Lisa is powered off.

In future versions, you will be able to double click on the preferences file to automatically load them at start up. (If you're running on Linux, or windows you can pass the preferences file name on the command line to LisaEm when launching, and it will open them for you.)

The idea here is that you can store the LisaEm preferences in either a folder, or on your desktop, then double click on whichever virtual Lisa you wish to work with.

The LisaEm Menus

The File Menu:



Open Preferences: Loads a preferences file

Save Preferences As: Saves the current preferences to a new file.

Preferences: Brings up the Preferences dialog. (Under LisaEm menu on OS X)

Run: Equivalent to the **Key** menu **Power** item. Used to turn the virtual Lisa on or off.

Pause: Pauses emulation

Insert diskette: Inserts a DiskCopy 4.2 or DART image into the Lisa's floppy drive. DART images are converted to dc4.2. The media that the images reside on must be writeable!

Insert blank diskette: Creates a blank Disk Copy 4.2 image, and then inserts it into the Lisa.

Screenshot: Save a screenshot of the display. Only the screen is saved. You'll get exactly what the screen shows.

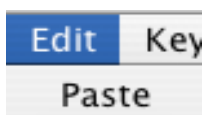
Full Screenshot: Same as screenshot, but will also include skins if they are turned on.

Raw Screenshot: saves a screenshot, without aspect ratio correction, anti aliasing or gray replacement.

Flush Print Jobs: Closes the current print job. Useful when printing to PDF files.

Quit LisaEm: Exits the emulator (even if it's running! Power off before using!) On OS X, this item is under the **LisaEm** menu, on other host systems, it's under the **File** menu.

The Edit Menu:



Paste: Paste the clipboard text into the emulator's keyboard.

The Key Menu:

Key	Display	Throttle	V
	Power Button		
	Apple+Power Button		
	Apple .		
	Apple S		
	Apple Enter		
	Apple Right Enter		
	Apple 1		
	Apple 2		
	Apple 3		
	Option 0		
	Option 4		
	Option 7		
	NMI Key		
	Reset Button		
✓	ASCII Keyboard		
	Raw Keyboard		
	Raw Buffered Keyboard		

Power Button: Pushes the power key. Equivalent to the **File** Menu **Run** command, or clicking on the skin's power button.

Apple + Power Button: Pushes the power key while the Apple key is down. This is useful while Lisa Office System is running as it will allow you to enter the **Environments** window so that you can reboot your Lisa without powering it off.

Apple {key}: Sends the Apple-key combination.

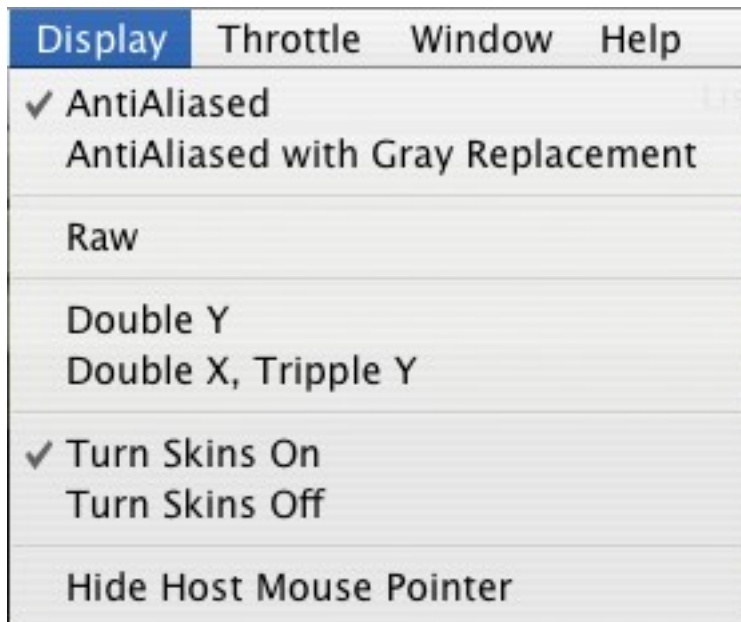
NMI Key: Sends a Non Maskable Interrupt key. This is used to enter LisaBug.

ASCII Keyboard: Does keystroke translation in ASCII between the host and the Lisa. Use this for normal operations.

Raw Keyboard: Directly maps keystrokes from the host computer to the Lisa.

Raw Buffered Keyboard: same as above, but, buffer keystrokes to prevent unwanted repeats when the CPU throttle is set to higher than 5MHz.

The Display Menu:



Anti Aliased: This is the normal mode you should use with the Lisa Office System. This corrects the square pixel issues and uses anti-aliasing to fix most artifacts.

Anti Aliased with Gray Replacement: As above, but attempts to replace the 50% desktop gray patterns with an actual gray color. The side effect is that some text will become fuzzy.

Raw: Uncorrected square pixel display. Will show an incorrect aspect ratio. This is the right mode to use with MacWorks.

Double Y: Same as Raw mode, only will double the vertical size.

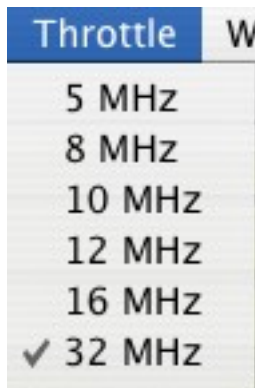
Doube X, Tripple Y: This mode is for giant displays. It corrects the square pixel problem by stretching the display.

Note: *the 3A ROM will disable all of the display mode menu items, and enter it's own mode.*

Turn Skins On/Off: Turns on the Lisa Skins. Skins On is the default, however, it should not be used with host systems that are low on memory, nor with small displays such as notebook computers.

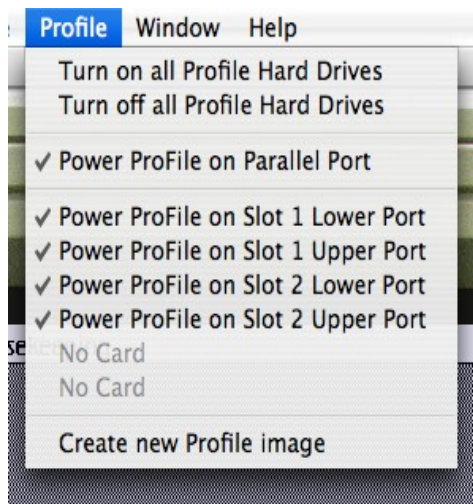
Hide Host Mouse Pointer: Hides the host OS mouse pointer when it hovers over the Lisa screen. Recommended for fast host machines. When this is unchecked, you'll see two mouse cursors, one from the emulated Lisa, and another, either a crosshair or a small square mouse cursor for the host operating system when the mouse is over the Lisa's screen.

The Throttle Menu:



This sets the throttle speed attempting to limit the emulator's CPU usage. Normally at 5MHz. Slower machines will not be able to reach 32MHz.

The Profile Menu:

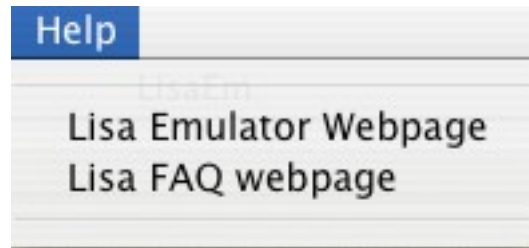
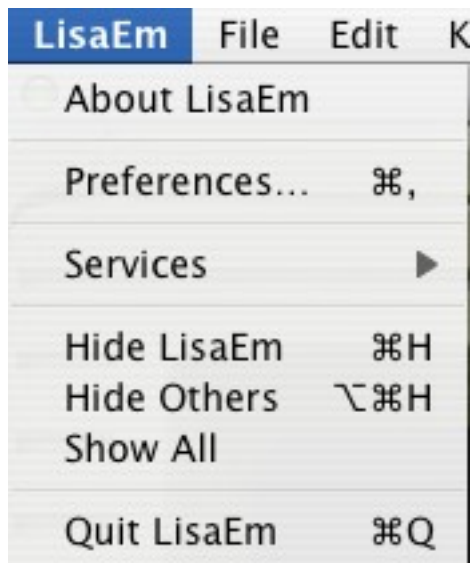


This menu allows you to switch power on individual ProFile hard drives, or all of them simultaneously, or to create new, blank ProFile disk images.

Temporarily switching power off to ProFile drives can be useful when you wish to boot from floppy in order to perform repairs.

Creating new Profile hard drive disk images also happens if they've been configured in the Preferences but the actual file does not exist.

The Help Menu:



The help menu provides links to the LisaEm project webpage. Future versions may include a help browser.

On OS X, the **LisaEm** menu contains the **About LisaEm** item which tells you what version of LisaEm you're running. On other operating systems, this option is under the **Help** menu.

Glossary

Glossary:

ADMP	Apple Dot Matrix Printer. Identical to the ImageWriter I printer, except that it connected on the Parallel Port instead of the serial port.
DART	Disk Archive and Transfer program. Like Disk Copy 4.2, this Macintosh program allows you to make disk images of floppies.
Disk Copy 4.2	Apple's Disk Copy 4.2 program for the Macintosh. This is the preferred format for disk images used on LisaEm and also for Lisas in general. Can properly format real 400K floppies on older Macintosh computers for use on actual Lisa's.
Disk Image	A sector by sector copy of a floppy or hard drive that contains all of the data from the original media saved to a file. Disk images are used by LisaEm instead of actual floppies and Profile hard disk.
Dual Parallel Card	A popular I/O expansion to the Lisa. It added two parallel ports to one of the Lisas 3 expansion slots. Parallel ports could be connected to devices such as ADMP's or Profiles.
Dual Parallel ROM	The ROM on the Dual Parallel Card which allows the Lisa Boot ROM to recognize and boot off Profile drives attached to the Dual Parallel Card.
expansion slots	Three slots in the back of the Apple Lisa Computer which could be populated by cards providing additional functionality such as the Dual Parallel Card.
Generator	A Sega Genesis emulator written by James Ponder. The CPU core from Generator has been modified for use in LisaEm.
I/O ROM	The Lisa computer has an I/O board which contains a 6504 which acts as a disk controller for the Lisa. The I/O ROM is not emulated by LisaEm, however, the version of the I/O ROM is used by certain software to determine the kind of Lisa that it runs on. For example Xenix incorrectly uses the I/O ROM version to decide what size hard drive is attached to the Lisa.
ImageWriter	A serial port version of the Apple Dot Matrix Printer. This was later updated to the ImageWriter II which was a popular addition to Macintosh computers.
Lisa	Apple's Lisa Computer. Apple claims that this is an acronym which stands for Locally Integrated System Architecture. The Lisa computer is the Macintosh's predecessor. This is the computer that LisaEm emulates.
Lisa Office System	Lisa Office System is the original windowed environment for use on the Apple Lisa. It was later replaced with Macworks when Apple decided to discontinued the Lisa as a compatibility tool with Macintosh computers.
Lisa Pascal Workshop	The Lisa Pascal (or Programmer's) Workshop is a non-gui version of the Lisa Office System meant to be used by developers who wish to build Lisa software.
LisaEm	LisaEm is a concatenation of Lisa Emulator. This is the software that emulates Apple's Lisa computer.

MacWorks	MacWorks is a Lisa environment that allows Macintosh software to run Macintosh software. It's not quite an emulator, but rather, it's closer to something like virtualization software.
microdiskette	Lisa speak for 3.5" floppy. The Lisa used 3.5" SS/DS 400K GCR encoded floppies, which are readable on older Macintosh computers.
Parallel Port	One of Lisa's connector ports which allowed connectivity to the Apple Dot Matrix Printers and Profile hard drives. These are analogous to PC parallel ports, but not compatible with them. Lisa's parallel ports were bidirectional. A single parallel port is provided on the motherboard on Lisa 2's and 2/5's but not 2/10's. Lisa 2/10's had an internally connected Parallel port. These are also available on the Dual Parallel Card.
PRAM	Parameter Random Access Memory. This is a battery backed up portion of memory where the Lisa stored information and preferences.
Profile	The Lisa's 5MB and 10MB external hard drive.
ROM	Read Only Memory. In this context, refers to the Lisa's boot ROM which performed Power-On Self Tests, and provided a graphical user interface that allowed the Lisa's user to select which device to boot from. Also contains a hidden Service Mode.
sector	A 512 byte chunk of data stored on a floppy, Profile, or disk image.
Serial Number	A hard coded number stored in the Lisa's Video ROM which was used to lock down Installed applications to a specific Lisa.
Serial Port	The Lisa used standard RS-232 25 pin serial ports. These are industry standard and used to connect to printers such as the ImageWriter, LocalTalk networks, modems, null-modems, and other such devices.
tags	A 12 byte chunk of meta data attached to each disk sector. Was used to allow the Lisa to boot as well as help a repair program known as the scavenger to repair the disk.
Widget	Code name for the Lisa 2/10's internal hard drive. Unlike Profile hard drives, these used a voice coil instead of a stepper motor. Because of this, they make interesting whistling or squeaking sounds.
Xenix	Microsoft's and SCO's version of Unix for the Lisa (as well as 286 PC's). This is one of the several operating systems available for the Lisa computer.

Contact and Support Information

Contact and Support Information:

<http://lisaem.sunder.net> This is the LisaEm project's official web site. Please visit this site every month to see if updated versions of the emulator are available.

<http://lisafaq.sunder.net> The Lisa Frequently Asked Questions site provides information about the Lisa computer. It is not specific to the emulator, but can be helpful.

lisafaq@sunder.net Please send comments about the LisaFAQ to this address.

lisaem-bugs@sunder.net Please send bug reports to this address.

lisaem@sunder.net Please send questions or comments about the emulator here.

ray.arachelian@gmail.com This is my email address for topics other than LisaEm.

The Lisa List Google Group:

<http://groups.google.com/group/lisalist>

The LisaList mailing list is run on GoogleGroups. While it is not affiliated with the Lisa Emulator Project, it is a forum for Lisa enthusiasts, and questions about the emulator are welcome there provided the Subject line starts with "[lisaem]" to distinguish between topics about actual Lisas.

If you have a Lisa or have questions about them, this is the place to ask. Be sure to look at the archives as well.

Credits

Credits:

My thanks go out to the following people:

David T. Craig for providing the wealth of Lisa information which he allowed me to scan in, for the many contacts with Lisa developers and faithfully listening to status reports over the ages.

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James Ponder for his wonderful Generator project, one of the better Sega Genesis emulators out there, whose CPU core is the very heart of the LisaEm project. <http://squish.net/generator>

Adam Firester for providing the many years of bandwidth for the project website.

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