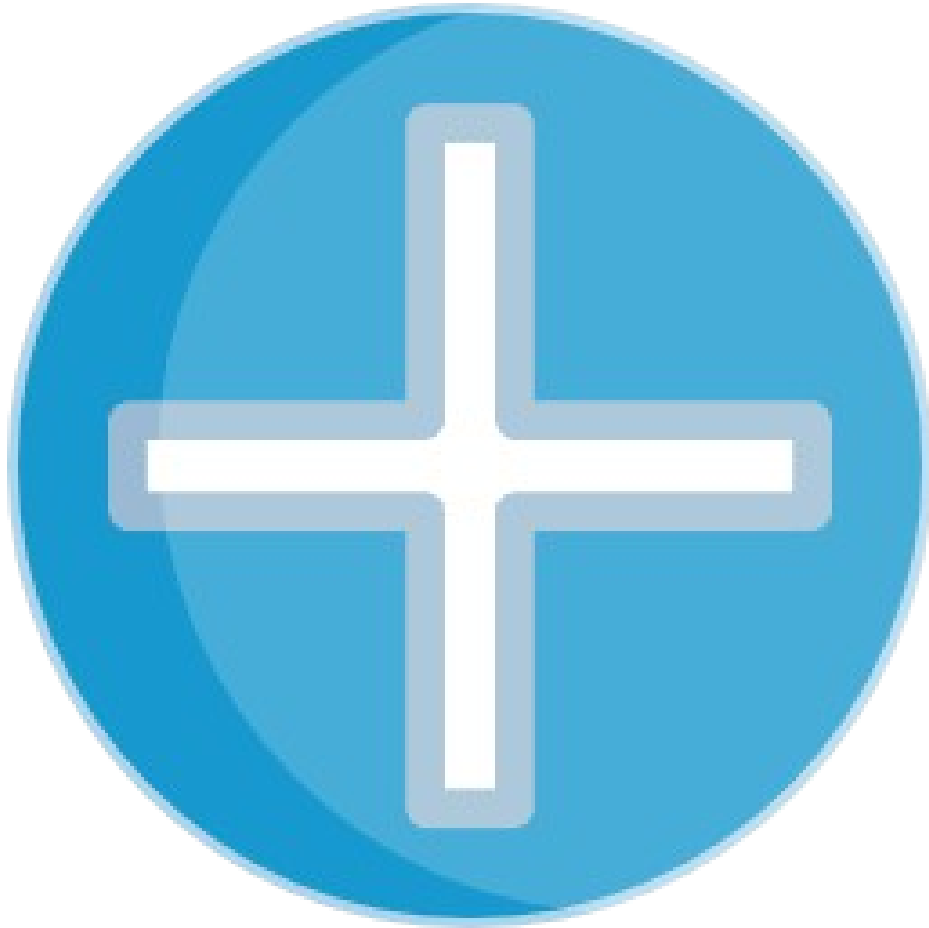


GB ENHANCED+ USER MANUAL



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1. Foreword

This manual will attempt to cover all the functions users may encounter while operating GB Enhanced+. The information contained herein doubles as both an operating guide and reference to the emulator's various features.

GB Enhanced+ is the successor to the original GB Enhanced project (note the shiny "+"). It is a Game Boy, Game Boy Color, and Game Boy Advance emulator that aims to provide as many enhancements as reasonably possible. Although there is much work to be done in later releases, such as cheat code support, emulation of the GB Camera and Printer, and implementing pixel shaders, GBE+ is dedicated to pursuing these types of things.

Perhaps most importantly, GBE+ supports an emerging emulation technique for 2D games, what the project refers to as **Custom Graphics**, or **CGFX** for short. Like HD textures for N64 games, CGFX lets users replace in-game graphics with their own pixels, from simple recolors to full-blown high-definition versions. While replacing graphics for 2D systems is not common among other emulators, GBE+ is proud to push the boundaries in this field of emulation.

What started as an idle dream to make my own NDS emulator has become something much more than the humble project I founded in 2012. GBE+ is still in early development, despite its 1.0 release. Many, many rough edges remain. There is still a lot more to go through before I can see my vision completed, however, I believe this project is on the right path. In the coming years, we'll see where the road takes this emulator. In the meantime, I hope this manual will give users an insight to how the program works, what it's capable of, and where it's going.

D.S. Baxter - aka Shonumi

2. Getting Started

Getting started with GBE+ is relatively simple. The emulator does not have many requirements to build from source, and installation should be simple for most operating systems. Please consider, however, that GBE+ has not been tested on OS X in any way, shape, or form. This is due to the lack of access to the operating system. Users can still build it themselves on OS X.

Currently, GBE+ has minimal hardware requirements. Any recent computer should be able to run the emulator just fine. Certain tasks, such as processing large amounts of CGFX, require more single-threaded processing power. Under some circumstances CGFX may also benefit from more RAM. Generally, however, these scenarios are reserved for intense use of HD graphics. Otherwise GBE+ is not a demanding emulator.

It should be noted, however, that as of 1.0, GBA games in general eat up a lot of CPU resources. This is due to inefficiencies in the GBA core that will be addressed in the very near future.

GBE+ aims to build and run with minimal software dependencies. The recommended minimum version of OpenGL is 2.1. Any computer released in the past decade should support this without any trouble. Future versions of GBE+ will move to OpenGL 3.3 (for backward compatibility) and Vulkan.

Currently, GBE+ supports both 32-bit and 64-bit systems. For the foreseeable future, this will remain the case. For CPU emulation, any dynamic recompilers added to later releases, will only target x64 systems. Nevertheless, GBE+ will technically continue support 32-bit systems at that time through CPU interpreters.

For a general roadmap of where GBE+ will go from here, please see the FAQ in **Section 6** for more details.

2.1 Obtaining, Compiling, & Installing GBE+

For Windows users who do not want to build from source code, please visit the project's GitHub page and check out the 1.0 release on the Release page. Download the zip file and extract it. Simply double-click the executable file *gbe_plus_qt.exe* to run the GUI version of the emulator. For those interested in the command-line version of GBE+, run the *gbe_plus.exe* file from the command prompt. The majority of this manual focuses on the Qt version of GBE+, however, please refer to **Section 2.2** for more details about running the command-line version.

Linux users have to compile the source code themselves. Compiling from source requires prior installation of the following programs and libraries:

- GIT
- CMake
- SDL 1.2
- OpenGL
- Qt4 or Qt5 (optional)

CMake will check to make sure it can find all of the necessary dependencies before the build process begins. Before that happens, however, GIT must retrieve the source, or the source tarball from the Release page must be downloaded and extracted. The following terminal instructions detail how to download the source code through GIT, compile it, and install the emulator:

```
git clone https://github.com/shonumi/gbe-plus.git
cd gbe-plus
mkdir build && cd build
cmake ..
make && make install
```

Note that this will install the very latest source code. GIT can check out specific revisions based on the hash of that commit. Consult the GIT documentation for checking out revisions and the GBE+ GitHub repository for the appropriate hash. Once CMake installs GBE+, the emulator can be called via *gbe_plus* for the command-line version, or *gbe_plus_qt* for the Qt version.

2.2 Command-Line Options

The command-line version of GBE+ accepts several parameters. Below are all the valid arguments for the emulator along with a short description of what they do:

-b or --bios [FILE]:

This instructs GBE+ to boot a system's BIOS or Boot ROM with the provided file when loading a game. The second argument is the exact path for the BIOS or Boot ROM on the user's computer.

-d or --debug:

This starts GBE+ in debug mode. It will pull up the command-line debugger. See **Section 5.7** for details on how to use properly use this version of the debugger.

--opengl:

This forces GBE+ to use OpenGL for all drawing/blitting operations instead of SDL.

--2x, --3x, --4x, --5x, --6x:

Scales the screen by a given factor. Only applicable when OpenGL is enabled.

--sys-auto:

Sets the emulated system type to AUTO. In this mode, GBE+ will automatically determine what system to emulate based on the game.

--sys-dmg:

Sets the emulated system type to DMG (old black and white Gameboy). This option is not valid when running GBA games and is ignored by the emulator.

--sys-gbc:

Sets the emulated system type to GBC. This option is not valid when running GBA games and is ignored by the emulator. DMG games will run as if on a GBC.

--sys-gba:

Sets the emulated system type to GBA. DMG/GBC games will run as if on a GBC, however, like a real GBA, the screen can be stretched horizontally by pressing the L and R triggers.

--multicart:

Forcibly emulates MBC1 games as MBC1M variants. Use this option for games like Mortal Kombat I & II, or Bomberman Collection.

--h, or --help:

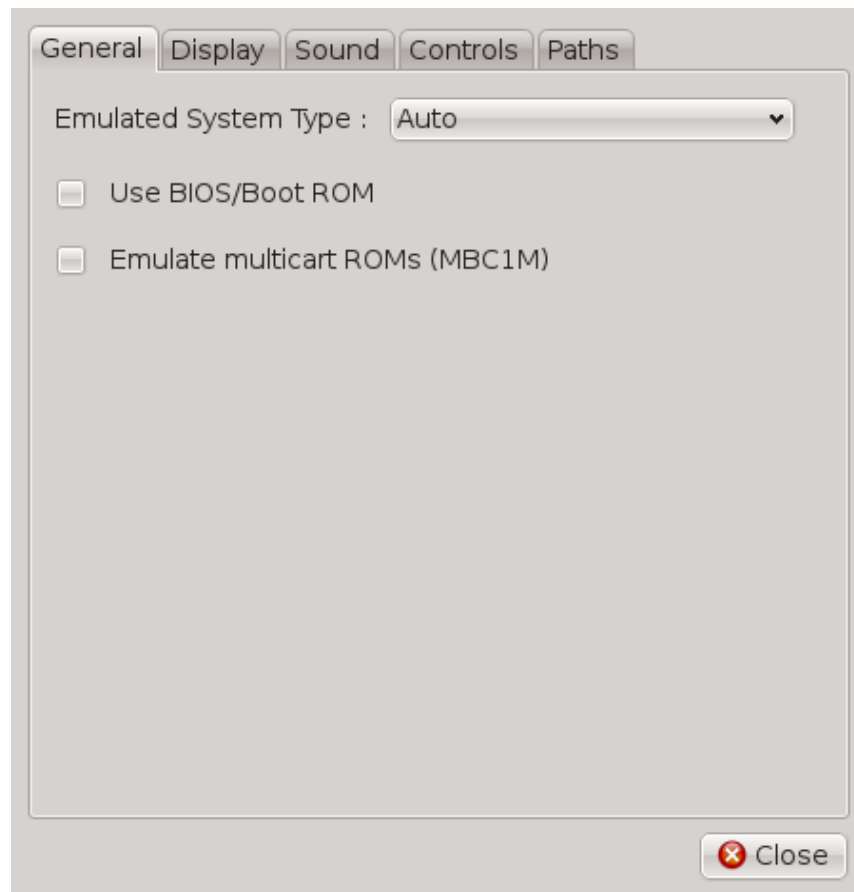
Displays a brief help message explaining all of the above options.

3. Configuration

GBE+ has many options that will affect how the program runs games. There are 5 major areas of configuration: General Settings, Display Settings, Sound Settings, Control Settings, and Paths. The following sections detail what these options do for the Qt version of the emulator.

3.1 General Settings

This section deals with miscellaneous settings that don't belong to any particular category.



Emulated System Type:

Forces GBE+ to emulate a certain system. The following options are:

Auto - In this mode, GBE+ will automatically determine what system to emulate based on the game.

Game Boy [DMG] - Emulates the DMG (old black and white Gameboy). This option is not valid when running GBA games and is ignored by the emulator.

Game Boy Color [GBC] - Emulates the GBC. This option is not valid when running GBA games and is ignored by the emulator. DMG games will run as if on a GBC.

Game Boy Advance [GBA] - Emulates the GBA. DMG/GBC games will run as if on a GBC, however, like a real GBA, the screen can be stretched horizontally by pressing the L and R triggers.

Use BIOS/Boot ROM:

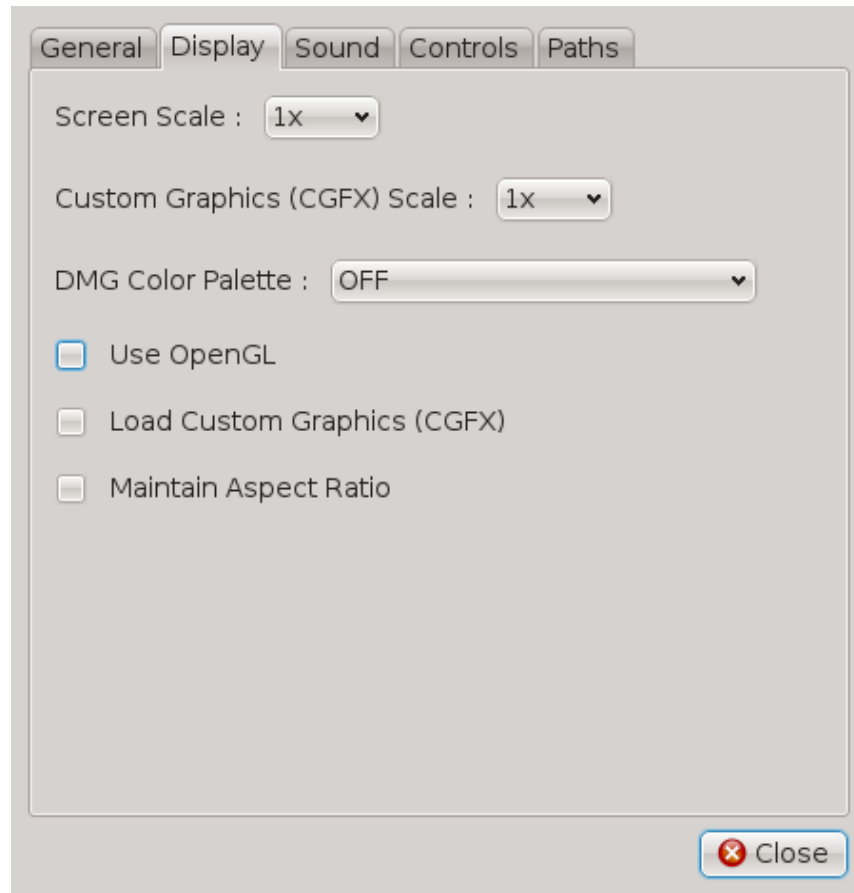
This instructs GBE+ to boot a system's BIOS or Boot ROM. When checking this option, users must ensure that the proper paths to the DMG, GBC, or GBA files are configured. See **Section 3.5** for more details on configuring BIOS and Boot ROM files.

Emulate multcart ROMS (MBC1M):

Forcibly emulates MBC1 games as MBC1M variants. Use this option for games like Mortal Kombat I & II, or Bomberman Collection. Please note, however, that only a rare handful of games need this option. It is not necessary for most games and can cause issues if left checked for the wrong ones. If unsure, leave unchecked.

3.2 Display Settings

Display settings deal with how GBE+ draws things on screen.



Screen Scale:

Determines what factor to scale the original game screen. Factors of 1x to 10x are applicable. Unlike the command-line version, the Qt version can scale the image regardless of whether OpenGL is used or not.

Custom Graphics (CGFX) Scale:

Determines what the input scale for CGFX is. *When loading CGFX into the emulator, this option must be set to the correct scale.* For example, if a user makes HD graphics that are 4x the size of the original graphics, this option must be set to 4x. Mismatching the scale will result in graphical errors when using CGFX. This scale is also multiplied by the Screen Scale to get the final screen size.

DMG Color Palette:

DMG games can be colorized with special palettes. **OFF** emulates standard grayscale colors. **DMG - Classic Green** emulates the old-school green LCD. The other options emulate palettes from the GBC Boot ROM.

Use OpenGL:

Use OpenGL for all drawing/blitting operations. This option is faster than using software, especially when increasing the Screen Scale.

Load Custom Graphics (CGFX):

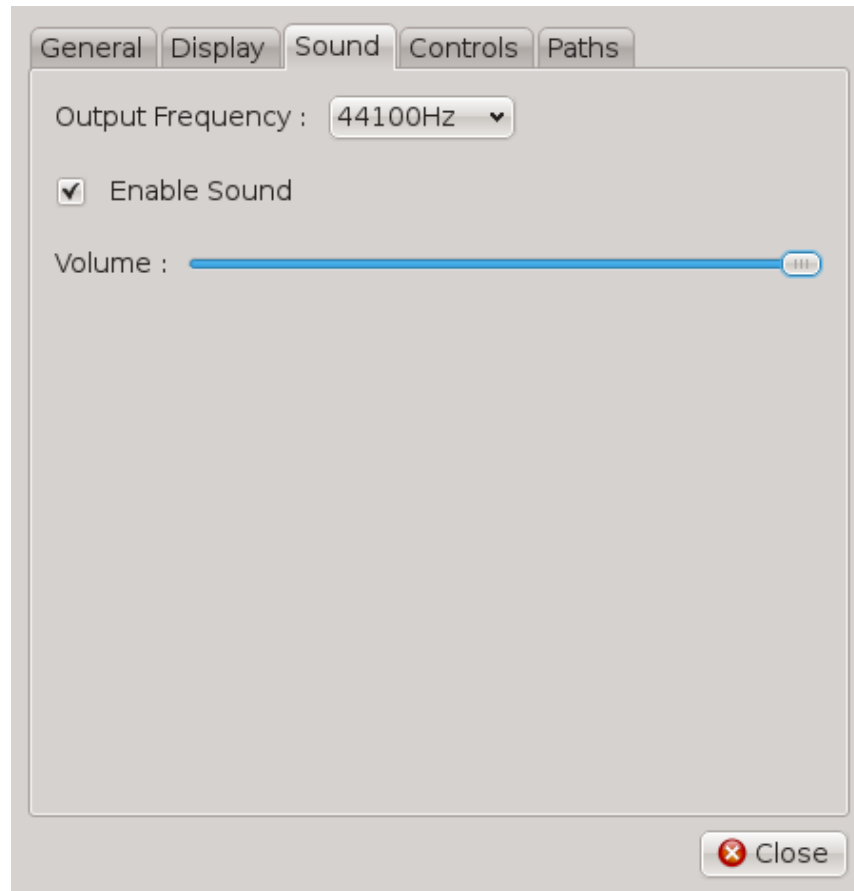
Loads Custom Graphics into the emulator. This option must be enabled in order to play using CGFX. Additionally, a manifest file must be selected in Paths. For full details on how to set up CGFX, refer to **Section 4.4**.

Maintain Aspect Ratio:

Forces GBE+ to maintain the same aspect ratio as the original system regardless of the window size. Leaving this option unchecked will let GBE+ fill in the available window space.

3.3 Sound Settings

Sound settings determine how GBE+ will process audio.



Output Frequency:

Determines the final output frequency of all sound. The available options are **11025Hz**, **22050Hz**, **44100Hz**, and **48000Hz**. With higher frequencies, GBE+ will produce better audio quality. Please note, changing this option only takes effect when booting or resetting a game. If unsure, please leave this option at its default setting.

Enable Sound:

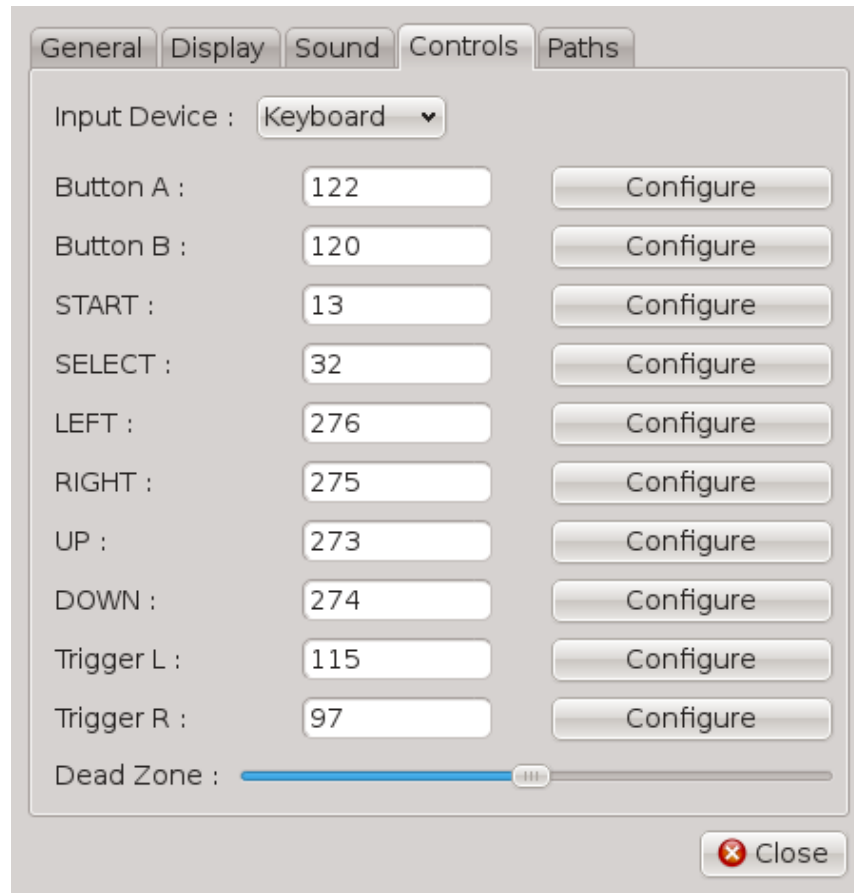
Checking this option enables sound output. Unchecking this option will mute any sounds from GBE+

Volume:

This slider controls the master volume for all sound output from GBE+. Turning it all the way down to zero will effectively mute the emulator.

3.4 Controls Settings

Controls settings allow users to configure input for the emulator via the keyboard or joysticks



Input Device:

Selects the input device to configure. Both keyboards and joysticks can be configured. This option will contain a list of all available joysticks GBE+ can detect. Please note that both keyboard and joysticks can be used at the same time, regardless of what this option is set to.

Buttons:

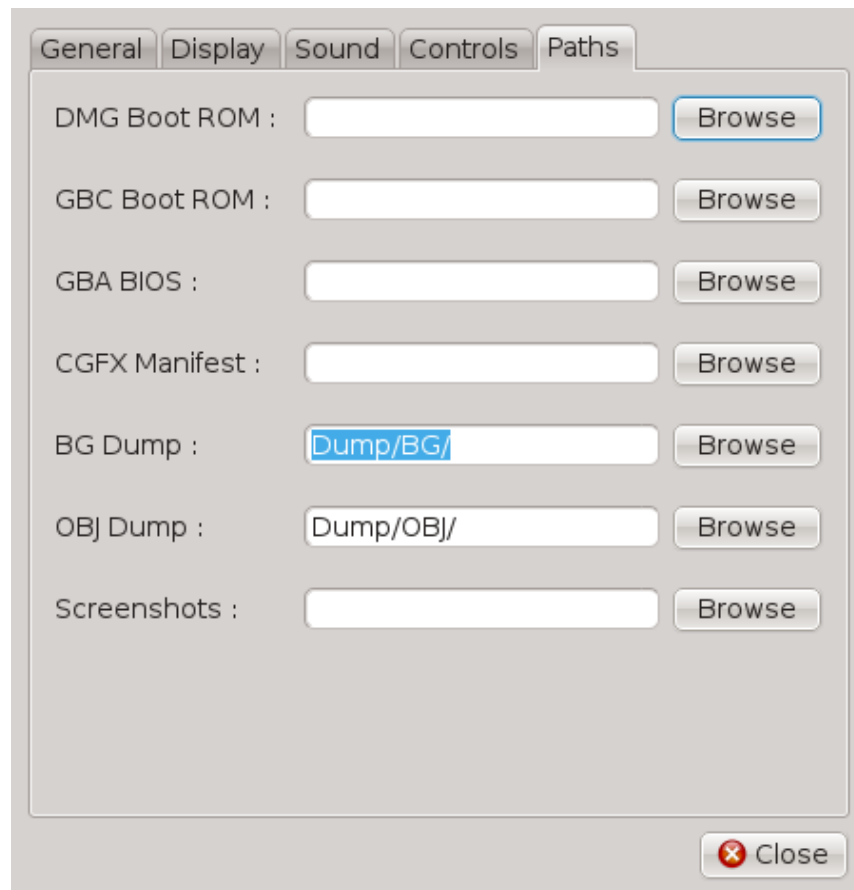
These are the individual buttons that can be configured. Press the **Configure** button for GBE+ to map input from a device. For joysticks, there is a 3 second delay before configuration is processed. During this time, please continue holding down on the joystick for GBE+ to finish mapping.

Dead Zone:

Configures the dead zone for joystick axes. A smaller dead zone means less tilt on an axis is needed to trigger an input. A larger dead zone means more tilt on an axis is needed to trigger an input. If unsure, please leave this option at its default setting.

3.5 Paths Settings

Paths settings determine the location GBE+ will look to for important files such as screenshot directories, or the location of BIOS or Boot ROMs. To set a location, click the **Browse** button and choose a folder or file from the pop-up.



DMG Boot ROM:

This is the original Game Boy's Boot ROM file. Although booting this will have no effect on overall emulation, this will let users see the scrolling "Nintendo" logo.

GBC Boot ROM:

This is the Game Boy Color Boot ROM file. Booting up this will let users choose color palettes when running DMG games, and some DMG games (like *Metroid II: Return of Samus*) will have custom palettes.

GBA BIOS:

This is the Game Boy Advance BIOS file. Booting this up will let users see the GBA's "Nintendo" logo and the boot animation. Currently, all BIOS functions are high-level emulated, so GBE+ does not actually run the code from the GBA BIOS. In the future, low-level emulation of the BIOS will be possible.

CGFX Manifest:

This is the manifest file GBE+ will use when loading Custom Graphics or when dumping them via the Advanced Menu. See **Section 4** for more details about Custom Graphics.

BG Dump:

This is the folder GBE+ will look to when loading or dumping Background Tiles for Custom Graphics. By default, this is located in the **data** folder for GBE+. This folder *must* be located within the **data** folder for GBE+ to correctly find the image files.

OBJ Dump:

This is the folder GBE+ will look to when loading or dumping Sprite Tiles for Custom Graphics. By default, this is located in the **data** folder for GBE+. This folder *must* be located within the **data** folder for GBE+ to correctly find the image files.

Screenshots:

This is the folder GBE+ will use to store screenshots.

3.6 The .ini File

GBE+ can be configured through a .ini text file. This file includes nearly all of the same options as the Qt options previously described. For both the SDL and Qt versions of GBE+, the .ini file will be loaded and automatically set up any options. The .ini file and its format are self-documented, so please refer to the default .ini file to see how it works and how to edit it.

GBE+ will always search for a .ini file in the same folder as the emulator itself. If no such file exists, GBE+ will search in the **data** folder for its .ini file. If no .ini file exists in the **data** folder either, GBE+ will its default settings.

For the Qt version, GBE+ will always update and save the .ini file. This way, changes to settings are remembered during the next play session.

4. Custom Graphics (CGFX)

Custom Graphics (referred to as CGFX) are an exciting new way of modding in-game graphics, much like custom textures used on other platforms. This section details how GBE+ can extract and replace tiles for backgrounds and sprites.

4.1 Overview



CGFX works by first grabbing tile data from a game, which GBE+ offers numerous tools for achieving. Once the graphics have been extracted or “dumped”, they are edited to look like something else. The changes can be simple 1:1 recolors of black-and-white-only games such as the screenshot above, or they can be bigger, high-definition versions. Once those changes are made, GBE+ can automatically load the graphics and draw them on-screen when running the game.

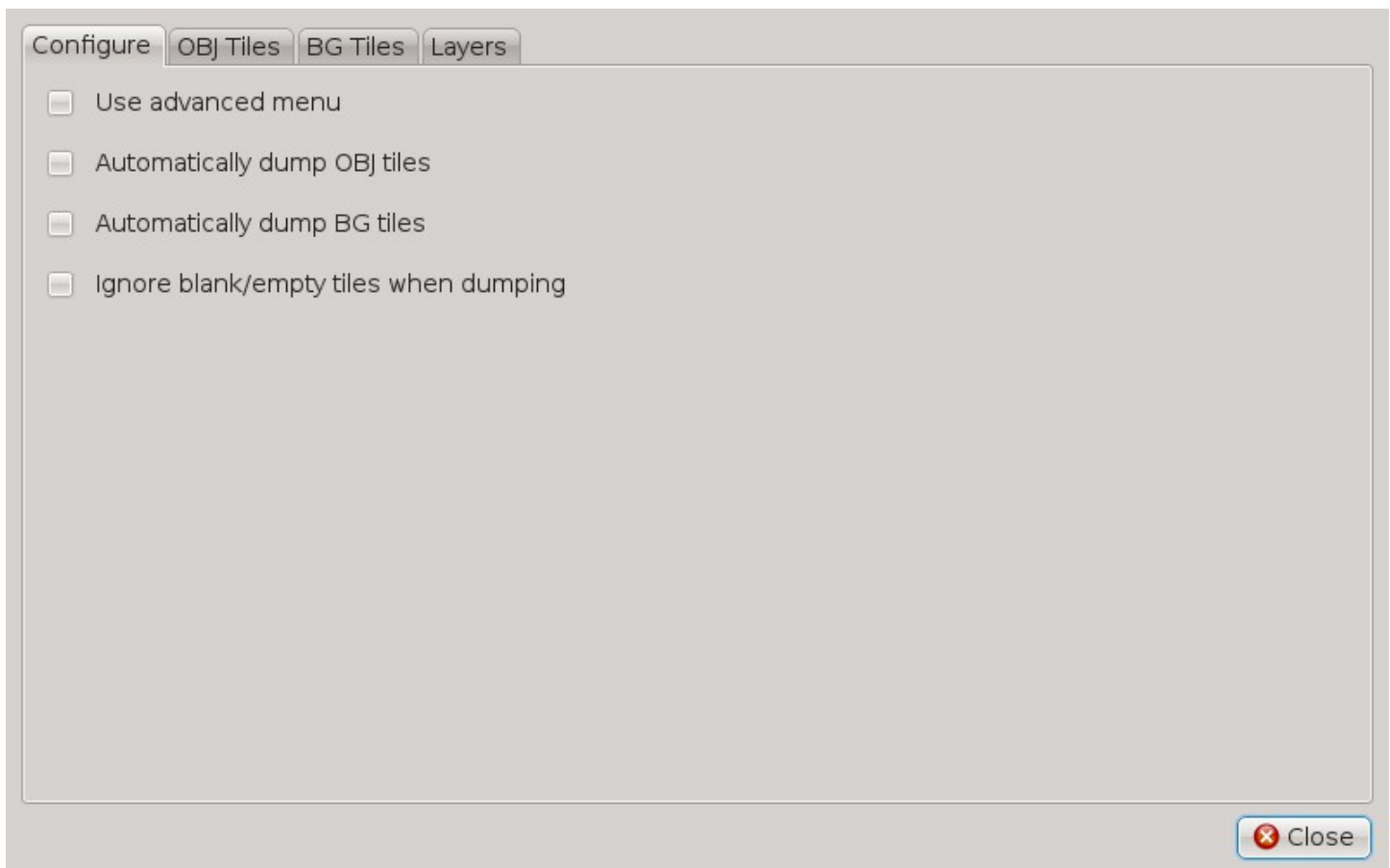
4.2 Dumping Graphics

In order to replace a game's original graphics with CGFX, the original graphics must first be extracted from the game. This process is known as "dumping" or "ripping". GBE+ provides a dedicated user interface for this very purpose. **At this time, it is important to note that CGFX only work for GB and GBC games.** Support for GBA games will come in later releases. The guide is applicable to the Qt version only.

Before beginning, please make sure the paths for the BG and OBJ dump folders are correct. Go to **Options -> Paths** to check or change any settings. **The BG and OBJ dump folders must always be in GBE+'s data folder.** By default, these two folders are data/Dump/BG and data/Dump/OBJ, but they can be changed, moved or renamed (so long as they remain in the data folder).

When dumping custom graphics, a manifest file should be specified. This is simply a text file that will tell GBE+ where to look for custom graphics and how it should load and handle them. Go to **Options -> Paths** and make sure the CGFX Manifest points to a valid text file. When starting new CGFX projects, the manifest may be left as an empty text file.

To get started, load a game from the menu. Once the game starts, click on **Advanced -> Custom Graphics...** The screen below will appear:



Use advanced menu:

Every time graphics are dumped, GBE+ will let users specify additional options through an advanced menu. See **Section 4.4** for an extended explanation of the advanced menu and its features.

Automatically dump OBJ tiles:

GBE+ will automatically dump sprites as users play the game. This option is not recommended for beginners, as a lot of data can be generated. It can be hard to keep track of what graphics GBE+ is extracting, making editing harder as well. Use this only if you know what you're doing.

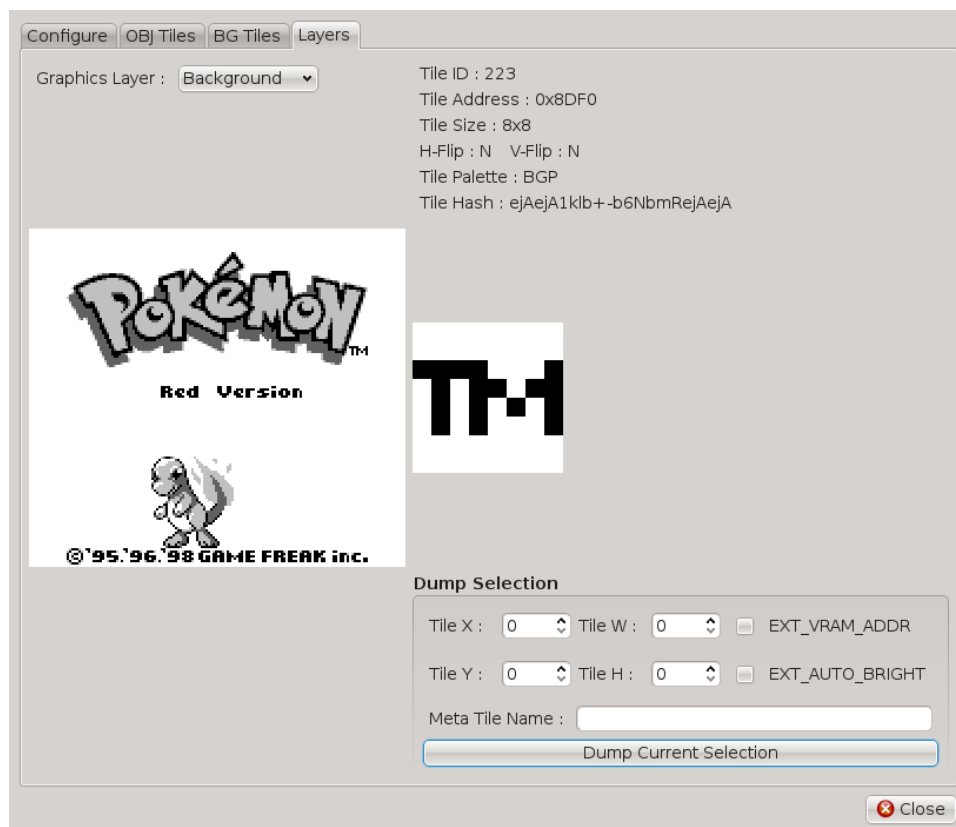
Automatically dump BG tiles:

GBE+ will automatically dump background tiles as users play the game. This option is not recommended for beginners, as a lot of data can be generated. It can be hard to keep track of what graphics GBE+ is extracting, making editing harder as well. Use this only if you know what you're doing.

Ignore blank/empty tiles when dumping:

Useful for the above automatic dumping options. Sometimes games generate graphics that are blank tiles (solid colors), that GBE+ may mistake for graphics that might be relevant. This option will prevent GBE+ from dumping them at all.

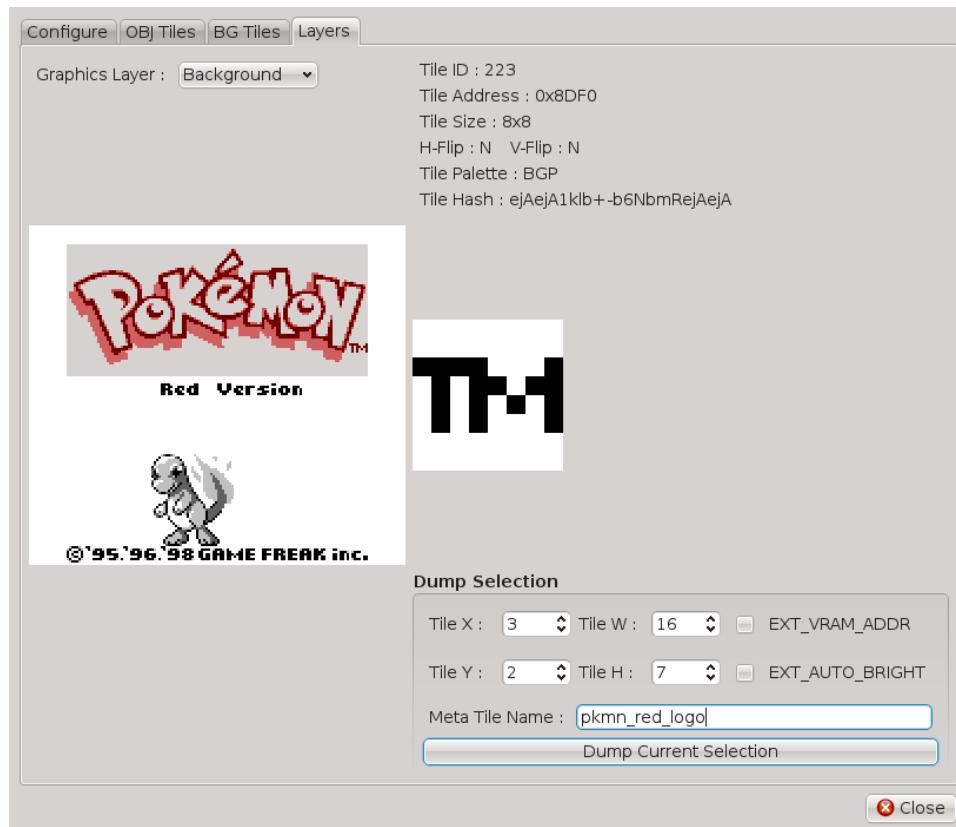
The automatic options only require users to check the boxes, close the Custom Graphics dialog, and run the game. This is generally not the recommended way to dump graphics because a lot of graphics can be dumped at once. This makes editing things quite hard in some cases. A better approach is to dump only a few graphics at a time manually. There are tabs specifically for dumping BG and OBJ tiles. Clicking on one of the tiles will dump it. For even greater control over dumping graphics, the Layers tab provides a better interface.



This is the recommended method of dumping graphics due to its ease of use. Here, users can switch between the Game Boy's Background, OBJ, and Window layers. The present screen will be displayed. Use the mouse to hover over a specific tile. A magnified version will appear on the right along with detailed data about the tile itself. Clicking here will dump the tile.

4.3 Dumping Meta-tiles

Meta-tiles offer users a way to dump a section of the screen all at once, then save the results as a single image. Take, for example, the POKEMON logo from Pokemon Red. The logo itself is just short of 100 8x8 background tiles. Normally, it would take many people hours to dump each tile and edit them by hand. As a convenience, GBE+ will let users save that logo as a single bitmap file which can be edited and loaded later.

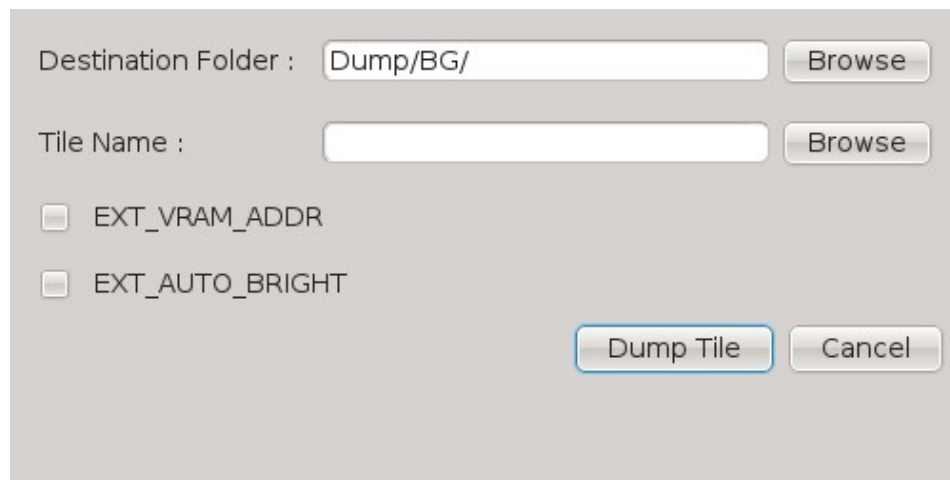


To create a meta-tile, simply go to the Layers tab and go to **Dump Selection**. In this area are parameters to control which section will be dumped. The X and Y boxes determine where the on-screen selection will begin. The W and H boxes determine the dimensions of the selection. The selection will automatically highlight which area is going to be dumped. Additionally, **EXT_VRAM_ADDR** and **EXT_AUTO_BRIGHT** options are available (see **Section 4.4** for more details). Once the selection has been made, enter in a name for the file. **This file will automatically appear in data/Dump/BG and will automatically be saved as a .BMP file.** All the necessary manifest entries are written when saving as well.

At this time, dumping meta-tiles is only supported for Background tiles, not OBJs. OBJs can still take advantage of meta-tiles if dumped manually and if the manifest file is edited by hand. See **Section 4.5** for more info about the manifest file.

4.4 Using the Advanced Menu

Manifest files are necessary for properly loading custom graphics in GBE+. They act like lists that describe what the emulator should do when loading custom graphics. GBE+ will let users automatically add entries into a manifest file via the Advanced Menu. Simply check the above Use advanced menu option, and every time a tile is dumped, GBE+ will write the manifest file for you. The following screen will pop up every time a tile is dumped:

The image shows a screenshot of a software dialog box titled "Advanced Menu". It has a light gray background. At the top, there is a label "Destination Folder :" followed by a text input field containing "Dump/BG/" and a "Browse" button to its right. Below this is a label "Tile Name :" followed by an empty text input field and another "Browse" button. Underneath these are two checkboxes. The first is labeled "EXT_VRAM_ADDR" and is unchecked. The second is labeled "EXT_AUTO_BRIGHT" and is also unchecked. At the bottom right of the dialog are two buttons: "Dump Tile" and "Cancel". The "Dump Tile" button is highlighted with a blue border.**Destination Folder:**

This will specify what folder to use to dump this tile. By default, it is either the BG or OBJ dump folder specified in **Options -> Paths**.

Tile Name:

This gives the tile a unique name. By default, GBE+ will name the graphics after its hash. Use this to give it a descriptive name like "Mario_Hat_1.bmp" or "Link_Sword.bmp"

EXT_VRAM_ADDR:

Checking this will allow GBE+ to associate this tile with its VRAM address. This is useful for dumping graphics that have the same hash but are located in different parts of VRAM. Often, games like Super Mario Land used a blank, white tile for the "sky" and the "ground". Ordinarily, GBE+ thinks these two are the same (they have the same data after all), but since they are located in different areas of VRAM, they can be replaced separately. This is an advanced option; if unsure, leave unchecked!

EXT_AUTO_BRIGHT:

This option is generally only applicable to GBC games. This will force GBE+ to automatically adjust the brightness of this tile based on the game's original colors. With the GBC, many games had "fade in" and "fade out" effects programmed. When EXT_AUTO_BRIGHT is enabled for a tile, GBE+ will try to lighten or darken an image appropriately when this happens in a game. Generally, this can be reserved for things like intro logos or title screen elements. This is an advanced option; if unsure, leave unchecked!

Manifest files can be edited manually however. See **Section 4.5** for more info about the manifest file.

4.5 The Manifest File

Manifests describe what files GBE+ needs to load when using CGFX. The manifest basically acts like a detailed list, pointing the emulator to the correct images. Entries within the manifest may also provide additional information on how to process the images. The primary advantage of manifests is that it reduces the time it takes for GBE+ to search for the correct CGFX assets and it gives users greater flexibility for organizing their projects.

Manifests allow the user to associate a hash with any file name they want. Even a relatively simple looking tile like this:



could end up having a complex hash like this: `0630_07507J05X04T05X07J07503-`

That's not very descriptive, and it's hard for most people to remember. Manifests allow GBE+ to associate that hash with a simpler name like "X_FONT.BMP" or whatever users want, as long as that name points to a valid image file. The format of manifest files is simple. Each entry is enclosed in brackets ([]), and each parameter is separated by a colon (:).

4.5.1 Tile Entries

Manifest files are made up of 2 different kinds of entries, **Tile Entries** and **Meta-tile Entries**. **Tile Entries** describe the individual tiles that are loaded up, while **Meta-tile Entries** point to a bitmap image made up of multiple tiles which are then broken down into smaller, individual tiles. Below is the format for a **Tile Entry**

1. GBE+ hash:

This is the hash GBE+ computes (obtained while dumping graphics), such as

`"0630_07507J05X04T05X07J07503-"`

2. Image file name:

This is the file name for the image associated with the above hash. Use a path relative to GBE+'s data folder. **Enclose path in single-quotes!** When a **Tile Entry** is used in conjunction with a **Meta-tile Entry**, this parameter refers to the Meta-tile's **Meta Name** parameter followed by its ID in the form of "_123".

3. Image type:

This determines what type of image the file represents.

1 = DMG Sprite, 2 = GBC Sprite, 10 = DMG Background Tile, 20 = GBC Background Tile.

4. EXT_VRAM_ADDR:

The address of a tile in VRAM, necessary for CGFX under certain scenarios. GBE+ will generate this. If uncertain, set to 0!

5. EXT_AUTO_BRIGHT:

Setting this to 1 will let GBE+ automatically correct the brightness of CGFX to match the original game's brightness. If uncertain, set to 0!

4.5.2 Meta-tile Entries

Meta-tiles (from **Section 4.3**) are simply large bitmaps that consist of multiple tiles. GBE+ will grab this image and automatically break it down into separate tiles. For example, if you are editing a title screen that is 80x40 pixels, GBE+ will load this and break it down into 8x8 tiles. If you are doing a 3x HD version with a 320x120 image, GBE+ will also break it down accordingly into 24x24 tiles.

Meta-tile Entries specify where to look for this bitmap, and how it should be broken down. A **Meta-tile Entry** simply gives this bitmap an ID called the **Meta Name**, and the original dimensions of each tile. In order for GBE+ to actually use any of the tiles from the Meta-tile bitmap, a regular **Tile Entry** must follow and use the **Meta Name** to grab a specific tile number. Below is the format for a **Meta-tile Entry**.

1. Image file name:

This is the file name for the image associated with the above hash. Use a path relative to GBE+'s data folder. **Enclose path in single-quotes!**

2. Meta Name:

This is a unique text-based ID for a specific meta-tile. It can be named anything, however, **do not use quotes (single or double) or colons in the name.**

3. Meta Type:

Specifies the base tile type of meta-tile. This represent the tile's original format, not the modified format. 0 = 8x8 Background Tile, 1 = 8x8 Sprite Tile, 2 = 8x16 Sprite Tile.

4.5.3 Example Manifest File

A working manifest file would look something like this:

```
#Comments look like this

#This is a basic Tile Entry
#Font stuff below, pulling data from our Font folder, these are sprites btw
#The CGFX folder is in GBE+'s "data" folder
[07507J05X04T05X07J07503-:'CGFX\Font\X.bmp':1:0:0]
[07X07507507X07507507503-:'CGFX\Font\R.bmp':1:0:0]
[05X07506-05X04507505X03-:'CGFX\Font\S.bmp':1:0:0]

#You can even divide up graphics into your own categories for easier editing!
#Imagine we're loading Mario sprites or something here
[10102128173--1312123211:'CGFX\Mario\M_1.bmp':1:0:0]
[101053232223--333123211:'CGFX\Mario\M_2.bmp':1:0:0]

#This is a Meta-tile Entry
#It specifies a group tiles to extract from a single, large bitmap
#The Meta Name is "T_SCREEN"
['CGFX\Screens\Title.bmp':T_SCREEN:0]

#After the Meta-tile Entry, populate the manifest with regular Tile Entries
#Instead of a file path, the second parameter is "T_SCREEN_XXX"
[eJafdsHadd-adfdsgfdsaaaq:T_SCREEN_0:10:0:0]
[ejAejAejAejAejAejAejAejA:T_SCREEN_1:10:0:0]
[AddaAddaDDapp-4322102934:T_SCREEN_2:10:0:0]
```

Obviously, editing the manifest file by hand can be a bit daunting, therefore, it is only recommended for people who know what they are doing, or for troubleshooting problems with CGFX.

4.6.1 Editing Graphics

Once the graphics have been dumped/ripped, the next step is to edit them. Locate the files you have recently dumped (in GBE+ data folder) and open them in an image editor of your choice. Decide on what scale you want, e.g. 1x for 1:1 replacements or something like 3x for HD replacements. Scale the source image appropriately by that factor, then make any change necessary. At this time, GBE+ only supports 24-bit BMPs for dumping and loading. Please make sure the images saved are in the correct format.

For sprites, GBE+ supports a transparency color. By default, this is ugly green (#00FF00) so use that color to make transparent areas. This color can be changed by editing the gbe.ini file.

4.6.2 Loading Graphics

When loading custom graphics, a manifest file **must** be specified. This is simply a text file that will tell GBE+ where to look for custom graphics and how it should load and handle them. Go to **Options -> Paths** and make sure the CGFX Manifest points to a valid text file. This manifest file will automatically contain entries if these graphics were dumped through the Advanced Menu of the Custom Graphics window. Otherwise, users will have to manually create the manifest file themselves. Read more about manifest files [here](#).

Before loading a game, go to **Options -> Display**. Change the **Custom Graphics (CGFX) Scale** to match the scale factor of the graphics you will be loading. Lastly, check the **Load Custom Graphics** option. Enjoy the results of your work.

5. Debugging

GBE+ offers a wide range of debugging options for those interested in what makes games run. Currently, GBE+ supports command-line debugging features for both the DMG and GBA cores. Additionally, GBE+ has a specific interface for debugging DMG/GBC games through the Qt GUI. Below the GUI version is detailed first. To access this, run a DMG or GBC game and go to **Advanced -> Debugger**. When opening the debugger, the game will automatically pause; it will resume when the window is closed.

5.1 Memory Mapped I/O Registers

This is the first tab of the debugger. It shows the current state of various MMIO registers.

I/O	Palettes	Memory	Disassembly	Obj Tiles	BG Tiles		
0xFF40 - LCDC:	0xC3	0xFF12 - NR12:	0x08	0xFF22 - NR43:	0x00	0xFF69 - BCPD:	0xFF
0xFF41 - STAT:	0x41	0xFF13 - NR13:	0x00	0xFF23 - NR44:	0x80	0xFF6A - OCPS:	0x80
0xFF42 - SY:	0x00	0xFF14 - NR14:	0x80	0xFF24 - NR50:	0x77	0xFF6B - OCPD:	0x00
0xFF43 - SX:	0x00	0xFF16 - NR21:	0x00	0xFF25 - NR51:	0xFF	0xFF70 - SVBK:	0x00
0xFF44 - LY:	0x90	0xFF17 - NR22:	0x08	0xFF26 - NR52:	0x80	0xFF00 - P1:	0xFF
0xFF45 - LYC:	0xC7	0xFF18 - NR23:	0x00	0xFF4D - KEY1:	0x80	0xFF01 - SB:	0xE1
0xFF46 - DMA:	0xCB	0xFF19 - NR24:	0x80	0xFF4F - VBK:	0x00	0xFF02 - SC:	0x80
0xFF47 - BGP:	0xE4	0xFF1A - NR30:	0x00	0xFF51 - HDMA1:	0x00	0xFF04 - DIV:	0x84
0xFF48 - OBP0:	0xE4	0xFF1B - NR31:	0xFF	0xFF52 - HDMA2:	0x00	0xFF05 - TIMA:	0xAE
0xFF49 - OBP1:	0x6C	0xFF1C - NR32:	0x9F	0xFF53 - HDMA3:	0x00	0xFF06 - TMA:	0x77
0xFF4A - WY:	0xC7	0xFF1D - NR33:	0x00	0xFF54 - HDMA4:	0x00	0xFF07 - TAC:	0x04
0xFF4B - WX:	0xC7	0xFF1E - NR34:	0xBF	0xFF55 - HDMA5:	0x00	0xFF0F - IE:	0x0F
0xFF10 - NR10:	0x08	0xFF20 - NR41:	0xFF	0xFF56 - RP:	0x00	0xFFFF - IF:	0x00
0xFF11 - NR11:	0x00	0xFF21 - NR42:	0x08	0xFF68 - BCPS:	0x80		

Refresh
Close

5.2 Palettes

The Palettes tab displays the current Background and Object palettes. On DMG games, there is only 1 BG palette, and 2 OBJ palettes, however on the GBC there are 8 for both. The relative RGB values for each color (0 - 31) will be displayed when clicking on a color. An enlarged preview of the color will appear on the right-hand side as well.



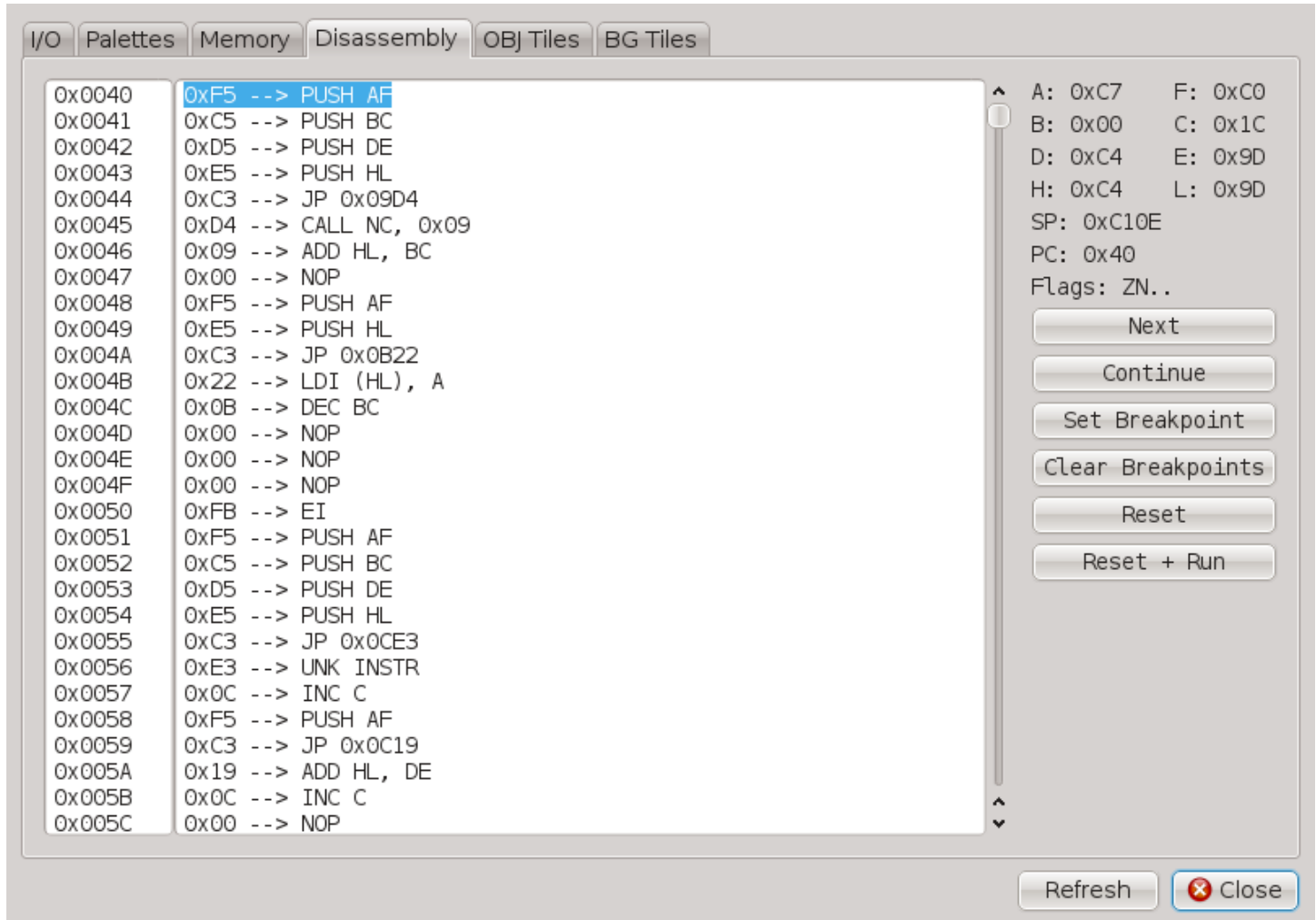
5.3 Memory

The Memory tab will display the entire contents of the memory map (0x0 through 0xFFFF on the DMG/GBC). All the values can be scrolled through and examined in detail. Additionally, as a convenience, the memory contents are also displayed as ASCII characters on the right-hand side.

Address	Hex Data	ASCII
0x0000	87 E1 85 6F 30 01 24 2A 66 6F E9 00 00 00 00 00	...o0.\$*fo.....
0x0010	85 6F D0 24 C9 00 00 00 C5 4F 06 00 09 09 C1 C9	.o.\$.....0.....
0x0020	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x0030	00 00 00 00 00 00 00 00 00 00 00 E1 D1 C1 F1 D9
0x0040	F5 C5 D5 E5 C3 D4 09 00 F5 E5 C3 22 0B 00 00 00"
0x0050	FB F5 C5 D5 E5 C3 E3 0C F5 C3 19 0C 00 00 00 00
0x0060	D9 00 00 00 00 00 00 00 83 5F D0 14 C9 81 4F D0_.....0.
0x0070	04 C9 E5 87 6F 3E 00 8F 67 19 5D 54 E1 C9 E5 87o>..g.]T....
0x0080	6F 3E 00 8F 67 09 4D 44 E1 C9 FA 97 FF F5 7B EA	o>..g.MD.....{.
0x0090	97 FF EA 22 22 CD A0 00 F1 EA 97 FF EA 22 22 C9"....."
0x00A0	E9 42 44 46 47 48 4A 4C 4D 13 BD 12 11 23 4E 51	.BDFGHJLM....#NQ
0x00B0	52 53 54 57 59 21 10 7E 7F 2B 2D 62 64 66 67 68	RSTWY!..~.+~bdfgh
0x00C0	6A 6D 24 2A 2F 3A 5C 6E 71 72 73 74 77 79 3F 25	jm\$*/:\nqrstwy?%
0x00D0	26 3C 3D 3E 32 33 34 35 36 37 38 39 15 16 17 18	&<=>23456789....
0x00E0	40 00 00 00 00 00 00 00 FF 00 00 00 00 00 00 00	@.....
0x00F0	00 00 00 00 00 00 00 00 01 02 04 08 10 20 40 80 @.
0x0100	00 C3 50 01 CE ED 66 66 CC 0D 00 0B 03 73 00 83	..P...ff.....s..
0x0110	00 0C 00 0D 00 08 11 1F 88 89 00 0E DC CC 6E E6n.
0x0120	DD DD D9 99 BB BB 67 63 6E 0E EC CC DD DC 99 9Fgcn.....
0x0130	BB B9 33 3E 5A 45 4C 44 41 20 44 49 4E 00 00 41	..3>ZELDA DIN..A
0x0140	5A 37 45 C0 30 31 00 1B 05 02 01 33 00 EE FE 8F	Z7E.01.....3....
0x0150	00 F3 FE 11 3E 00 20 07 3C CB 40 28 02 3E FF E0>. .<.@(>..
0x0160	96 3E 37 E0 94 3E 0D E0 95 31 10 C1 3E 03 E0 97	.>7..>...1..>...
0x0170	EA 22 22 C3 00 40 06 00 87 30 01 04 B7 20 F9 78	..".@...0... .x
0x0180	C9 7E 81 27 22 7E 88 27 32 D0 3E 63 22 32 C9 7E	..~.'~.'2.>c"2.~
0x0190	91 27 22 7E 98 27 32 D0 AF 22 32 37 C9 1E 08 06	..'"~.'2.."27....
0x01A0	00 68 60 29 87 30 01 09 1D 20 F8 C9 CB 37 47 E6	.h`) .0... ..7G.
0x01B0	F0 4F 78 E6 0F 47 C9 CB 37 0F 47 E6 F8 4F 78 E6	.0x..G..7.G..0x.
0x01C0	07 47 C9 06 00 87 CB 10 87 CB 10 4F C9 06 FF CB	.G.....0....

5.4 Disassembly

The Disassembly tab shows instructions and allows the user to step through game code in real-time. Below are descriptions of all of the functions in this tab:



Next:

Jumps to the next instruction and waits for further input. When running in **Continue** mode, this will pause the emulator and resume debugging.

Continue:

Runs the emulator normally until it hits a breakpoint or the **Next** button is pressed. In either case, the emulator will pause and resume debugging.

Set Breakpoint:

Creates a break point on the current PC. Any breakpoints are highlighted in yellow. A breakpoint will force the emulator to stop when running in **Continue** mode.

Clear Breakpoints:

Erases all existing breakpoints from the debugger.

Reset:

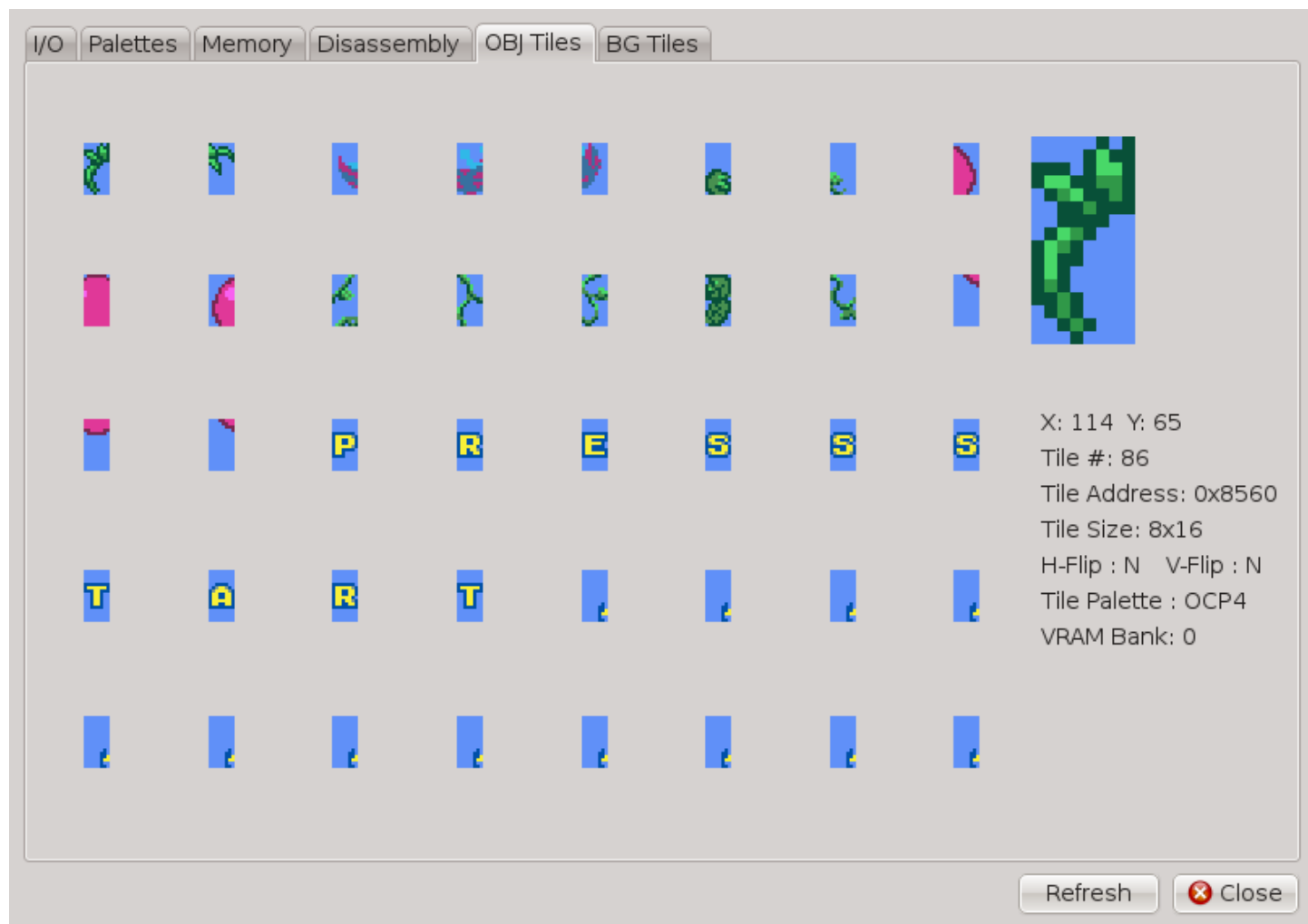
Resets emulation back to the beginning and pauses.

Reset + Run:

Resets emulation back to the beginning and runs in **Continue** mode.

5.5 OBJ Tiles

The OBJ Tiles tab displays all of the sprites currently in use by a game. Each sprite can be clicked on, and then GBE+ will displayed an enlarged preview on the right-hand side along with detailed information about the sprite's OAM data.



5.6 BG Tiles

The BG Tiles tab displays the background tiles currently in use by a game. Each BG tile can be clicked on, and then GBE+ will display an enlarged preview on the right-hand side. Please note that this feature is not complete at this time and may experience issues for some GBC games.



5.7 The Command-Line Debugger

GBE+ offers another debugger for the SDL version. Although not as powerful as the Qt GUI version, it offers many of the features found in the disassembler such as breakpoints and viewing instructions. To enter into debugging mode use the **-d** or **--debug** arguments when running GBE+ from the command-line.

GBE+ will start off paused, and from the command-line, debugging commands are entered. GBE+ will print information to the command-line console as necessary. The DMG and GBA cores both have this debugging functionality, unlike the Qt version which currently only works with DMG and GBC games. The debugging commands vary slightly between the DMG and GBA cores. Below are the all the commands for the DMG core:

- n:**
Run next Fetch-Decode-Execute stage.
- c:**
Continue until next breakpoint.
- bp:**
Set breakpoint, format 0x1234ABCD.
- u8:**
Show BYTE @ memory, format 0x1234ABCD.
- u16:**
Show WORD @ memory, format 0x1234ABCD.
- dq:**
Quit the debugger, return to normal emulation.
- dc:**
Toggle CPU cycle display.
- cr:**
Reset CPU cycle counter.
- rs:**
Reset emulation.
- pa:**
Toggles printing all instructions to the screen.
- q:**
Quit GBE+.
- h:**
Display the above help messages.

Below are all the commands for the GBA core:

- n:**
Run next Fetch-Decode-Execute stage.
- c:**
Continue until next breakpoint.
- bp:**
Set breakpoint, format 0x1234ABCD.
- u8:**
Show BYTE @ memory, format 0x1234ABCD.
- u16:**
Show HALFWORD @ memory, format 0x1234ABCD.
- u32:**
Show WORD @ memory, format 0x1234ABCD.
- dq:**
Quit the debugger, return to normal emulation.
- dc:**
Toggle CPU cycle display.
- cr:**
Reset CPU cycle counter.
- rs:**
Reset emulation.
- pa:**
Toggles printing all instructions to the screen.
- q:**
Quit GBE+.
- h:**
Display the above help messages.

6.1 General FAQ

Q) Will there be an Android port of GBE+?

A) Unlikely in the foreseeable future. My focus has always been to target “desktop” usage. Android just isn’t something I have my sights set on. Having said that, GBE+ runs on very little dependencies outside of SDL and Qt. It would be fairly easy for someone to port even a basic version of Android and refine it from there. If others work on it, I’d be more than happy to answer any questions and offer advice.

Q) Will there be a Libretro port of GBE+?

A) Unlikely in the foreseeable future. It’s just not something I’m currently interested in. I have a dozen other priorities at the moment (GB Printer, GB Link Cable, Super Game Boy, and NDS support). As I said above, if anyone else is attempting to work on it, I would be more than happy to answer questions about GBE+’s code and give advice.

Q) Will you make Custom Graphics (CGFX) for [insert random game console]?

A) No. I am only interested in the Game Boy, Game Boy Color, Game Boy Advance, and Nintendo DS, and I am only pursuing CGFX on those systems. NES, Genesis, SNES, Wonderswan, etc are not my thing. Learning the ins and outs of [insert random game console] is not easy at any rate; it takes a lot of time. Regardless, I will be publishing my work on CGFX so other emulator developers can implement in themselves.

Q) What about GBE+ and emulation accuracy?

A) For GBE+, accuracy is a long-term sub-goal. This means that accuracy gets handled as something incremental, but things like cycle or per-pixel accuracy are not the main focus of this project. That is not to say GBE+ does not care about accuracy. Eventually, these things should be pursued, however other features have priority.

Q) But... accuracy!

A) That’s not a question ;)

As said above, accuracy will be tackled in due time, step-by-step. General game compatibility is very important, but extreme, detailed hardware accuracy comes at its own pace.

Q) What is the general state of emulation in GBE+?

A) As of 1.0, support for DMG and GBC games is very high. Only a few dozen games on each system still exhibit graphical or music errors or freezes. The vast majority will play without issue as the DMG/GBC core is quite mature at this point.

The situation on the GBA is a bit more precarious. Most games will play fine, notwithstanding certain missing features (sprite rotation and scaling is absent in 1.0) and the occasional non-gamebreaking graphical glitch. However, sound quality is generally not optimal at this point and needs further work. Some “Mode 7”-like game such as Mario Kart: Super Circuit or the F-Zero games are currently broken and unplayable. The GBA core need more work done to it. Gameplay is acceptable overall, but GBE+ probably won’t replace your default GBA emulator any time soon.

Q) Will Custom Graphics (CGFX) come to other systems supported by GBE+?

A) Yes. The current plan is to rewrite most of the GBA LCD rendering code to be faster, and then attempt to do CGFX on the GBA. In the future, GBE+ aims to emulate the NDS as well. CGFX should be applicable to the NDS as well, at least for the 2D LCD engine (which is strikingly similar in many ways to the GBA). Having said that, getting CGFX running on the GBA core will not be an easy task and is going to take some time.

Q) When will the next version of GBE+ come out?

A) When it's done, and not a moment sooner. Release Candidates will generally be made available before a new stable version comes out.

Q) Why are there so many .dll files in the GBE+ 1.0 download?

A) Unfortunately, I find Windows to be a bit painful to work with as a development environment. I have not found a good way to get mingw and CMake to statically link some libraries. This is necessary to reduce the number of .dll files (since that code will be put into the .exe files instead). If anyone can get MSYS2, mingw, CMake, and Qt5 to play nice with each other and statically link libraries, I would appreciate that very much. Pull Requests for this would be accepted gladly.

Q) Why doesn't my DS3 controller work in GBE+?

A) This is a known issue with various driver reports input from the controller to SDL. On Linux, the DS3 seems to indicate that everything is pressed instead of an individual joystick or button. For those curious, this affects other emulators such as PPSSPP. It's something either SDL or the driver will have to fix.

Q) Where can I find ROMs online?

A) lol, no.

6.2 GBE+ Road Map

Here is a rough roadmap of where GBE+ is heading from 1.0 to the expected 2.0 version. Note that various other versions may be released before 2.0, and the goals here may change.

- * Update to SDL 2.0.
- * Add support for 2D GLSL shaders.
- * Improve the Qt UI to list games with user specified icons.
- * Improve the GBA core to a reasonable level of maturity and game compatibility.
- * Further improve DMG/GBC game compatibility.
- * Improve the GBA core sound quality.
- * Add support for the Super Game Boy (mainly borders + colors).
- * Add support for the Game Boy Printer.
- * Add support for the DMG/GBC Link Cable (networked gameplay)
- * Add experimental support for the NDS in some capacity.

7. Credits & Acknowledgments

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