

NAME

rgbasm — language documentation

DESCRIPTION

This is the full description of the language used by *rgbasm*(1). The description of the instructions supported by the GameBoy CPU is in *gbz80*(7).

GENERAL**Syntax**

The syntax is line-based, just as in any other assembler, meaning that you do one instruction or pseudo-op per line:

```
[label] [instruction] [;comment]
```

Example:

```
John: ld a,87 ;Weee
```

All pseudo-ops, mnemonics and registers (reserved keywords) are case-insensitive and all labels are case-sensitive.

Sections

Before you can start writing code, you must define a section. This tells the assembler what kind of information follows and, if it is code, where to put it.

```
SECTION "CoolStuff",ROMX
```

This switches to the section called "CoolStuff" (or creates it if it doesn't already exist) and it defines it as a code section. All sections assembled at the same time that have the same name, type, etc, are considered to be the same one, and their code is put together in the object file generated by the assembler. All other sections must have a unique name, even in different source files, or the linker will treat it as an error.

Possible section types are as follows:

ROM0 A ROM section. Mapped to memory at \$0000-\$3FFF (or \$0000-\$7FFF if tiny ROM mode is enabled in *rgblink*(1)).

ROMX

A banked ROM section. Mapped to memory at \$4000-\$7FFF. Valid banks range from 1 to 511. Not available if tiny ROM mode is enabled in *rgblink*(1).

VRAM

A banked video RAM section. Mapped to memory at \$8000-\$9FFF. Can only allocate memory, not fill it. Valid banks are 0 and 1 but bank 1 isn't available if DMG mode is enabled in *rgblink*(1).

SRAM A banked external (save) RAM section. Mapped to memory at \$A000-\$BFFF. Can only allocate memory, not fill it. Valid banks range from 0 to 15.

WRAM0

A general-purpose RAM section. Mapped to memory at \$C000-\$CFFF, or \$C000-\$DFFF if DMG mode is enabled in *rgblink*(1). Can only allocate memory, not fill it.

WRAMX

A banked general-purpose RAM section. Mapped to memory at \$D000-\$DFFF. Can only allocate memory, not fill it. Valid banks range from 1 to 7. Not available if DMG mode is enabled in *rgblink*(1).

OAM An object attributes RAM section. Mapped to memory at \$FE00-\$FE9F. Can only allocate memory, not fill it.

HRAM

A high RAM section. Mapped to memory at \$FF80-\$FFFE. Can only allocate memory, not fill it.

NOTE: If you use this method of allocating HRAM the assembler will NOT choose the short addressing mode in the LD instructions **LD [\$FF00+n8],A** and **LD A,\$[FF00+n8]** because the actual address calculation is done by the linker. If you find this undesirable you can use **RSET / RB / RW** instead or use the **LDH [\$FF00+n8],A** and **LDH A,\$[FF00+n8]** syntax instead. This forces the assembler to emit the correct instruction and the linker to check if the value is in the correct range.

A section is usually defined as a floating one, but the code can restrict where the linker can place it.

If a section is defined with no indications, it is a floating section. The linker will decide where to place it in the final binary and it has no obligation to follow any specific rules. The following example defines a section that can be placed anywhere in any ROMX bank:

```
SECTION "CoolStuff",ROMX
```

If it is needed, the following syntax can be used to fix the base address of the section:

```
SECTION "CoolStuff",ROMX[$4567]
```

It won't, however, fix the bank number, which is left to the linker. If you also want to specify the bank you can do:

```
SECTION "CoolStuff",ROMX[$4567],BANK[3]
```

And if you only want to force the section into a certain bank, and not it's position within the bank, that's also possible:

```
SECTION "CoolStuff",ROMX,BANK[7]
```

In addition, you can specify byte alignment for a section. This ensures that the section starts at a memory address where the given number of least-significant bits are 0. This can be used along with **BANK**, if desired. However, if an alignment is specified, the base address must be left unassigned. This can be useful when using DMA to copy data or when it is needed to align the start of an array to 256 bytes to optimize the code that accesses it.

```
SECTION "OAM Data",WRAM0,ALIGN[8]; align to 256 bytes
```

```
SECTION "VRAM Data",ROMX,BANK[2],ALIGN[4]; align to 16 bytes
```

HINT: If you think this is a lot of typing for doing a simple **ORG** type thing you can quite easily write an intelligent macro (called **ORG** for example) that uses **@** for the section name and determines correct section type etc as arguments for **SECTION**.

POPS and **PUSHS** provide the interface to the section stack. **PUSHS** will push the current section context on the section stack. **POPS** can then later be used to restore it. Useful for defining sections in included files when you don't want to destroy the section context for the program that included your file. The number of entries in the stack is limited only by the amount of memory in your machine.

Sections can also be placed by using a linkerscript file. The format is described in *rgblink(5)*. They allow the user to place floating sections in the desired bank in the order specified in the script. This is useful if the sections can't be placed at an address manually because the size may change, but they have to be together.

SYMBOLS

Symbols

RGBDS supports several types of symbols:

Label Used to assign a memory location with a name

EQUate Give a constant a name.

SET Almost the same as **EQUate**, but you can change the value of a **SET** during assembling.

Structure (the RS group) Define a structure easily.

String equate (EQU) Give a frequently used string a name. Can also be used as a mini-macro, like #define in C.

MACRO A block of code or pseudo instructions that you invoke like any other mnemonic. You can give them arguments too.

A symbol cannot have the same name as a reserved keyword.

Label

One of the assembler's main tasks is to keep track of addresses for you so you don't have to remember obscure numbers but can make do with a meaningful name, a label.

This can be done in a number of ways:

```
GlobalLabel
AnotherGlobal:
.locallabel
.yet_a_local:
AnotherGlobal.with_another_local:
ThisWillBeExported:: ;note the two colons
ThisWillBeExported.too::
```

In the line where a label is defined there mustn't be any whitespace before it. Local labels are only accessible within the scope they are defined. A scope starts after a global label and ends at the next global label. Declaring a label (global or local) with :: does an EXPORT at the same time. Local labels can be declared as scope.local or simply as .local. If the former notation is used, the scope must be the actual current scope.

Labels will normally change their value during the link process and are thus not constant. The exception is the case in which the base address of a section is fixed, so the address of the label is known at assembly time.

The subtraction of two labels is only constant (known at assembly time) if they are two local labels that belong to the same scope, or they are two global labels that belong to sections with fixed base addresses.

EQU

EQUates are constant symbols. They can, for example, be used for things such as bit-definitions of hardware registers.

```
EXIT_OK EQU $00
EXIT_FAILURE EQU $01
```

Note that a colon (:) following the label-name is not allowed. EQUates cannot be exported and imported. They don't change their value during the link process.

SET

SETs are similar to EQUates. They are also constant symbols in the sense that their values are defined during the assembly process. These symbols are normally used in macros.

```
ARRAY_SIZE EQU 4
COUNT      SET 2
COUNT      SET ARRAY_SIZE+COUNT
```

Note that a colon (:) following the label-name is not allowed. SETs cannot be exported and imported. Alternatively you can use = as a synonym for SET.

```
COUNT = 2
```

RSSET, RERESSET, RB, RW

The RS group of commands is a handy way of defining structures:

```

                                RSRESET
str_pStuff    RW    1
str_tData     RB    256
str_bCount    RB    1
str_SIZEOF    RB    0

```

The example defines four equated symbols:

```

str_pStuff = 0
str_tData  = 2
str_bCount = 258
str_SIZEOF = 259

```

There are four commands in the RS group of commands:

Command	Meaning
RSRESET	Resets the _RS counter to zero.
RSSET <i>constexpr</i>	Sets the _RS counter to <i>constexpr</i> .
RB <i>constexpr</i>	Sets the preceding symbol to _RS and adds <i>constexpr</i> to _RS .
RW <i>constexpr</i>	Sets the preceding symbol to _RS and adds <i>constexpr</i> * 2 to _RS .
RL <i>constexpr</i>	Sets the preceding symbol to _RS and adds <i>constexpr</i> * 4 to _RS .

Note that a colon (:) following the symbol-name is not allowed. **RS** symbols cannot be exported and imported. They don't change their value during the link process.

EQUUS

EQUUS is used to define string-symbols. Wherever the assembler meets a string symbol its name is replaced with its value. If you are familiar with C you can think of it as the same as #define.

```

COUNTREG EQUUS "[hl+]"
ld a,COUNTREG

PLAYER_NAME EQUUS "\"John\""
db PLAYER_NAME

```

Note that : following the label-name is not allowed, and that strings must be quoted to be useful.

This will be interpreted as:

```

ld a,[hl+]
db "John"

```

String-symbols can also be used to define small one-line macros:

```
PUSHA EQUUS "push af\npush bc\npush de\npush hl\n"
```

Note that a colon (:) following the label-name is not allowed. String equates can't be exported or imported.

Important note: An EQUUS can be expanded to a string that contains another EQUUS and it will be expanded as well. This means that, if you aren't careful, you may trap the assembler into an infinite loop if there's a circular dependency in the expansions. Also, a MACRO can have inside an EQUUS which references the same MACRO, which has the same problem.

MACRO

One of the best features of an assembler is the ability to write macros for it. Macros also provide a method of passing arguments to them and they can then react to the input using IF-constructs.

```

MyMacro: MACRO
        ld    a,80
        call MyFunc
ENDM

```

Note that a colon (:) following the macro-name is required. Macros can't be exported or imported. It's valid to call a macro from a macro (yes, even the same one).

The above example is a very simple macro. You execute the macro by typing its name.

```
add    a,b
ld     sp,hl
MyMacro ;This will be expanded
sub    a,87
```

When the assembler meets MyMacro it will insert the macrodefinition (the text enclosed in **MACRO** / **ENDM**).

Suppose your macro contains a loop.

```
LoopyMacro: MACRO
            xor    a,a
.loop      ld     [hl+],a
            dec    c
            jr     nz,.loop
            ENDM
```

This is fine. That is, if you only use the macro once per scope. To get around this problem there is a special label string equate called \@ that you can append to your labels and it will then expand to a unique string.

\@ also works in REPT-blocks should you have any loops there.

```
LoopyMacro: MACRO
            xor    a,a
.loop\@    ld     [hl+],a
            dec    c
            jr     nz,.loop\@
            ENDM
```

Important note: Since a MACRO can call itself (or a different MACRO that calls the first one) there can be problems of circular dependency. They trap the assembler in an infinite loop, so you have to be careful when using recursion with MACROS. Also, a MACRO can have inside an EQU which references the same MACRO, which has the same problem.

Macro Arguments

I'd like LoopyMacro a lot better if I didn't have to pre-load the registers with values and then call it. What I'd like is the ability to pass it arguments and it then loaded the registers itself.

And I can do that. In macros you can get the arguments by using the special macro string equates \1 through \9, \1 being the first argument specified on the calling of the macro.

```
LoopyMacro: MACRO
            ld     hl,\1
            ld     c,\2
            xor    a,a
.loop\@    ld     [hl+],a
            dec    c
            jr     nz,.loop\@
            ENDM
```

Now I can call the macro specifying two arguments. The first being the address and the second being a bytecount. The macro will then reset all bytes in this range.

```
LoopyMacro MyVars,54
```

Arguments are passed as string equates. There's no need to enclose them in quotes. An expression will not be evaluated first but passed directly. This means that it's probably a very good idea to use brackets around \1 to \9 if you perform further calculations on them. For instance, if you pass `1 + 2` as the first argument and then do `PRINTV \1 * 2` you will get the value 5 on screen and not 6 as you might have expected.

In reality, up to 256 arguments can be passed to a macro, but you can only use the first 9 like this. If you want to use the rest, you need to use the keyword **SHIFT**.

SHIFT is a special command only available in macros. Very useful in REPT-blocks. It will "shift" the arguments by one "to the left". \1 will get the value of \2, \2 will get the value in \3 and so forth.

This is the only way of accessing the value of arguments from 10 to 256.

Exporting and importing symbols

Importing and exporting of symbols is a feature that is very useful when your project spans many source-files and, for example, you need to jump to a routine defined in another file.

Exporting of symbols has to be done manually, importing is done automatically if the assembler doesn't know where a symbol is defined.

```
EXPORT label [, label , ...]
```

The assembler will make label accessible to other files during the link process.

```
GLOBAL label [, label , ...]
```

If label is defined during the assembly it will be exported, if not, it will be imported. Handy (very!) for include-files. Note that, since importing is done automatically, this keyword has the same effect as **EXPORT**.

Purging symbols

PURGE allows you to completely remove a symbol from the symbol table as if it had never existed. **USE WITH EXTREME CAUTION!!!** I can't stress this enough, you seriously need to know what you are doing. **DON'T** purge symbol that you use in expressions the linker needs to calculate. In fact, it's probably not even safe to purge anything other than string symbols and macros.

```
Kamikaze EQU  "I don't want to live anymore"
AOLer    EQU  "Me too"
PURGE Kamikaze, AOLer
```

Note that string symbols that are part of a **PURGE** command **WILL NOT BE EXPANDED** as the **ONLY** exception to this rule.

Predeclared Symbols

The following symbols are defined by the assembler:

Type	Name	Contents
EQU	@	PC value
EQU	_PI	Fixed point π
SET	_RS	_RS Counter
EQU	_NARG	Number of arguments passed to macro
EQU	__LINE__	The current line number
EQU	__FILE__	The current filename
EQU	__DATE__	Today's date
EQU	__TIME__	The current time
EQU	__ISO_8601_LOCAL__	ISO 8601 timestamp (local)
EQU	__ISO_8601_UTC__	ISO 8601 timestamp (UTC)
EQU	__UTC_YEAR__	Today's year
EQU	__UTC_MONTH__	Today's month number, 1-12

```

EQU    __UTC_DAY__    Today's day of the month, 1-31
EQU    __UTC_HOUR__   Current hour, 0-23
EQU    __UTC_MINUTE__ Current minute, 0-59
EQU    __UTC_SECOND__ Current second, 0-59

```

DEFINING DATA

Defining constant data

DB defines a list of bytes that will be stored in the final image. Ideal for tables and text.

```
DB 1,2,3,4,"This is a string"
```

Alternatively, you can use **DW** to store a list of words. Strings are not allowed as arguments to **DW**.

You can also use **DB** and **DW** without arguments. This works exactly like **DS 1** and **DS 2** respectively. Consequently, **DB** and **DW** can be used in a **WRAM0** / **WRAMX** / **HRAM** / **VRAM** / **SRAM** section.

Declaring variables in a RAM section

DS allocates a number of bytes. The content is undefined. This is the preferred method of allocating space in a RAM section. You can, however, use **DB** and **DW** without any arguments instead.

```
DS str_SIZEOF ;allocate str_SIZEOF bytes
```

Including binary files

You probably have some graphics you'd like to include. Use **INCBIN** to include a raw binary file as it is. If the file isn't found in the current directory, the include-path list passed to the linker on the command line will be searched.

```

INCBIN "titlepic.bin"
INCBIN "sprites/hero.bin" ; UNIX
INCBIN "sprites\\hero.bin" ; Windows

```

You can also include only part of a file with **INCBIN**. The example below includes 256 bytes from data.bin starting from byte 78.

```
INCBIN "data.bin",78,256
```

THE MACRO LANGUAGE

Printing things during assembly

These three instructions type text and values to stdout. Useful for debugging macros or wherever you may feel the need to tell yourself some important information.

```

PRINTT "I'm the greatest programmer in the whole wide world\n"
PRINTV (2+3)/5
PRINTF MUL(3.14,3987.0)

```

PRINTT prints out a string.

PRINTV prints out an integer value or, as in the example, the result of a calculation. Unsurprisingly, you can also print out a constant symbols value.

PRINTF prints out a fixed point value.

Automatically repeating blocks of code

Suppose you're feeling lazy and you want to unroll a time consuming loop. **REPT** is here for that purpose. Everything between **REPT** and **ENDR** will be repeated a number of times just as if you done a copy/paste operation yourself. The following example will assemble **add a,c** four times:

```

REPT 4
add  a,c
ENDR

```

You can also use **REPT** to generate tables on the fly:

```

; --
; -- Generate a 256 byte sine table with values between 0 and 128
; --

```

```

    ANGLE SET    0.0
        REPT    256
            DB    (MUL( 64.0, SIN( ANGLE ) ) + 64.0) >> 16
        ANGLE SET ANGLE + 256.0
    ENDR

```

REPT is also very useful in recursive macros and, as in macros, you can also use the special label operator `\@`. **REPT**-blocks can be nested.

Aborting the assembly process

FAIL and **WARN** can be used to print errors and warnings respectively during the assembly process. This is especially useful for macros that get an invalid argument. **FAIL** and **WARN** take a string as the only argument and they will print this string out as a normal error with a line number.

FAIL stops assembling immediately while **WARN** shows the message but continues afterwards.

Including other source files

Use **INCLUDE** to process another assembler-file and then return to the current file when done. If the file isn't found in the current directory the include-path list will be searched. You may nest **INCLUDE** calls infinitely (or until you run out of memory, whichever comes first).

```
INCLUDE "irq.inc"
```

Conditional assembling

The three commands **IF**, **ELSE** and **ENDC** are used to conditionally assemble parts of your file. This is a powerful feature commonly used in macros.

```

IF 2+2==4
    PRINTT "2+2==4\n"
ELSE
    PRINTT "2+2!=4\n"
ENDC

```

The **ELSE** block is optional. **IF** / **ELSE** / **ENDC** blocks can be nested.

Integer and Boolean expressions

An expression can be composed of many things. Expressions are always evaluated using signed 32-bit math.

The most basic expression is just a single number.

Numeric Formats

There are a number of numeric formats.

- Hexadecimal: `$0123456789ABCDEF`. Case-insensitive
- Decimal: `0123456789`
- Octal: `&01234567`
- Binary: `%01`
- Fixedpoint (16.16): `01234.56789`
- Character constant: `"ABYZ"`
- Gameboy graphics: ``0123`

The last one, Gameboy graphics, is quite interesting and useful. The values are actually pixel values and it converts the “chunky” data to “planar” data as used in the Gameboy.

```
DW `01012323
```

Admittedly, an expression with just a single number is quite boring. To spice things up a bit there are a few operators you can use to perform calculations between numbers.

Operators

A great number of operators you can use in expressions are available (listed in order of precedence):

Operator	Meaning
()	Precedence override
FUNC ()	Function call
~ + -	Unary not/plus/minus
* / %	Multiply/divide/modulo
<< >>	Shift left/right
& ^	Binary and/or/xor
+ -	Add/subtract
!= == <=	Boolean comparison
>= < >	Boolean comparison (Same precedence as the others)
&&	Boolean and/or
!	Unary Boolean not

The result of the boolean operators is zero if when FALSE and non-zero when TRUE. It is legal to use an integer as the condition for IF blocks. You can use symbols instead of numbers in your expression if you wish.

An expression is said to be constant when it doesn't change its value during linking. This basically means that you can't use labels in those expressions. The instructions in the macro-language all require expressions that are constant. The only exception is the subtraction of labels in the same section or labels that belong to sections with a fixed base addresses, all of which must be defined in the same source file (the calculation cannot be passed to the object file generated by the assembler). In this case, the result is a constant that can be calculated at assembly time.

Fixed-point Expressions

Fixed point constants are basically normal 32-bit constants where the upper 16 bits are used for the integer part and the lower 16 bits are used for the fraction (65536ths). This means that you can use them in normal integer expression, and some integer operators like plus and minus don't care whether the operands are integer or fixed-point. You can easily convert a fixed-point number to an integer by shifting it right 16 bits. It follows that you can convert an integer to a fixed-point number by shifting it left.

Some things are different for fixed-point math, though, which is why you have the following functions to use:

Name	Operation
DIV (x,y)	x/y
MUL (x,y)	x*y
SIN (x)	sin(x)
COS (x)	cos(x)
TAN (x)	tan(x)
ASIN (x)	arcsin(x)
ACOS (x)	arccos(x)
ATAN (x)	arctan(x)
ATAN2 (x,y)	Angle between (x,y) and (1,0)

These functions are extremely useful for automatic generation of various tables. A circle has 65536.0 degrees. Sine values are between [-1.0; 1.0].

```
; --
; -- Generate a 256 byte sine table with values between 0 and 128
; --
ANGLE SET 0.0
REPT 256
    DB (MUL(64.0,SIN(ANGLE))+64.0)>>16
ANGLE SET ANGLE+256.0
ENDR
```

String Expressions

The most basic string expression is any number of characters contained in double quotes ("for instance"). Like in C, the escape character is `\`, and there are a number of commands you can use within a string:

String	Meaning
<code>\\</code>	Backslash
<code>\"</code>	Double quote
<code>\,</code>	Comma
<code>\{</code>	Curly bracket left
<code>\}</code>	Curly bracket right
<code>\n</code>	Newline (\$0A)
<code>\t</code>	Tab (\$09)
<code>\1 - \9</code>	Macro argument (Only the body of a macros)
<code>\@</code>	Label name suffix (Only in the body of macros and repts)

A funky feature is `{symbol}` withing a string. This will examine the type of the symbol and insert its value accordingly. If symbol is a string symbol, the symbols value is simply copied. If it's a numeric symbol, the value is converted to hexadecimal notation and inserted as a string.

HINT: The `{symbol}` construct can also be used outside strings. The symbol's value is again inserted as a string. This is just a short way of doing `"{symbol}"`.

Whenever the macro-language expects a string you can actually use a string expression. This consists of one or more of these function (yes, you can nest them). Note that some of these functions actually return an integer and can be used as part of an integer expression!

Name Operation

`STRLEN(string)` Returns the number of characters in string

`STRCAT(str1, str2)` Appends str2 to str1.

`STRCMP(str1, str2)` Returns negative if str1 is alphabetically lower than str2, zero if they match, positive if str1 is greater than str2.

`STRIN(str1, str2)` Returns the position of str2 in str1 or zero if it's not present (first character is position 1).

`STRSUB(str, pos, len)` Returns a substring from str starting at pos (first character is position 1) and with len characters.

`STRUPR(str)` Converts all characters in str to capitals and returns the new string.

`STRLWR(str)` Converts all characters in str to lower case and returns the new string.

Other functions

There are a few other functions that do various useful things:

Name Operation

`BANK(label)` Returns the bank number label is in. The linker will have to resolve this so it can't be used when the expression has to be constant.

`DEF(label)` Returns TRUE if label has been defined.

`HIGH(r16/cnst/lbl)` Returns the top 8 bits of the operand if it is a label or constant, or the top 8-bit register if it is a 16-bit register.

`LOW(r16/cnst/lbl)` Returns the bottom 8 bits of the operand if it is a label or constant, or the bottom 8-bit register if it is a 16-bit register (AF isn't a valid register for this function).

MISCELLANEOUS

Changing options while assembling

OPT can be used to change some of the options during assembling the source instead of defining them on the commandline.

OPT takes a comma-seperated list of options as its argument:

```
PUSHO
OPT   g.oOX ;Set the GB graphics constants to use these characters
DW    '..ooOXX
```

```

      POPO
      DW      '00112233

```

The options that OPT can modify are currently: **b**, **e** and **g**.

POPO and **PUSHO** provide the interface to the option stack. **PUSHO** will push the current set of options on the option stack. **POPO** can then later be used to restore them. Useful if you want to change some options in an include file and you don't want to destroy the options set by the program that included your file. The stacks number of entries is limited only by the amount of memory in your machine.

ALPHABETICAL LIST OF KEYWORDS

```

"@
"__DATE__"
"__FILE__"
"__ISO_8601_LOCAL__"
"__ISO_8601_UTC__"
"__LINE__"
"__TIME__"
"_NARG"
"_PI"
"_RS"
"ACOS"
"ASIN"
"ATAN"
"ATAN2"
"BANK"
"COS"
"DB"
"DEF"
"DIV"
"DS"
"DW"
"ELSE"
"ENDC"
"ENDM"
"ENDR"
"EQU"
"EQU"
"EXPORT"
"FAIL"
"GLOBAL"
"HIGH"
"HRAM"
"IF"
"INCBIN"
"INCLUDE"
"LOW"
"MACRO"
"MUL"
"OPT"
"POPO"
"POPS"
"PRINTF"

```

“PRINTT”
“PRINTV”
“PURGE”
“PUSHO”
“PUSHS”
“REPT”
“RB”
“RL”
“ROM0”
“ROMX”
“RSRESET”
“RSSET”
“RW”
“SECTION”
“SET”
“SHIFT”
“SIN”
“SRAM”
“STRCAT”
“STRCMP”
“STRIN”
“STRLEN”
“STRLWR”
“STRSUB”
“STRUPR”
“TAN”
“VRAM”
“WRAM0”
“WRAMX”
“WARN”

SEE ALSO

rgbasm(1), *rgbblink(1)*, *rgbblink(5)*, *rgbds(5)*, *rgbds(7)*, *gbz80(7)*

HISTORY

rgbds was originally written by Carsten Sørensen as part of the ASMotor package, and was later packaged in RGBDS by Justin Lloyd. It is now maintained by a number of contributors at <https://github.com/rednex/rgbds>.