

PICO-8
40.2.0H

The logo is a small, pixelated cross shape. The center is a white pixel. The four arms of the cross are composed of two pixels each, with colors: top is red, bottom is blue, left is yellow, and right is pink.

PICO-8 v0.2.0h

<https://www.pico-8.com>

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PICO-8 is built with:

SDL2 >> <http://www.libsdl.org>

Lua 5.2 >> <http://www.lua.org>

GIFLIB >> <http://giflib.sourceforge.net/>

WiringPi >> <http://wiringpi.com/>

libb64 by Chris Venter

miniz by Rich Geldreich

ws281x by jgarff

WELCOME TO PICO-8!

PICO-8 is a fantasy console for making, sharing and playing tiny games and other computer programs. When you turn it on, the machine greets you with a shell for typing in Lua programs and provides simple built-in tools for creating sprites, maps and sound.

The harsh limitations of PICO-8 are carefully chosen to be fun to work with, encourage small but expressive designs and hopefully to give PICO-8 cartridges their own particular look and feel.

KEYS

Toggle Fullscreen: Alt+Enter

Quit: Alt+F4 or CMD+Q

Reload/Run/Restart cart: Ctrl+R

Quick-Save: Ctrl+S

Mute/Unmute: Ctrl+M

Default Controls

Player 1 defaults: Cursors + ZX / NM / CV

Player 2 defaults: SDFE + tab,Q / shift A Enter or P for pause menu (while running)

Use **KEYCONFIG** to change the defaults.

SPECS

Display: 128x128, fixed 16 colour palette

Input: 6-button controllers

Cartridge size: 32k

Sound: 4 channel, 64 definable chip blerps

Code: Lua (max 8192 tokens of code)

Sprites: Single bank of 128 8x8 sprites (+128 shared)

Map: 128x32 8-bit cells (+128x32 shared)

HELLO WORLD

After PICO-8 boots, try typing some of these commands followed by enter:

```
PRINT("HELLO WORLD")
RECTFILL(80,80,120,100,12)
CIRCFILL(70,90,20,14)
FOR I=1,4 DO PRINT(I) END
```

(Note: PICO-8 only displays upper-case characters -- just type normally without caps-lock [shifted characters produce glyph characters])

You can build up an interactive program by using commands like this in the code editing mode along with two special callback functions `_UPDATE` and `_DRAW`. For example, the following program allows you to move a circle around with the cursor keys. Press Esc to switch to the code editor and type or copy & paste the following code:

```
X=64 Y=64
```

```
FUNCTION _UPDATE()
```

```
IF (BTN(0)) THEN X=X-1 END
IF (BTN(1)) THEN X=X+1 END
IF (BTN(2)) THEN Y=Y-1 END
IF (BTN(3)) THEN Y=Y+1 END

END

FUNCTION _DRAW() CLS(5)
CIRCFILL(X,Y,7,14)

END
```

Now press ESC to return to the console and type RUN (or press CTRL-R) to see it in action.

Please refer to the demo cartridges for more complex programs (type INSTALL_DEMOS).

If you want to store your program for later, use the SAVE command:

```
SAVE <NAME>
```

e.g.

```
SAVE PINKCIRC
```

And to load it again:

```
LOAD <NAME>
```

e.g.

```
LOAD PINKCIRC
```

EXAMPLE CARTRIDGES

These cartridges are included with PICO-8 and can be installed by typing:

```
INSTALL_DEMOS  
CD DEMOS  
LS
```

HELLO

Greetings from PICO-8

API

Demonstrates most PICO-8 functions

JELPI

Platform game demo w/ 2p support

CAST

2.5D Raycaster demo

DRIPPY

Draw a drippy squiggle

WANDER

Simple walking simulator

COLLIDE

Example wall and actor collisions

To run a cartridge, open PICO-8 and type:

```
LOAD JELPI  
RUN
```

Press ESC to stop the program, and once more to enter editing mode.

A small collection of BBS carts can also be installed with:

```
INSTALL_GAMES
```

FILE SYSTEM

These commands can be used to manage files and directories (folders):

LS	list the current directory
CD <NAME>	change directory
CD ..	go up a directory
CD /	go up to PICO's home directory
MKDIR <NAME>	make a directory
FOLDER	open the current directory in the host OS's file browser
LOAD <NAME>	load a cart from the current directory
SAVE <NAME>	save a cart to the current directory

If you want to move files around, duplicate them or delete them, use the **FOLDER** command and do it in the host operating system. The default location for PICO-8's drive is:

Windows: C:/Users/Yourname/AppData/Roaming/pico-8/carts

macOS: ~/Library/Application Support/pico-8/carts

Linux: ~/.lexaloffle/pico-8/carts

You can change this and other settings in **pico-8/config.txt**

Tip: The drive directory can be mapped to a cloud drive (provided by Dropbox or similar) in order to create a single disk shared between PICO-8 machines spread across different host machines.

LOADING AND SAVING

When using `LOAD` and `SAVE`, the `.P8` extension can be omitted and is added automatically.

Saving to a `.p8.png` extension will save the cartridge in a special image format that looks like a cartridge.

Use a filename of `"CLIP"` to load or save to the clipboard.

Once a cartridge has been loaded or saved, it can also be quick-saved with `CTRL-S`.

SAVING .P8.PNG CARTS WITH A TEXT LABEL AND PREVIEW IMAGE

To generate a label image saved with the cart, run the program first and press `CTRL-7` to grab whatever is on the screen. The first two lines of the program starting with `--` are also drawn to the cart's label.

e.g.

```
-- OCEAN DIVER LEGENDS -- BY LOOPY
```

CODE SIZE RESTRICTIONS FOR .PNG FORMAT

When saving in `.png` format, the compressed size of the code must be less than 15360 bytes. To find out the current size of your code, use the `INFO` command. The compressed size limit is not enforced for saving in `.p8` format.

USING AN EXTERNAL TEXT EDITOR

It is possible to edit .p8 files directly with a separate text editor. Using CTRL-R to run a cartridge will automatically reload the file if:

- 1 There are no unsaved changes in the PICO-8 editors, AND
- 2 The file differs in content from the last loaded version

If there are changes to both the cart on disk and in the editor, a notification is displayed:

DIDN'T RELOAD; UNSAVED CHANGES

PICO-8 does not fully support upper-case characters, and they are automatically converted to lower-case when viewed in the code editor. Note that this also causes unsaved changes to exist, which means that CTRL-R will stop automatically reloading the version on disk until it is manually `LOAD()`d.

Glyph characters (typed with shift-A..Z) are stored in .p8 format and in the host operating system's clipboard as rough Unicode equivalents.

BACKUPS

If you quit without saving changes, or overwrite an existing file, a backup of the cartridge is saved to `{appdata}/pico-8/backup`. An extra copy of the current cartridge can also be saved to the same folder by typing `BACKUP`.

CONFIGURATION

CONFIG.TXT

You can find some settings in `config.txt`. Edit the file when PICO-8 is not running.

Windows: `C:/Users/Yourname/AppData/Roaming/pico-8/config.txt`

OSX: `/Users/Yourname/Library/Application Support/pico-8/config.txt`

Linux: `~/.lexaloffle/pico-8/config.txt`

Use the `-home` switch (below) to use a different path `config.txt` and other data. Some settings can be changed while running PICO-8 by

`CONFIG SETTING VALUE`.

(type `CONFIG` by itself for a list)

COMMANDLINE PARAMETERS

note: these override settings found in `config.txt`

`pico-8 [switches] [filename.p8]`

<code>-width n</code>	set the window width
<code>-height n</code>	set the window height
<code>-windowed n</code>	set windowed mode off (0) or on (1)

<code>-volume n</code>	set audio volume (0..256)
<code>-joystick n</code>	joystick controls starts at player n (0..7)
<code>-pixel_perfect n</code>	1 for unfiltered screen stretching at integer scales (on by default)
<code>-preblit_scale n</code>	scale the display by n before blitting to screen (useful with <code>-pixel_perfect 0</code>)
<code>-draw_rect x,y,w,h</code>	absolute window coordinates and size to draw pico-8's screen
<code>-run filename</code>	load and run a cartridge
<code>-x filename</code>	execute a PICO-8 cart headless and then quit (experimental!)
<code>-export param_str</code>	run EXPORT command in headless mode and exit (see notes under export)
<code>-p param_str</code>	pass a parameter string to the specified cartridge
<code>-splore</code>	boot in splore mode
<code>-home path</code>	set the path to store config.txt and other user data files
<code>-root_path path</code>	set the path to store cartridge files
<code>-desktop path</code>	set a location for

	screenshots and gifs to be saved
<code>-screenshot_scale n</code>	scale of screenshots. default: 3 (368x368 pixels)
<code>-gif_scale n</code>	scale of gif captures. default: 2 (256x256 pixels)
<code>-gif_len n</code>	set the maximum gif length in seconds (1..120)
<code>-gui_theme n</code>	use 1 for a higher contrast editor colour scheme
<code>-timeout n</code>	how many seconds to wait before downloads timeout (default: 30)
<code>-software_blit n</code>	use software blitting mode off (0) or on (1)
<code>-foreground_sleep_ms n</code>	how many milliseconds to sleep between frames.
<code>-background_sleep_ms n</code>	how many milliseconds to sleep between frames when running in background
<code>-accept_future n</code>	use 1 to allow loading cartridges made with future versions of PICO-8

CONTROLLER SETUP

PICO-8 uses the SDL2 controller configuration scheme. It will detect common controllers on startup and also looks for custom mappings in `sdl_controllers.txt` in the same directory as `config.txt`. `sdl_controllers.txt` has one mapping per line.

To generate a custom mapping string for your controller, use

either the `controllermap` program that comes with SDL2, or try <http://www.generalarcade.com/gamepadtool/>

To find out the id of your controller as it is detected by SDL2, search for "joysticks" or "Mapping" in `log.txt` after running PICO-8. This id may vary under different operating systems. See: <https://www.lexaloffle.com/bbs/?tid=32130>

To set up which keyboard keys trigger joystick buttons presses, use `KEYCONFIG`.

SCREENSHOTS, VIDEOS AND CARTRIDGE LABELS

While a cartridge is running use:

CTRL-6	Save a screenshot to desktop
CTRL-7	Capture cartridge label image
CTRL-8	Start recording a video
CTRL-9	Save GIF video to desktop (8 seconds by default)

You can save a video at any time (it is always recording); CTRL-8 simply resets the video starting point. To record more than 8 seconds, use the `CONFIG` command (maximum: 120):

```
CONFIG GIF_LEN 60
```

If you would like the recording to reset every time (to create a non- overlapping sequence), use:

```
CONFIG GIF_RESET_MODE 1
```

The gif format can not match 30fps exactly, so PICO-8 instead

uses the closest match: 33.3fps.

If you have trouble saving to the desktop, try configuring an alternative desktop path in `config.txt`

SHARING CARTRIDGES

There are three ways to share carts made in PICO-8:

1. Share the .p8 or .p8.png file directly with other PICO-8 users. Type `FOLDER` to open the current folder in your host operating system.
2. Post the cart on the Lexaloffe BBS to get a web-playable version: <http://www.lexaloffle.com/pico-8.php?page=submit>
3. Export the cartridge to a stand-alone html/js or native binary player: (see the exporters section for details)

EXPORTERS / IMPORTERS

The `EXPORT` command can be used to generate .png, .wav files and stand-alone .html and native binary cartridge players. The output format is inferred from the filename extension (e.g. .png).

You are free to distribute and use exported cartridges and data as you please, provided that you have permission from the author and contributors.

SPRITE SHEET (.PNG)

Expects 128x128 png and colour-fits to the pico-8 palette

`IMPORT BLAH.PNG`

Use `FOLDER()` to locate the exported .png

`EXPORT BLAH.PNG`

SFX AND MUSIC (.WAV)

Export music from the current pattern (when editor mode is MUSIC):

```
EXPORT <NAME>.WAV
```

Export the current SFX (when editor mode is SFX):

```
EXPORT <NAME>.WAV
```

Exports all of the SFXs as blah0.wav, blah1.wav .. blah63.wav

```
EXPORT <NAME>%D.WAV
```

HTML PLAYER (.HTML)

To generate a stand-alone HTML player (foo.html, foo.js):

```
EXPORT FOO.HTML
```

Or just the .js file:

```
EXPORT FOO.JS
```

Use **-F** to write the files to a folder called foo_html, using index.html instead of foo.html

```
EXPORT -F FOO.HTML
```

Optionally provide a custom HTML template with the **-P** switch:

```
EXPORT FOO.HTML -P ONE_BUTTON
```

This will use the file {application data}/pico-8/plates/one_button.html as the

HTML shell, replacing a special string, ##js_file##, with the .js filename.

Use **-W** to export as .wasm + .js: (still experimental!)

```
EXPORT -W FOO.HTML
```

BINARY PLAYER (.BIN)

To generate stand-alone executables for Windows, Linux (64-bit), Mac and Raspberry Pi:

```
EXPORT FOO.BIN
```

By default, the cartridge label is used as an icon with no transparency. To specify an icon from the sprite sheet, use **-i** and optionally **-s** and/or **-c** to control the size and transparency.

-I N Icon index N with a default transparent colour of 0 (black).

-S N Size NxN sprites. Size 3 would be produce a 24x24 icon.

-C N Treat colour N as transparent. Use 16 for no transparency.

For example, to use a 2x2 sprite starting at index 32 in the spritesheet, using colour 12 as transparent:

```
EXPORT -I 32 -S 2 -C 12 FOO.BIN
```


Technical note: Windows file systems do not support the file metadata needed to create a Linux or Mac executable. PICO-8 works around this by exporting zip files in a way that preserves the file attributes, as long as the zip files are not re-packaged. Otherwise, a Linux user who then downloads the binaries may need to "chmod a+x foo" the file to run it, and Mac user would need to "chmod a+x foo.app/Contents/MacOS/foo". This issue can be avoided by distributing exported .zip files as-is after using the `EXPORT` command on Windows.

UPLOADING TO ITCH.IO

If you would like to upload your exported cartridge to itch.io as playable html:

1. From inside PICO-8: `EXPORT -F FOO.HTML`
2. Create a new project from your itch dashboard.
3. Zip up the folder and upload it (set "This file will be played in the browser")
4. Embed in page, with a size of 750px x 680px.
5. Set "Mobile Friendly" on (default orientation) and "Automatically start on page load" on. (No need for the fullscreen button; the default PICO-8 template has its own.)
6. Set the background (BG2) to something dark (e.g. #232323) and the text to something light (#cccccc)

EXPORTING MULTIPLE CARTRIDGES

Up to 16 cartridges can be bundled together by passing them to `EXPORT`, when generating stand-alone html or native binary players.

```
EXPORT FOO.HTML DAT1.P8 GAME2.P8
```

During runtime, the extra carts can be accessed as if they were local files:

Load spritesheet from DAT1.P8:

```
RELOAD(0,0,0x2000, "DAT1.P8")
```

Load and run another cart:

```
LOAD("GAME2.P8")
```

RUNNING EXPORT FROM THE HOST OPERATING SYSTEM

Use the `-export` switch when launching PICO-8 to run the exporter in headless mode. Output is to the current directory rather than the PICO-8 file system. Parameters to the EXPORT command are passed along as a single (lowercase) string:

```
=====
pico8 foo.p8 -export "-i 32 -s 2 -c 12 foo.bin dat0.p8 dat1.p8"
=====
```

LIMITATIONS OF EXPORTED CARTRIDGES

Exported cartridges are unable to load and run BBS cartridges e.g. via `LOAD("#FOO")`

SPLORE

SPLORE is a built-in utility for browsing and organising

both local and bbs (online)
cartridges. Type `SPLORE` to launch it, or launch PICO-8 with
`-splore`.

It is possible to control `SPLORE` entirely with a joystick:
`LEFT` and `RIGHT` to navigate lists of cartridges
`UP` AND `DOWN` to select items in each list
`X,0` or `MENU` to launch the cartridge

While inside a cart, press `MENU` to favourite a cartridge or
exit to `splore`. If you're using a keyboard, it's also possible
to press `F` to favourite an item while it is selected in the
cartridge list view.

When viewing a list of BBS carts, use the top list item to
re-download a list of cartridges. If you are offline, the last
downloaded list is displayed, and it is still possible to play
any cartridges you have downloaded.

If you have installed PICO-8 on a machine with no internet
access, you can also use `INSTALL_GAMES` to add a small selection
of pre-installed BBS carts to `/games`

QUIRKS of PICO-8

Common gotchas to watch out for:

- The bottom half of the spritesheet and bottom half of the map occupy the same memory. (Best use only one or the other if you're unsure how this works).
- PICO-8 numbers have limited accuracy and range; the minimum step between numbers is approximately 0.00002 (0x0.0001), with a range of -32768 (-0x8000) to approximately 32767.99999 (0x7fff.ffff)[If you add 1 to a counter each frame, it will overflow after around 18 minutes!]
- Lua arrays are 1-based by default, not 0-based. `FOREACH` starts at `TEL[1]`, not `TEL[0]`.
- `COS()` and `SIN()` take `0..1` instead of `0..PI*2`, and `SIN()` is inverted.
- `SGN(0)` returns 1.

- Toggle fullscreen: use `OPTION-ENTER` on macOS (`CMD-F` is used for searching text).
- When you want to export a .png cartridge, use `SAVE`, not `EXPORT`. `EXPORT` will save only the spritesheet!

EDITOR MODE

Press `ESC` to toggle between console and editor.

Click editing mode tabs at top right to switch or press `ALT+LEFT/RIGHT` (macOS: `OPTION+LEFT/RIGHT`)

WARNING: The second half of the sprite sheet (banks 2 and 3), and the bottom half of the map share the same cartridge space. It's up to you how you use the data, but be aware that drawing on the second half of the sprite sheet could corrupt data on the map and vice versa.

macOS users: If you see a command with a **PINK CTRL** replace the `CTRL` with a `CMD` (some commands below conflict with macOS's native commands)

CODE EDITOR

Hold shift to select (or click and drag with mouse)

`CTRL-X`, `C`, `V` to cut copy or paste selected

`CTRL-Z`, `Y` to undo, redo

`CTRL-F` to search for text in the current tab

`CTRL-G` to repeat the last search again

`CTRL-L` to jump to a line number

CTRL-UP, **DOWN** to jump to start or end

ALT-UP, **DOWN** to navigate to the previous, next function

CTRL-LEFT, **RIGHT** to jump by word

`CTRL-W`, `E` to jump to start or end of current line

CTRL-D to duplicate current line
TAB to indent a selection (shift to un-indent)
CTRL-B to comment / uncomment selected block

To enter special characters that represent buttons (and other glyphs), use SHIFT-L,R,U,D,O,X. There are 3 additional font entry modes that can be toggled:

CTRL-J : Hiragana	type romanji equivalents (ka, ki, ku..)
CTRL-K : Katakana	+ shift-0..9 for extra symbols
CTRL-P Puny font	hold shift for the standard font.

TABS

Click the [+] button at the top to add a new tab.
Navigate tabs by left-clicking, or with CTRL-TAB*, SHIFT-CTRL-TAB*.
To remove the last tab, delete any contents and then moving off it (CTRL-A, BACKSPACE/DELETE, CTRL-TAB*)
When running a cart, a single program is generated by concatenating all tabs in order.

CODE LIMITS

The current number of code tokens is shown at the bottom right. One program can have a maximum of 8192 tokens. Each token is a word (e.g. variable name) or operator. Pairs of brackets, and strings each count as 1 token. Commas, periods, **LOCALs**, semi-colons, **ENDs**, and comments are not counted.

Right click to toggle through other stats (character count, compressed size). If a limit is reached, a warning light will flash. This can be disabled by right-clicking.

SPRITE EDITOR

The sprite editor is designed to be used both for sprite-

wise editing and for freeform pixel-level editing. The sprite navigator at the bottom of the screen provides an 8x8-wise view into the sprite-sheet, but it is possible to use freeform tools (pan, select) when dealing with larger or oddly sized areas.

Draw Tool

- Click and drag on the sprite to plot pixels
- Applies to visible area
- Hold CTRL to search and replace a colour
- Use right mouse button to select colour

Stamp Tool

- Click to stamp whatever is in the copy buffer
- Hold LCTRL to treat colour 0 (black) as transparent

Select Tool (shortcut: LSHIFT or S)

- Create a selection
- Enter or click to select none.

If a pixel-wise selection is not present, many operations are instead applied to a sprite-wise selection, or the visible view. To select sprites, shift-drag in the sprite navigator. To select the spritesheet press CTRL-A (repeat to toggle off the bottom half shared with map data)

Pan Tool (shortcut: spacebar)

- View the spritesheet.

Fill Tool

- Fill with the current colour
- Applies to the current selection
- If no selection, applies to visible area

Shape Tools

- Click the tool button to cycle through: circle, rectangle, line
- Hold CTRL to get a filled circle or rectangle

Extra keys

- CTRL-Z to undo
- CTRL-C to copy selected area or selected sprites
- CTRL-V to paste to current sprite location
- Q,W to switch to previous/next sprite
- 1,2 to switch to previous/next colour
- Tab to toggle fullscreen view
- Mousewheel or < and > to zoom (centred in fullscreen)

Operations on selected area or selected sprites:

- F to flip
- V to flip vertically
- R to rotate (must be square selection)
- Cursor keys to move (loops if sprite selection)

Sprite flags

The 8 coloured circles are sprite flags for the current sprite.

Each one can be true (on) or false (off), and are accessed by using the **FSET** and **FCET** functions. They are indexed from 0, from the left (0,1,2..7). See **FSET()** for more information.

MAP EDITOR

The PICO-8 map is a 128x32 (or 128x64 using shared space) block of 8-bit values. Each value is shown in the editor as a reference to a sprite (0..255), but you can, of course, use the data to represent whatever you like.

The tools are similar to the ones used in sprite editing mode. Select a sprite and click and drag to paint values into the map.

To draw multiple sprites, select from sprite navigator with SHIFT+drag.

To copy a block of values, use the selection (LSHIFT or S) tool and then stamp tool to paste.

To pan around the map, use the pan tool or hold space.

Press Q,W to switch to the previous/next sprite.

Mousewheel or < and > to zoom (centred in fullscreen)

To move sprites in the spritesheet without breaking references to them in the map:

1. Back up your cartridge!
2. Optionally select the area of the map you would like to alter; it defaults to the top half.(Press CTRL-A twice for whole map **including shared memory**.)
3. Select the sprites you would like to move (while still in map view), and press CTRL-X
4. Select the destination sprite (also while still in map view) and press CTRL-V

SFX EDITOR

There are 64 SFX ("sound effects") in a cartridge, used for both sound and music.

Each SFX has 32 notes, and each note has:

A frequency	(C0..C5)
An instrument	(0..7)
A volume	(0..7)
An effect	(0..7)

Each SFX also has these properties:

A play speed (SPD) : the number of 'ticks' to play each note for. (1 is fastest, 3 is 3x as slow, etc.)

Loop start and end : this is the note index to loop back and to (Looping is turned off when the start index \geq end index)

There are 2 modes for editing/viewing a SFX: Pitch mode (more suitable for sound effects) and tracker mode (more

suitable for music). The mode can be changed using the top-left buttons, or toggled with TAB.

1. Pitch Mode

Click and drag on the pitch area to set the frequency for each note, using the currently selected instrument (indicated by colour).

Hold SHIFT to apply only the selected instrument

Hold CTRL to snap entered notes to the C minor pentatonic scale

2. Tracker Mode

Each note shows: frequency octave instrument volume effect

To enter a note, use

```
|q-2-w-3-e-r-5-t-6-y-7-u-i|  
|z-s-x-d-c-v-g-b-h-n-j-m|
```

(piano-like layout)

Hold SHIFT when entering a note to transpose -1 octave .. +1 octave.

New notes are given the selected instrument/effect values.

To delete a note, use BACKSPACE or set the volume to 0.

Click and then SHIFT-click to select a range that can be copied(CTRL-C) and pasted (CTRL-V). Note that only the selected attributes are copied. Double-click to select all attributes of a single note.

Navigation:

PAGEUP/DOWN or CTRL-UP/DOWN to skip up or down 4 notes

HOME/END to jump to the first or last note

CTRL-LEFT/RIGHT to jump across columns

3. Controls for both modes

- + to navigate the current SFX.

< > to change the speed.

SPACE to play/stop.

SHIFT-SPACE to play from the current SFX quarter (group of 8 notes)

A to release a looping sample

Left click or right click to increase / decrease the SPD or LOOP values (Hold shift when clicking to increase / decrease by 4, alternatively, click and drag left/right or up/down)

SHIFT-click an instrument, effect, or volume to apply to all notes.

EFFECTS

0 none

1 slide

Slide to the next note and volume

2 vibrato

Rapidly vary the pitch within one quarter-tone

3 drop

Rapidly drop the frequency to very low values

4 fade in

Ramp the volume up from 0

5 fade out

Ramp the volume down to 0

6 arpeggio fast

Iterate over groups of 4 notes at speed of 4

7 arpeggio slow

Iterate over groups of 4 notes at speed of 8

If the SFX speed is ≤ 8 , arpeggio speeds are halved to 2, 4

MUSIC EDITOR

Music in PICO-8 is controlled by a sequence of 'patterns'. Each pattern is a list of 4 numbers indicating which SFX will be played on that channel.

FLOW CONTROL

Playback flow can be controlled using the 3 buttons at the top right.

When a pattern has finished playing, the next pattern is played unless:

- there is no data left to play (music stops)
- a `STOP` command is set on that pattern (the third button)
- a `LOOP BACK` command is set (the 2nd button), in which case the music player searches back for a pattern with the `LOOP START` command set (the first button) or returns to pattern 0 if none is found.

When a pattern has SFXes with different speeds, the pattern finishes playing when the left-most non-looping channel has finished playing. This can be used to set up time signatures that don't divide into 32, double-time drum beats, etc.

COPYING MUSIC BETWEEN OR WITHIN CARTRIDGES

To select a range of patterns: click once on the first pattern in the pattern navigator, then `SHIFT`-click on the last pattern. Selected patterns can be copied and pasted with `CTRL-C` and `CTRL-V`. When pasting into another cartridge, the SFX that each pattern points to

will also be pasted (possibly with a different index) if it does not already exist.

SFX INSTRUMENTS

In addition to the 8 built-in instruments, custom instruments can be defined using the first 8 SFX. Use the toggle button to the right of the instruments to select an index, which will show up in the instrument channel as **green** instead of **pink**.

When an SFX instrument note is played, it essentially triggers that SFX, but alters the note's attributes:

- Pitch is added relative to C2

- Volume is multiplied

- Effects are applied on top of the SFX instrument's effects

For example, a simple tremolo effect could be implemented by defining an instrument in SFX 0 that rapidly alternates between volume 5 and 2. When using this instrument to play a note, the volume can further be altered as usual (via the volume channel or using the fade in/out effects). In this way, SFX instruments can be used to control combinations of detailed changes in volume, pitch and texture.

SFX instruments are only re-triggered when the pitch changes, or the previous note has zero volume. This is useful for instruments that change more slowly over time.

For example: a bell that gradually fades out. To invert this behaviour, effect 3 (normally 'drop') can be used when triggering the note. All other effect values have their usual meaning when triggering SFX instruments.

LUA SYNTAX PRIMER

PICO-8 programs are written using Lua syntax, but do not use the standard Lua library. The following is a brief summary of essential Lua syntax. For more details, or to find out about proper Lua, see www.lua.org.

COMMENTS

```
-- USE TWO HYPHENS LIKE THIS TO IGNORE EVERYTHING
UNTIL THE END OF THE LINE
--[[ MULTI-LINE
   COMMENTS ]]
```

TYPES AND ASSIGNMENT

Types in Lua are numbers, strings, booleans and tables:

```
NUM = 12/100
S = "THIS IS A STRING"
B = FALSE
T = {1,2,3}
```

Numbers in PICO-8 are all 16:16 fixed point. They range from -32768.0 to 32767.99999

Hexadecimal notation with optional fractional parts can be used:

0x11	17
0x11.4000	17.25

Numbers written in decimal are rounded to the closest fixed point value. To see the 32-bit hexadecimal representation, use `PRINT(TOSTR(VAL,TRUE))`:

?TOSTR(-32768,TRUE)	0x8000.0000
?TOSTR(32767.99999,TRUE)	0x7fff.ffff

Dividing by zero evaluates to `0x7fff.ffff` if positive, or `-0x7fff.ffff` if negative.

CONDITIONALS

```
IF NOT E THEN
    PRINT("E IS FALSE")
ELSE
    PRINT("E IS NOT FALSE")
END

-- WITH ELSEIF

IF X == 0 THEN
    PRINT("X IS 0")
ELSEIF X < 0 THEN
    PRINT("X IS NEGATIVE")
ELSEIF X > 0 THEN
    PRINT("X IS POSITIVE")
ELSE
    PRINT("THIS LINE IS NEVER REACHED")
END

IF (4 == 4) THEN PRINT("EQUAL") END
IF (4 != 3) THEN PRINT("NOT EQUAL") END
IF (4 <= 4) THEN PRINT("LESS THAN OR EQUAL") END
IF (4 > 3) THEN PRINT("MORE THAN") END
```

Loops

```
FOR X=1,5 DO
    PRINT(X)
END
-- PRINTS 1,2,3,4,5

X = 1
WHILE(X <= 5) DO
    PRINT(X)
    X = X + 1
END

FOR X=1,10,3 DO PRINT(X) END    -- 1,4,7,10
FOR X=5,1,-2 DO PRINT(X) END  -- 5,3,1
```

FUNCTIONS AND LOCAL VARIABLES

```
y=0
function PLUSONE(x)
    local y = x+1
    return y
end
print(PLUSONE(2)) -- 3
print(y)          -- 0
```

TABLES

In Lua, tables are a collection of key-value pairs where the key and value types can both be mixed. They can be used as arrays by indexing them with integers.

```
A={} -- CREATE AN EMPTY TABLE
A[1] = "BLAH"
A[2] = 42
A["FOO"] = {1,2,3}

-- ARRAYS USE 1-BASED INDEXING BY DEFAULT

A = {11,12,13,14}
print(A[2]) -- 12

-- THE SIZE OF A TABLE INDEXED WITH SEQUENTIAL 1-BASED
-- INTEGERS:

print(#A) -- 4

-- INDEXES THAT ARE STRINGS CAN BE WRITTEN USING DOT
-- NOTATION

PLAYER = {}
PLAYER.X = 2 -- IS EQUIVALENT TO PLAYER["X"]
PLAYER.Y = 3

-- SEE ALSO THE TABLES SECTION IN THE API REFERENCE
-- BELOW.
```

PICO-8 SHORTHAND

PICO-8 also allows several non-standard, shorter ways to write common patterns.

1. IF THEN END statements, and WHILE THEN END can be written on a single line with:

```
IF (NOT E) I=1 J=2
```

```
-- IS EQUIVALENT TO: IF NOT E THEN I=1 J=2 END  
-- NOTE THAT BRACKETS AROUND THE SHORT-HAND CONDITION  
-- ARE REQUIRED.
```

2. Assignment operators

Shorthand assignment operators can also be used if the whole statement is on one line. They can be constructed by appending a '=' to any binary operator, including arithmetic (+, -, ..), bitwise (&=, |= ..) or the string concatenation operator (..=):

```
A += 2 -- EQUIVALENT TO: A = A + 2
```

3. != operator

Not shorthand, but pico-8 also accepts != instead of \neq for "not equal to"

API

PICO-8 is built on the Lua programming language, but does not include the Lua standard library. Instead, a small API is offered in keeping with PICO-8's minimal design and limited screen space. For an example program that uses most of the API functions, see [/DEMOS/API.P8](#)

Functions are written here as:

FUNCTION_NAME **PARAMETER** [OPTIONAL_PARAMETER]

System functions called from commandline can omit the usual brackets and string quotes:

LOAD ELAH.P8 --> LOAD("ELAH.P8")

SYSTEM

LOAD FILENAME [BREADCRUMB [PARAM_STR]]
SAVE FILENAME

Load or save a cartridge.

When loading from a running cartridge, the loaded cartridge is immediately run with parameter string param_str, and a menu item is inserted and named breadcrumb, that returns the user to the loading cartridge.

Filenames that start with 'H' are taken to be a BBS cart followed by its ID:

LOAD("H1234") -- DOWNLOAD (AND RUN) CART NUMBER 1234

If the ID is the cart's parent post, or a revision

number is not specified, then the latest version is fetched. BBS carts can be loaded from other BBS carts or local carts, but not from exported carts.

FOLDER

Open the cart's folder in the host OS.

LS (also aliased as DIR)

List files in the current directory. When called from a running program, returns a list of all .p8 and .p8.png files in the same directory.

RUN

Run from the start of the program
Can be called from inside a program to reset program.

STOP [MESSAGE]

Stop the cart and optionally print a message.

RESUME

Resume the program. Use R for short.

Use a single "." from the commandline to advance a single frame. This enters frame-by-frame mode, that can be read with STAT(110). While frame-by-frame mode is active, entering an empty command (by pressing enter) advances one frames.

REBOOT

Reboot the machine
Useful for starting a new project

INFO

Print out some information about the cartridge:
Code size, tokens, compressed size

Also displayed:

UNSAVED CHANGES

When the cartridge in
memory differs to the one
on disk

EXTERNAL CHANGES

When the cartridge on disk
has changed since it was
loaded (e.g. by editing the
program using a separate
text editor)

FLIP

Flip the back buffer to screen and wait for next frame
(30fps)
Don't normally need to do this `_DRAW()` calls it for
you.

If your program does not call flip before a frame is
up, and a `_DRAW()` callback is not in progress, the
current contents of the back buffer are copied to
screen.

PRINTH STR [FILENAME] [OVERWRITE]

Print a string to host operating system's console for
debugging.

If filename is set, append the string to a file on the host operating system (in the current directory -- use `FOLDER` to view) Setting `overwrite` to true causes that file to be overwritten rather than appended. Use a filename of `"CLIP"` to write to the host's clipboard. (use `STAT(4)` to read the clipboard, but the contents of the clipboard are only available after pressing `CTRL-V` during runtime (for security reasons)).

TIME / T

Returns the number of seconds elapsed since the cartridge was run.

This is not the real-world time, but is calculated by counting the number of times `_UPDATE` or `_UPDATE(60)` is called. Multiple calls of `TIME()` from the same frame return the same result.

STAT %

Get system status where % is:

0	Memory usage (0..2048)
1	CPU used since last flip (1.0 == 100% CPU at 30fps)
4	Clipboard contents (after user has pressed CTRL-V)
6	Parameter string
7	Current framerate
16..19	Index of currently playing SFX on channels 0..3
20..23	Note number (0..31) on channel 0..3
24	Currently playing pattern index
25	Total patterns played
26	Ticks played on current pattern
80..85	UTC time: year, month, day, hour, minute, second
90..95	Local time

100	Current breadcrumb label, or nil
110	Returns true when in frame-by-frame mode

EXTCMD X

Special system command, where X is a string:

"PAUSE"	request the pause menu be opened
"RESET"	request a cart reset
"GO_BACK"	follow the current breadcrumb (if there is one)
"LABEL"	set cart label
"SCREEN"	save a screenshot
"REC"	set video start point
"VIDEO"	save a .gif to desktop
"AUDIO_REC"	start recording audio
"AUDIO_END"	save recorded audio to desktop
"SHUTDOWN"	quit cartridge (from exported binary)

PROGRAM STRUCTURE

There are 3 special functions that, if defined by the user, are called during program execution:

<code>_UPDATE()</code>	Called once per update at 30fps
<code>_DRAW()</code>	Called once per visible frame
<code>_INIT()</code>	Called once on program startup

`_DRAW()` is normally called at 30fps, but if it can not complete in time, PICO-8 will attempt to run at 15fps and call `_UPDATE()` twice per visible frame to compensate.

RUNNING PICO-8 AT 60FPS

If `_UPDATE60()` is defined instead of `_UPDATE()`, PICO-8 will run in 60fps mode:

- both `_UPDATE60()` and `_DRAW()` are called at 60fps
- half the PICO-8 CPU is available per frame before dropping down to 30fps

Note that not all host machines are capable of running at 60fps. Older machines, and / or web versions might also request PICO-8 to run at 30 fps (or 15 fps), even when the PICO-8 CPU is not over capacity. In this case, multiple `_UPDATE60()` calls are made for every `_DRAW()` call in the same way.

HINCLUDE

Source code can be injected into a program at cartridge boot (but not during runtime), using `"HINCLUDE FILENAME"`, where `FILENAME` is either a plaintext file (containing Lua code), a tab from another cartridge, or all tabs from another cartridge:

```
HINCLUDE SOMECODE.LUA
HINCLUDE ONETAB.P8:1
HINCLUDE ALLTABS.P8
```

When the cartridge is run, the contents of each included file is treated as if it had been pasted into the editor in place of that line.

- Filenames are relative to the current cartridge (so, need to save first)
- Includes are not performed recursively.
- Normal character count and token limits apply.

When a cartridge is saved as `.P8.PNG`, or exported to a binary, any included files are flattened and saved with the

cartridge so that there are no external dependencies.

MINCLUDE can be used for things like:

- Sharing code between cartridge (libraries or common multi-cart code)
- Using an external code editor without needing to edit the .p8 file directly.
- Treating a cartridge as a data file that loads a PICO-8 editing tool to modify it.
- Loading and storing data generated by an external (non-PICO-8) tool.

GRAPHICS

PICO-8 has a fixed capacity of 128 8x8 sprites, plus another 128 that overlap with the bottom half of the map data ("shared data"). These 256 sprites are collectively called the sprite sheet, and can be thought of as a 128x128 pixel image.

All of PICO-8's drawing operations are subject to the current draw state. The draw state includes a camera position (for adding an offset to all coordinates), palette mapping (for recolouring sprites), clipping rectangle, a drawing colour, and a fill pattern.

The draw state is reset each time a program is run. This is equivalent to calling:

CLIP() **CAMERA()** **PAL()** **COLOR()**

Colours indexes: (use American spellings)

0 black	1 dark_blue	2 dark_purple	3 dark_green
4 brown	5 dark_gray	6 light_gray	7 white
8 red	9 orange	10 yellow	11 green
12 blue	13 indigo	14 pink	15 peach

CLIP [X Y W H]

Sets the screen's clipping region in pixels
CLIP() to reset

PGET X Y

PSET X Y [C]

Get or set the colour (C) of a pixel at X, Y.

SGET X Y

SSET X Y [C]

Get or set the colour (C) of a spritesheet pixel.

SGET N [F]

SSET N [F] Ψ

Get or set the value (Ψ) of a sprite's flag
F is the flag index 0..7
Ψ is boolean and can be true or false

The initial state of flags 0..7 are settable in the
sprite editor, using the line of little colourful
buttons.

The meaning of sprite flags is up to the user, or can
be used to indicate which group ('layer') of sprites
should be drawn by map.

If the flag index is omitted, all flags are retrieved/
set as a bitfield:

```
FSET(2, 1+2*8)  -- SETS BITS 0,1 AND 3  
FSET(2, 4, TRUE) -- SETS BIT 4  
PRINT(FGET(2))  -- 27 (1+2*8+16)
```



```
PRINT STR X Y [COL]
PRINT STR [COL]
```

Print a string and optionally set the colour to col.

If x and y are not supplied, the text will automatically wrap and cause carriage returns / vertical scrolling similar to the command prompt.

```
CURSOR X Y [COL]
```

Set the cursor position and carriage return margin
If col is specified, also set the current colour.

```
COLOR [COL]
```

Set the current colour to be used by drawing functions
If col is not specified, the current colour is set to 6

```
CLS [COL]
```

Clear the screen and reset the clipping rectangle.
col defaults to 0 (black)

```
CAMERA [X Y]
```

Set a screen offset of -x, -y for all drawing operations
`CAMERA()` to reset

```
CIRC X Y R [COL]
CIRCFILL X Y R [COL]
```

Draw a circle or filled circle at X,Y with radius R
If R is negative, the circle is not drawn

LINE *X0 Y0 [X1 Y1] [COL]*

Draw line, if *X1,Y1* are not given the end of the last drawn line is used.

RECT *X0 Y0 X1 Y1 [COL]*
RECTFILL *X0 Y0 X1 Y1 [COL]*

Draw a rectangle or filled rectangle.

PAL *C0 C1 [P]*

Swap palette colour *C0* for *C1*, either in subsequent draw calls, or screen-wide.

PICO-8's draw state has two palettes. *P* specifies which one to modify, and defaults to 0:

0 draw palette: colours are remapped on draw (e.g. to re-colour sprites)

1 screen palette: colours are remapped on display (e.g. for fades or screen-wide effects)

For example, to swap colour 12 (blue) for colour 8 (red) when drawing a sprite:

```
PAL(8,12)  
SPR(1,60,60)
```

PAL() to reset to system defaults (including transparency values and fill pattern)

PAL TEL [*P*]

When the first parameter of *pal* is a table, colours are assigned for each entry.

For example, to re-map colour 12 and 14 to red:

```
PAL({[12]=9, [14]=8})
```

Or to re-colour the whole screen shades of grey (including everything that is already drawn):

```
PAL({1,1,5,5,5,6,7,13,6,7,7,6,13,6,7}, 1)
```

PALT C [T]

Set transparency for colour index to T (boolean)
Transparency is observed by `SPR()`, `SSPR()`, `MAP()` and `TLINE()`.

```
PALT [8, TRUE]
```

red pixels not drawn in subsequent sprite/`TLINE` draw calls. `PALT[]` resets to default: all colours opaque except colour 0.

When c is the only parameter, it is treated as a bitfield used to set all 16 values. For example: to set colours 0 and 1 as transparent:

```
PALT(0E1100000000000000)
```

SPR n x y [W H] [FLIP_X] [FLIP_Y]

draw sprite n (0..255) at position x,y
width and height are 1,1 by default and specify how many sprites wide to blit.

Colour 0 drawn as transparent by default (see `PALT[]`)

`FLIP_X=TRUE` to flip horizontally

`FLIP_Y=TRUE` to flip vertically

SSPR SX SY SW SH DX DY [DW DH] [FLIP_X] [FLIP_Y]

Stretch rectangle from sprite sheet (SX, SY, SW, SH) [given in pixels] and draw in rectangle (DX, DY, DW, DH). Colour 0 drawn as transparent by default (see **PALTI**). DW, DH defaults to SW, SH.
FLIP_X=**TRUE** to flip horizontally
FLIP_Y=**TRUE** to flip vertically

FILLP P

The PICO-8 fill pattern is a 4x4 2-colour tiled pattern observed by:

```
CIRC()  
CIRCFILL()  
RECT()  
RECTFILL()  
PSET()  
LINE()
```

P is a bitfield in reading order starting from the highest bit. To calculate the value of p for a desired pattern, add the bit values together:

32768	16384	8192	4096
2048	1024	512	256
128	64	32	16
8	4	2	1

For example, **FILLP**(**4+8+64+128+256+512+4096+8192**) would create a checkerboard pattern.

This can be more neatly expressed in binary:

```
FILLP(0E0011001111001100)
```

The default fill pattern is 0, which means a single solid colour is drawn.

To specify a second colour for the pattern, use the high bits of any colour parameter:

```
FILLP(0E0011010101101000)
CIRCFILL(64,64,20, 0X4E)
-- BROWN AND PINK
```

An additional bit **0E0.1** can be set to indicate that the second colour is not drawn.

```
FILLP(0E0011001111001100.1)
-- CHECKERBOARD WITH TRANSPARENT SQUARES
```

The fill pattern can also be set by setting bits in any colour parameter:

```
POKE(0X5F34, 1)
-- SETS INTEGRATED FILLPATTERN + COLOUR MODE
CIRCFILL(64,64,20, 0X114E.ABCD)
-- SETS FILL PATTERN TO ABCD

-- BIT 0X1000.0000 MEANS THE NON-COLOUR BITS
  SHOULD BE OBSERVED
-- BIT 0X0100.0000 TRANSPARENCY BIT
-- BITS 0X00FF.0000 ARE THE USUAL COLOUR BITS
-- BITS 0X0000.FFFF ARE INTERPRETED AS THE FILL
  PATTERN
```

TABLES

```
ADD T 4
```

Add value 4 to the end of table T.
Equivalent to **T[HT+1] = 4**

```

FOO={}           Create empty table
ADD(FOO, 11)
ADD(FOO, 22)
PRINT(FOO[2])   22

```

DEL T V

Delete the first instance of value `V` in table `T`
The remaining entries are shifted left one index to avoid holes.

Note that `V` is the value of the item to be deleted, not the index into the table!

`DEL()` can be called safely on a table's item while iterating over that table.

```

A={1,10,2,11,3,12}
FOR ITEM IN ALL(A) DO
    IF (ITEM < 10) THEN DEL(A, ITEM) END
END
FOREACH(A, PRINT) -- 10,11,12
PRINT(A[3])      -- 12

```

ALL T

Used in `FOR` loops to iterate over all items in a table (that have a 1-based integer index), in the order they were added.

```

T = {11,12,13};
ADD(T,14)
ADD(T,"HI")
FOR V IN ALL(T) DO PRINT(V) END -- 11 12 13 14 HI
PRINT(NT) -- 5

```

FOREACH T F

For each item in table `T`, call function `F` with the item as a single parameter.

```

FOREACH (T, PRINT)

```

PAIRS T

Used in **FOR** loops to iterate over table **T**, providing both the key and value for each item.

Unlike **ALL()**, **PAIRS()** iterates over every item regardless of indexing scheme.

Order is not guaranteed.

```
T = {["HELLO"]=3, [10]="BLAH"}
T.BLUE = 5;
FOR K,V IN PAIRS(T) DO
    PRINT("K: "..K.."  V:"..V)
END
```

Output:

```
K: 10  V:BLAH
K: HELLO  V:3
K: BLUE  V:5
```

INPUT

ETN [I] [P]

get button **I** state for player **P** (default 0)

I: 0..5: left right up down button_o button_x

P: player index 0..7

Instead of using a number for **I**, it is also possible to use a button glyph.

(In the coded editor, use SHIFT - L R U D O X)

If no parameters supplied, returns a bitfield of all 12 button states for player 0 & 1 (P0: bits 0..5 P1: bits 8..13)

Default keyboard mappings to player buttons:

```
Player 0: [DPAD]: Cursor Keys, [O]: Z C N  [X]: X V M
Player 1: [DPAD]: SFED,  [O]: LSHIFT  [X]: TAB W Q A
```

**** Note for cart authors:** when using a physical gamepad, certain combinations of buttons can be awkward (UP to jump/accelerate instead of [X] or [O]) or even impossible (LEFT + RIGHT)

ETNP [I [P]]

ETNP is short for "Button Pressed"; Instead of being true when a button is held down, **ETNP** returns true when a button is down AND it was not down the last frame. It also repeats after 15 frames, returning true every 4 frames after that (at 30fps -- double that at 60fps). This can be used for things like menu navigation or grid-wise player movement.

The state of **ETNP** is reset at the start of each call to **_UPDATE** or **_UPDATE60**, so it is preferable to use **ETNP** from inside one of those functions.

Custom delays (in frames @ 30fps) can be set by poking the following memory addresses:

POKE(0X5F5C, DELAY)	set the initial delay before repeating. 255 means never repeat.
POKE(0X5F5D, DELAY)	set the repeating delay.

In both cases, 0 can be used for the default behaviour (delays 15 and 4)

Audio

SFX N [CHANNEL [OFFSET [LENGTH]]]

play **SFX N** on channel (0..3) from note offset (0..31) for length notes

N -1 to stop sound on that channel

N -2 to release sound on that channel from looping

Any music playing on the channel will be halted
offset in number of notes (0..31)

channel -1 (default) to automatically choose a channel
that is not being used

channel -2 to stop the sound from playing on any
channel

MUSIC [N [FADE_LEN [CHANNEL_MASK]]]

Play music starting from pattern N (0..63).

N -1 to stop music.

FADE_LEN in ms (default: 0).

CHANNEL_MASK specifies which channels to reserve for
music only (e.g. to play on channels 0..2: 1+2+4 = 7).

Reserved channels can still be used to play sound
effects on, but only when that channel index is
explicitly requested by SFX().

MAP

The PICO-8 map is a 128x32 grid of 8-bit cells, or 128x64
when using the shared memory. When using the map editor,
the meaning of each cell is taken to be an index into the
spritesheet (0..255). However, it can instead be used as a
general block of data.

MGET X Y

MSET X Y V

get or set map value (V) at X,Y

MAP CELL_X CELL_Y SX SY CELL_W CELL_H [LAYERS]

Draw section of map (starting from CELL_X, CELL_Y) at
screen position SX, SY (pixels)

`MAP(0, 0, 20, 20, 4, 2)` -- DRAWS A 4x2 BLOCKS OF CELLS STARTING FROM 0,0 IN THE MAP, TO THE SCREEN AT 20,20

If `CELL_W` and `CELL_H` are not specified, defaults to `128, 32` (the top half of the map). To draw the whole map (including the bottom half shared with the spritesheet), use:

`MAP(0, 0, 0, 0, 128, 32)`

`Layers` is an 8-bit bitfield. When it is specified, only sprites with matching flags are drawn.

For example, when `layers` is `0x5`, only sprites with flag `0` and `2` are drawn.

Sprite `0` is always taken to mean empty, and is never drawn.

TLINE `%0 %0 %1 %1 %X %Y [%DX %DY] [LAYERS]`

Draw a textured line from `(%0,%0)` to `(%1,%1)`, sampling colour values from the map.

When `layers` is specified, only sprites with matching flags are drawn (similar to `MAP()`)

`%X, %Y` are map coordinates to sample from, given in tiles.

Colour values are sampled from the 8x8 sprite present at each map tile. For example:

`2.0, 1.0` means the top left corner of the sprite at position `2,1` on the map. `2.5, 1.5` means pixel `(4,4)` of the same sprite.

`%DX, %DY` are deltas added to `%X, %Y` after each pixel is drawn. (Defaults to `0.125, 0`).

The map coordinates `(%X, %Y)` are masked by values calculated by subtracting `0x0.0001` from the values at address `0x5F38` and `0x5F39`. In simpler terms, this means you can loop a section of the map by poking the

width and height you want to loop within, as long as they are powers of 2 (2,4,8,16..).

For example, to loop every 8 tiles horizontally, and every 4 tiles vertically:

```
POKE(0X5F38, 8)
POKE(0X5F39, 4)
TLINE(...)
```

The default values (0,0) gives a masks of 0XFF.FFFF, which means that the samples will loop every 256 tiles.

An offset to sample from (also in tiles) can also be specified at addresses 0X5F3A, 0X5F3B

```
POKE(0X5F3A, OFFSET_X)
POKE(0X5F3B, OFFSET_Y)
```

MEMORY

PICO-8 has 3 types of memory:

1. Base RAM (32k): see layout below. Access with `PEEK()` `POKE()` `MENCPY()` `MENSET()`
 2. Cart ROM (32k): same layout as base RAM until 0X4300
 3. Lua RAM (2MB): compiled program + variables
- (Technical note: You probably don't need to know ^this.)

While using the editor, the data being modified is in cart ROM, but API functions such as `SPR()` and `SFX()` only operate on base RAM. PICO-8 automatically copies cart ROM to base RAM (i.e. calls `RELOAD()`) in 3 cases:

1. When a cartridge is loaded
2. When a cartridge is run
3. When exiting any of the editor modes (can turn off with: `POKE(0X5F37,1)`)

Base RAM memory layout

0x0	CFX
0x1000	CFX2/MAP2 (SHARED)
0x2000	MAP
0x3000	CFX FLAGS
0x3100	SONG
0x3200	SFX
0x4300	USER DATA
0x5E00	PERSISTENT CART DATA (256 BYTES)
0x5F00	DRAM STATE
0x5F40	HARDWARE STATE
0x5F80	GPIO PINS (128 BYTES)
0x6000	SCREEN (8K)

User data has no particular meaning and can be used for anything via `MEMCOPY()`, `PEEK()` & `POKE()`. Persistent cart data is mapped to `0x5E00..0x5EFF` but only stored if `CARTDATA()` has been called. Colour format (`CFX/SCREEN`) is 2 pixels per byte: low bits encode the left pixel of each pair. Map format is one byte per cell, where each byte normally encodes a sprite index.

```
PEEK ADDR
POKE ADDR VAL
```

Read and write one byte to an address in base RAM.
Legal addresses are `0x0..0x7fff`
Reading out of range returns 0
Writing out of range causes a runtime error

```
PEEK2 ADDR
POKE2 ADDR VAL
PEEK4 ADDR
POKE4 ADDR VAL
```

16-bit and 32-bit versions. Read and write one number (val) in little-endian format:

16 bit: `0xffff.0000`
32 bit: `0xffff.ffff`

`ADDR` does not need to be aligned to 2 or 4-byte

boundaries.

Alternatively, the following operators can be used to **PEEK** (but not **POKE**), and are slightly faster:

CADDR	PEEK(ADDR)
WADDR	PEEK2(ADDR)
WADDR	PEEK4(ADDR)

MEMCPY DEST_ADDR SOURCE_ADDR LEN

Copy LEN bytes of base RAM from source to dest.
Sections can be overlapping.

RELOAD DEST_ADDR SOURCE_ADDR LEN [FILENAME]

Same as **MEMCPY**, but copies from cart ROM.
The code section ($\geq 0x4300$) is protected and can not be read.
If filename specified, load data from a different cartridge (must be local - BBS cartridges can not be read in this way).

CSTORE DEST_ADDR SOURCE_ADDR LEN [FILENAME]

Same as **MEMCPY**, but copies from base RAM to cart ROM
CSTORE() is equivalent to **CSTORE(0, 0, 0x4300)**
Can use for writing tools to construct carts or to visualise the state of the map / spritesheet using the map editor / GFX editor.
The code section ($\geq 0x4300$) is protected and can not be written to. If a filename is specified, the data is written directly to that cartridge on disk. Up to 64 cartridges can be written in one session. See the 'Cartridge Data' section for additional notes on using **CSTORE**.

MENSET DEST_ADDR VAL LEN

Set LEN bytes to VAL (quite fast; can use to draw unclipped horizontal scan-lines ASOASF)

MATH

MAX X Y
MIN X Y
MID X Y Z

Returns the maximum, minimum, or middle value of parameters. For example, **MID**(7.5,10) returns 7

FLR X
CEIL X

Returns the closest integer that is equal to or below / above x.

?**FLR** (4.1) --> 4
?**CEIL**(4.1) --> 5
?**FLR** (-2.3) --> -3
?**CEIL**(-2.3) --> -2

COS X
SIN X

Returns the cosine of X, where 1.0 indicates a full turn. Sin is inverted to suit screen space. e.g.
SIN(0.25) returns -1.

If you'd prefer radian-based trig functions without the **H** inversion, paste the following snippet near the start of your program:

```
COS1 = COS FUNCTION COS(ANGLE) RETURN COS1(ANGLE /  
(3.1415*2)) END
```

```
SIN1 = SIN FUNCTION SIN(ANGLE) RETURN -SIN1(ANGLE/  
(3.1415*2)) END
```

ATAN2 DX DY

Converts DX, DY into an angle from 0..1
As with COS/SIN, angle is taken to run anticlockwise
in screenspace
e.g. ATAN2(1, -1) returns 0.125

SQRT X

Return the square root of X

ABS X

Returns the absolute (positive) value of X

RND X

Returns a random number n, where $0 \leq n < x$
If you want an integer, use `FIR(RND(X))`
If X is an array-style table, return a random element
between `TABLE[1]` and `TABLE[#TABLE]`.

SRAND X

Sets the random number seed.
The seed is automatically randomised on cart startup.

BITWISE OPERATIONS

Bitwise operations are similar to logical expressions, except that they work at the bit level.

Say you have two numbers (written here in binary using the "0E" prefix):

```
X = 0E1010
Y = 0E0110
```

A bitwise **AND** will give you bits set when the corresponding bits in X and Y are both set:

```
PRINT(0EAND(X,Y)) -- RESULT:0E0010 (2 IN DECIMAL)
```

There are 9 bitwise functions available in PICO-8:

```
0EAND X Y -- BOTH BITS ARE SET
0EBOR X Y -- EITHER BIT IS SET
0EXOR X Y -- EITHER BIT IS SET, BUT NOT BOTH OF THEM
0ENOT X   -- EACH BIT IS NOT SET
0ESHL X N -- SHIFT LEFT N BITS (ZEROS COME IN FROM THE
           RIGHT)
0ESHR X N -- ARITHMETIC RIGHT SHIFT (THE LEFT-MOST BIT
           STATE IS DUPLICATED)
0ESHR X N -- LOGICAL RIGHT SHIFT (ZEROS COMES IN FROM
           THE LEFT)
0EOTL X N -- ROTATE ALL BITS IN X LEFT BY N PLACES
0EOTR X N -- ROTATE ALL BITS IN X RIGHT BY N PLACES
```

Operator versions are also available: **&**, **|**, **^^**, **~**, **<<**, **>>**, **>>>**, **<<<**, **>><** (respectively)

For example:

```
PRINT(67 & 63) -- RESULT:3  EQUIVALENT TO 0EAND(67,63)
```

Operators are slightly faster than their corresponding functions. They behave exactly the same, except that if any operands are not numbers the result is a runtime error (the

function versions instead default to a value of 0).

Integer Division

Integer division can be performed with a \

```
PRINT(9\2) -- RESULT:4  EQUIVALENT TO FLR(9/2)
```

CUSTOM MENU ITEMS

```
MENUITEM INDEX [LABEL CALLBACK]
```

Add an extra item to the pause menu

Index should be 1..5 and determines the order each menu item is displayed.

LABEL should be a string up to 16 characters long

CALLBACK is a function called when the item is selected by the users

When no label or function is supplied, the menu item is removed:

e.g.:

```
MENUITEM(1, "RESTART PUZZLE", FUNCTION()  
RESET_PUZZLE() SFX(10) END)
```

STRINGS

```
S = "THE QUICK BROWN FOX"

-- LENGTH
PRINT(WS)          -- 19

-- JOINING STRINGS
PRINT("THREE " .. 4) -- "THREE 4"

-- SUB() TO GRAB SUBSTRINGS
PRINT(SUB(S,5,9))   -- "QUICK"
PRINT(SUB(S,5))     -- "QUICK BROWN FOX"

-- CONVERSION
TOSTR(17)           -- RETURNS "17"
TOSTR(17,TRUE)      -- RETURNS "0X0011.0000"
TONUM("17")        -- RETURNS 17
CHR(64)             -- RETURNS "@"
ORD("@")            -- RETURNS 64
ORD("123",2)        -- RETURNS 50 (THE SECOND CHARACTER: "2")
```

TYPES

TYPE VAL

Returns the name of the type of value `V` as a string.

TOSTR VAL [HEX]

Returns `VAL` as a string.

If `hex` is true and `val` is a number, an unsigned hexadecimal writing of the number is returned in the

format "0x0000.0000". You can use this to inspect the internal representation of PICO-8 numbers.
If `VAL` is a boolean, it is written as "true" or "false".

All other `VAL` types are written as "[typename]" (use hex to include a hex identity in the string if available)

TONUM VAL

Converts `VAL` to a number.

If `VAL` is a string, the number is taken to be decimal unless prefixed with "0x" if the conversion fails, `TONUM` returns no value.

CARTRIDGE DATA

Using `CARTDATA()`, `DSET()`, and `DGET()`, 64 numbers (256 bytes) of persistent data can be stored on the user's PICO-8 that persists after the cart is unloaded or PICO-8 is shutdown. This can be used as a lightweight way to store things like high scores or to save player progress. It can also be used to share data across cartridges / cartridge versions.

If you need more than 256 bytes, it is also possible to write directly to the cartridge using `CSTORE()`. The disadvantage is that the data is tied to that particular version of the cartridge. e.g. if a game is updated, players will lose their save games. Also, some space in the data sections of the cartridge need to be left available.

Another alternative is to write directly to a second cartridge by specifying a fourth parameter to `CSTORE()`. This requires a cart swap (which in reality only means the user needs to watch a spinny cart animation for 1 second).

```
CSTORE(0,0,0x2000, "SPRITESHEET.P8")
-- LATER:
RELOAD(0,0,0x2000, "SPRITESHEET.P8")
-- RESTORE THE SAVED DATA
```

CARTDATA ID

CARTDATA() opens a permanent data storage slot indexed by id, that can be used to store and retrieve up to 256 bytes (64 numbers) worth of data using **DSET()** and **DGET()**.

```
CARTDATA("ZEP_DARK_FOREST")
    -- CAN ONLY BE SET ONCE PER SESSION
    -- LATER IN THE PROGRAM..
DSET(0, SCORE)
```

ID is a string up to 64 characters long, and should be unusual enough that other cartridges do not accidentally use the same **ID**.

e.g. **CARTDATA("ZEP_JELPI")**

Legal characters are a..z, 0..9 and underscore (_).
Returns true if data was loaded, otherwise false.

CARTDATA can not be called more than once per cartridge execution.

Once a **CARTDATA ID** has been set, the area of memory 0x5e00..0x5eff is mapped to permanent storage, and can either be accessed directly or via **DGET/DSET**.

DGET INDEX

Get the number stored at **INDEX** (0..63)
Use this only after you have called **CARTDATA()**

DSET INDEX VALUE

Set the number stored at **INDEX** (0..63)
Use this only after you have called **CARTDATA()**

There is no need to flush written data; it is automatically saved to permanent storage even if `POKE()`'ed directly.

GPIO

GPIO stands for "General Purpose Input Output", and allows machines to communicate with each other. PICO-8 maps bytes in the range 0x5f80..0x5fff to GPIO pins that can be `POKE()`'ed (to output a value; e.g. to make an LED light up) or `PEEK()`'ed (e.g. to read the state of a switch).

GPIO means different things for different host platforms:

CHIP: 0x5f80..0x5f87 mapped to XIO-P0..XIO-P7
Pocket CHIP: 0x5f82..0x5f87 mapped to GPIO1..GPIO6

(**XIO-P0 & P1 are exposed inside the prototyping area inside the case.)

Raspberry Pi: 0x5f80..0x5f9f mapped to wiringPi pins 0..31
(see <http://wiringpi.com/pins/> for mappings on different models.)

(**also: watch out for BCM vs. WiringPi GPIO indexing!)

CHIP and Pi values are all digital: 0 (LOW) and 255 (HIGH)

A simple program to blink any LEDs attached on and off:

```
T = 0
FUNCTION _DRAW()
  CLS(5)
  FOR I=0,7 DO
    VAL = 0
    IF (T > 2 < 1) VAL = 255
    POKE(0x5f80 + I, VAL)
    CIRCfill(20+I*12,64,4,VAL/11)
  END
  T += 0.1
END
```

SERIAL

For more precise timing, the `SERIAL()` command can be used. GPIO writes are buffered and dispatched at the end of each frame, allowing clock cycling at higher and/or more regular speeds than is possible by manually bit-banging using `POKE()` calls.

`SERIAL(CHANNEL, ADDRESS, LENGTH)`

CHANNEL:

`0x000..0x0fe`

corresponds to gpio pin numbers; send
0x00 for LOW or 0xFF for HIGH

`0x0ff`

delay; length is taken to mean "duration"
in microseconds (excl. overhead)

`0x100..0x101`

SPI read/write on channel 0,1
(experimental)

`0x400..0x401`

ws281x LED string (experimental)

ADDRESS:

The PICO-8 memory location to read from (and
subsequently write to in the case of SPI)

LENGTH:

Number of bytes to send. 1/8ths are allowed to
send partial bit strings.

For example, to send a byte one bit at a time to a
typical APA102 LED string:

```
VAL = 42
```

```
-- VALUE TO SEND
```

```
DAT = 16 CLK = 15
```

```
-- DATA AND CLOCK PINS DEPEND ON DEVICE
```

```
POKE(0x4300,0)
```

```

        -- DATA TO SEND (SINGLE BYTES: 0 OR 0xFF)
        POKE(0x4301, 0xFF)
        FOR B=0,7 DO
            -- SEND THE BIT (HIGH FIRST)
            SERIAL(DAT, BAND(VAL, SHL(1,7-B))>0 AND 0x4301 OR
                0x4300, 1)
        -- CYCLE THE CLOCK
        SERIAL(CLK, 0x4301)
        SERIAL(0xFF, 5) -- DELAY 5
        SERIAL(CLK, 0x4300)
        SERIAL(0xFF, 5) -- DELAY 5
    END

```

HTML

Cartridges exported as HTML / .js use a global array of integers (pico8_gpio) to represent GPIO pins. The shell HTML should define the array:

```
VAR PICO8_GPIO = ARRAY(128);
```

Mouse and Keyboard Input

Mouse and keyboard input can be achieved by enabling devkit input mode (experimental! The HTML implementation is still limited & buggy):

```
POKE(0x5F20, 1)
```

Note that not every PICO-8 will have a keyboard or mouse attached to it, so when posting carts to the Lexaloffle BBS, it is encouraged to make keyboard and/or mouse control optional and off by default, if possible. When devkit input mode is enabled, a message is displayed to BBS users warning them that the program may be expecting input beyond the standard 6-button controllers. The state of the mouse and keyboard can be found in `STAT(X)`:

<code>STAT(30)</code>	(Boolean) True when a keypress is available.
<code>STAT(31)</code>	(String) character returned by keyboard.
<code>STAT(32)</code>	Mouse X
<code>STAT(33)</code>	Mouse Y

```
STAT(34)      Mouse buttons (bitfield).
STAT(36)      Mouse wheel event.
```

ADDITIONAL LUA FEATURES

PICO-8 also exposes 2 features of Lua for advanced users: Metatables and Coroutines.

For more information, please refer to the Lua 5.2 manual.

METATABLES

Metatables can be used to define the behaviour of objects under particular operations. For example, to use tables to represent 2D vectors that can be added together, the '+' operator is redefined by defining an "__ADD" function for the metatable:

```
VEC2D={
  __ADD=FUNCTION(A,B)
    RETURN {X=(A.X+B.X), Y=(A.Y+B.Y)}
  END
}

V1={X=2,Y=9} SETMETATABLE(V1, VEC2D)
V2={X=1,Y=5} SETMETATABLE(V2, VEC2D)
V3 = V1+V2
PRINT(V3.X..","..V3.Y) -- 3,14
```

SETMETATABLE T, M

Set table T metatable to M.

GETMETATABLE T

Return the current metatable for table T, or nil if none is set.


```

RAWSET T KEY VALUE
RAWGET T KEY
RAWEQUAL T1 T2
RAWLEN T

```

Raw access to the table, as if no meta-methods were defined.

FUNCTION ARGUMENTS

The list of function arguments (or remain arguments) can be specified with ...

```

FUNCTION PREPRINT(PRE, S, ...)
  LOCAL S2 = PRE..TOSTR(S)
  PRINT(S2, ...)
  -- PASS THE REMAINING ARGUMENTS ON TO PRINT()
END

```

To accept a variable number of arguments:

```

FUNCTION FOO(...)
  LOCAL ARGS={...}
  -- BECOMES A TABLE OF ARGUMENTS
  FOREACH(ARGS, PRINT)
END

```

COROUTINES

Coroutines offer a way to run different parts of a program in a somewhat concurrent way, similar to threads. A function can be called as a coroutine, suspended with `YIELD()` any number of times, and then resumed again at the same points.

```

FUNCTION HEY()
  PRINT("DOING SOMETHING")
  YIELD()

```

```

        PRINT("DOING THE NEXT THING")
        YIELD()
        PRINT("FINISHED")
    END

    C = COCREATE(HEY)
    FOR I=1,3 DO CORESUME(C) END

```

COCREATE F

Create a COROUTINE for function F.

CORESUME C [P0 P1 ...]

Run or continue the coroutine c. Parameters p0, p1.. are passed to the coroutine's function. Returns true if the coroutine completes without any errors. Returns false, error_message if there is an error. (**Runtime errors that occur inside coroutines do not cause the program to stop running. It is a good idea to wrap CORESUME() inside an ASSERT(). If the assert fails, it will print the error message generated by CORESUME.)

```
ASSERT(CORESUME(C))
```

COSTATUS C

Return the status of coroutine C as a string:

- "running"
- "suspended"
- "dead"

YIELD

Suspend execution and return to the caller.