|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| machine language | assembly | x16joy | meaning | example |
| 0000 0000 0000 0001 | end | 1 😂 | finish running code | end |
| 0001 vvvv vvvv rrrr | sv\_ r v | 4096 😂 | reg[r] = v | sv\_ r12 22 |
| 0100 AAAA rrrr ssss | ALU r s | 16384 😂 | reg[r] = reg[r] ALU reg[s] | add r13 r10 |
| 1000 xxxx rrrr ssss | ld\_ r s | 32768 😂 | reg[r] = RAM[reg[s]] | ld r2 r10 |
| 1010 xxxx rrrr ssss | st\_ r s | 40960 😂 | RAM[reg[s]] = reg[r] | st r2 r10 |
| 1100 xxxx xxxx rrrr | jp\_ r | 49152 😂 | clc = reg[r] | jp r12 |
| 1111 xxxx cccc rrrr | jpcc r | 61440 😂 | if (c) -> clc = reg[r] | jpns r1 |
|  |  |  |  |  |
| 0010 |  | 8192 😂 |  |  |
| 0011 |  | 12288 😂 |  |  |
| 0101 xxxx xxxx xxxx | co\_ | 20480 😂 | clear output (pixel grid) | co\_ |
| 0110 xxxx rrrr ssss | dp\_ r s | 24576 😂 | if reg[r] > 0 draw px(reg[s]) | dp\_ r1, r2 |
| 0111 rrgg bbaa ssss | dpc rg ba s | 28672 😂 | draw px reg[rg] reg[ba] reg[s] | dp\_ r2, r3, r4 |
| 1001 xxxx xxxx rrrr | prc r | 36864 😂 | print char reg[r] | prc r10 |
| 1011 xxxm mmmm rrrr | prv r m | 45056 😂 | print int (m=num system) | prv r10 \_16 |
| 1101 |  | 53248 😂 |  |  |
| 1110 xxxx xxxx rrrr | gik r | 57344 😂 | Reg[r] = last event.key | gik r10 |

The following notation is used:

* vvvv vvvv is an 8 bit value that is embedded into the instruction. This is also called an ‘immediate value’ as it’s immediately available from the instruction.
* X stands for “don’t care.” These bits can be anything
* rrrr, ssss, rrgg, bbaa stand for register numbers (0-15)
* AAAA stands for ALU operation. The following operations are supported

|  |  |  |  |
| --- | --- | --- | --- |
| ALU | | | |
| bits | instruction name | description | operation |
| 0000 | NOP | No OPeration | A = B |
| 0001 | OR | bitwise OR | A |= B |
| 0010 | AND | bitwise AND | A &= B |
| 0011 | XOR | bitwise XOR | A ^= B |
| 0100 | ADD | addition | A = A + B |
| 0101 | SUB | subtraction | A = A – B |
| 0110 | LSL | Logical Shift Left | A = A << B |
| 0111 | LSR | Logical Shift Right | A = A >> B |
| 1000 | ASR | Arithmetic Shift Right | A = A >>> B |
| 1001 | NOT | logic inverse (1-comp) | A = ~B |
| 1010 | NEG | Negative (2-comp | A = -B |
| 1011 | MUL | multiplication | A = A \* B |
| 1100 | DIV | division | A = A / B |
| 1101 | POW | exponent | A = A ^ B |
| 1110 | ??? |  |  |
| 1111 | ??? |  |  |

* cccc stands for condition. Every time a calculation is done by the ALU, multiple flags are set according to the result. The following conditions can be checked:

|  |  |  |  |
| --- | --- | --- | --- |
| conditions | | | |
| bits | condition short | condition long | meaning |
| 0000 | c | carry | carried bit was 1 |
| 0001 | nc | no-carry | no carried bit |
| 0010 | z | zero | result = 0 |
| 0011 | nz | not-zero | result != 0 |
| 0100 | S | sign | result < 0 |
| 0101 | ns | no-sign | result >=0 |
| 0110 | o | overflow | result > 16bit max |
| 0111 | no | no-overflow | result <= 16bit max |

**prv** – print value - Prints value in the given register to terminal/console in provided numeral system. Examples: [:] prv r10 \_16 [:] prints the value inside of register 10 in hexadecimal, or base 16 format. [:] prv r6 \_10 [:] prints the value inside of register 6 in decimal, or base 10 format.

**prc** – print char - Prints char matching the value inside the given register. The char is printed in the terminal/console without any whitespace or new lines characters attached. Characters use binary to ASCII char conversion. Decimal 97 or hexadecimal 0x61 would be equal to char ‘a’, 98 to ‘b’ and so on.

**dp\_** - draw pixel - Draws pixel on output 16x16 canvas. Pixel can either be black or white. Register 1 gives the color value. If register 1 value is greater than 0, set color to max rgb(white). If register 1 is equal or less than 0, set color to min rgb(black). The value of the second register acts as coordinates. The 4 least significant bits act as the y coordinate while the next 4 more significant bits act as the x coordinate. Register value is as follows: 0000 0000 xxxx yyyy. Coordinates are from 0 to 15. This results in a 16x16 grid of pixels.

**dpc** – draw pixel (with) color - Draws pixel on output 16x16 canvas. Pixel use rgba values stores in register 1 and 2. Register 1 gives the red and green color values. (rrrr rrrr gggg gggg). Register 2 gives the blue and alpha values. (bbbb bbbb aaaa aaaa). The value of the third register acts as coordinates. The 4 least significant bits act as the y coordinate while the next 4 more significant bits act as the x coordinate. Register value is as follows: 0000 0000 xxxx yyyy. Coordinates are from 0 to 15. This results in a 16x16 grid of pixels.

**co\_** - clear output - Sets all pixels on the 16x16 output grid to rgba(0,0,0,0)

**gik** - get input key - Loads the value of the event.key of the last held button (and currently held) and stores it in the specified register. If you press and hold a butt­­­­on, that event key will be stored in the special input register. When you let go of a button, that event key will be cleared. If you press another button while still holding the old one, the new key will override the old. When that happens, the input register will be cleared only when you let go of the *new* key.