I-CHIP PS-1

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→ ~~We will use~~ As we also have to find the negatives of ~~sum~~ some numbers and also find difference of ~~su~~ 2 numbers. So we will write the negative numbers in 2's complement form let our 8 bit number be x. So its negative in 2's complement form is

$$-x = \sim x + 0000\_0001$$

→ Now we will see the proof of all the functions according to their opcode.

(1) $\theta = 0$ opcode = 101010

$zx = 1 \Rightarrow x = 0000\_0000$ $\quad ny = 0 \Rightarrow y = 0000\_0000$

$nx = 0 \Rightarrow x = 0000\_0000$ $\quad f = 1 \Rightarrow x+y = 0000\_0000$

$zy = 1 \Rightarrow y = 0000\_0000$ $\quad no = 0 \Rightarrow \boxed{\theta = x+y = 0000\_0000}$

(2) $\theta = 1$ opcode = 111111

$zx = 1 \Rightarrow x = 0000\_0000$ $\quad f = 1 \Rightarrow x+y = \overset{\text{neglect}}{1}\_1111\_1110$

$nx = 1 \Rightarrow x = 1111\_1111$ $\quad no = 1 \Rightarrow \sim(x+y) = 0000\_0001$

$zy = 1 \Rightarrow y = 0000\_0000$

$ny = 1 \Rightarrow y = 1111\_1111$

$$\boxed{\theta = 0000\_0001}$$

③ ~~111~~ $\theta = -1$ opcode = 111010

$Zx = 1 \Rightarrow x = 0000\_0000$

$nx = 1 \Rightarrow x = 1111\_1111$

$zy = 1 \Rightarrow y = 0000\_0000$

$ny = 0 \Rightarrow y = 0000\_0000$

$f = 1 \Rightarrow x + y = 1111\_1111$

$no = 0 \Rightarrow \boxed{\theta = 1111\_1111}$

↳ which is −1 in 2's complement form

④ $\theta = x$ opcode = 001100

$Zx = 0 \Rightarrow x = x$

$nx = 0 \Rightarrow x = x$

$zy = 1 \Rightarrow y = 0000\_0000$

$ny = 1 \Rightarrow y = 1111\_1111$

$f = 0 \Rightarrow x \& y = x$

$no = 0 \Rightarrow \boxed{\theta = x}$

⑤ $\theta = y$ opcode = 110000

$Zx = 1 \Rightarrow x = 0000\_0000$

$nx = 1 \Rightarrow x = 1111\_1111$

$zy = 0 \Rightarrow y = y$

$ny = 0 \Rightarrow y = y$

$f = 0 \Rightarrow x \& y = y$

$no = 0 \Rightarrow \boxed{\theta = y}$

⑥ $\theta = \sim x$ opcode = 001101

As derived in ④ for x we only have to complement it. So we only have to change no bit to 1

⑦ $\theta = \sim y$ opcode = 110001

Similar to 6 we only have to change no bit to 1 in opcode of ⑤

(8) $\theta = -x$ opcode $= 001111$

$zx = 0 \Rightarrow x = x$ $\quad$ $f = 1 \Rightarrow x + y = x + 1111\_1111$

$nx = 0 \Rightarrow x = x$ $\quad$ $no = 1 \Rightarrow \theta = \sim(x + 1111\_1111)$

$zy = 1 \Rightarrow y = 0000\_0000$

$ny = 1 \Rightarrow y = 1111\_1111$

Now 1111_1111 is -1 in 2's complement form.

$$\theta = \sim(x - 1)$$

Now using identity defined in begining

$$-x = \sim x + 1$$

Put $x = x - 1$

$$\Rightarrow -(x-1) = \sim(x-1) + 1$$

$$-x + \cancel{1} = \sim(x-1) + \cancel{1}$$

$$\sim(x-1) = -x$$

$$\Rightarrow \boxed{\theta = -x}$$

(9) $\theta = -y$ opcode $= 110011$

Similar as done in (8) only we have to get y in place of x. So we have to set $zx = 0$, $nx = 0$, $zy = 1$, $ny = 1$ and the rest will be same ($f = 1$, $no = 1$).

(10) $\theta = x + 1$ opcode $= 011111$

$zx = 0 \Rightarrow x = x$ $\quad$ $ny = 1 \Rightarrow y = 1111\_1111$

$nx = 1 \Rightarrow x = \sim x$ $\quad$ $f = 1 \Rightarrow x + y = \sim x + 1111\_1111$

$zy = 1 \Rightarrow y = 0000\_0000$ $\quad$ $no = 1 \Rightarrow \theta = \sim(\sim x + 1111\_1111)$.

Now 1111_1111 is -1 in 2's complement form

So $\theta = \sim(\sim x - 1)$.

Now $-x = \sim x + 1 \Rightarrow \sim x = -x - 1$

$$\Rightarrow \theta = \sim(-x-1-1) = \sim(-x-2)$$

Put $x = -x - 2$ in the identity

$$-(-x-2) = \sim(-x-2) + 1$$

$$x + 2 = \sim(-x-2) + 1$$

$$\sim(-x-2) = \boxed{x+1}$$

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(11) $O = y+1$ opcode = 110111

- This function is ~~sir~~ similar to the function in part (10) just we have to change the zx, nx, zy and ny control input ~~to~~ get y in place of x.

So $zx = 1, nx = 1, zy = 0, ny = 1$

(12) $O = x-1$ opcode = 001110

$zx = 0 \Rightarrow x = x$

$nx = 0 \Rightarrow x = x$

$zy = 1 \Rightarrow y = 0000\_0000$

$ny = 1 \Rightarrow y = 1111\_1111$

$f = 1 \Rightarrow x+y = x + 1111\_1111$

$no = 0 \Rightarrow O = x + 1111\_1111$

- Now 1111_1111 is -1 in 2's complement form

So $\boxed{O = x-1}$

(13) $O = y-1$ opcode = 110010

$zx = 1 \Rightarrow x = 0000\_0000$

$nx = 1 \Rightarrow x = 1111\_1111$

$zy = 0 \Rightarrow y = y$

$ny = 0 \Rightarrow y = y$

$f = 1 \Rightarrow x+y = y + 1111\_1111$

$no = 0 \Rightarrow O = y + 1111\_1111$

- Now 1111_1111 is -1 in 2's complement form

So $\boxed{O = y-1}$

(14) $O = x+y$ opcode = 000010

$zx = 0 \Rightarrow x = x$

$nx = 0 \Rightarrow x = x$

$zy = 0 \Rightarrow y = y$

$ny = 0 \Rightarrow y = y$

$f = 1 \Rightarrow x+y = x+y$

$no = 0 \Rightarrow \boxed{O = x+y}$

(15) $O = x-y$ opcode = 010011

$zx = 0 \Rightarrow x = x$

$nx = 1 \Rightarrow x = \sim x$

$zy = 0 \Rightarrow y = y$

$ny = 0 \Rightarrow y = y$

$f = 1 \Rightarrow x+y = \sim x + y$

$no = 1 \Rightarrow O = \sim(\sim x + y)$

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- Now using the identity $-x = \sim x + 1$

$$\sim x = -x - 1$$

$$\theta = \sim(-x-1+y)$$

Again using the identity

$$\sim(-x-1+y) = -(-x-1+y)-1$$

$$= x + \cancel{1} - y - \cancel{1}$$

$$\boxed{\theta = x - y}$$

(16) $\theta = y - x$ opcode $= 000111$

$zx = 0 \Rightarrow x = x$

$nx = 0 \Rightarrow x = x$

$zy = 0 \Rightarrow y = y$

$ny = 1 \Rightarrow y = \sim y$

$f = 1 \Rightarrow x + y = x + \sim y$

$no = 1 \Rightarrow \theta = \sim(x + \sim y)$.

- Now using the identity

$$-x = \sim x + 1$$

$$\sim y = -y - 1$$

Putting $x = x + (-y-1)$ in identity

$$-(x - y - 1) = \sim(x - y - 1) + 1$$

$$\sim(x - y - 1) = -x + y + \cancel{1} - \cancel{1}$$

$$\boxed{\theta = y - x}$$

(17) $\theta = x \& y$ opcode $= 000000$

$zx = 0 \Rightarrow x = x$

$nx = 0 \Rightarrow x = x$

$zy = 0 \Rightarrow y = y$

$ny = 0 \Rightarrow y = y$

$f = 0 \Rightarrow x \& y = x \& y$

$no = 0 \Rightarrow \boxed{\theta = x \& y}$

(18) $\theta = x | y$ opcode $= 010101$

$zx = 0 \Rightarrow x = x$

$nx = 1 \Rightarrow x = \sim x$

$zy = 0 \Rightarrow y = y$

$ny = 1 \Rightarrow y = \sim y$

$f = 0 \Rightarrow x \& y = \sim x \& \sim y$

$no = 1 \Rightarrow \theta = \sim(\sim x \& \sim y)$

So using De Morgan's Law

$$\boxed{\theta = x | y}$$