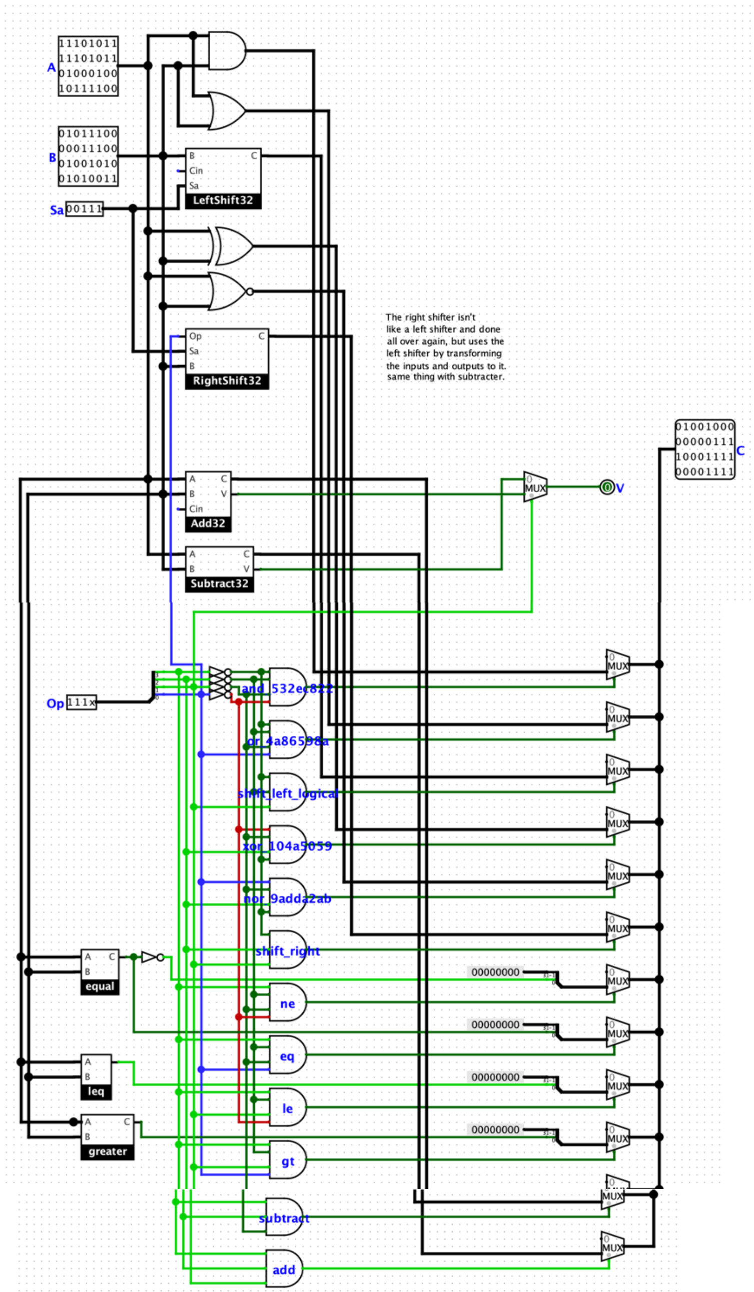
ALU32

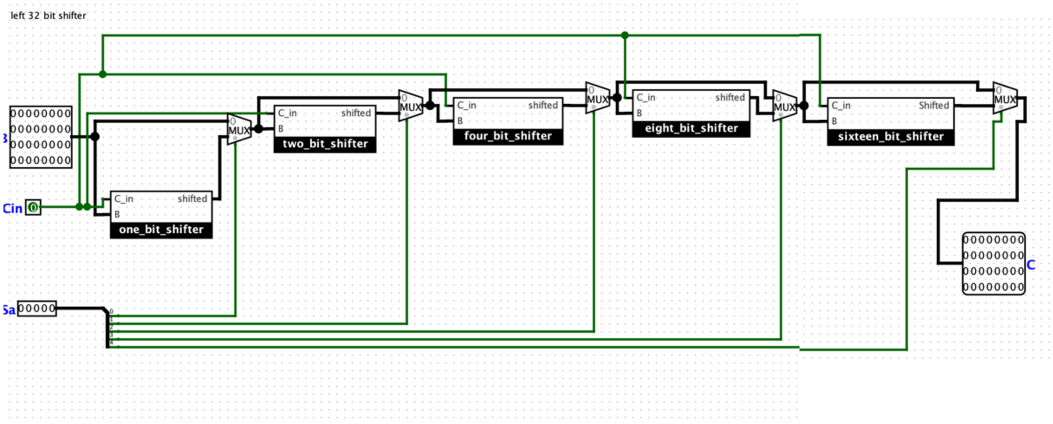


I implemented the Op codes using multi-input (3- or 4- input) AND gates and transferred the corresponding operation result to the output through a multiplexer without the 0 input.

I did not make a right shifter like how I made a left shifter, but followed the hint about transforming inputs and outputs to the right shifter.

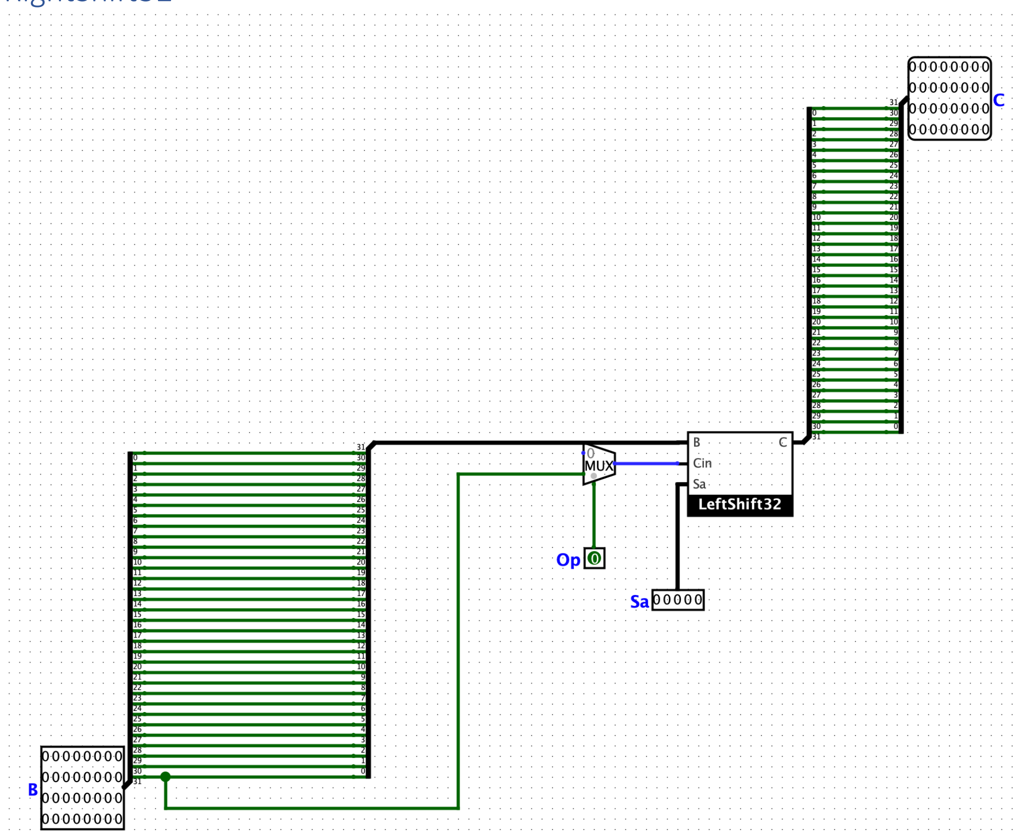
Similarly, with the subtractor, I just transformed B to be its two's complement and implemented overflow following rules about signed binary number addition/subtraction overflow.

LeftShift32



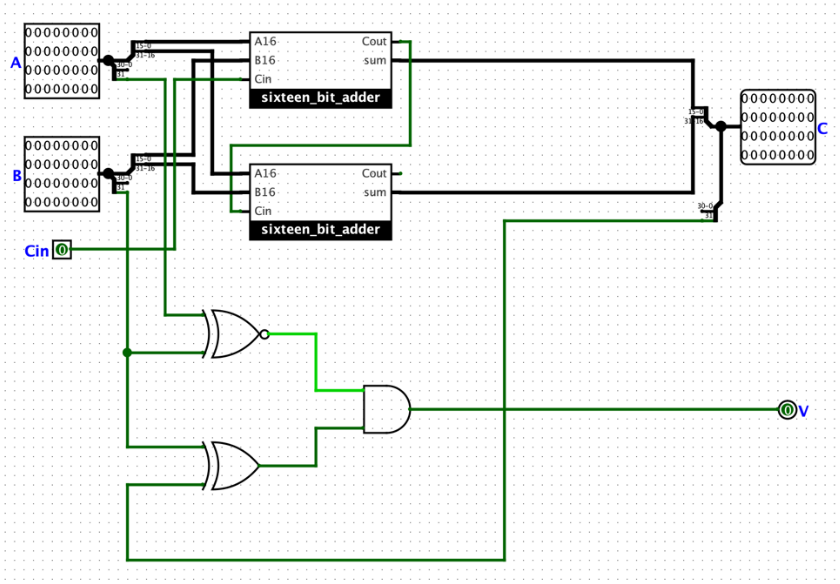
I used a one-bit shifter, a two-bit shifter, a four-bit shifter, an eight-bit shifter, and a sixteen-bit shifter to construct my thirty-two-bit shifter.

RightShift32



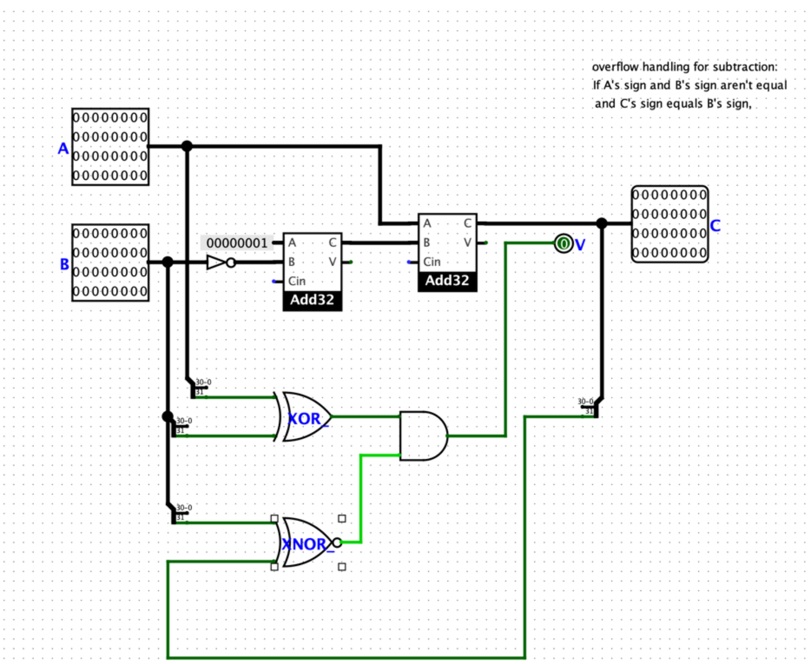
My thirty-two-bit right shifter is implemented by reversing (e.g. $11100 \rightarrow 00111$) the input then shifting it left using LeftShift32 then reversing it back. Op specifies whether it's arithmetic or logical shift.

Add32



I used two sixteen-bit adders in my thirty-two-bit adder. Each sixteen-bit adder is comprised of 4 four-bit adders, which are then comprised of 4 one-bit adders each. I handled overflow in the 32-bit adder by making it an unsigned adder first, then following the rule of if A and B are of the same sign and C is of the opposite sign, then overflow V is 1.

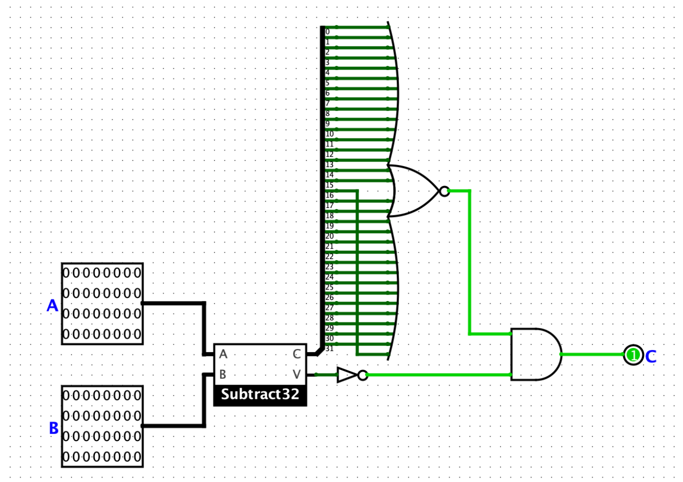
Subtract32



$A - B = A + (-B)$. So I turned B into its two's complement through NOT-ing it (inverting each bit) then adding 1 through my Add32, then added to Add32. I handled subtraction overflow by implementing the rule of if A and B are of different signs and C has the same sign as B, then there's overflow, so I have to set V to 1.

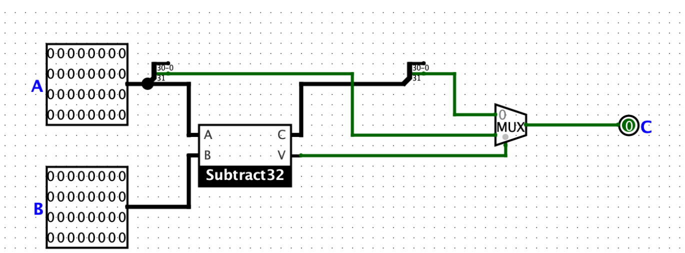
Comparators

equal



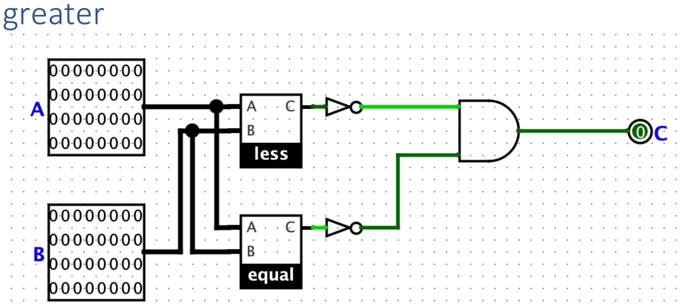
When $A - B = 0$, then $A = B$.

less



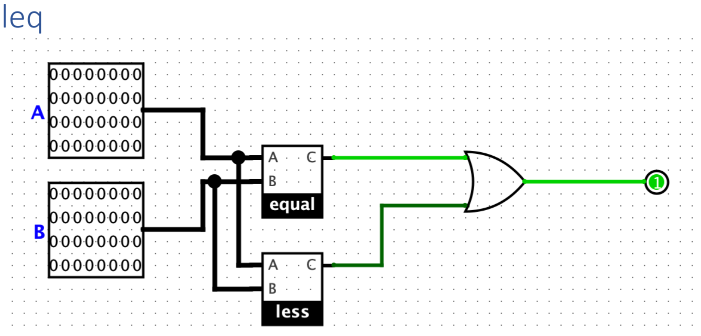
When $A - B < 0$, then $A < B$. When $A - B > 0$, then $A > B$.

greater



$A > B$ if and only if $\neg(A < B) \wedge \neg(A == B)$.

leq



$A \leq B$ if and only if $(A == B) \vee (A < B)$.