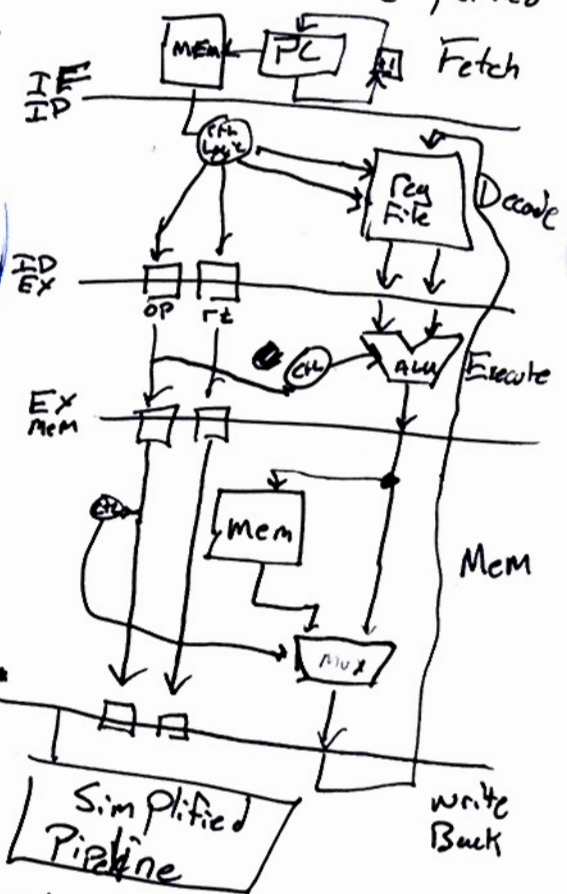
2. Discuss the technique of **PIPELINING** a processor design. What are the tricky implementation issues? What is the effect of pipelining on processor performance? (support your answer quantitatively)
Extra credit: what is the effect of pipelining on power dissipation? (support your answer quantitatively)

Pipelining a processor is the process of take the steps of a processor, Fetch, decode, Execute, Mem, ~~Wb~~ write Back, etc.) and putting State registers in between the Stages to store the current state of the processor. What this provides is a way to increase the Clockspeed of the system to match the longest of the Stages of the CPU. This means that in a single cycle of the CPU that multiple instructions can be operated upon concurrently. ie.

```
add r0,r1,r2     F D X M W
addi r1,r2,r3      F D X M W
NAND r2,r3,r4        F D X M W
NAND r3,r4,r5          F D X M W
add r4,r5,r6             F D X M W
```

5 operations concurrently

excellent 5



However this can bring about implementation issues such as dependent instruction and Load Use Penalties along with other data hazards. Most of these issues can be solved with data forwarding. for the Load-Use penalty where data is needed immediately after a load the ~~Execute~~ IDEX and IFID Pipeline registers must be stalled by Holding their values and inserting a NOP into the IDEX register. Additionally Branch Misprediction can use the Pipelines to be flushed there by losing the benefit of multiple ops at once.

The upside to all of this Complexity is that there is a performance gain due to the fact that there are 5 instructions being worked upon at once. even though overall on a per-instruction Basis. Each instruction takes longer to run than the non-Pipelined CPU the added throughput of the system increases performance dramatically

Finally the effect of pipelining on power dissipation is that there is added power being used for the extra Control logic and Pipe registers so the Power dissipation is increased from that but it is also decreased slightly from the fact that lower Voltages can be used to drive the data lines since the distances to the endpoints of the traces are less long. So overall it is a balancing game that requires analysis of the system on a whole since Changeing one thing can affect Each part of the system differently.

+1