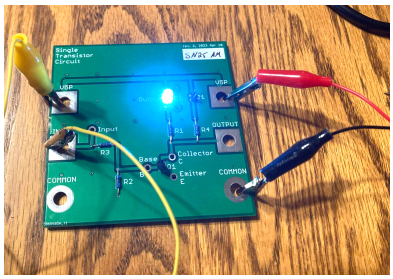
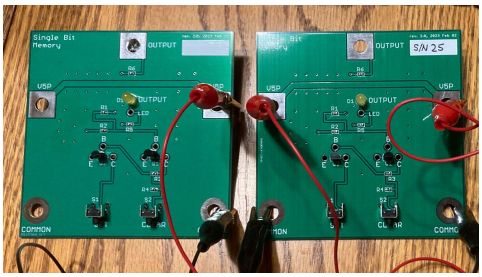
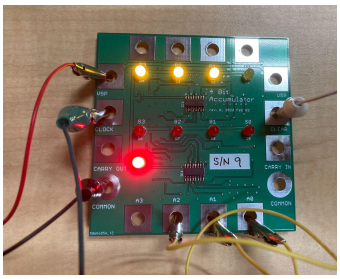
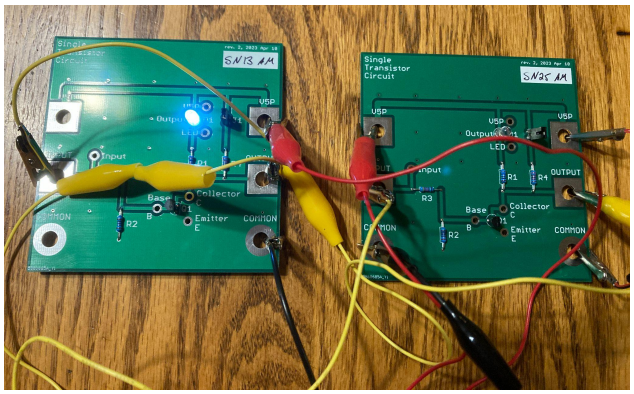
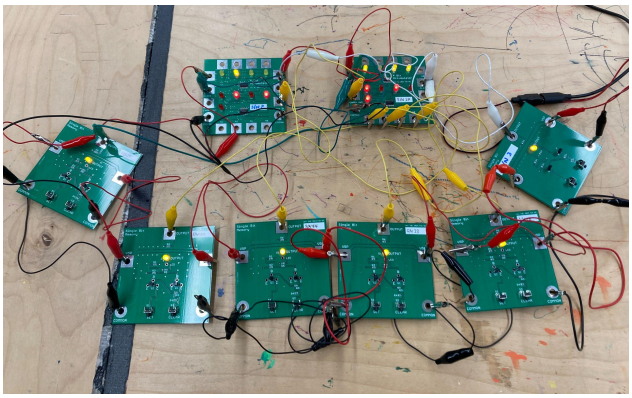




Single Transistor Circuit Board (STC) 2 Single Bit Memory Boards (SBM) 4 Bit Accumulator Board (4BA)

2 STC's connected as a Flip Flop (1 Bit Memory) 4 SBM's with 2 4BA's as Binary Adder Circuit

Opening the "Bit Blackbox" - understanding computer memory

Grade level(s) I use with: 7th and 8th (I have tried with 5th / 6th to simply model transistor function, worked well)

Lesson Overview: I have always hated the jump that I make in Design Tech going from having students create a relatively complex circuit involving buzzers, motors, LED's and a variety of switches to using the Micro:bit or coding an Edison robot. The background of circuits does help them understand hooking up power and even Micro:bit peripherals like an RGB LED or an external speaker but leaves what I see as a gaping hole of even slightly understanding how these circuits can be used to process information or "remember" anything. It was my great fortune last year to be introduced to a retired Apple / Google computer engineer who offered to work with me to see if we could create a lesson to fill the gap. My learning curve has been incredibly steep - but I do think we have a lesson that begins to fill in those gaps. I introduced the unit as a pilot with three classes last May and with a summer robotics camp - my favorite response was "I never thought I'd ever be able to understand something like this." Still lots of

tweaking to do, but I do think it's going to be a great 5-6 days of learning for all of my 7th and 8th graders this year.

Materials and equipment I use:
3 circuit boards that are printed by JLCPCB Electronics in Shenzhen, Guangdong, China

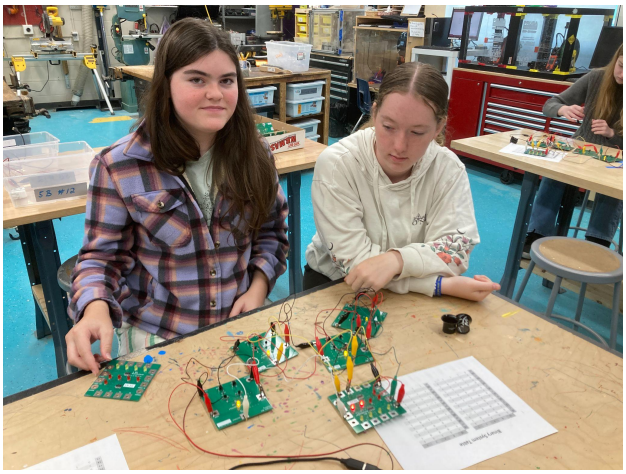
- A single transistor circuit used first to model how a transistor works
- A single bit memory circuit which is basically two STC's combined on a single board
- A fourbit accumulator circuit that when linked to 6 SBM's, four which are the first four places of a binary number and the other serving as clear and clock can complete simple binary addition processes

How I use it?
The entire unit begins with a question to students of "what do you think was the most life-changing invention of the 21st century?" That alone is really interesting discussion and at the end I hand everyone a tiny transistor with the message that I would argue it likely is this little thing. From there we go on a 5-6 day journey exploring how a transistor works - using the STC boards to test with a multimeter to expand on their knowledge of circuits to include volts, amps, resistors and build a basic understanding of the transistor as a switch. We also build a simple "telegraph" to start the idea of an electrical binary state of on / off being data with which we can both store and transmit complex information.

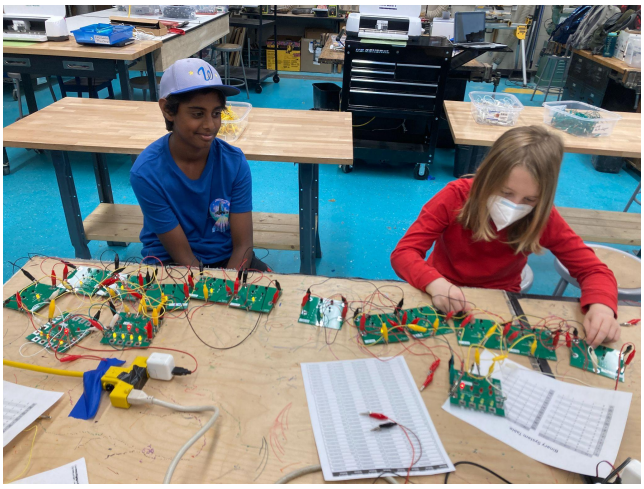
This also introduces the circuit board as a replacement for their previous mess of alligator clips and components, and when we add the Single Bit Memory circuit, it also becomes clear how circuit boards allow us to greatly reduce the size. This is another primary understanding I want all students to have, understanding the amazing technological progress that has been made over 50 years as we have been able to make integrated circuits. They have all heard about the "chip" shortage and we also happen to have a Global Foundries (previously IBM) integrated circuit plan less than 5 miles from our school as an important local employer.

From here we learn the basics of binary code, something my first experience says most students can at least understand and use if given a clear table but I love that for a few students it was as exciting as learning a new language - they were totally engaged using a connected set of SBM cards to click on / off and count. Our final exercise is take a set of 4 SBM cards, and connect them to a 4 bit accumulator card that can take and store their input and use the accumulator chip to add it to itself or a new number created on the SBM's. We ground this lesson in the idea that they are acting as the computer program - that there is a specific sequence of actions - clear the memory and the input, input the first number, cycle the clock so that the first total is added to the registry, then change the input number and cycle the clock

again creating the new sum in the registry. There is something pretty magical as they try more and more complicated addition sequences to see if they can “outsmart” their new circuit.



Ongoing questions and ideas for the future: Subtraction is possible, but requires understanding the complex idea of two’s complement. My first attempt to include this made it clear that my own understanding is not complete enough to dive into this with thirteen year olds. The lesson clearly is strong even if we stop with addition as it accomplishes my primary goal of creating a fun, hands-on activity that begins to unpack the complexity of how a circuit can store and process information, but I haven’t given up on the idea that subtraction is worth exploring.



Our big addition for this fall is that we have created a new single transistor circuit that we hope to be able to give a hands-on lesson in the basic of soldering and circuit creation. The board also includes a simple maze whose edges are connected to positive and a simple probe wire is connected to ground. This grows from our summer school students feedback that they all wanted to take a board home with them, as well as multiple 7th and 8th graders dabbling in soldering over the past few years when they recognized it’s utility to stabilizing their circuit projects such as scribblebots and operation games. I’m confident with proper scaffolding and classroom safety protocols we can get most 7th and 8th graders soldering resistor, LED and transistor connections and the learning will be great. Maybe we can let my student here take home all the extra alligator clips for his new hairpiece. Time will tell :-)