LED Pipe Dream

Our construction kit is based off of an old Nintendo® game titled “Pipe Dream”. In this game, the player is given a grid with a start and end piece. When the player presses the start button a timer starts counting down. Once this timer reaches zero, water starts flowing through the pipe (at a slow pace). The player is also given a stack of pipe sections. The object of the game is to connect the start piece to the end piece, with these pipe sections, before the water reaches the end of the plumbing. The longer the connection, the higher you score. We took this idea and applied it to a real-world physical construction kit.

All of the pieces for our project, pipe sections and grid, were cut out of Plexiglas by the laser cutter. We held the pipe sections together with glue, and the grid was bolted on. The grid has room – and supplies power for – nine pieces in a three-by-three arrangement. The connections are made possible by a combination of thin conductive fabric (the underlying circuit) and conductive Velcro®. The Velcro® is used to connect positive, negative, input and output to each piece. The grid also contains a place for a positive and negative connection to a power supply, this gives the 5V power needed to operate all of the pipe sections. An integrated switch allows the player to start and stop the timer. Each pipe section contains a programmable chip, LED, and a base that allows for positive, negative, input and output connections. The LEDs simulate water flowing by illuminating the pipe sections with blue light as time goes on. These pipe sections are made of clear and black plastic, as shown below. In total, there are nine pipe sections: a start piece, an end piece, three straight connector pieces, and four curved connector pieces (two for each direction).
Throughout the construction of the project, our main design stayed the same. It had Plexiglas pieces, LED lights, delay between each piece, and a circuit placed underneath a grid. Although the overall design was consistent, we had to overcome many problems along the way. Many of these problems were related more to electrical engineering – something completely new to us – than computer science. We originally planned to build it in a way that would simply complete a circuit from the start piece to end piece. Connecting the pieces in serial would have caused several problems, though, including the need for extremely high voltage and no way to light up pieces before the connection was complete. A fix to these serial issues involved redesigning our circuit by connecting the pieces in parallel. The difficulty with this solution, however, was that each piece, no matter which way it is rotated, be supplied with both positive and negative.

We designed a circuit with concentric circles under each pipe section (outer circle supplying the positive and inner circle supplying the negative). This design allows for each piece to receive positive and negative connections, regardless of orientation. We kept the original design of having conductive Velcro® pass between each grid border to
allow the pipe sections to give and receive input and output. The circuit itself was made from thin conductive fabric so as not to interfere with piece connections. In order to create the connection from the circuit to the pipe sections, we added conductive Velcro® in the appropriate places. We cut the circuit from the conductive fabric using the laser cutter and also etched the same design in the black Plexiglas base. The etching made it possible to glue the circuit down in the exact location so that the conductive Velcro® would sit perfectly under each pipe section. Unfortunately, this glue interfered with the switch connection and the soldering of the power supply wires. To fix the switch we simply sanded away the glue and applied some acetone. However, for the power supply wires we ended up using the same technology as the pipe sections (conductive Velcro® pushing against soldered wires). The switch is what sends the first signal to the start piece (just like any pipe section sending a signal to the next pipe section). We also added some non-conductive Velcro® to the corners so that the pieces would sit evenly within the grid.

Figure 2 - Grid with Circuit, Velcro® and Switch
The pipe sections were created from black and clear plastic. We sanded the clear plastic so that the blue light from the LED would diffuse better. To increase diffusion even more we lined the inside of each pipe section with aluminum foil and turned the LED sideways. This method was preferred over an actual 3D pipe structure for the ability of diffusing. The inside of each piece contains a programmable chip and LED. Originally we created a circuit from basic components such as NOT gates, capacitors, resistors, and diodes. Although we knew nothing about electrical engineering or circuits, we did create a working version that would allow for almost all of the functionality. The only functionality that we did not support in these earlier prototypes was stopping the “water” from flowing into a pipe section that was placed too late (i.e. the pipe section before it had already sent out a signal). To add this last piece of functionality – and allow for an easier production process – we used programmable microchips.

![Figure 3 - Schematic of Old Pipe Section Circuit](image3.png)  ![Figure 4 - Current Pipe Section Circuit](image4.png)

There are many improvements that could be applied to this project if given the time. First and most importantly, the connections can be quite finicky. This could be fixed by using pins or adding weight to the pieces. Bolting the pipe sections together instead of gluing them would allow for easier repairing. Many new types of pipe sections could be made, including splitters, crossovers, and bridges (span more than one grid...
Being able to have a visual or audible winning or losing signal would be nice. The timing for each piece could be variable. Increasing the size of the grid would allow for more path possibilities. Currently the switch must be turned off and the power supply must be cut in order to reset the game. Obviously using just the switch or just the power supply would be better. We also wanted to integrate a battery into the board instead of using an external power supply.

Below is a list of the most interesting construction and implementation facts that were discovered during the production of Pipe Dream.

- Glue can block conductance if it covers the fabric and dries before whatever is being glued to it is attached.
- Solder cannot connect to the fabric if there is glue covering it (it just burns it).
- Iron-on fabric is a good way to fix broken or burnt connections.
- Conductive epoxy would probably work better for gluing fabrics and connecting wire to fabric.
- The laser cutter will inadvertently bevel each cut because the top part will melt more than the bottom while it is cutting (can be fixed by doing several passes of a lower intensity or faster speed).
- It is best to cut sections of a large design and be ready to stop the laser cutter if it gets off track due to driver errors in the laser cutter.
- If two pieces need to fit together snugly, it is best to cut them completely separate and account for the thickness of the laser.
- Acetone can react with conductive fabric.
- Rubbing alcohol removes excess glue but dulls the shine of Plexiglas.
- LEDs may look like they handle 5V directly but are actually heating up and being damaged if they don’t have a resistor in front of them.
- Sanding clear plastic works well for diffusion of light.
- “Floating” wire connections (wires that aren’t attached to anything) are not the same as a grounded connection and can actually damage CMOS chips.
- You can use the drill press on Plexiglas if you’re careful.
- Conductive Velcro® cannot create a short if only a small number of wires are connected from ground to positive (they burn up and break the connection)