How I Designed the Video Coat
by David Forbes

I was thinking about what to do for Burning Man as I waited the 9 hours for my ticket order to go through. I thought about dressing up the car with an LED display. Man, that would cost a lot! But wait... what about dressing me up in LEDs?

I did some quick math and some visiting of Digikey's website. They sold RGB LEDs for about 40 cents each. I figured that I'd need a display with at least as many pixels per square inch as my SatanVision screen, and it would be larger to cover my entire body. SatanVision has 13,000 pixels arranged as 96x128. The next size bigger would be 120x160 or 19,200 pixels. That's $8,000 just for the LEDs! Holy shit!

On the other hand, wouldn't that be cool.

I was on the verge of shipping a metric buttload of Nixie watches to eagerly-waiting customers around the world. I had no doubt that I could sell a hundred Nixie watches in a couple months. That would leave $20k in the bank by May.

I chatted with my lovely wife about this. She said, "What??!!!?" Then she said that she trusted my judgement and I could do whatever I wanted with the profits from my watch sales, as long as I didn't throw it down a rathole.

I made some sketches of the pixel PC board layout, since it would be critical to get that ever-so-right for the project to work. It looked like I could use a tiny 4mm square part to drive 16 LEDs. The part was also available in a larger TSSOP package, which I could solder easily myself. I did sketches of both the QFN and the TSSOP parts, with the QFN on the front of the board and the TSSOP on the rear.

Then I had to figure out what on earth to use for PC boards. I have only ever designed rigid PC boards before. They have this problem, when mounted on clothing, that they're stiff. There are also flexible PC boards, such as used inside cameras and disk drives. They are orange and cost way more than rigid boards. But they would really solve the problem of flexibility.

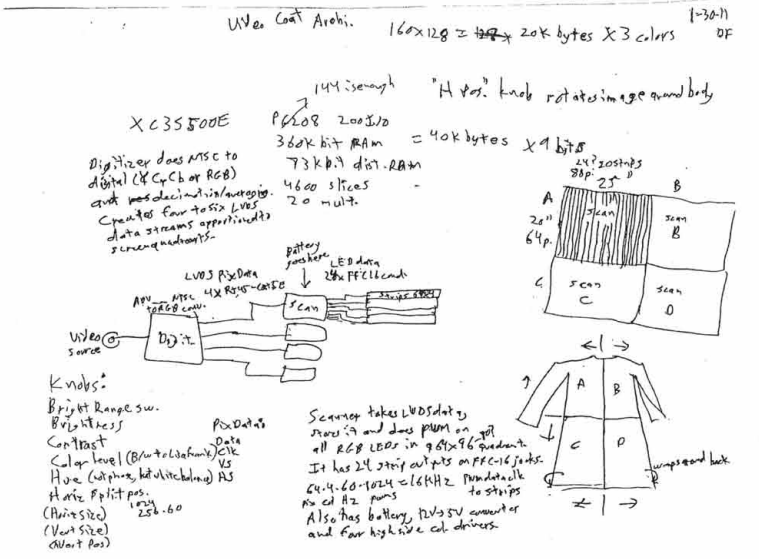
I thought about how to do the draping of the displays on the coat. Naturally, I decided to copy someone else's work. That's what all the best engineers do. I looked to the LED video dresses designed by Hussein Chalayan and Moritz Waldemeyer. They used a bunch of 1" square rigid boards, each with a 2x2 pixel array. The boards were suspended from ribbon cables in vertical strips. Why not do the same thing, but with vertical strips of flex boards?

I thought about it, an made some paper strip prototypes to see if it made sense. It seemed to.

I had to find a supplier of flex boards. The Internet turned up a few companies. I selected a small one whose owner was happy to discuss the technical ins and outs of the job with me.

Many compromises were made in order to get the pixels to all fit on 0.30" centers. I used three individual LEDs instead of an RGB block, because they were smaller and 20,000 of each were in stock at Digikey. I had to route some signals next to each other that didn't seem like a good idea to do so, and later proved to have been a not good idea.

Eventually, the boards were designed and I received some prototypes. I built three rigid LED boards and a set of driver boards. Soldering a thousand LEDs by hand is not exactly interesting, but it wasn't too hard either.



I discovered that even though I thought that I knew a thing or two about how color TV worked, I actually had no clue how to turn the thing coming out of a yellow RCA plug into red, green and blue pulses of the proper duty cycles to make an image that looked good. So I bought a book and read up on it. It turns out that those guys who invented the NTSC color video system in the 1950s were doing some amazing alchemy with half a dozen vacuum tubes!

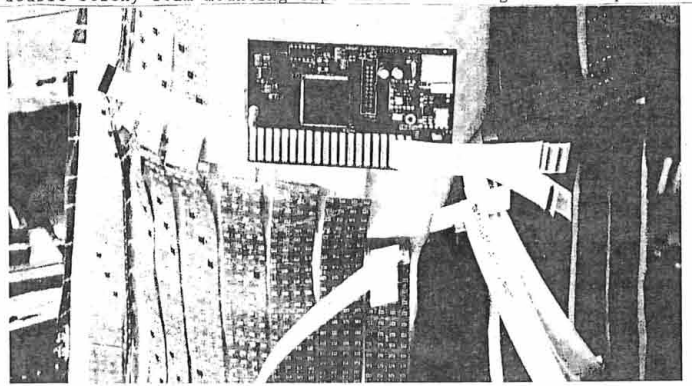
I found that Xilinx, the big maker of FPGA chips, has published a set of RGB video conversion functions for their chips that I could download and use for free. So I did. I also discovered that these free modules generate a shit-ton of warnings when compiled. So many that it was hard to find the REAL warnings about problems in MY code.

I found that the LEDs were manufactured with enough consistency that I didn't have to make corrections for each pixel's brightness, as I thought I was going to have to do. That was very good, since it would take a lot of work to do the correction. I did have a vague plan for it, but no desire to implement that plan.

If you've ever wondered what gamma correction is, all you have to do to find out is to build a video display from scratch. It has to do with applying a nonlinear brightness mapping to the LEDs to make the dark scenes dark enough and the bright scenes contrasty enough. Fortunately, it's documented fairly well in the literature.

I ran into all sorts of trouble getting the video to display correctly. The data rate was very high (27 Mbits/sec), so the clock and data signals had a hard time making it down the ribbon cables and through the LED strips cleanly. I had not used very good signal integrity methods in laying out the PC boards, as there wasn't much room for such niceties. I do regret this shortcoming.

Assembly of the video coat required a lot of work with a hot glue gun. The LED strips were glued to the outside of a lab coat, and the dozens of white ribbon cables were stuck together with double-sticky foam mounting tape and sometimes glued into place.



The four scanning PC boards, one on each shoulder and each hip, were held on with metal brackets glued onto the coat. It ended up being rather bulky and hard to handle, but it all worked.

When it was mostly done, I took it out to a Fourth of July party. It seemed to attract attention. I also wore it into a bar a couple days later. The bouncer asked me if I had copied that guy that he saw in the YouTube video. You see, I had a friend make a short video of me wearing the coat in my workshop. The video went viral. I explained to him that no, there's only one of these in the world.

I knew I was in trouble when it showed up in a Wall Street Journal blog.

Eventually, I prepared to take the coat to the Maker Faire in Detroit at the end of July. I had to disassemble it and pack it into a suitcase to take it on the airplane, as it was rather unwieldy and difficult to carry. Besides, festooned with wires and circuit boards, it looks a bit intimidating. More on that later.

I went on a week of vacation with my family, then the time came to assemble the coat in preparation for the Maker Faire. I was at a hotel in Ohio two days before, at a water park resort with my kids. I had my older son Henry act as my mannequin while I put the coat back together. This involved installing the four display scanning PC boards and all the attendant ribbon cables, then testing it to see if it still worked. Of course, it didn't. I eventually discovered that I needed to put the four display scanning boards in exactly the same places they were before so that it would work. I hadn't done that, assuming that it didn't matter.

Finally it started to work. I wore it while walking through the hotel, and found that it attracted a lot of attention. Kids would run up to it to see what was going on.

It was a hit at the Maker Faire. I also attended a street party with my wife in downtown Detroit one evening. It took me half an hour to walk into the place to find a beer, as so many people wanted to photograph it.

Eventually it was time to go home. I had to catch the flight back to Tucson directly from the Maker Faire, since my vacation plans were made without the Maker Faire in mind. I didn't have time to pack the video coat into its suitcase, so I wore it into the airport. A bit of commotion ensued, as a cop walked up to me at the checkin counter and told me that he'd had about 50 calls about some guy wearing a coat with wires all over it. Apparently, wires = danger. So I took some time to pack it back into the suitcase and check it as luggage.

Then the TSA decided that since I was such a risk, they'd subject my entire family to their super-special screening, just to make sure we didn't have anything dangerous on us. We got poked and prodded and felt up and bombarded with X-rays and swabbed and so forth. However, they didn't seem to be bothered by the eight high-power lithium-polymer batteries I had placed in my son's backpack.

It only dawned on me later, at Burning Man, as I plugged two batteries into each other (they have special crappy connectors that let you do that!) and I saw the sparks fly, just how badly the TSA had screwed up in allowing me to carry those batteries on board. Tee hee.