Steve Wozniak and the Apple 1
by Mike Willegal

In the first half of 1976, Liza Loop took delivery of the very first Apple 1 computer that was sold. I write took delivery, not bought, because Steve Wozniak bought it for her. Though I have known this for a long time, as I wrote this story, it occurred to me, that I didn't really know why Woz would do such a generous thing for Liza. In order to clear up the mystery of why, I did what I usually did when confronted with such a mystery about the early days of personal computers. I sent the participants an email.

"Hi Steve and Liza,
It's been a while… I'm doing a paper for an English class. Since the professor said I should be passionate about the subject, I decided the topic would be the Apple 1. While reviewing all my old emails and such, one thing stuck out. What always puzzled me was exactly what motivated you to buy a board for Liza and where did you two meet?
Just curious…
Best regards,
Mike Willegal"

One thing to note about this email, is that most everyone addresses Steve Wozniak as Woz. I'm not sure why, but I have always addressed him as Steve. Anyway, later on the same day, I received this reply from Woz.

"I encountered Liza at a meeting of the Homebrew Computer Club. She described how she rolled a minicomputer into elementary schools to show young students how to use a computer and spoke to them about how it worked and what software was. I may have been showing my computer at the club by this time but Steve Jobs didn't even know that it existed and was out of state and had never attended the club.
When Steve Jobs came into town I brought him to the club, not the other way around. He saw the excitement and wanted to turn this device into a company. My own employer, HP, tuned it down and Steve and I proceeded toward a sellable product. I took Steve up to Cotati, California, maybe a 2-hour drive, to meet Liza and see what she had there. The entire way home I implored Jobs to join me and give the very first Apple I computer to Liza, since it would inspire young students. Jobs refused, in the end, but said that I could buy it from our company for $300. I agreed to this and was our first official customer. I paid the $300 and gave the board to Liza. She is a person of high integrity who saw the benefits of computers to society similarly to myself."

It is an interesting story and reveals much about Woz's character. Like many people associated with the Apple 1, Liza is an interesting person with a surprising background. Liza is the great-granddaughter of Isidor and Ida Straus. Isidor and his brother, Nathan, shared ownership in Macy's department store from 1896 until Isidor and Ida's death with the sinking of the Titanic in 1912. Liza has long held an interest in education and the uses of computers in education. In 1975, Liza had opened the LO*OP Center, a non-profit computer learning center and around that time she started attending Homebrew Computer Club meetings where she met Woz. Note that Liza is still operating the LO*OP center and currently is involved in a project documenting the history of computers in education.
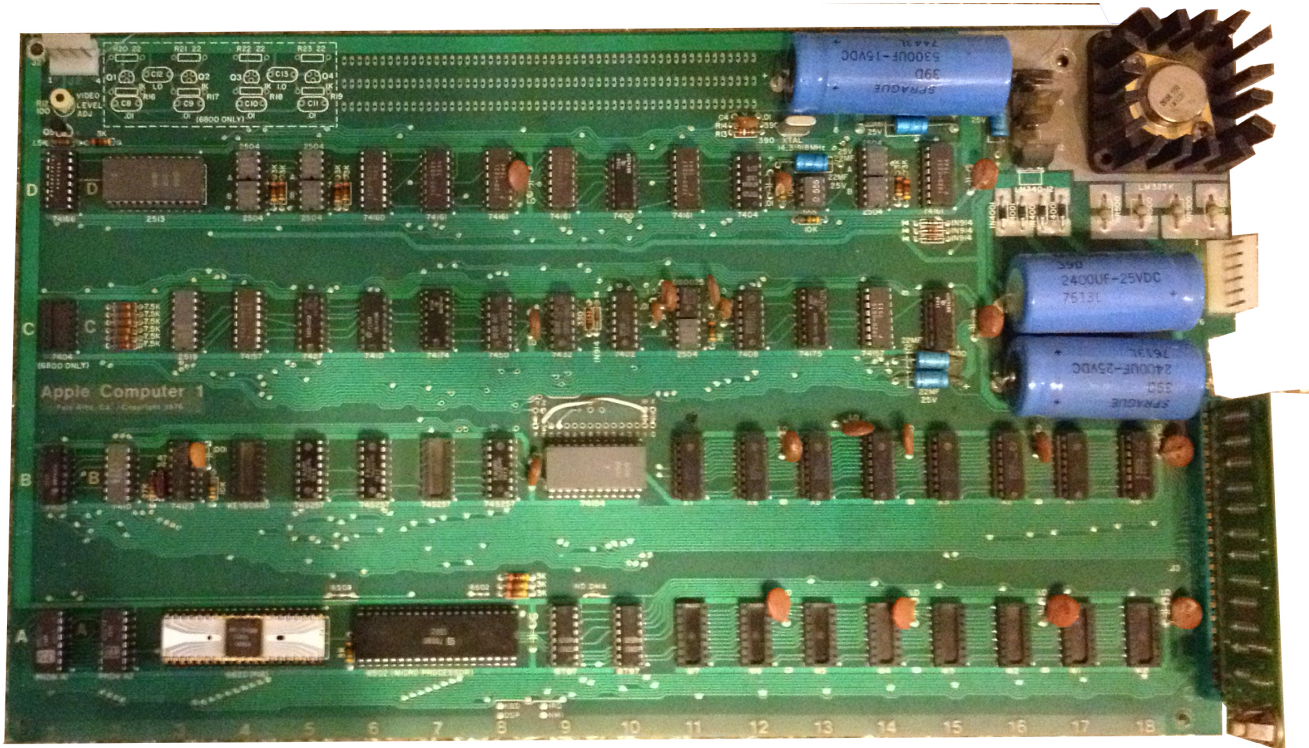
Liza Loop's Apple 1 Computer

These boards, plus a manual, is all you received when you bought an Apple 1

The story of that first Apple 1 turns out to be a bit complicated, as Liza could never get it working properly. She returned it to Woz for repair, but when Woz gave it back, it didn't work any better for her. Eventually Woz told her to wait a bit and said that he would get her a better computer. So Liza has the first Apple 1 to be sold and also has a very early model Apple II computer that Woz also gave to her to replace the Apple 1 that didn't work.

Woz was a college dropout at the time of the founding of Apple Computer, but after he stopped working at Apple he went back to school and obtained a college degree. He has taught elementary school, and remains a great advocate of technology in education and elsewhere.

The Apple 1 was the first product manufactured by Apple Computer. It was originally designed by Steve Wozniak, because he wanted a computer of his own. Not many people owned their own computers in those days. He first demonstrated his homemade computer at the Homebrew Computer Club which met in Palo Alto, California. This is also where he met Liza Loop. Woz shared his design by giving out plans of his computer to club members. His design featured the new 6502 microprocessor coupled to a video system that could display 24 lines of 40 characters on a TV. His friend, Steve Jobs, thought that the computer had some promise, and together they decided make a production run of those computers.

The process of turning a handmade custom one-off computer into a commercial product in Steve Job's parent's garage is the stuff of legend, and many books describe what happened. Though Woz's prototype was made up of several boards, connected together with wires, it was decided to build the production units on a single printed circuit board. The two sold a car and Woz's expensive handheld calculator to fund the design of the printed circuit board. They knew of an independent board designer, Howard Canton. Howard had designed boards for Atari, Steve Job's employer. Woz and Jobs paid Howard to layout the new board, for them.

Years later, I interviewed Howard about this project. Though I only talked to him once, he seemed to be a bit of an eccentric person. He is the only person that I can recall meeting that told me about his high IQ. He insisted on calling the Apple 1, a hobby computer, and the Apple II design, which he also was involved with, as the first Apple computer.

Steve Jobs found a potential customer. Paul Terrel, who was the owner of a new computer store, was interested in buying a batch. That interest by a retail store, proved to be important. Jobs and Woz didn't have the money on hand to buy the needed parts from an local electronics distributor. Since Paul Terrel had promised to buy 50 units, the distributor gave them 30 days to pay. The two Steve's had those 30 days to get 50 boards built and over to Paul Terrel's Byte Shop, so they could pay the distributor. They worked long hours to get the boards built and delivered.

Apple 1 owners had to find a compatible keyboard, TV for display, build a power supply and somehow mount it in an enclosure of some sort. Paul Terrel, owner of the shop, thought he was buying complete computers and was surprised when the guys showed up with boards and nothing else. He wasn't exactly happy with having to piece together the systems he bought from Jobs and Wozniak, but he went through with the deal, anyway.

Reproducing historically significant vintage computers is a hobby of mine, and in 2008, I became interested in building a reproduction of the Apple 1 computer. The electrical design of a computer is drawn in a form called schematics. The schematics should contain all the connections between the components in the circuit. In essence they are the electrical plans for the computer. Though I found schematics for the Apple 1 online, I needed good high-resolution images of original Apple 1 computers in order to build a faithful reproduction.

I started searching the internet for high quality images of the front and back of the circuit boards. Though they were scarce, I did come up with several good images. Eventually, over time, I made contacts with original Apple 1 owners, who provided better images and helped me figure out some things that couldn't be understood from looking at schematics and images, alone. They also shared many interesting stories about their Apple 1s. Among the more interesting people was Wendell Sander, an early employee of Apple, who became lead design engineer for the Apple III computer. Wendell was very helpful and was still in contact with many early employees of Apple, including Woz and many others. This group of early Apple employees has stayed in touch with each other over the years. Many of these early Apple employees had Apple 1's. They had taken them home from a stack of returned and unsold machines that were stored in a cabinet in the lab. I ended up selling parts to number of them, as they attempted to get these machines into working condition. Wendell Sander fixed a few of those machines for his friends.

One of the first things that I discovered, when examining the detailed images of the Apple 1 computer, was that production Apple 1 computers were not soldered by hand in Steve Jobs parent's garage as many of the history books say. They were soldered using a process known as wave soldering, which is only done in a proper factory. You can tell the difference between hand soldering and wave soldering by how uniform the soldering is. Even the best technician cannot replicate the uniformity of wave soldering. When I noticed that the Apple 1 boards were wave soldered in a factory, I sent a message to a friend, Cameron Cooper who was also interested in the history of early personal computers. When Cameron learned what I had found, he sent Woz an email asking about it. Woz responded with this email, which Cam forwarded on to me.

"At 9:34 PM -0600 2/8/10, Cameron Cooper wrote:

I was wondering if you could tell me if any Apple 1s were ever assembled by hand? Legend tells that some were built by hand in Jobs' parents garage or sold as bare board kits, but every Apple 1 I have seen has been wave soldered.

Wondered if you could shed some light..."

Woz replied,

"From: Steve Wozniak
Date: Mon, Feb 8, 2010 at 9:40 PM
Subject: Re: Wave soldered?
To: Cameron Cooper

We never designed or constructed any breadboards or computers in the garage. We picked up the wave soldered boards where they were made in Santa Clara and brought them to the garage for final assembly and testing.

I did construct either 2 or 3 Apple I's by hand, with the chips tightly spaced on HP breadboards (just holes) and I used wirewrap wire cut to length for each wire I soldered on. It's very compact that way and visible, compared to using wirewrap sockets. One of the Apple I's I built this way was for my friend Randy Wigginton.

I still have my main Apple I prototype board.

I believe that I only constructed one Apple II that way.
--

-- tv is wake zone"

The first thing to note about this email, is how quickly Woz responded to the inquiry. Cam sent his message at 9:34 and the response is listed as being sent at 9:40. This is not an aberration, I have found that Woz often responds to emails remarkably quickly. The second is how he signed "tv is wake zone", an anagram of Steve Wozniak. Steve likes to sign his email in clever ways. I have received quite a few emails from Woz, and his signature is often displayed upside down.

This email also shows that the myth of 50 boards that were hand soldered and delivered in 30 days, is just that, a myth. I have hand soldered a few reproduction Apple 1's and there are close to a thousand connections to solder. You would be lucky to get one board soldered and tested in a full day. If you were working a regular job, like Jobs and Wozniak were at the time, I can't imagine how long it would take to hand solder, build, and debug 50 boards.

Here is what really happened. Steve Jobs worked at Atari at the time. Just down the block was Santa Clara Circuits. Santa Clara Circuits was a contract printed circuit board manufacturer, who probably made that first batch of Apple 1s. They then loaded the boards with parts and wave soldered them. Printed circuit manufacturers often add their own logo to the boards that they make. Though the first batch of Apple 1 motherboards, don't have a manufacturing logo on them, surviving Apple 1 computer cassette interface boards have the initials, SCC printed on them, most likely the logo for Santa Clara Circuits. Later Apple 1 motherboards have the initials NTI printed on them. Most experts think that Jobs and Woz changed printed circuit board manufacturers for the second batch of Apple 1s. Steve and Steve used the connections that they had established in their normal work place to get the Apple 1's built. They were in the midst of a thriving technology culture that had the infrastructure needed to support their plans. They were not working in isolation.

This isn't to say that the Apple 1's were completely built and tested in a factory. The 56 chips that made up the Apple 1 design had to be stuffed into the sockets that were soldered on the board by the factory. After being stuffed, the whole, completed unit, needed to be tested and if any problems were found, resolved. Steve Jobs recruited his college buddy, Daniel Kottke to do this work. Daniel has given a number of presentations covering Apple's early years, and he has said that Woz was not at the Jobs' home very much. Daniel says that Woz would primarily come over to the Jobs' residence only to help troubleshoot some particularly difficult to repair Apple 1s. In fact, Daniel has said that he was often at the Job's home alone, bringing up Apple 1 computers all by himself. Later batches of the Apple 1 computers might have had a slightly different bring up process, as it is known that Steve Jobs' sister, Patty, stuffed some of the chips into boards, while watching TV.

One thing I learned about the Apple 1, during my efforts to reproduce it, is that there were some less than stellar design practices incorporated into the design. For instance, standard design practice says that inputs to chips should not be left unconnected. With the Apple 1, there are a number of unconnected inputs. Though it can cause problems, this design shortcut doesn't seem to affect reliability of the Apple 1. Woz has a reputation as a brilliant designer, but this basic design practice was ignored. This was not repeated on the Apple II, as all inputs were connected on that machine, as they should have been on the Apple 1.

As I worked on the reproduction of the Apple 1, I discovered that the design appeared to be a pretty basic interfacing of a TV Typewriter circuit to a very basic 6502 microprocessor circuit. The TV Typewriter was a design that was described in electronic hobby magazines well before the Apple 1 was designed. Don Lancaster had the first article about the TVT, as the TV Typewriter is called, published in the September, 1973 issue of Radio-Electronics magazine. The TVT was a video display circuit that could display 16 lines of 32 characters on a regular TV. A TV was used because, at the time, video monitors were rare and expensive. TVs were far more accessible to the typical person. The Apple 1 video circuit was a little different from the TV Typewriter in that it supported 24 lines of 40 characters and included special handling of end of line and the carriage return characters.

I exchanged some emails with Woz, about the idea of him using the TVT design as a basis for the video system in the Apple 1, and he responded "I was totally unaware of Don Lancaster's TV Typewriter when I designed my TV Terminal to access the Arpanet. I only found out about Don's device in subsequent years." Years later, when I met Woz for the first and only time, we talked a little bit about the Apple 1's video system. He said he copied it from some terminal product, but didn't say which one.

It's possible that Woz was not aware of the TV Typewriter, which had spawned a number of other copycat video systems, and that Woz had actually copied a modified version of the TV Typewriter that he had access to. The other thing that could have happened is that different designers could have independently come up with solutions to the same problem that turned out to be very similar. I don't think Woz is lying about not knowing about the TV Typewriter when he developed his video system. In fact, he is probably one of the most honest people that you could possibly find.

This raises another point about Woz, and that is his memory. Woz gives a lot of public appearances, and in many of them, he gives a talk about the early days at Apple Computer. I heard him give this talk one time, when we he was invited to speak at Cisco Systems, a past employer of mine. I have seen other videos of similar talks that he has given. Woz's talk is usually geared toward an interested person, and that person may not be an engineer, so it tends to light on engineering details.
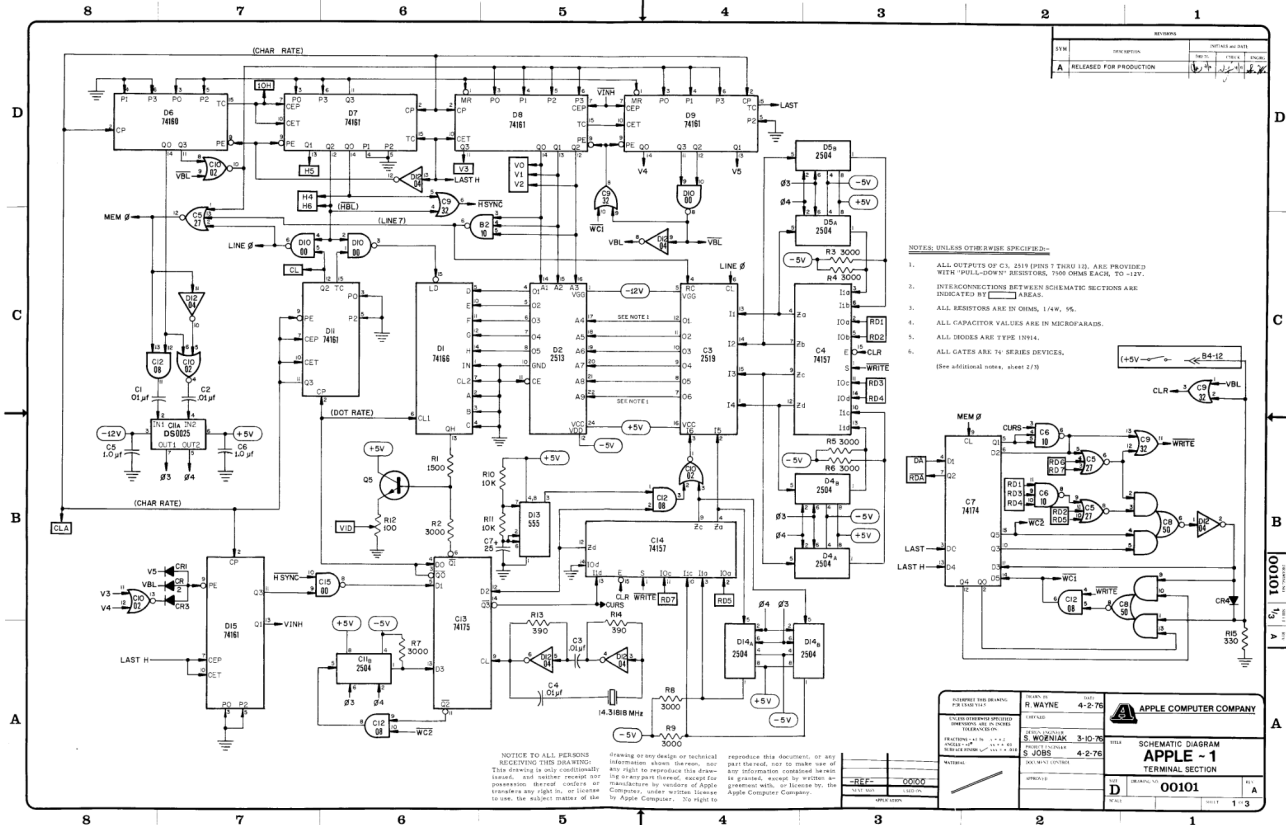
Apple 1 Computer Schematics

This Page is the Video Circuit that is so similar to the TV Typewriter

Over the years, I found that when I asked Woz detailed technical questions through email, he sometimes didn't remember the answer, especially if the question deviates from his usual presentation material. An example is the question I asked him about who manufactured the Apple 1 boards. He responded that he didn't remember. I don't know if his memory is especially faulty, as most of us can't remember clearly what we were doing 30 or 40 years ago. However, Woz had a plane accident back in 1981, that resulted in minor head injury and some amnesia. His memory may be worse than some of the rest us. My friends in the vintage computer hobby that also are acquainted with Woz, also seem to think that he has a poor memory, so maybe there is something to this idea. I don't think that it is related, but it is also said that Woz suffers from a problem called Prosopagnosia, or face blindness, the inability to recognize faces.

If you really want to know about the early history of Apple computer, I can recommend listening to Daniel Kottke. Daniel lived much of it, and has investigated much of what he didn't directly experience and mixed it all into a great presentation that he gives to interested groups.

When Woz and I met at a reunion of the Homebrew Computer Club in 2017, we spent a little while talking about the Apple 1 and Apple II. Woz confessed that he didn't really understand the part of the video circuit that handled end of line and carriage return functions in the Apple 1. I found that confession interesting, as I never really completely understood that part of the circuit, either. I still wonder where Woz got his video design from and who did the original design of that circuit.

There is one aspect of the Apple 1 design that I think is rather clever. That is how the video system was used to refresh the processor memory. Any memory from that period required that all rows of memory be read on a frequent basis or the memory would forget it's contents. There are different ways to walk through memory rows to maintain it, but the way that Woz did it in Apple 1, was quite efficient. He used the counters that were walking the video output raster across the screen to also walk across memory rows at the same time. This technique was expanded in the Apple II to completely integrate video and processor memory and memory refresh.

I consider the Apple II design to be brilliant, but it also was an evolution of what Woz had started with, in the Apple 1. Brilliant designs don't appear out of nowhere, even brilliant designers need to build upon a foundation. Woz had started with a TV Typewriter type design and added a basic 6502 micro-processor with DRAM to create the Apple 1. Over time, Woz, with the help of a number of other engineers, developed the design into the Apple II, which turned out to be an incredibly clever design.

When I completed my reproduction Apple 1, I had to bring it up and get it working. In the process, I discovered a few flaws in the design. First of all, the power distribution across the board, particularly the – 5 volt power supply had some issues. At first this didn't affect my reproductions, but later on, when I switched to using older, more period correct capacitors like the original Apple 1 had used, suddenly it became difficult to get memory working reliably. I solved that problem by testing and only using the best capacitors.

The software that Jobs and Wozniak supplied for the Apple 1 was limited to a BASIC interpreter that was written by Woz. Like the TV interface, Woz was able to learn about and adopt an existing design. Woz was currently working at Hewitt-Packard in their calculator division. At the time, they sold a desktop calculator called the 9830A. This calculator supported a BASIC interpreter and Woz must have had access to HP's design documents for HP BASIC. He adapted the design to the 6502 microprocessor which was used in the Apple 1.

The design of the HP calculator and a 6502 microprocessor are dramatically different and developing BASIC for the Apple 1 could not have been an easy task. It was always a work in progress. Woz would release a number of versions over the life of the Apple 1. I found at least four different versions still in existence while developing my reproduction. Wendell Sander, original Apple 1 owner and early Apple employee, told me that new versions of BASIC were frequently made available to Apple 1 owners.

One shortcoming that was never resolved in Apple BASIC, was the lack of support for large or fractional numbers. All numbers in Woz's implementation had to be in the range of 32767 to -32768. This integer BASIC was finally finished when the Apple II was released, but even then, it only supported integer numbers in that very limited range. Meanwhile, Bill Gates and Paul Allen had developed Microsoft BASIC which supported fractional numbers in a floating point notation. In Microsoft BASIC, numbers can range from $-(10^{38})$ to 10^{38}. Microsoft BASIC, with it's vastly better number handling, was available on a number of competing computers, which caused a problem for Apple.

Apple eventually licensed Microsoft BASIC from Bill Gates and Paul Allen and had it released for the Apple II. It was never made available for the Apple 1, though a few years ago, someone using a reproduction Apple 1, did port it back to that machine.

In the first days of the Apple 1, there was no means of storing programs. Every time the computer was powered off and back on, data had to be manually re-entered using a small program that Woz had written and burned permanently into memory. This little program could take user input from the keyboard and write and read memory, but little else. Once the user had entered his program into memory with the keyboard, the user could use the keyboard to start the program.

To load BASIC into memory, Woz had to manually enter up to 4000 characters of data using the keyboard. I once tried to manually load BASIC on my Apple 1 reproduction this way. After about 10 minutes of effort, I gave up. I decided that it would have taken hours to get all of BASIC loaded correctly using the keyboard method. The difficulty was such that I thought to myself that Woz must have done this only a couple of times. However, at the Homebrew Computer Club reunion that I attended, this topic came up. A number of people that knew Woz back in the Apple 1 days, confirmed that they witnessed him loading BASIC by hand into an Apple 1 and that he did it frequently, not just a couple of times.

Like most early home computers, Woz eventually developed an interface for the Apple 1 in order to store data and programs on ordinary audio cassette tape. This made loading, saving and running programs much more convenient. When building my reproduction, I found that the Apple 1 cassette interface barely worked. It took me a long time to figure out how to make the cassette tape work somewhat reliably. I finally got it working fairly well, when I looked at how Apple had tweaked the design for the Apple II, which didn't have the same reliability problems. Later on, I found out that some, but not all, of the surviving original Apple 1s suffer from the same cassette tape reliability issue that my reproduction had. One owner of an original Apple 1 that I know, completely gave up on using his cassette tape interface. I often wonder if the cassette tape interface was at the root of the problems that prevented Liza Loop from using her Apple 1. The cassette tape interface did work well for other people, as Wendell Sander told me that his always worked well.

Woz has amazing digital design skills. The heart of the Apple II design was his and that machine ended up selling about 6.5 million units in various versions over a period of about 16 years. However, when it came to the analog end of things, his designs occasional seem to have problems. It turns out that Woz had support from other engineers when it came to the power supply, peripheral bus and a few other aspects of the Apple II computer. With the Apple 1, Jobs and Wozniak didn't have the benefit of additional engineers to help them out. As a result, it had some problems, and sold less than 200 units. In the great scheme of things, however, the Apple 1 gave Steve Jobs and Steve Wozniak a stepping stone, which they managed to use to build an amazing company. In that respect, the Apple 1 was a fantastic success.

There is one final, most remarkable thing about Steve Wozniak, that I would like to share. The vast majority of people that have attained success or notoriety, have also found some detractors. I have met many people that have shared stories with me about Woz, and I have never heard anyone who knows him, say anything negative about him. In my experience, he is an honest, straight forward person, who is always himself, and doesn't know how to put on an act.

December, 2019

Some of the Characters in this Story at the Homebrew Computer Club and Apple Reunion

at the Living Computers: Museum + Lab,

Seattle, Wa, Spring of 2017