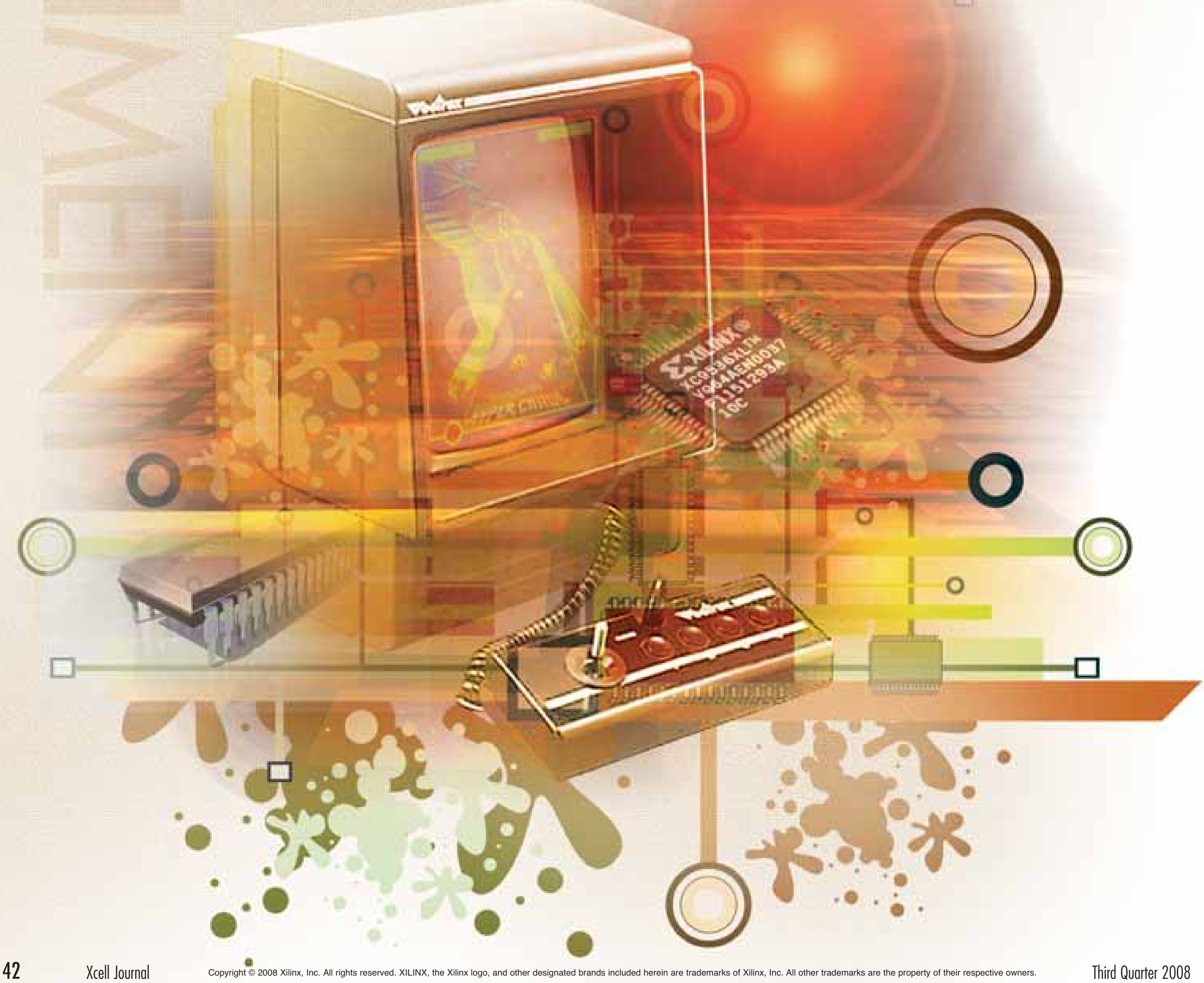
Replacing Obsolete Video Game Circuits with Xilinx CPLDs

Replacing obsolete parts with a Xilinx XC9536XL CPLD gives new life to a Vectrex video game system.

In this article, designer In Choi describes a project for his home business in which he replaces a defective part in a 1980s game system to show his full-time employer that they can adopt a methodology using Xilinx® programmable devices to replace a range of parts that other semiconductor vendors are no longer producing.



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[The Vectrex video game system] was a self-contained game unit much like the full-sized game machines in arcades but scaled down for home use. It was somewhat portable as long as you could plug it into an AC outlet.

Parts obsolescence is nothing new, but it has attracted more attention recently, particularly in the semiconductor industry. Sometimes chip companies no longer produce parts for older products; others go out of business.

Although no single optimal solution exists, you can typically manage parts obsolescence using one of three methods:

- Find a form, fit, and functional substitute.
- Redesign the subsystem containing the obsolete part.
- Replace or redesign the entire system.

From a practical perspective, the last two methods are generally too expensive; it would probably be more cost-effective to replace the subsystem or the entire system.

Thus, the first method is the most practical, and we'll show how we at Retro Devices Technology did it using a Xilinx® XC9536XL CPLD – specifically targeted for 5-V transistor-to-transistor logic (TTL) gates and digital logic functions – to replace a 74LS32 microcircuit in the PCB of a 1980s video game system called Vectrex. For the sake of this project, we are assuming that the 74LS32 is obsolete.

Vectrex System Overview

The Vectrex video game system was originally licensed and distributed by General Consumer Electric (GCE) in the early 1980s. It was a self-contained game unit much like the full-sized game machines in arcades but scaled down for home use. It was somewhat portable as long as you could plug it into an AC outlet.

The Vectrex system comprises an 8-bit 6809 microprocessor running at 1.5 MHz, an AY-3-8912 sound chip from General Instruments, a 9 x 11-inch monochrome monitor, and a game controller with four buttons, as shown in Figure 1. The Vectrex uses a vector graphics system as opposed to a pixel-based raster graphics system.

Figure 1 – The Vectrex gaming system

In this design, we used the XC9536XL CPLD to replace a part called the 74LS32 Quad-OR gate in the Vectrex video game system. The original designers used this part as decoding logic to perform read and write access to the RAM by the processor in the Vectrex (more information is available from the Vectrex website at *www.vectrex.nl*). I chose to replace the 74LS32 with the XC9536XL CPLD to minimize development cost and to prove out my scalable design methodology simultaneously.

Design Description

Our design requirements were to keep the physical size of the replacement part as small as possible, meet all of the electrical specifications, keep the power level at least equal to the obsolete part, and use a replacement part that is configurable to replace as many 5-V TTL 74LS series gates and digital functions as possible.

I created the customized functions using VHDL, then synthesized the code into a configuration file and programmed the design into the CPLD. For the sake of this article, I'll refer to the replacement part as the retro logic device (RLD). Figure 2 shows the fully operational RLD device next to the 74LS32.

The design footprint of the RLD is a little larger than the 74LS32 because of the PCB vendor's manufacturing limitations, but there was sufficient room in the original game circuit board to accommodate the RLD.

The electrical performance of the RLD was a non-issue, since the Xilinx XC9536XL CPLD already has TTL I/O compatibility. You can read the XC9536XL data sheet if you are not familiar with the specifications or how to properly power the I/O for TTL compatibility.

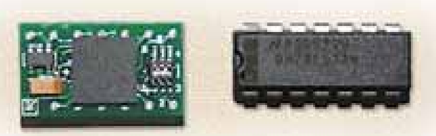

Figure 2 – The RLD (left) and the original 74LS32 part it replaced (right)

The power of the RLD is also comparable to many 74LS series functions. I achieved this power compliance by using a 3.3-V low power voltage regulator on the RLD's PCB. I placed a bypass capacitor at the output of the voltage regulator to provide filtering for the CPLD.

From a signal integrity perspective, it is typically best to place the capacitor directly under the board and attach it to the CPLD's voltage and ground planes to provide the shortest (lowest inductance) path. However, the Vectrex circuit board didn't require a high level of performance.

I then placed a 6-pin JTAG connector on the RLD to configure the CPLD. Finally, I created a custom mating connector for the RLD for configuring the RLD. I attached this custom connector to the platform cable USB using flying leads.

Design Operation

I needed to find the right power source to configure the RLD. Therefore, I used a breadboard to power the RLD configuration before applying the design to the Vectrex circuit board. I achieved the power regulation using a 6-V power adapter from a development kit that was lying around. Experimenting with several capacitors and resistors, I came up with the appropriate current and voltage settings to properly operate the RLD.

The cost of low-end laptop computers has dropped significantly and their performance is quite good, so I did not need a high-performance modeling environment for this project. Therefore, I used a cheap laptop running Windows XP, loads of vendor trial software, and Xilinx WebPACK software, which is freely available for downloading from the Xilinx website. The laptop proved more than sufficient to run the software.

I used the Xilinx WebPACK to create the 74LS32 project, which essentially consisted of creating four concurrent statements in VHDL. VHDL is a simple code for OR-ing two inputs to a single output, and I repeated the step three times to different I/O ports, making sure to use the proper I/O constraints file for the design.

I attached the laptop to the RLD with the cable. I then synthesized the 74LS32 VHDL code and downloaded the design into the RLD using the Impact tool integrated into Xilinx WebPACK.

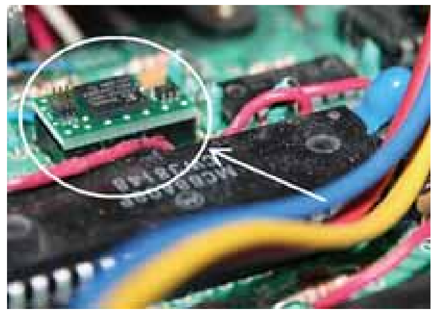

Figure 3 – The RLD placed on the Vectrex board

I then physically removed the 74LS32 part from the Vectrex circuit board. To make maintenance easier, I soldered a 14-pin socket onto the circuit board. I then inserted the RLD into the Vectrex game circuit board, as shown in Figure 3. I switched the Vectrex game system to "on" and played a game.

I created the RLD so that I could configure it while it was on the Vectrex circuit board. In general, using this method can often prove unpredictable and may even be catastrophic in some designs. If you are planning to use the method I've described here, be prepared to have a lot of sacrificial hardware on hand in case something doesn't go as planned. If your configuration is successful and passes the no-smoke test, push the reset button on the Vectrex unit and everything should work fine. But do this at your own risk – and don't call me if you smell or see smoke.

There will always be some degree of parts obsolescence, but this procedure serves as an alternate solution to manage it more effectively. If anything, it allows more time for managers to make economical business decisions. With further research and development, this scalable solution can be retargeted to replace other legacy devices of varying technologies and complexities, thus providing a truly unified solution to parts obsolescence.

Please visit our website at *www.retrodevices.com* for more technical information about the RLD, including purchasing information.

Design Notes

You may be wondering why I did this exercise. Wouldn't it have been easier to buy a video game console from this or even the last decade? I didn't do the design simply to restore the video game – I did it for a number of reasons.

First off, I think logic design is fun (and I'm lucky enough to get paid to do it). Second, I wanted to show that I could create the RLD to directly replace a failed part. But my main reason for doing the project was to create a methodology with an FPGA to show that there are indeed practical ways to overcome chip obsolescence.

The approach I demonstrated in this article is scalable. Although this article focuses on the configuration of an XC9500XL series CPLD to replace 74LS series devices, I could have conceivably applied the same method to replace even more complex devices in this system, even the 6809 microprocessor on the Vectrex game board. The 6809 VHDL IP core is readily available from multiple sources and can fit within a Xilinx Spartan™-II FPGA.

In fact, with the resources available to us today through the Internet, a designer could conceivably add more functionality to the processor and actually improve the Vectrex system, or develop their own version of the microprocessor. If you do a search on the Internet, you will be amazed at how many people have developed their own processors.

This isn't the first time I've used an FPGA to replace an obsolete part. Indeed, over my long career I've done many of these projects. I'm currently working on a project at my full-time job, in which my employer has asked me to port a series of 12-year-old FPGA designs that were originally implemented on one-time programmable FPGA technology – technology that is now obsolete – to a newer series of one-time-programmable FPGAs from the same manufacturer. The design files comprise EDIF files, logic schematics, Abel code, and circuit diagrams (Does anyone remember Abel?).

To get around the challenges of moving the design from an obsolete OTP FPGA to a newer OTP FPGA, I am currently trying to work with my managers to run a pilot project based on the RLD methodology demonstrated in this article.

For the pilot project, I've outlined a new methodology in which I'll review all the circuit boards and identify and create a list of obsolete parts. From the list, we'll group the parts based on packaging and find the largest design in the list using the same package. We can then select a Xilinx FPGA that can fit the largest design.

Better yet, we can select the largest Xilinx part possible that fits comfortably within the package footprint and use the extra resources to add functionality from other FPGAs on one device, add new functionality, or simply avoid any unanticipated design problems. We can then create a custom circuit board with the FPGA and mass-produce it. This methodology is repeatable for any other parts that are now obsolete, so long as they have a suitable package footprint.

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