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Using CoolRunner-II CPLDs in Portable Educational Toys

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Portable educational electronic toys are becoming increasingly common in the home. There are a huge variety of electronic gaming products aimed at educating children of all different needs and requirements. This White Paper shows how the low power CoolRunner™-II CPLD can be used to incorporate new functionality into a portable educational toy quickly, cost effectively, and with very little additional power consumption.

Introduction

People started harnessing the power of digital electronics for educational purposes as early as the 1950s. In 1955 an engineer named Edmund Berkeley designed a toy called Geniac (Genius Almost-Automatic Computer) which used six rotary wheels with electrical contacts to perform basic electrical functions. Priced at $15.95, it was a luxury item that only wealthier families could afford. Several years later, Berkeley released a reduced-cost, reduced-functionality version of Geniac called Brainiac. Even in the early days of educational toys, people recognized the need to reduce the cost of their products in order to establish greater market appeal.

The educational toy market continued to grow throughout the 1960s and 1970s, but the majority of the toys were still relatively expensive. In 1978, Texas Instruments released a simple battery-powered toy consisting of a vacuum-fluorescent display, a speech-synthesis processor and a keyboard, all housed in a colorful plastic case. Speak and Spell was born! The aim of Speak and Spell was to teach children how to say and spell commonly used words, rather than to educate them on the principles of electronics, as had been the case with most previous electronic educational toys. While it was considered very advanced for its time, with two 128 kb ROMs for storing the encoded speech data, Speak and Spell was one of the first educational toys that was not prohibitively expensive. Three years later the Speak and Math was created as a sister device to Speak and Spell, this time to help children learn the basics of arithmetic. The success of these simple machines fuelled the increase in portable, battery-powered educational toys. Now, there are electronic educational toys in a vast number of homes and it comes as little surprise that the worldwide market for "edutainment" toys is expected to reach $7.3 billion by 2011. See **http://www.instat.com/newmk.asp?ID=1981**

The complexity of educational toys has increased significantly in recent years with ever increasing levels of interactivity. A typical system will receive inputs from human interface equipment such as joysticks, push buttons and keypads – from wireless media such as IrDA and from analog sensors through an ADC. The interactivity is enhanced by the inclusion of cameras, audio outputs, motors, LEDs and LCD screens. A Central Control Unit (CCU) stitches all these elements together. The complexity of the CCU depends on the functions the toy needs to perform. Commonly, there will be some sort of processor at the heart of the system. Figure 1 shows a block diagram of a typical educational toy.

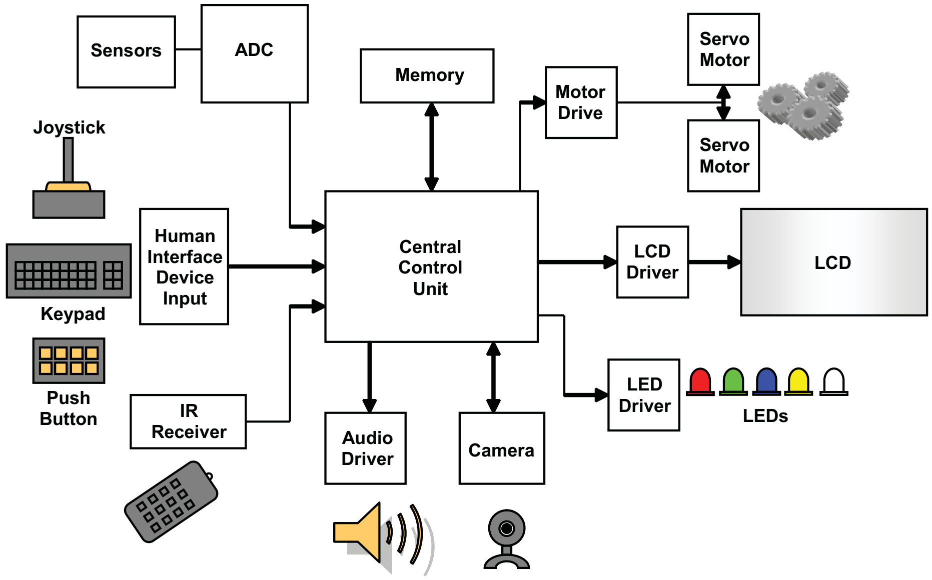

Figure 1: **Block Diagram of a Typical Educational Toy**

The common strategy of using an off-the-shelf processor within the CCU has the benefit that a single platform can be used to build multiple end products – all with different functionality. Xilinx CoolRunner-II CPLDs are the perfect solution to enhance the base platform by adding extra functionality.

CoolRunner-II CPLDs

CPLDs are programmable logic devices that can be programmed to perform almost infinitely many functions for very little cost. CoolRunner-II CPLDs combine very low power with high speed, high density, and high I/O counts in a single device. The CoolRunner-II family ranges in density from 32 to 512 macrocells. CoolRunner-II CPLDs feature RealDigital technology, allowing the devices to draw virtually no power in standby mode. This makes them ideal for the fast-growing market of battery-operated portable electronic equipment.

Each member of the family includes RealDigital design technology that combines low power *and* high speed. With this design technique, the family offers true pin-to-pin speeds of 5.0 ns, while simultaneously delivering power that is less than 16 µA (standby) without the need for special power down bits that can negatively affect device performance. By replacing conventional amplifier methods for implementing product terms (a technique that has been used in PLDs since the bipolar era) with a cascaded chain of pure CMOS gates, the dynamic power is also substantially lower than any competing CPLD. CoolRunner-II devices are the only total CMOS PLDs. The patented DataGATE technology permits a straightforward approach to additional power reduction. Each I/O pin has a series switch that can block the arrival of unused free-running signals that may increase power consumption. Disabling these switches enables the user to select any pins they chose to be disconnected from the device fabric, thereby preventing unnecessary toggling from entering the device and resulting in significant power reduction.

Using CoolRunner-II CPLDs to enhance the functionality of educational toys has several key benefits:

- The same base platform can be used for all products
- Base processor functionality can be enhanced in multiple ways using just one cost effective device
- Additional functions can be performed using less power than asking the CCU to perform the functions
- Very little board space is required to perform additional functions due to the ultra small packaging offerings

Figure 2 shows the functionality that the CoolRunner-II CPLD can perform inside the educational toy. Each of the blue blocks represents a single function performed by the CPLD, but, of course, multiple functions can be consolidated into the same CPLD!

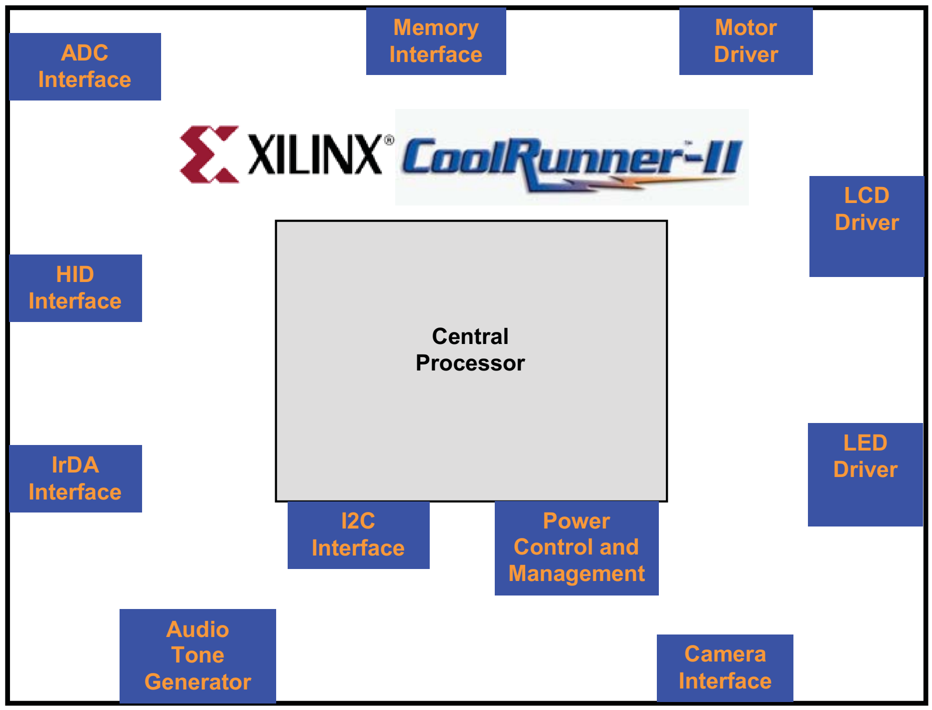

Figure 2: **Functions Performed by a CoolRunner-II CPLD**

Inputs

CoolRunner-II CPLDs are rich in general purpose I/O and can drive and receive a range of different voltages. This makes them ideal for interfacing the various input devices to the central processor. Human interface devices can require debouncing of push buttons and decoding of keypads. Xilinx Application Note XAPP512 illustrates a CoolRunner-II CPLD scanning and decoding a keypad. Other input devices may take the form of analog sensors. Whether they detect motion, movement, temperature or some other parameter, they always need to be digitized before they can be recognized, hence the need for an ADC. Of course the signals coming out of this ADC need to be translated – another job perfect for a CoolRunner-II as shown in Xilinx Application Note XAPP355. If any handheld remote control devices are used with the toy, an IrDA interface will need to be included to receive and decode the data. Xilinx Application Note XAPP345 provides an IrDA and UART system that can easily be implemented in a CoolRunner family CPLD.

Interfaces

With cameras becoming significantly cheaper, they are being used in a greater number of applications. Incorporating a camera into an educational toy means that the toy can interact with the movement of the child, providing greater stimulus and prolonged use and enjoyment. In Xilinx Application Note XAPP390, a Micron CMOS image sensor is controlled with a CoolRunner-II CPLD.

Commonly, the system will require a couple of different types of memory, perhaps for storing code, constants, or encoded audio data. Xilinx Application Notes XAPP354 and XAPP384 show how easy it is for CoolRunner-II CPLDs to interface to various different memory standards.

System Management

Several of the system peripherals used in the educational toy will use a common interface by which to communicate with the main processor. The Inter-Integrated Circuit (I^2C) bus is perfect for connecting low speed peripherals, including memories, ADCs, simple displays and other components to a system. I^2C can operate at a variety of different speeds. Xilinx Application Note XAPP385 provides a working I^2C controller implemented in a CoolRunner-II CPLD.

System Management Bus (SMBus) is a subset of I^2C that was introduced primarily to control processor based systems, mostly for system and power management in applications using batteries and temperature and voltage sensors. Xilinx Application Note XAPP353 provides a fully functional SMBus controller that can fit into a Xilinx CoolRunner-II or CoolRunner XPLA3 CPLD.

Alternatively, if the I^2C or SMBus controller are already present and therefore the CPLD does not need to act as a full controller, it can be used to incorporate extra I/O ports in order that the system can communicate with more I^2C or SMBus compatible peripherals. Xilinx Application Note XAPP799 shows how easy it is for a Xilinx CoolRunner-II CPLD to add extra ports into a system.

The extra architectural features inside the CoolRunner-II device can be used in combination with the SMBus controller (or independently) to manage the power of the entire application. The more devices and peripherals that can be powered down, the longer the battery will last. The DataGATE feature introduced above is an exceptionally useful tool to aid in power management. CoolRunner-II DataGATE can freeze signals to other chips when they are not required, signals that would otherwise be driving the other chips. These signals will be held at the logic level that was last on the input pad when DataGATE was asserted, providing the last known reference data. Xilinx Application Note XAPP436 gives great insight into the power of using DataGATE to aid system power management.

Microprocessors have a number of operating modes such as Normal, Run, Sleep, Suspend, Standby, Stop, and Idle. System power management can also take the form of offloading tasks from the main processor in order to stay in the lowest power mode for as long as possible. Because the CoolRunner-II CPLD consumes so little power even when active, significant power reductions and increased battery life can be achieved. Xilinx Application Note XAPP347 gives some pointers on how to lower system power by letting a CoolRunner-II handle interrupts, resets, and wake-up signals.

Outputs

Perhaps the most important aspect of any educational toy is the way in which it interacts with a child. The input section above covered how a child communicates with a toy. It is important to the success of the product and the education of a child that the system effectively communicate back to them. The three main methods most educational toys use to communicate back a child are through light, movement, and sound.

LEDs are a great, simple method of communicating to children the success or failure of their actions, with the added bonus that it is a basic human response to be attracted to flashing lights. There are many different types of LEDs on the market, all of which have different drive requirements. Xilinx Application Note **XAPP805** shows how a CoolRunner-II CPLD is the perfect solution for driving LEDs, including how best to attach LEDs to a CPLD, how to achieve the best and brightest results, and how to drive multiple LEDs with one device.

Simple LCD screens are rapidly becoming commonplace on toys. Technology has improved since the vacuum-fluorescent display used by Speak and Spell, but the principles remain the same. With a modern character LCD display, data is written to the data bus in a specific order by a state machine. Of course, as screens get larger, the amount of control logic required also increases. Xilinx Application Note **XAPP904** illustrates how easy it is to implement a character LCD module control state machine inside a CoolRunner-II CPLD.

Movement in a toy can take many forms: blinking eyes, moving heads, or waving arms. But, one thing is certain – all movement must be controlled by a motor of some kind. Xilinx Application Note **XAPP940** provides a design in which a CoolRunner-II steps a stepper motor forward. More complex movement can easily be achieved with the addition of pulse width modulation (PWM), which can also be used to drive the LEDs, effectively synchronizing movement with brightening and fading of lights.

Combining lights and movement with audio stimuli provide complete electronic interaction. Creating sounds that a child can recognize can be as simple as providing a tone that is instantly recognized as positive or negative. If this is required, a CPLD can retrieve encoded audio data from the memory (as if it were a large look up table) and output the data through an audio driver. If more complex audio is required, the CPLD can be used as a complete MP3 player as described in Xilinx Application Note **XAPP328**.

Conclusion

Educational toys have progressed a great deal from the first handheld battery-powered developments of the 1970s. However, many principles and traits remain the same thirty years hence. Educational toys are still limited by the length of time the battery lasts, and, despite the advances in battery technology, designers are still up against a challenge. This document shows how Xilinx CoolRunner-II CPLDs can be used to enhance and augment the functionality of an educational toy, and make it more successful in the market for very little increase in system power consumption and little additional cost. While on board, the CPLD can also act as a system power manager, shutting down the rest of the application whenever possible, giving the product the longest possible use from one charge or set of batteries.

Revision History

The following table shows the revision history for this document:

Date	Version	Description of Revisions
04/23/08	1.0	Initial Xilinx release.

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