Design and Development of Voice Integrated Electronic Educational Toys

K Ediriweera, J P D S Athuraliya and R.M. Tilakeratne

Abstract: Educational toys of colourful appearance with displays giving numbers, letters and messages, attract the interest of sighted children, making learning especially enjoyable. Visually impaired children, however, cannot be benefited by the colourful appearance or by attention-grabbing objects on displays. Nor can they experience an easy and natural introduction to computer based educational aids. This paper presents the design and development of a microcontroller based educational toy, which has two versions to suit both the normal and visually impaired children. The first version is for the normal children, which catches their interest by the colourful appearance and LCD display, supplemented by voice/sound effects. The other is a complete voice/sound integrated version developed for blind children, by incorporating verbally presented problems and verbal phrases in lieu of the visually presented problems and visual indicators in the first version. The paper also highlights the low power design techniques adopted in order to make the device suitable for battery operation.

Keywords: Educational Toys, Visually Impaired, Voice Reproduction

1. Introduction

Educational toys of colourful appearance with displays giving numbers, letters and messages, attract the interest of children, making learning especially enjoyable. At present, the Sri Lankan electronic toy market is completely dominated by imported toys. Also there is a scarcity of good quality educational toys in the market. Therefore, one aim of this project was to design and develop a good quality, voice integrated, and attractive educational toy locally. At the same time, it was possible to design a complete voice/ sound integrated second version suitable for visually impaired children, who cannot be benefited by the colourful appearance or by attention-grabbing objects on displays. This was done by incorporating verbally presented problems and verbal phrases in lieu of the visually presented problems and visual indicators in the first version.

This paper commences with a description of the two versions of the product. Then it gives the design requirements and how the Integrated Circuits (ICs)/modules were selected considering their features, other compromising factors and design requirements. The paper then presents a functional description of the product, emphasizing on several low power design techniques that have been adapted for making it suitable for battery operation. Finally, the paper describes the firmware implementation using the system state diagram, followed by the results and the conclusion.

2. Product description

The first version of “Math Master” Play and Learn System is an educational toy for children of age between 4 and 10, to learn simple mathematics. It has four selectable levels (ability levels) to suit with the ability level/age group of the child. Each ability level has four different activities to select from, out of COUNTING, ADDITION, SUBTRACTION, NEXT NUMBER, DIVISION and MULTIPLICATION, as suitable for that level.
Two keys are provided for the selection of ACTIVITY and LEVEL. From the moment the unit is powered on, step-by-step verbal instructions are given on “how to play” (either in English or to any other language to which the unit is programmed). The unit is incorporated with a 16*4 character, alphanumeric-LCD, to display the random problem generated corresponding to the activity, to display the answer entered and to display the correct answer if the child fails to enter the correct answer in three tries. A 12-key pad is provided for entering the answer.

In the second version, the information displayed on the LCD was replaced by verbally presented problems and verbal phrases and the information given by the LED indicators was replaced by verbal announcements.

In order to get the required volume of sound, several audio power amplifiers, low voltage audio amplifiers and low voltage audio amplifiers with shut down mode were considered. Although, a low voltage audio amplifier with shut down mode was technically preferred, MIK386 IC, a low voltage audio power amplifier without shut down mode, was selected considering the cost and availability. The MIK386 [2] is a power amplifier designed for use in low voltage consumer applications. The gain is internally set to 20 to keep external part count low, but the addition of an external resistor and capacitor between pins 1 and 8 will increase the gain to any value up to 200. The quiescent power drain is only 24 milliwatts when operating from a 6-volt supply, making the MIK386 ideal for battery operation.

A PIC16F877 microcontroller [1] with 8kB of programmable Flash memory was selected by considering the input/output pin requirement for interfacing the peripheral chips, program memory size, the low power design capabilities and the cost.

4. Functional Description

Figure 1 illustrates the functional block diagram of the “Math Master” Play and Learn System.

The microcontroller interfaces the record/playback IC, keypad, LCD and LED latch.

![Functional Block Diagram of the “Math Master” Play and Learn System](image)

The other main ICs/ modules required are the display, audio amplifier and the microcontroller.

A 16*4 character, alphanumeric LCD display, with Hitachi 44780 based LCD controller was selected considering its adequacy for the display of mathematical problems and simple messages and the ease of interfacing without additional hardware.
keypad matrix, and uses the same I/O pins to write to the LED latch, which drives the LEVEL and ACTIVITY indicator LEDs.

The microcontroller uses the record/playback IC (ISD2590) [4] to selectively playback the messages pre-recorded [6] at known address locations. The IC is hardwired to playback mode. During a play back cycle [5], the microcontroller powers up the record and playback IC, sets up the address pins, waits for stabilizing and then drops the chip enable. The record and playback IC, then plays back the selected message. The speaker out of the IC is amplified and given to the speaker.

### 4.1 Keypad Interfacing for Low Power Operation

Out of the several methods available for keypad interfacing, continuous polling of keypad’s rows and columns was adapted. However, an interrupt generated with the press of any of the keys is used to wake-up the microcontroller from sleep mode [1] and to control the voltage supply to audio amplifier.

### 4.2 Record/playback IC (ISD2590) Operation for Low Power Consumption

This IC incorporates a power down mode [4], which can be used effectively for low power standby operation. The IC is powered up at the start of a phrase and powered down at the end of the phrase by the microcontroller. The firmware for message playback is designed in such a way to identify the pre and post power down/up state of the IC, so that smooth message concatenation can be achieved by avoiding power down of IC between concatenated messages, which forms continuous phrases. By using ISD2590 in power down mode during the periods it is idling, it is possible to reduce the current consumption of “Math Master” Play and Learn System, operating at 5.0V by more than 13 mA.

### 4.3 Microcontroller Considerations for Reduced Power Consumption [3]

Several techniques were used to reduce the power consumption of the microcontroller. The use of PIC microcontroller in sleep mode with wake-up from sleep to an external interrupt is used to reduce power consumption. In sleep mode the oscillator is shut off, which causes the microcontroller to consume very little current, typically in the order of a few microamperes. Selection of a suitable oscillator frequency was another important consideration.

The power consumption is also dependent on the oscillator frequency of the microcontroller. Table 1 gives a comparison of circuit current consumption of “Math Master” Play and Learn System, at different oscillator frequencies with V=5.0V, ISD2590 in power down mode and three LEDs on. The microcontroller must operate fast enough to interface with external circuitry, yet slow enough to conserve power. The difference between 4MHz and 1MHz operation is only 0.7 mA. Therefore, the 3.579545 MHz, colour burst crystal oscillator was selected because of its low cost.

### Table 1- Circuit current consumption at different microcontroller oscillator frequencies

<table>
<thead>
<tr>
<th>Microcontroller oscillator frequency</th>
<th>Circuit current consumption (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20MHz</td>
<td>36.0</td>
</tr>
<tr>
<td>4 MHz</td>
<td>33.1</td>
</tr>
<tr>
<td>1 MHz</td>
<td>32.4</td>
</tr>
</tbody>
</table>

### 4.4 Audio Amplifier Operation for Low Power Consumption

Low voltage audio amplifiers operating from 5 – 6V have lower quiescent currents than audio amplifiers operating from higher voltages. In order to further reduce the idle current consumption of the audio amplifier, it is powered through a switching transistor, which cuts off the power to the audio amplifier during the periods in which the microcontroller goes to sleep mode.

### 5. System state diagram and Firmware Modules

There are four operational states and these operational states are implemented using several firmware modules. The functions of main firmware modules are described below.
Figure 2 - illustrates the state diagram of the “Math Master” Play and Learn System.

(i) Initialization state
Initialization module: Initialize the system Settings

(ii) Startup State
Startup module: Initializes peripherals and waits for selection of basic settings (i.e., activity)

(iii) Operation State
ProblemGen module: Generates a random problem according to level and activity.
CalAnswer module: Generates answer
CheckAnswer module: Checks the value entered with the correct answer.
KeyScan module: Scans the keys column by column and sets the key index
SetActivity module: Set the activity according to pressing of activity key.
SetLevel module: Set the activity according to pressing of level key.
LedWrite module: Sets the activity and level indicator LEDs
SendDispl module: Sends problems, user answers, comments or correct answer to display.
Sound module: Sets the address, controls and necessary delays to playback the sound phrase required [5].

(iv) Sleep State
There are no modules in this state. The microcontroller firmware waits in this state until the receipt of an interrupt by key press.

The following additional firmware modules were added to the Operation State, in order to modify version 1 to suit the visually impaired children.

NumToSound module: Converts a number to sound by analysing as a whole or as digits as appropriate
ProbToSound module: Converts the problem to sound segments of numbers and activity

6. Results

The design, development and packaging of version 1 of the “Maths Master” Play and Learn System are completed. Figure 3 illustrates the photograph of the first prototype of “Math Master” Play and Learn System. The firmware design for the “Maths Master” Play and Learn System for visually impaired children is also completed and tested using the hardware of version 1. The development of the second version unit is planned to include hardware design improvements for low power consumption and resulting firmware design modifications, which are currently in progress.

Figure 3 - Photograph of the “Math Master” Play and Learn System
7. Conclusions

The “Maths Master” Play and Learn System is a locally designed and developed educational toy, which is competitive with the imported products both technically and in educational value. The similar educational toys available in Sri Lankan market are less in cost since they are produced in mass scale, in countries, which are giants of electronic industry. However, the availability of the product with verbal instructions in a native Sri Lankan language is a special feature.

The subsequent version of “Maths Master” Play and Learn System, will benefit the specific group of community, namely, the visually impaired children. The features of the unit can be further enhanced and/or customized to suit different target groups.

References


4. Windbond Electronics Corp., “ISD2560/75/90/120 Data Sheet”, April 21, 2005, Revision 1.1


Acknowledgements

The authors would like to acknowledge the Technical Officers, Dinesh Dissanayaka and Thushantha Jayakody, for the great support given during the design and development of the device and Science and Technology Officers, Nilmini Kumari and Damith Jayathilake for the support given for designing the display and keyboard artwork for enclosure.