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Handheld Sound Bouncer

Summary

This document describes the implementation of the Sound Bouncer design submission in the recently publicized "Cool Module Design Contest". All development for this contest was performed using the Insight Springboard development platform which allows for rapid development of Handspring™ modules. This development platform incorporates the reprogrammable Xilinx CoolRunner™ XPLA3 CPLD and uses the Handspring Visor PDA expansion slot. Low power CoolRunner CPLDs are the ideal programmable logic solution for portable, handheld applications.

The Sound Bouncer is an ultrasonic distance-measuring device contained within a Springboard module for the Handspring Visor. The CPLD and Handspring design files for the Sound Bouncer are available and can be found at **Download Pack**, page 11.

A visual presentation of the Sound Bouncer is provided to show operation and functionality. This on demand video is available on the Xilinx website at: **http://www.xilinx.com/apps/video.htm**.

Introduction

In the winter of 2001, Xilinx, HandSpring, and Portable Design Magazine collaborated on a design contest to highlight using Xilinx CoolRunner XPLA3 CPLDs to quickly develop Springboard modules for the HandSpring Visor PDA. About 250 contest registrations were received and nearly 100 contest design ideas were submitted. From these submissions, ten were chosen to receive a HandSpring Visor and an Insight Springboard development kit. These ten finalists were given three months to complete their designs in order to compete for a "winner takes all" grand prize of $10,000. All finalists were required to included a written description of the project, all design files and necessary software to make their Springboard module prototype operate. All the finalists did a great job. This application note is derived from the submission supplied by Aaron Bonner, John Hopkins, and Greg Powers of Bothell, WA.

Appendix A outlines existing Xilinx application notes that are appropriate for understanding this application note. These are available on the Xilinx website at: **http://www.xilinx.com/**.

Design Description

The Sound Bouncer is an ultrasonic distance-measuring device contained within a Springboard module for the Handspring Visor. Distances are measured by emitting bursts of ultrasonic waves and timing their travel to and from an object. The Visor software application will then display the measured distance in the desired measurement unit. Figure 1 shows the Sound Bouncer module operating together with the Handspring Visor.

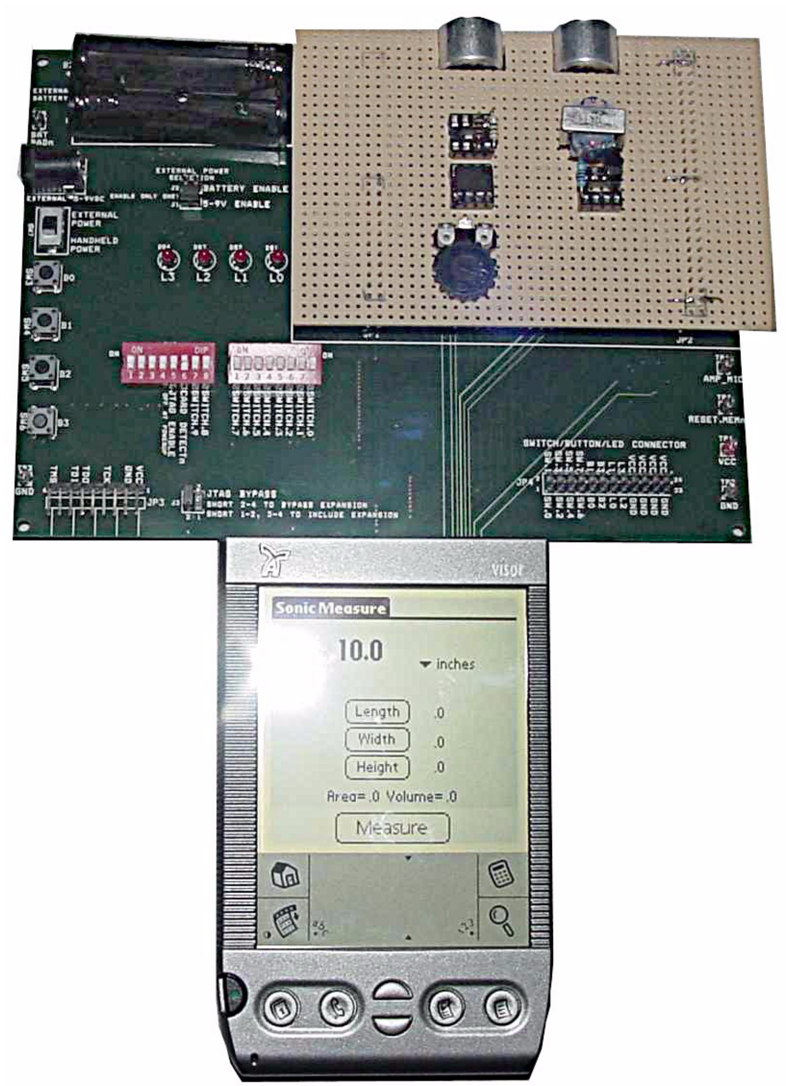

Figure 1: **Sound Bouncer Prototype**

Theory of Operation

Ultrasonic waves are sound waves that have a higher frequency than average humans can hear. Many ultrasonic sensors transmit and receive at 40 kHz. Waves at this frequency reflect from objects such as metal, wood, concrete and glass with very little attenuation. Since ultrasonic waves travel at the speed of sound, the distance to an object can be calculated by measuring the time it takes the sound wave to travel the distance and back, as calculated by the following equation.

$$\text{Distance} = \frac{\text{Velocity} \cdot \text{Time}}{2}$$

where:

- **Distance** is given in meters
- **Velocity** = 344 m/s at 20°C
- **Time** is in seconds

Figure 2 shows the side view of the Sound Bouncer prototype board where the transmit and receive sonic transducers can be seen. A more detailed description of the CPLD and software design is presented later in this application note.

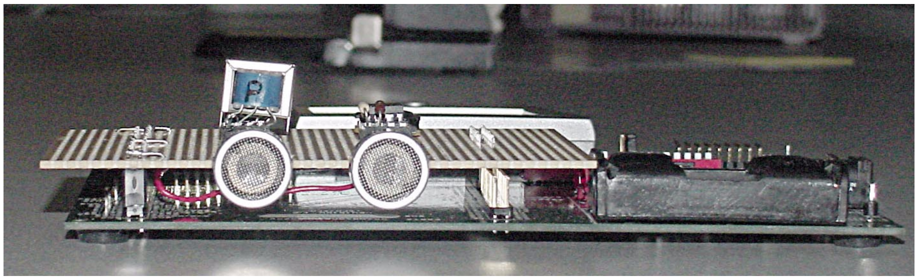

Figure 2: **Sound Bouncer Sonic Transducers**

Features and Specifications

The Sound Bouncer implements the following features:

- Measures the distance to an object at the press of a button
- Distances can be represented in four units — feet, inches, meters, and centimeters
- Measured distances can be stored to length, width, and height fields
- Area and volume are calculated and displayed from length, width, and height fields

Table 1 lists the functional specifications of the Sound Bouncer.

Table 1: **Sound Bouncer Functional Specifications**

Parameter	Min.	Max.	Unit
Range (theoretical)	0.24	30.7	Feet
Range (experimental)	0.2	10.0	Feet
Accuracy (theoretical)	-	0.01	Inches
Accuracy (experimental)	-	0.25	Inches

Operating Instructions

The Sound Bouncer design can be downloaded from the Xilinx website. The download pack includes the necessary files needed to run the Sound Bouncer, see **Download Pack**, page 11.

Using the Application

1. Insert the Sound Bouncer Development module and toggle the "CARD DETECTn" DIP switch to the on position.
2. Tap on the "Sonic Measure" application from within the "Sound Design" program group.
3. Aim the Visor at a wall a few feet away. Make sure the transducers at the front edge of the development board are unobstructed. Best results are obtained if the wall is parallel to the front edge of the development board.
4. Either tap the Measure button or press the hardware UP or DOWN buttons.
5. The Visor will beep if sound is enabled and the measured distance will be displayed.
6. Tap on the Length, Width, or Height buttons to save the current measurement to the corresponding Length, Width, or Height field. The Area and Volume will be recalculated and displayed whenever values are changed.
7. Repeat steps 3 - 6 to take additional measurements.

8. Tap the current unit to display a drop down list of available units. Choose the desired unit. All values will change to reflect the new unit.

Hardware Description

The external analog circuit, shown in Figure 3, consists of a driver for the transmit transducer and an amplifier circuit for the receive transducer.

A pulse signal from the CPLD drives into the base of the transistor which subsequently drives the transformer in an open-collector fashion. The transmit transducer is driven by the stepped-up voltage of the transformer. Power is supplied to the external circuit at 3.3V by the Handspring Visor. Using the step-up transformer allows the ability to drive the transducer with a 20-30 V peak-to-peak wave.

The receive transducer produces a signal in the mV range. With a gain of 2000, the first operational amplifier boosts the transducer output to a usable level. Configured as a comparator, the second operational amplifier compares the incoming signal against a threshold determined by the potentiometer and produces the digital signal echo to the CPLD.

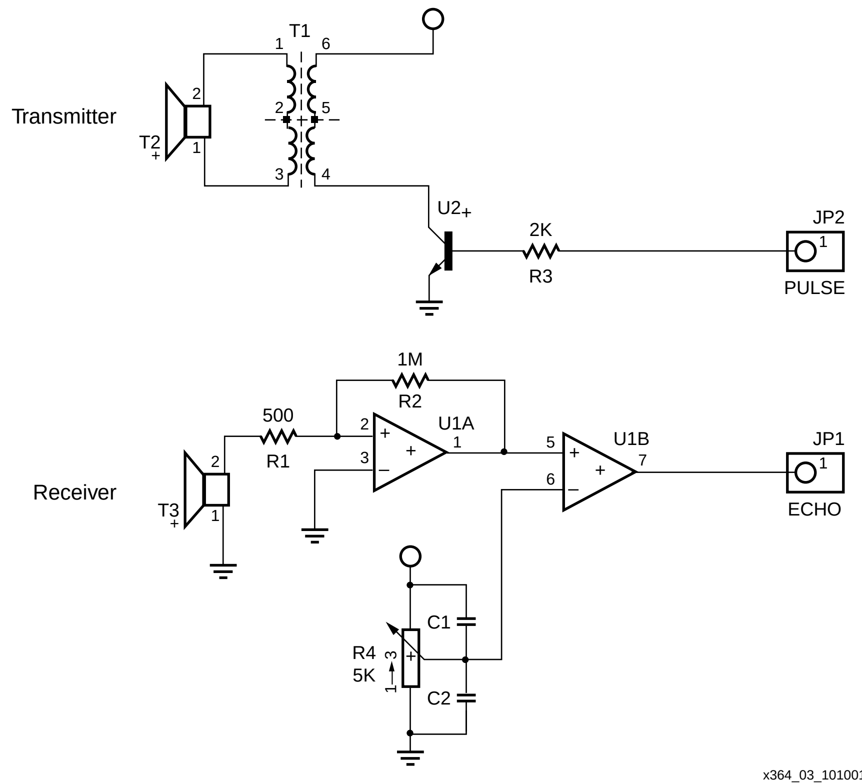

Figure 3: **Analog Circuitry**

CPLD Design

The Xilinx CoolRunner CPLD design contains the digital circuitry for a read mux, register write circuit, clock divider, measurement state machine, and the interface from the Springboard connector to the flash memory. Figure 4 shows the CPLD functional block diagram for the Sound Bouncer design.

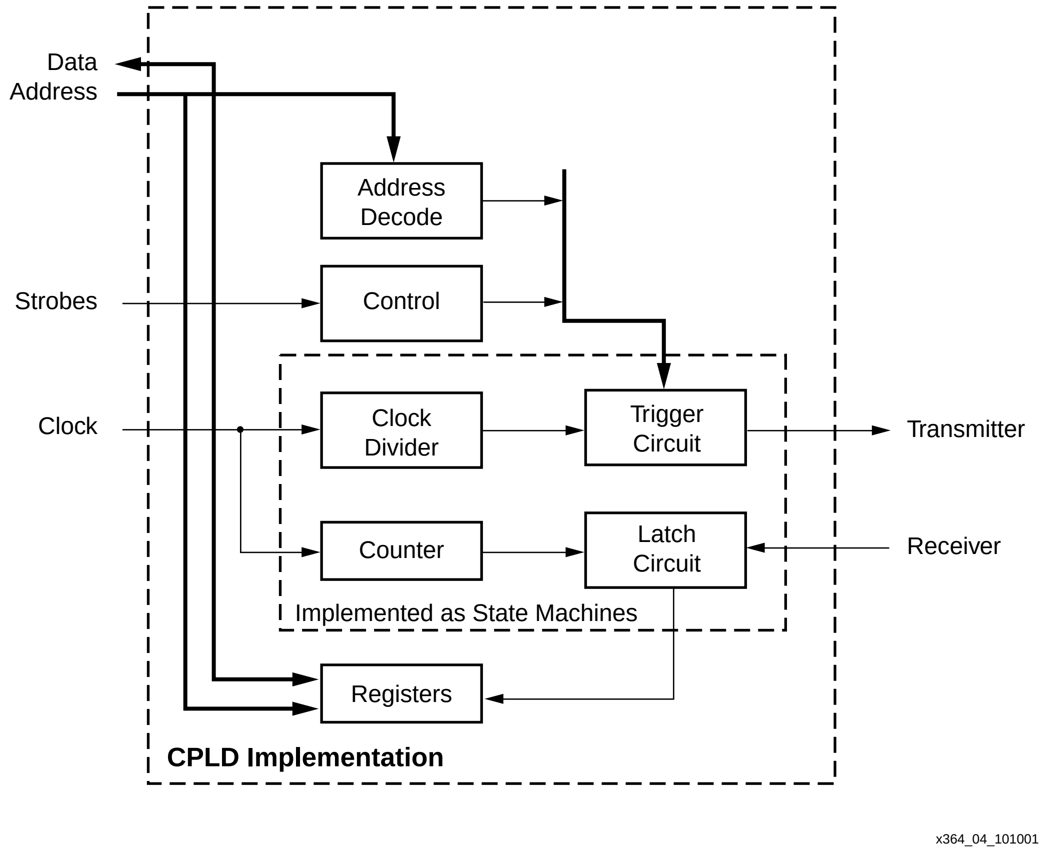

Figure 4: **CPLD Functional Block Diagram**

A description of each CPLD sub-module is described in the following sections.

Read and Write Logic

The read mux allows the CPLD to return values of several internal registers to the host software. The write circuit allows the host to write a value to the trigger register, which will start the measurement process. Registers are detailed in Figure 5.

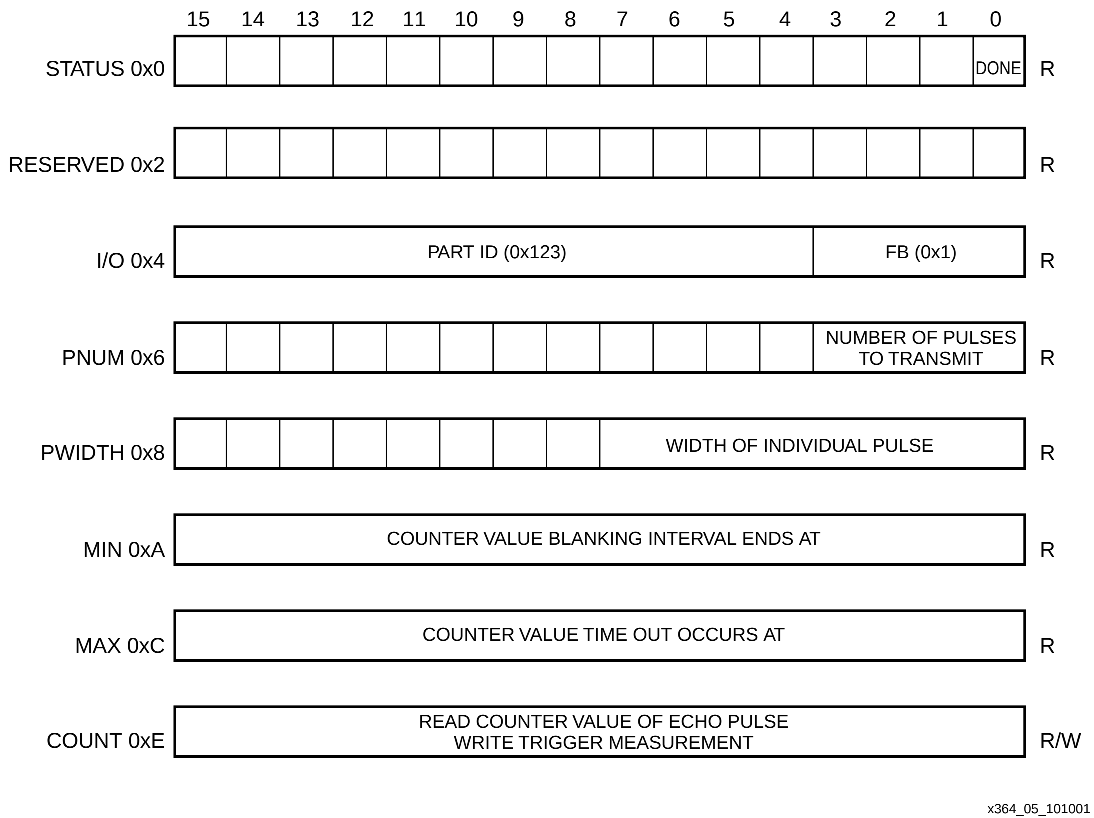

Figure 5: **Register Map**

Clock Divider

The clock divider pre-scales the input clock of approximately 2.5 MHz from the A/D converter by four to approximately 625 kHz. This pre-scaling allows the state machine to simply divide by 16 to approximate 40 kHz.

Measurement State Machine

The measurement state machine performs all the timing-critical details of controlling the hardware when taking a measurement. When triggered, it causes the pulse output signal to pulse high 16 times at approximately 40kHz. Simultaneously, it starts a 16-bit timer and resets the DONE bit in the STATUS register. The circuit then waits for the timer to count up to the TIME_MIN value. Noise from the transmitter will be ignored in this fashion.

After TIME_MIN has been reached, either sampling echo HIGH or reaching TIME_MAX will cause the timer value to be latched into reg_timer and the DONE bit will be set. The operation of the state machine is outlined in Figure 6.

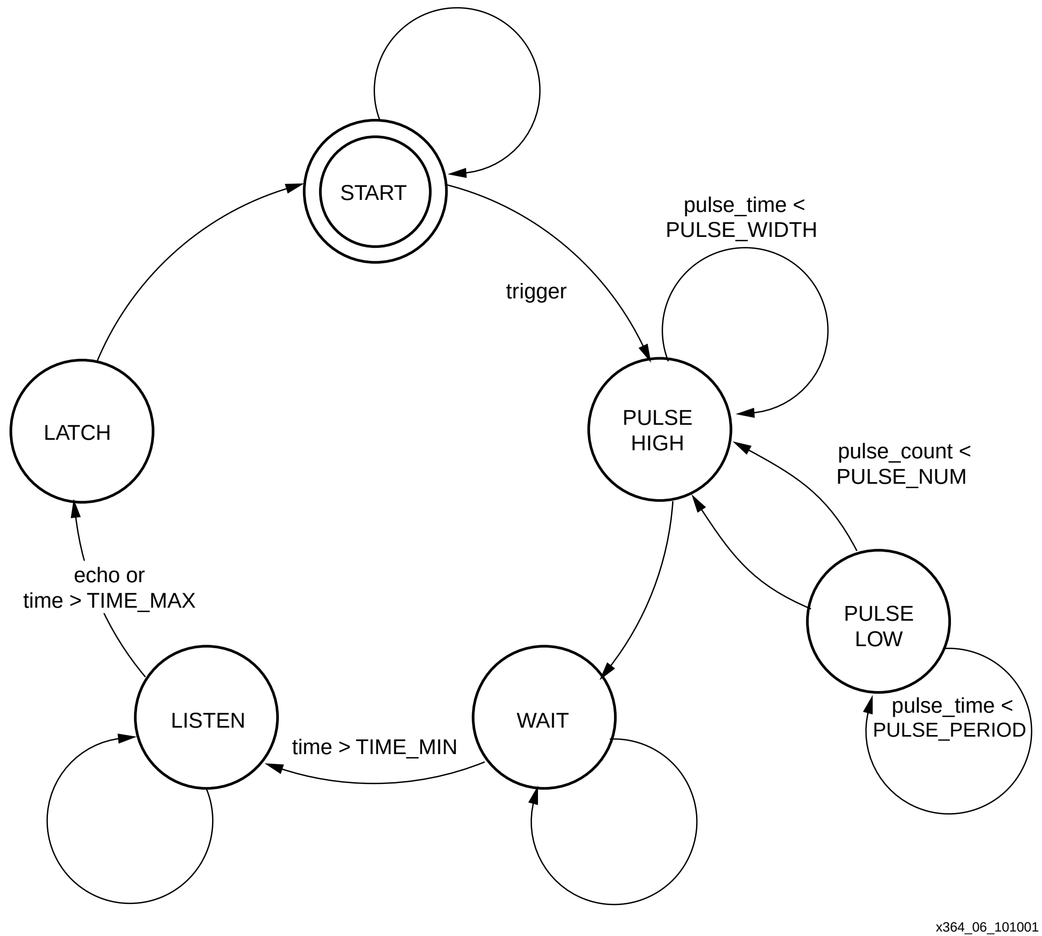

Figure 6: **Measurement State Machine**

Handspring Visor Interface

The software needs to trigger the state machine and then poll the DONE bit until it is set. The time measurement will then be accessible from the COUNT register and is represented in ticks of the internal clock. Driver functions must be used to convert this to a usable value.

Module Descriptions

The verilog file named bouncer.v includes the read mux, write circuit, trigger edge detect, main state machine, and all top level I/O.

Another verilog file named clk_divider.v divides the main clock down to a reasonable value for the main state machine to produce the desired 40kHz (25us period) output.

The source code and implementation results for the CPLD design are included in the available download pack (see **Download Pack**, page 11).

Handspring Software Design

The Sound Bouncer software, Sonic Measure, was written using Codewarrior since the tool provides an interface to the Application Program Interface (API) calls in the Handspring Software Developer's Kit (SDK) as well as the Palm SDK and offers a run time debugger.

Figure 7 displays the Sonic Measure application main flow chart. The software for the Sonic Bouncer has two main components: Hardware Access layer and Application layer. The Hardware Access layer contains the standard interface to the hardware and converts the time elapsed to a distance measured. The Application layer displays, formats, and organizes the measurements. The Hardware Access layer's interface has two main functions. First, the SB_InitSofware function is executed by the application when it starts. SB_InitSofware verifies a Handspring module is connected, stores the base address of the card in memory, and verifies the module is the Sound Bouncer Module. Second, the SB_TakeMeasurement function shown in Figure 8 triggers the hardware, takes five measurements, disregards the highest and lowest value, and averages the remaining valid measurements.

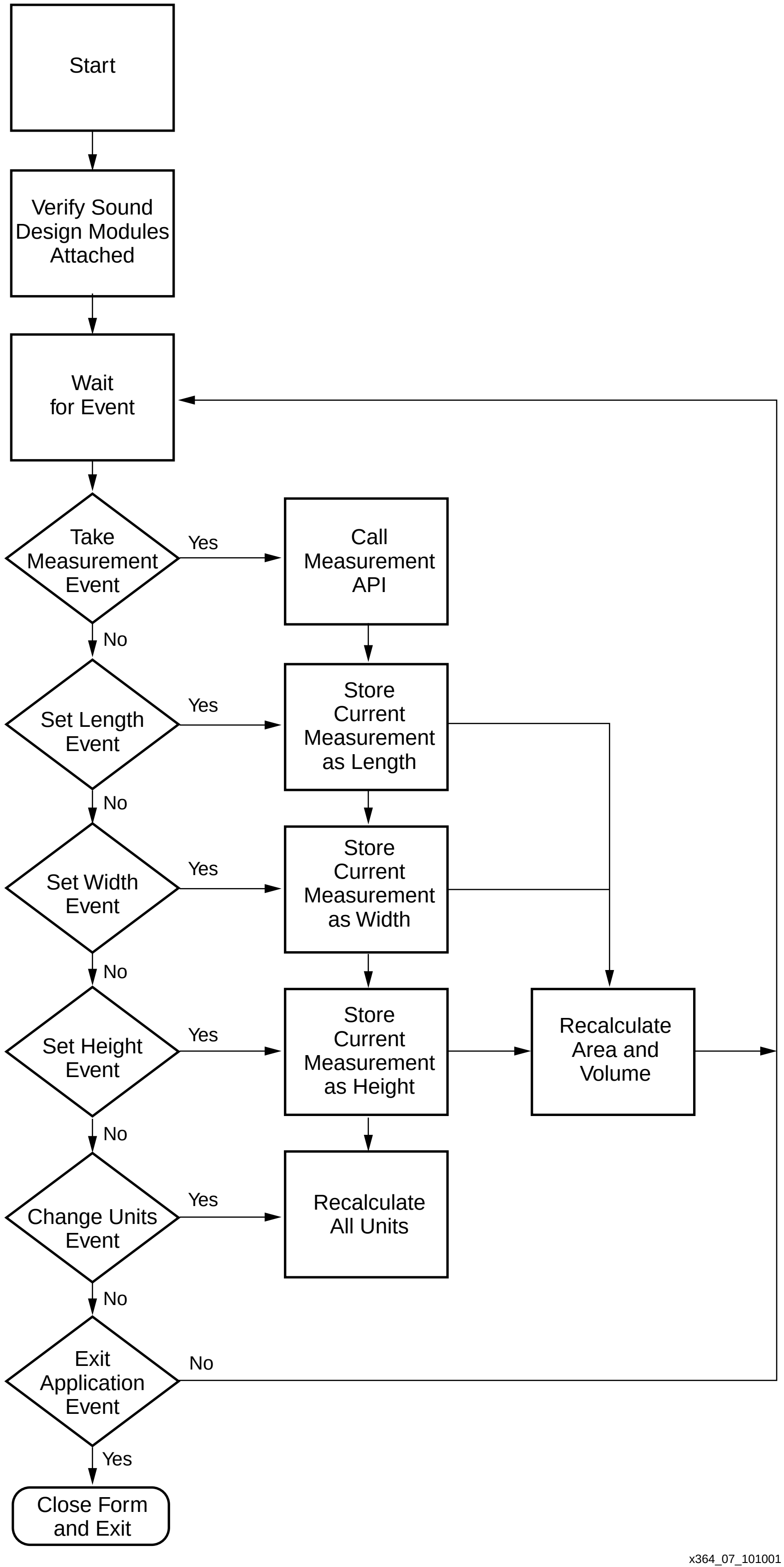

Figure 7: **Sonic Measure Main Flow Chart**

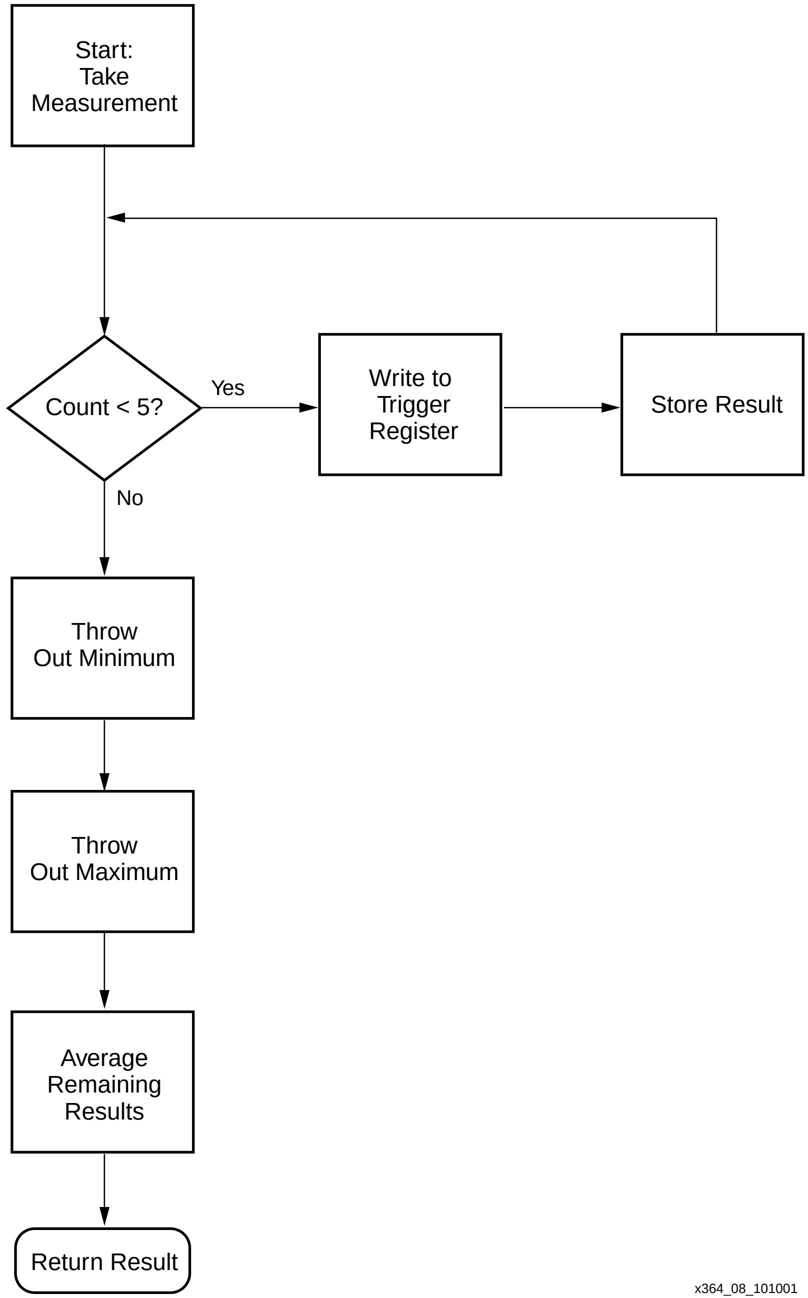

Figure 8: **SB_TakeMeasurement Flow Chart**

The remaining functions convert the results from the measurement to a distance and return the distance as a string. SB_ConvertTimeToDistance uses a constant, derived by using the speed of sound and the clock speed, to return the distance in the required units. SB_ConvertTimeToString displays a floating point number since there is no built in method to perform this operation. SB_ConvertTimeToString calculates the distance, rounds the number to the nearest tenth, and returns it as a string.

The application Sonic Measure provides a simple easy to use interface to measure distances, areas, and volumes using the Sound Bouncer. Other applications can be written simply by using the Hardware Access layer functions to interface to the Sound Bouncer.

Download Pack

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XAPP364 - **http://www.xilinx.com/products/xaw/coolvhdlq.htm**

Conclusion

This design submission for the Cool Module Design Contest is a perfect application of a low power Springboard module using the Xilinx CoolRunner CPLDs. Low power CoolRunner CPLDs are the ideal programmable logic solution for portable, handheld applications. The Sound Bouncer is a portable distance measuring module utilizing the Springboard expansion port of the Handspring Visor. The Sound Bouncer design submission can be used in a variety of end applications.

Appendix A

Appendix A lists appropriate Xilinx CoolRunner CPLD application notes. These application notes can be found by searching the Xilinx website and keying on the specific XAPP number. Many include appropriate driver software along with high level design code. All have been constructed and work.

PDA Springboard Design Application Notes

XAPP147: Low Power Handspring Springboard Module Design with CoolRunner CPLDs

XAPP359: Understanding the Insight Springboard Development Kit

XAPP357: CoolRunner Visor Springboard LED Test

XAPP355: Serial ADC Interface Using a CoolRunner CPLD

XAPP146: Designing an Eight Channel Digital Volt Meter with the Insight Springboard Kit

XAPP149: Designing an Oscilloscope for the Insight Springboard Development Kit

References

Handspring website: **http://www.handspring.com/**

Revision History

The following table shows the revision history for this document.

Date	Version	Revision
10/15/01	1.0	Initial Xilinx release.