ECEN 427 Lab 6
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Lab 7: Creative Project

Section 7.1: Short Description of Project

We integrated a classic NES controller with Space Invaders. We created a communication driver for the controller in VHDL and then created a software driver to be able to use the VHDL in our C code.

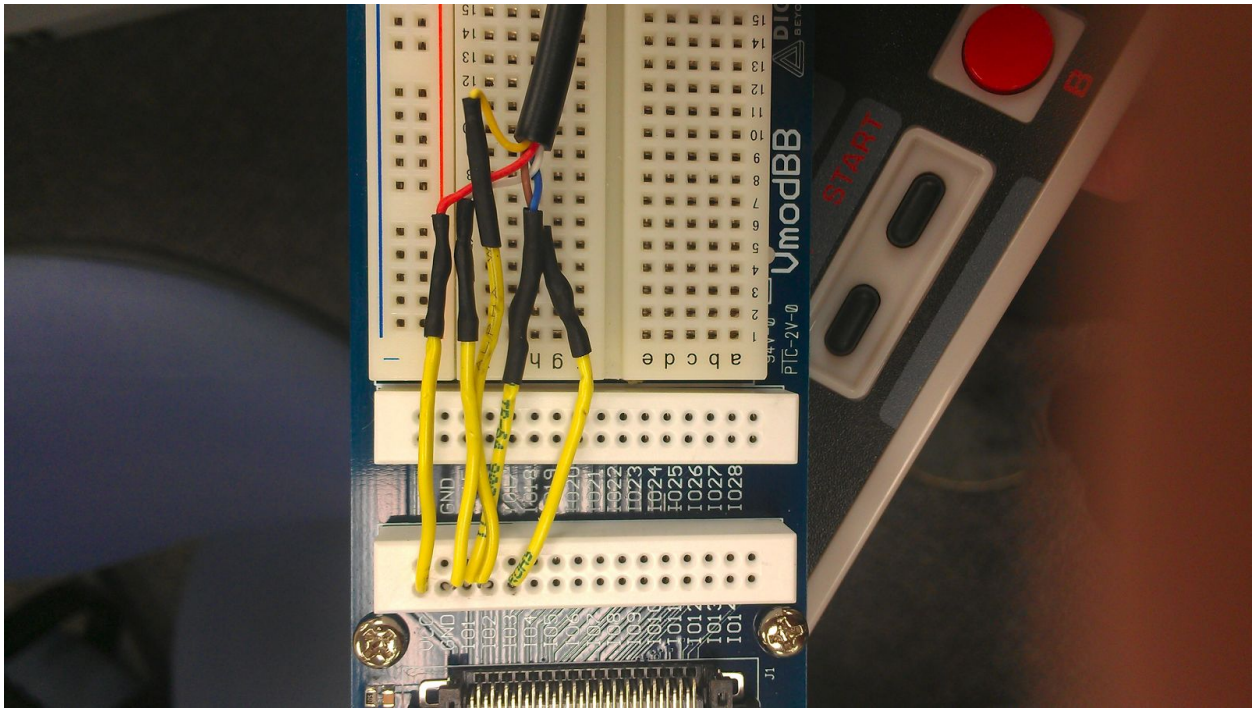
Section 7.1A: VHDL Communication Driver

The NES controller uses a UART similar form to tell what buttons are being pushed. It is a little more simple than a UART because there is no timing involved. The system driving the controller has two signals that control the output of the controller. It polls the buttons by sending a latch signal. This lets the controller know we want to read the value of the buttons so it gets it ready. We could then read the first button value after waiting a short period of time. The only constraint on the timing is that it has to be at least six microseconds. Then the VHDL sends another signal called pulse that lets the controller know we are ready for the value of the next button. This cycles through until all of the buttons have been read. We would send the latch at a frequency of 60 Hz and pulse every eight microseconds. We only sent an interrupt to our C code when a button changed a value.

Section 7.1B: Software Driver

Integrating the NES controller into our space invaders software was fairly easy. We made a driver API with a function that returns the button states. This was a simple read to the slave register in our IP. Also, our IP uses an interrupt that fires whenever the button state changes. In our handler for this interrupt we just check each button bit and mask it with out variable for buttons debounced. This way we did not have to create a new global variable for the NES controller button states. This was convenient because we didn't have to change any existing code, just add the new NES controler driver code and interrupt handler.

Section 4.2: Picture



From left to right the pins are VCC, Ground, Pulse, Latch, and Data

Bug Report

The biggest bug we had was that our cheap chinese NES controllers from Amazon has the same colored wires as a normal NES controller, but the wires all go to different places. We didn't realize this at first (and weren't expecting that either) so we had problems. It turns out that Red is vcc, white ground, blue pulse, yellow latch, and brown is data. Fortunately we had a second NES controller which we broke open to see which sockets on the D connector each wire went to.

```c
#include "stdint.h"

//Reads the buttons register of the NES controller
uint32_t nes_readButtons();
```

```c
#include "nes.h"
#include "xparameters.h"
#include "xil_io.h"

//Reads the buttons register of the NES controller
uint32_t nes_readButtons(){
    return Xil_In32(XPAR_NES_CONTROLLER_0_BASEADDR);
}
```

```
/*
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 */

#include "xgpio.h"          // Provides access to PB GPIO driver.
#include "xintc_l.h"        // Provides handy macros for the interrupt controller.
#include <stdio.h>
#include "platform.h"
#include "xparameters.h"
#include "xaxivdma.h"
#include "xio.h"
#include "time.h"
#include "unistd.h"
#include "aliens.h"
#include "screenState.h"
#include "sounds.h"
#include "thePITS.h"
#include <stdlib.h>
#include <string.h>
#include "nes.h"

#define DEBUG

#define DEBOUNCE_TICKS 5//Number of ticks to debounce for
#define DRAW_TIMER 20//Number of ticks to debounce for
#define FRAME_BUFFER_0_ADDR 0xC1000000  // Starting location in DDR where we will store
the images that we lay.
#define AUTO_INCREMENT_DELAY_TICKS 50//Ticks between auto increments when holding button
down
#define PENULTIMATE_DEBOUNCE_COUNT 1//The second to last count of the debounce counter

#define SHOOT_BUTTON_MASK 0x10//Mask for inc button
#define RIGHT_BUTTON_BIT 0x02//Value of the seconds bit
#define LEFT_BUTTON_BIT 0x08//Value of the hours bit
#define BUFFER_SIZE 100 //Buffer for getting chars from uart
#define LOWEST_VALUE 10000 //Lowest possible count down for PIT

#define VALUE_TO_SHIFT 1 //Value that is shifted assign and find values for the buttons
#define NES_CONTROLLER_LEFT 6 //Number of bits shifted to get the left button status
#define NES_CONTROLLER_RIGHT 7 // Number of bits shifted to get the right button status

#define GAME_TANK_LEFT 3 // Number of bits shifted to tell the tank to move left
#define GAME_TANK_RIGHT 1 // Number of bits shifted to tell the tank to move right
#define GAME_TANK_FIRE 4 // Number of bits shifted to tell the tank to fire
```

```
XGpio gpLED; // This is a handle for the LED GPIO block.
XGpio gpPB; // This is a handle for the push-button GPIO block.

static uint32_t currentButtonState = 0;//Current state of the buttons
static uint32_t currentButtonStateDebounced = 0;//Current state of the buttons after
debouncing

static uint8_t debounceCount = DEBOUNCE_TICKS;//Countdown before button input is
considered debounced

void print(char *str);

void pit_interrupt_handler() {
    screenState_update(currentButtonStateDebounced);

    //If the debounce counter is running
    if(debounceCount != 0)
    {
        //If the denounce counter is on the last count.
        if(debounceCount == PENULTIMATE_DEBOUNCE_COUNT)
        {
            //currentButtonStateDebounced = currentButtonState;//Set the switched debounce
 state
            //Note: we only do this once per button press (which is why it is only done
on the last count of the debounce count)
        }
        //Otherwise just decrement the debounce counter
        debounceCount--;
    }
}
uint32_t button = 0;
void nes_interrupt_handler() {
    button = nes_readButtons();
    //191 is left on NES controller
    //127 is right on NES controller
    //254 is fire on NES controller

    //2 is left in game
    //8 is right in game
    //16 is fire in game
    currentButtonStateDebounced = 0;
    if(!(button & (VALUE_TO_SHIFT << NES_CONTROLLER_LEFT))){ //left
        //Sets the bit that makes the tank move to the left
        currentButtonStateDebounced = currentButtonStateDebounced | VALUE_TO_SHIFT <<
GAME_TANK_LEFT;
    }
    if(!(button & (VALUE_TO_SHIFT << NES_CONTROLLER_RIGHT))){ //right
        //Sets the bit that makes the tank move to the right
        currentButtonStateDebounced = currentButtonStateDebounced | VALUE_TO_SHIFT <<
GAME_TANK_RIGHT;
    }
    if(!(button & (VALUE_TO_SHIFT))){ //fire
        //Sets the bit that makes the tank fire
        currentButtonStateDebounced = currentButtonStateDebounced | VALUE_TO_SHIFT <<
GAME_TANK_FIRE;
    }
}
```

```
// This is invoked each time there is a change in the button state (result of a push or a
bounce).
void pb_interrupt_handler() {

    // Clear the GPIO interrupt.
    XGpio_InterruptGlobalDisable(&gpPB); // Turn off all PB interrupts for now.
    currentButtonState = XGpio_DiscreteRead(&gpPB, 1); // Get the current state of the
buttons.

    debounceCount = DEBOUNCE_TICKS;//Set the debounce counter

    XGpio_InterruptClear(&gpPB, 0xFFFFFFFF); // Ack the PB interrupt.
    XGpio_InterruptGlobalEnable(&gpPB); // Re-enable PB interrupts.
}

uint32_t ticks = 0;
// Main interrupt handler, queries the interrupt controller to see what peripheral
// fired the interrupt and then dispatches the corresponding interrupt handler.
// This routine acks the interrupt at the controller level but the peripheral
// interrupt must be ack'd by the dispatched interrupt handler.
// Question: Why is the timer_interrupt_handler() called after ack'ing the interrupt
controller
// but pb_interrupt_handler() is called before ack'ing the interrupt controller?
void interrupt_handler_dispatcher(void* ptr) {
    ticks++;
    int intc_status = XIntc_GetIntrStatus(XPAR_INTC_0_BASEADDR);
    if(ticks > 1000){

    }

    // Check the NES buttons.
    if (intc_status & XPAR_NES_CONTROLLER_0_IP2BUS_INTERRUPT_MASK) {
        nes_interrupt_handler();
        XIntc_AckIntr(XPAR_INTC_0_BASEADDR,
                XPAR_NES_CONTROLLER_0_IP2BUS_INTERRUPT_MASK);
    }

    /*
    // Check the FIT interrupt first.
    if (intc_status & XPAR_FIT_TIMER_0_INTERRUPT_MASK) {
        XIntc_AckIntr(XPAR_INTC_0_BASEADDR, XPAR_FIT_TIMER_0_INTERRUPT_MASK);
        timer_interrupt_handler();
    }
    */

    // Check the PIT interrupt first.
    if (intc_status & XPAR_PIT_0_IP2BUS_INTERRUPT_MASK) {
        XIntc_AckIntr(XPAR_INTC_0_BASEADDR, XPAR_PIT_0_IP2BUS_INTERRUPT_MASK);
        pit_interrupt_handler();
    }



    // Check the push buttons.
    if (intc_status & XPAR_PUSH_BUTTONS_5BITS_IP2INTC_IRPT_MASK) {
        pb_interrupt_handler();
        XIntc_AckIntr(XPAR_INTC_0_BASEADDR,
                XPAR_PUSH_BUTTONS_5BITS_IP2INTC_IRPT_MASK);
    }
```

```
    // Check AC97 Interrupts
    if (intc_status & XPAR_AXI_AC97_0_INTERRUPT_MASK) {
        sounds_ac97_interrupt_handler();
        XIntc_AckIntr(XPAR_INTC_0_BASEADDR,
                XPAR_AXI_AC97_0_INTERRUPT_MASK);
    }
}

int main() {
    init_platform(); // Necessary for all programs.
    thePITS_init();
    int Status; // Keep track of success/failure of system function calls.
    XAxiVdma videoDMAController;
    // There are 3 steps to initializing the vdma driver and IP.
    // Step 1: lookup the memory structure that is used to access the vdma driver.
    XAxiVdma_Config * VideoDMAConfig = XAxiVdma_LookupConfig(
            XPAR_AXI_VDMA_0_DEVICE_ID);
    // Step 2: Initialize the memory structure and the hardware.
    if (XST_FAILURE == XAxiVdma_CfgInitialize(&videoDMAController,
            VideoDMAConfig, XPAR_AXI_VDMA_0_BASEADDR)) {
        xil_printf("VideoDMA Did not initialize.\r\n");
    }
    // Step 3: (optional) set the frame store number.
    if (XST_FAILURE == XAxiVdma_SetFrmStore(&videoDMAController, 2,
            XAXIVDMA_READ)) {
        xil_printf("Set Frame Store Failed.");
    }
    // Initialization is complete at this point.

    // Setup the frame counter. We want two read frames. We don't need any write frames
but the
    // function generates an error if you set the write frame count to 0. We set it to 2
    // but ignore it because we don't need a write channel at all.
    XAxiVdma_FrameCounter myFrameConfig;
    myFrameConfig.ReadFrameCount = 2;
    myFrameConfig.ReadDelayTimerCount = 10;
    myFrameConfig.WriteFrameCount = 2;
    myFrameConfig.WriteDelayTimerCount = 10;
    Status = XAxiVdma_SetFrameCounter(&videoDMAController, &myFrameConfig);
    if (Status != XST_SUCCESS) {
        xil_printf("Set frame counter failed %d\r\n", Status);
        if (Status == XST_VDMA_MISMATCH_ERROR)
            xil_printf("DMA Mismatch Error\r\n");
    }
    // Now we tell the driver about the geometry of our frame buffer and a few other
things.
    // Our image is 480 x 640.
    XAxiVdma_DmaSetup myFrameBuffer;
    myFrameBuffer.VertSizeInput = 480; // 480 vertical pixels.
    myFrameBuffer.HoriSizeInput = 640 * 4; // 640 horizontal (32-bit pixels).
    myFrameBuffer.Stride = 640 * 4; // Dont' worry about the rest of the values.
    myFrameBuffer.FrameDelay = 0;
    myFrameBuffer.EnableCircularBuf = 1;
    myFrameBuffer.EnableSync = 0;
    myFrameBuffer.PointNum = 0;
```

```
    myFrameBuffer.EnableFrameCounter = 0;
    myFrameBuffer.FixedFrameStoreAddr = 0;
    if (XST_FAILURE == XAxiVdma_DmaConfig(&videoDMAController, XAXIVDMA_READ,
            &myFrameBuffer)) {
        xil_printf("DMA Config Failed\r\n");
    }
    // We need to give the frame buffer pointers to the memory that it will use. This
memory
    // is where you will write your video data. The vdma IP/driver then streams it to the
HDMI
    // IP.
    myFrameBuffer.FrameStoreStartAddr[0] = FRAME_BUFFER_0_ADDR;
    myFrameBuffer.FrameStoreStartAddr[1] = FRAME_BUFFER_0_ADDR + 4 * 640 * 480;

    if (XST_FAILURE == XAxiVdma_DmaSetBufferAddr(&videoDMAController,
            XAXIVDMA_READ, myFrameBuffer.FrameStoreStartAddr)) {
        xil_printf("DMA Set Address Failed Failed\r\n");
    }
    // Print a sanity message if you get this far.
    xil_printf("Woohoo! I made it through initialization.\n\r");

    // Now, let's get ready to start laying some stuff on the screen.
    // The variables framePointer and framePointer1 are just pointers to the base address
    // of frame 0 and frame 1.
    unsigned int * framePointer0 = (unsigned int *) FRAME_BUFFER_0_ADDR;

    screenState_setFramePointer(framePointer0);

    // This tells the HDMI controller the resolution of your lay (there must be a better
way to do this).
    XIo_Out32(XPAR_AXI_HDMI_0_BASEADDR, 640*480);

    // Start the DMA for the read channel only.
    if (XST_FAILURE == XAxiVdma_DmaStart(&videoDMAController, XAXIVDMA_READ)) {
        xil_printf("DMA START FAILED\r\n");
    }
    int frameIndex = 0;
    // We have two frames, let's park on frame 0. Use frameIndex to index them.
    // Note that you have to start the DMA process before parking on a frame.
    if (XST_FAILURE == XAxiVdma_StartParking(&videoDMAController, frameIndex,
            XAXIVDMA_READ)) {
        xil_printf("vdma parking failed\n\r");
    }
    sounds_init();
    screenState_init();
    // Initialize the GPIO peripherals.
    int success;
    success = XGpio_Initialize(&gpPB, XPAR_PUSH_BUTTONS_5BITS_DEVICE_ID);
    // Set the push button peripheral to be inputs.
    XGpio_SetDataDirection(&gpPB, 1, 0x0000001F);
    // Enable the global GPIO interrupt for push buttons.
    XGpio_InterruptGlobalEnable(&gpPB);
    // Enable all interrupts in the push button peripheral.
    XGpio_InterruptEnable(&gpPB, 0xFFFFFFFF);

    microblaze_register_handler(interrupt_handler_dispatcher, NULL);
    XIntc_EnableIntr(
            XPAR_INTC_0_BASEADDR,
            (XPAR_PIT_0_IP2BUS_INTERRUPT_MASK
```

```
                    | XPAR_PUSH_BUTTONS_5BITS_IP2INTC_IRPT_MASK
                        | XPAR_AXI_AC97_0_INTERRUPT_MASK
                            | XPAR_NES_CONTROLLER_0_IP2BUS_INTERRUPT_MASK));
    XIntc_MasterEnable(XPAR_INTC_0_BASEADDR);
    microblaze_enable_interrupts();
    while (1){
        xil_printf("Enter new count down from value in ticks (100,000, 000 is one
second)\r\nPress ENTER to write to register\r\n");
        char array[BUFFER_SIZE];//Buffer for uart input
        char input;//Input from uart
        uint32_t i;//For for loop
        uint8_t problem = 0;//Flag for when the user puts in a non number
        for(i = 0; i < BUFFER_SIZE; i++){//For each buffer value
            input = getchar();//Get input from uart

            if(input == '\r' || i == BUFFER_SIZE){//If the enter key
                array[i] = '\0';//Null terminate buffer
                break;
            }
            if(input < '0' || input > '9'){//If not a number
                xil_printf("Only enter digits (0 to 9), please try again\r\n");
                problem = 1;//Raise flag so we don't try to write value to pit
                break;
            }
            array[i] = input;//Otherwise store the number in buffer
        }
        if(!problem){//If data is valid
            int valueToWrite = atoi(array);//char * to int
            if(valueToWrite < LOWEST_VALUE){//Don't let the value go to low (will never
yield to idle task if tick rate is to high
                valueToWrite = LOWEST_VALUE;
            }
            thePITS_setTicksCountDownFrom(valueToWrite);//Write new count down to control
register in pit
        }
    }
    cleanup_platform();
    return 0;
}
```