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Electronic Class Schedule with Wireless Network Access

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<p>This project is the initial research and development carried out for the possible implementation of electronic class schedules on the Leppävaara campus of Metropolia University of Applied Sciences. The goal is to develop a working model that will retrieve classroom information from the online school calendar and present the information in the form of a schedule for the user. Additionally, the product should be kept within a budget that allows for the replication of many new productions.</p> <p>An electronic picture frame was purchased and studied to see how to combine the wireless capability. A preconfigured embedded wireless network card was purchased for communications. A small server program was designed to listen for the microcontroller. The main microcontroller was then programmed to request a file from the server program and write the returned data to a Secure Digital (SD) memory card in a way that the electronic picture frame could read the picture.</p> <p>The project was successful in that the final version is able to deliver pictures from the server computer and display them on the screen. The cost of the development was also kept low enough to allow the production of more units.</p>	
Keywords	Electronic class schedule, digital, network access, schedule server

Preface

I would like to thank Antti Piironen and Anssi Ikonen for grabbing me in the hallway and proposing this project to me. This project has been a real good learning experience in many ways. I would like to thank Kimmo Sauren for help in debugging certain areas of the project. Without his assistance I might have not finished the project to the extent that I did. I would like to thank my father Lawrence for instilling in me a strong work ethic, and my wife Tanja for putting up with my strong work ethic when it kept me in my office for so many hours. And I would like to thank God for providing the opportunities and the tools to achieve my goals.

Table of Contents

Abstract

Table of Contents

List of Figures

List of Abbreviations

1 Introduction	1
2 Digital Photo Frame and Memory Type	2
2.1 Digital Photo Frame General Operation	2
2.2 SD Card File System	4
2.3 SD Card Command Format	7
3 Cypress Programmable System on a Chip	10
3.1 PSoC Overview	10
3.2 PSoC Functionality	10
4 Microcontroller Interfaces	13
4.1 UART Communication	13
4.2 SPI Communication	14
4.3 WiFly WLAN Module	15
4.4 Capacitive Touch	16
5 Microcontroller Environment of the Electronic Class Schedule	19
5.1 Functional Division of Microcontrollers	19
5.2 Design of Capacitive Touch User Interface	22
5.3 Interfacing WLAN Module	23
5.4 Integration of SD Card	25
6 Client - Server Functionality of the Electronic Class Schedule	30
6.1 Schedule File Server Overview	30
6.2 Creation of JPG Schedule Files	31
6.3 Connection and Delivery of Schedule Files	32
7 Discussion	34
7.1 Implementation Issues	34
7.2 Results	36
7.3 Future Development	36

8 Conclusions	39
References	40
Appendix 1: Microcontroller Specifications	
Appendix 2: Program Code	
Appendix 3: List of Electrical Components	
Appendix 4: Circuit Board Diagrams	

List of Figures

Figure 1:	Flow Diagram of Basic Operation	1
Figure 2:	User Controls of Digital Picture Frame	2
Figure 3:	Screenshot of File Allocation Table Using HxD Hex Editor	5
Figure 4:	Screenshot of Root Directory Table Using HxD Hex Editor	6
Figure 5:	PSoC Designer SPI CMD 0	7
Figure 6	Response Token	8
Figure 7:	SD Card Initialization Flowchart	9
Figure 8:	PSoC Designer Digital and Analogue Blocks	11
Figure 9:	Global Settings in PSoC Designer	12
Figure 10:	UART Packet Construction	13
Figure 11:	WiFly RN-131GSX Wireless Module	15
Figure 12:	Capacitive Sensor Relaxation Oscillator	17
Figure 13:	Capacitive Sense Button Layout	18
Figure 14:	System Sequence Block Diagram	20
Figure 15:	HEF4066 Bilateral Switch Integrated Circuit	21
Figure 16:	PADS Software Capsense Board Design	22
Figure 17:	Manual Switching of WiFly Connections	23
Figure 18:	SD Card Interface to PSoC Microcontroller	25
Figure 19:	SD Card File Information Arrays	27
Figure 20:	PSoC Designer SPI CMD 25	28
Figure 21:	Schedule File Server Functional Block Diagram	30
Figure 22:	Server Program Application Console in Microsoft Visual Studio	31

List of Abbreviations

ADC	- Analogue to Digital Converter
bps	- Bits Per Second
CRC	- Cyclic Redundancy Check
CSR	- Capacitive Sensor Relaxation Oscillator
CPU	- Central Processing Unit
DAC	- Digital to Analogue Converter
dB	- Decibels
DHCP	- Dynamic Host Configuration Protocol
FAT	- File Allocation Table
Gnd	- Ground Electrical Connection
JPG	- JPEG File, Joint Photographic Experts Group
IP	- Internet Protocol
LCD	- Liquid Crystal Display
MBR	- Master Boot Record
MCU	- Microcontroller Unit
MISO	- Master Input Slave Output
MMC	- Multi Media Card
MOSI	- Master Output Slave Input
NFS	- Network File Server
PSoC	- Programmable System on a Chip, Microcontroller
PWM	- Pulse Width Modulation
RAM	- Random Access Memory
SCK	- Serial Data Clock
SD	- Secure Digital Memory
SDHC	- Secure Digital High Capacity
SPI	- Serial Peripheral Interface
SS (CS)	- Slave Select (Chip Select)
TCP/IP	- Transmission Control Protocol / Internet Protocol
UART	- Universal Asynchronous Receiver Transmitter
USART	- Universal Synchronous/Asynchronous Receiver/Transmitter
UDP	- User Datagram Protocol
USB	- Universal Serial Bus
WLAN	- Wireless Local Area Network
Vcc	- Voltage at the Common Collector

1 Introduction

The goal of this project was to design a system that would retrieve class schedules over a Wireless Local Area Network (WLAN) and display the schedule on an electronic picture frame upon a user's requests. At the Leppävaara campus of Metropolia University of Applied Sciences, the method for delivering the schedules in the past was to post a paper schedule outside every classroom. This did not allow for easy schedule changes or last minute notifications. The idea was then proposed to design an electronic system that could take the place of the paper schedules, with the ability to be updated via the wireless local area network.

The electronic class schedule system consists of a digital photo frame to show the schedule, a microcontroller environment used to manipulate picture data, an embedded WLAN card to retrieve the data, and a server program located on a host computer to create, store, and send the requested schedules. Several steps must be accomplished in order to display the schedule on the screen. These can be seen in figure 1.

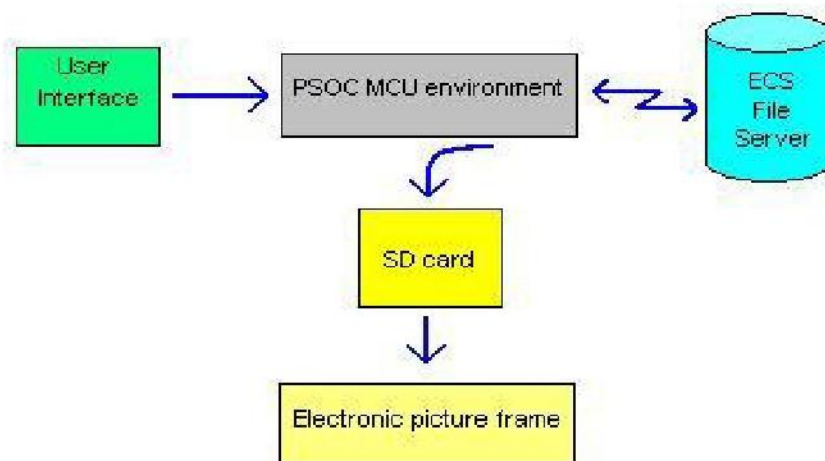


Figure 1: Flow Diagram of Basic Operation.

As can be seen in the figure, first a request is made by selecting a button on the user interface. The Microcontroller Unit (MCU) system sends a file request to the server program according to the selection that was made. The server program will then return

the requested file, and the MCU system will write that file to a Secure Digital Memory (SD) card that is shared by the digital photo frame. The digital photo frame can then, in normal operation, read the SD card and display the schedule as a picture to the user. The digital photo frame, being the only limitation of the project, was used because it is inexpensive compared to many embedded electronics design screens available for purchase as kits.

2 Digital Photo Frame and Memory Type

2.1 Digital Photo Frame General Operation

The digital photo frame was chosen as the display for the project because of its inexpensive cost. Displays commonly sold for embedded projects are expensive and would make the cost of the electronic picture frame unreasonable. The digital photo frame can be purchased at Clas Ohlson, a known hardware chain store, and the price is between 35 and 45 Euros depending on which store branch it is purchased from. There are also several other models from differing stores that would suit the project. The only requirement is that they have an SD card interface. The Digital photo frame chosen for this project is shown in figure 2.

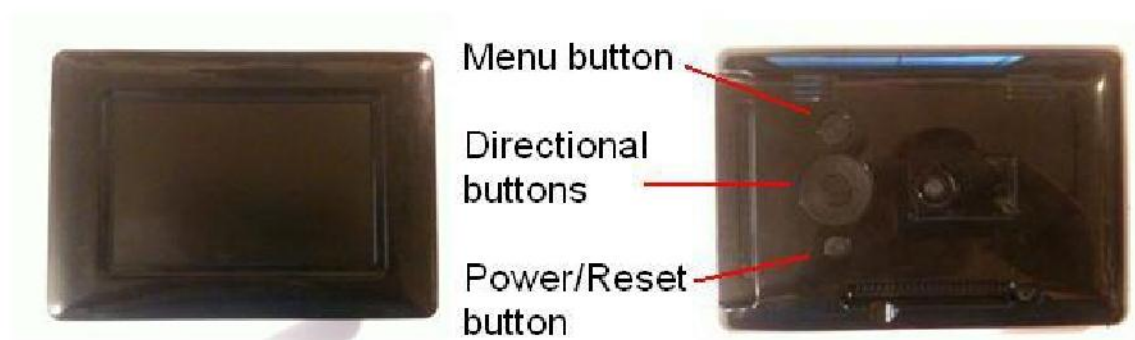


Figure 2: User Controls of Digital Picture Frame.

The buttons on the back, shown in figure 2, consist of a Menu button, Directional buttons, and a Power/Reset button. These are used to set the display characteristics of the frame. Once set, the unit will display the pictures automatically. The unit has a

seven inch screen and wide screen capability. The resolution of the unit is high, as the resolution is 800 x 480 or 16:10. The frame itself can be placed in the horizontal or vertical position. It includes a rotatable leg on the back to hold it up and give it the appearance of a traditional picture frame. It can be purchased with the choice of a black or white body color. The side of the digital photo frame has three interfaces which consist of a power adaptor port, Universal Serial Bus (USB) port, and an SD port that can also take a Multi Media Card (MMC) or a Secure Digital High Capacity (SDHC) memory card.

To use the digital photo frame a memory card must be inserted into either the USB port or the SD card port. The unit then reads the memory card for any existing picture files. After it gathers a list, it will automatically develop a slideshow and begin to display the pictures. The default setting shows each picture for three seconds with a transition to the next picture. Once finished with the slide show, the cycle of pictures will start over.

In the menu the user is able to see which pictures are in which files. Manually displaying pictures can be done by choosing the picture with the directional button and selecting it. The menu also gives system settings that can be configured. There is a calendar setting which allows the user to pick certain photos to be shown on certain dates. Time and date, as well as time format can all be changed within the settings. The user is also given the language choices of English, Swedish, Finnish, or Norwegian.

Among the visual settings the user is able to set the unit to display horizontally or vertically. The possibility of showing up to four pictures at a time is given. The photos can be changed to show in mono or color. They can also be stretched or configured to show for the best quality. The screen can be fully configured with controls over contrast, brightness, saturation, and tint. In addition, the user is also able to control the type of transition that the pictures use during the viewing of a slide show.

2.2 SD Card File System

The SD memory card is a flash memory card which was originally designed to be used with audio and video devices as higher speeds and higher storage became necessary. Within the SD memory card there is a microcontroller that is designed to work directly with the flash memory chips. This microcontroller keeps current information on the internal workings of the SD card, as well as provides an interface for the user to the flash chips. Voltage levels for SD cards from different companies may vary. The common voltage range is 3.3 volts which works well with most microcontrollers. The communication format and pin configuration of an SD memory card is that of a simple SPI connection. The SPI pins consist of Slave Select (SS), Serial Data Clock (SCK), Master In Slave Out (MISO), Master Out Slave In (MOSI), voltage at the Common Collector (Vcc), and Ground (Gnd). This is a common SPI interface found with most microcontrollers. There are also additional data lines that can be used if the designer desires to use the SD bus format of communication. Although higher data rates can be attained, the programming for this format of communication proves to take more memory and more processor use than the SPI connection.

The SD card is designed to be able to allow hot insertion. This is when an SD card can be inserted into the host device, while the device is on, without creating any problems. This is accomplished by a hardwired connection that is made by pin connectors when the card is inserted. The host device will see the signal and know to start communication with the card.

The memory organization of an SD card can be formatted as FAT 16, FAT 32, or exFAT. In the FAT 16 format the memory is divided up into groups of 512 byte sections called sectors. These sectors are then organized in groups called clusters. The number of sectors per cluster can vary with card size. As an example a 2 GB memory card may have 64 sectors per cluster. These sectors can be used to store data that can be erased and rewritten frequently. Although most memory is used for raw data, there are sectors which maintain the file system of the card that must not be tampered with in order to maintain proper card operation.

The first sector, the Master Boot Record (MBR), is reserved and contains the partition table and other vital information concerning how the memory is organized. It reserves the entire first sector of the card and typically includes information such as bytes per sector, sectors per cluster, reserved sectors, File Allocation Table (FAT) entries, number of root entries, and number of small sectors. This sector, too, is written only by the internal microcontroller as it keeps the organization of the card. Writing to this sector using the SPI interface will cause errors and possibly disable the card from working altogether.

The next sector is the first FAT. In this area there are different entries for each file which show how many clusters are used for that particular file. In figure 3 it can be seen that offset 400 is the beginning of the file allocation table in sector 2.

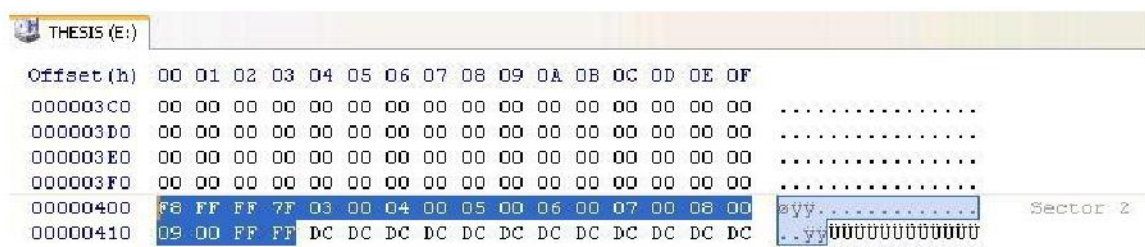


Figure 3: Screenshot of File Allocation Table Using HxD Hex Editor. Screenshot [1].

Each cluster here is represented by two bytes. As can be seen in the figure, there are ten clusters available for this specific file. The FAT entry shown starts with the byte 0xF8 and ends with the byte 0xFF. This is kept for the purpose of referencing the size of the file. The FAT 16 format also needs an exact copy of this file allocation table in a second FAT entry on the disk for data safety reasons. In the case of data corruption on one entry, the second is still intact and can be used by the host device. The location of the second FAT entry can vary depending on the size and make of the card.

The next critical section of the memory is the root directory. This contains different entries, each 32 bytes long, for each file stored in memory. Figure 4 shows a root directory with one file.

Offset (h)	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F	
0003C000	54	48	45	53	49	53	20	20	20	20	20	08	00	00	00	00	THEESIS
0003C010	00	00	00	00	00	00	72	86	9E	3D	00	00	00	00	00	00r†ž=.....
0003C020	46	49	4C	45	20	20	20	4A	50	47	20	18	30	A9	86		FILE JPG .00†
0003C030	9E	3D	9E	3D	00	00	9A	9E	66	3D	02	00	19	0F	00	00	ž=ž=..š'†=.....
0003C040	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0003C050	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00

File name Ascii 'JPG' File type Ascii 'JPG' File size 0x000F19 = 3865 Bytes
 Volume name Ascii 'FILE'

Figure 4: Screenshot of Root Directory Table Using HxD Hex Editor. Screenshot [1].

Shown in the file are examples of information given in the directory section. A total list of given information includes file name, file type, creation time, last accessed time, modified time, file cluster, and file size in bytes. This data allows the user to find all the information about the file and allows the host device to find the raw data in the memory. The first cluster gives the starting position of the file, and the file size allows the end of the file to be found.

The last section of the FAT 16 format is the volume boot record. This section is used to store the raw data of the file. The read and write function will work with a continuous stream of data in or out but must be moved in chunks of 512 bytes as the SD card uses responses to ensure data was transferred correctly.

When these entries are properly written to the SD card memory, the file can then be read by a computer's operating system or similar devices such as the electronic picture frame used as the display for this project. [2.]

2.3 SD Card Command Format

There are two different modes of communication through the data lines of the SD memory card. The usual method used by host devices is the SD Bus mode, also called the SD mode. The other method is the SPI mode. Both modes have similar protocols but the SD mode allows for multiple data lines operating simultaneously. The SPI mode is slower than the SD mode but it is easier to implement and it is a well known interface.

The commands for using the SPI mode of the SD card consist of six bytes which give the SD card the information it needs to perform the required task. In figure 5 the command 0, which is used to initialize the card into the SPI mode, can be seen as given by the PSoC microcontroller over SPI connection.

```
SPIM_SendTxData(0x40); // set message to transmit // CMD 0
while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE)){};
SPIM_SendTxData(0x00); // set message to transmit
while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE)){};
SPIM_SendTxData(0x00); // set message to transmit
while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE)){};
SPIM_SendTxData(0x00); // set message to transmit
while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE)){};
SPIM_SendTxData(0x00); // set message to transmit
while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE)){};
SPIM_SendTxData(0x95); // set message to transmit
while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE)){};
```

Figure 5: PSoC Designer SPI CMD 0. Screenshot [3].

The first byte, called the command byte, is made by converting the command number from a decimal value to a hex value and then adding a hex value of 0x40. Figure 5 shows a command number of 0 added to 0x40 which would give an argument of 0x40. Another example could be the command 55. First the command number 55 would be changed to a hex 0x37 and then added to a hex 0x40 to give a command byte of 0x77.

The following four bytes in the command are 0x00. These are called the argument bytes. For a read or write operation the address would be given with these bytes. There is no argument for a command 0, so these are all given as 0x00.

The final byte is the Cyclic Redundancy Check (CRC). This is used by the SD card to ensure that the information was read correctly. The default setting for the use of the CRC is off, so while the SD card is in SPI mode, it ignores all CRC values, and dummy bytes such as 0x95 can be used. The only CRC that is necessary to give is for the command 0. After the dummy clock pulses are sent to the SD card, it will wait for an incoming command.

Every full command issued to the SD card will be responded to with a response token from the SD card. This shows if the command was received and carried out correctly. Figure 6 shows the makeup of the token response.

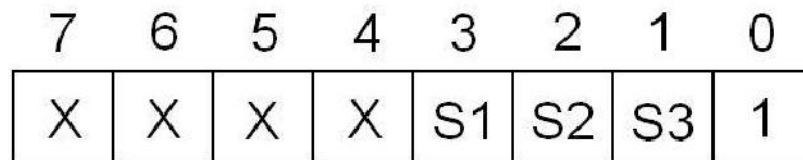


Figure 6: Response Token. Taken from SD Specifications Part 1 Version 2.00 [4, 111].

As the figure shows there are three bits, S1 to S3, that make up the response token. These bits show the results of the command given. For example, there are three possible response tokens for a write operation which are 101 indicating a CRC error, 110 indicating a data write error, and 010 indicating the data has been accepted. [5.]

Many commands need to be issued in order to determine how to proceed with the communications of the SD card as there are many different makes and models of SD cards that should be able to be used in the same systems. These commands are used for example to ensure the card is working at the correct voltage level and that the commands given to the card are in the correct format. This process alone could easily take up a lot of the microcontroller's memory.

The additional commands that are needed to distinguish which kind of card has been inserted can be seen in figure 7.

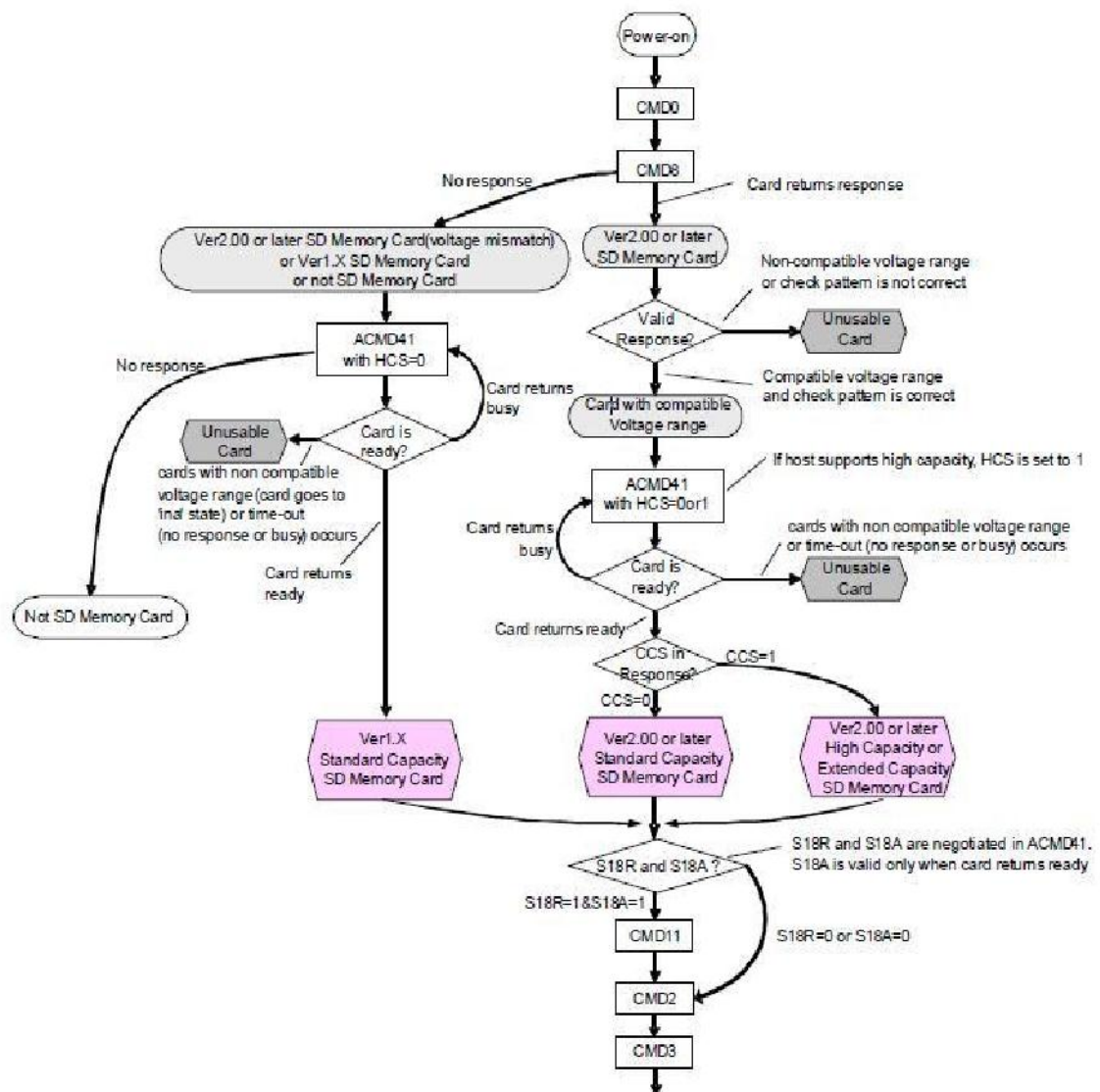


Figure 7: SD Card Initialization Flowchart. Taken from SD Specifications Part 1 Version 2.00 [4, 16].

The flowchart in figure 7 can be programmed into the MCU unit to automatically distinguish the card type during the initialization of the SD card. After this is accomplished, normal operation can be followed until power has been taken away from the SD card.

3 Cypress Programmable System on a Chip

3.1 PSoC Overview

The Programmable System on a Chip (PSoC) microcontroller is a very flexible addition to the microcontroller world. Its processor is of Harvard architecture and can run up to 24 MHz. The MCUs can have up to 16 KB of flash memory and 512 bytes of SRAM. Possible number of I/O ports can be up to 44 depending on which processor type is purchased. The microcontrollers include internal Analogue to Digital Converters (ADC), Digital to Analogue Converters (DAC), filters, timers, counters, digital communication ports, and other functional capability at the disposal of the user. When configuring the program for the PSoC, the user is asked to identify which processor type is being used so that the PSoC design software may tailor the programming environment specifically for that PSoC. [6, 25-42.]

3.2 PSoC Functionality

The PSoC has what are referred to as digital and analogue blocks. These blocks can be programmed to represent any digital or analogue electrical component that is given as an option in the design software. Every PSoC MCU has a different virtual layout within the PSoC Designer software, and the number of digital and analogue blocks may differ with different PSoC MCU types.

Of the digital block type there are digital building blocks and digital communication blocks. Each is tailored slightly different for multiple needs. For example if a Serial Peripheral Interface (SPI) or Universal Asynchronous Receiver/Transmitter (UART) connection is needed when the user selects the module to be placed, only the digital communication blocks will be used. Within the analogue blocks there are continuous time blocks and switch capacitor blocks. These too are designed differently to serve different purposes. The continuous time blocks are built of operational amplifier configurations, while the switch capacitor blocks are composed of capacitors that are switched to achieve the desired result.

Figure 8 shows the layout of these analogue and digital blocks and the basic structuring that the designer has to work with.

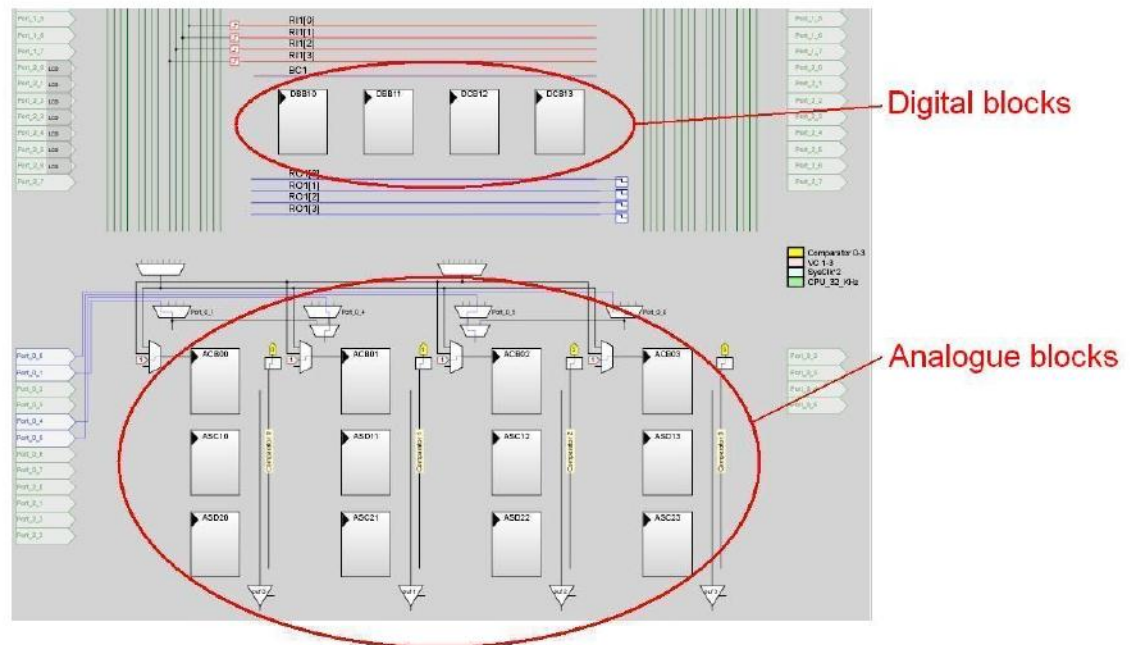


Figure 8: PSoC Designer Digital and Analogue Blocks. Screenshot [3].

As figure 8 shows these blocks, once placed, can then be interconnected with visual routing. All busses that are available for use are visible as well as external pins that might need to be accessed by the user. If several inputs were to be multiplexed into a single block, this could be achieved through the visual routing and configuration of the PSoC Designer software. However, bus comparators are also available for logical operations of inputs or outputs.

Each block will also give available options for the clock inputs. These can be set to the system clock, a divider of the system clock, a pulse width modulator, or an external clock input. With each block there also comes a set of parameters that can be configured. For example, an SPI Master block will allow the user to set which pins are used for SS, MISO, MOSI, and SCK. Additionally, it gives the options of which clock to synchronize to and whether the output should be inverted.

Once the blocks are set and the pin routes have been placed, global settings can be configured. Figure 9 shows the available global settings in the PSoC designer.



Global Resources - sd_card	
CPU_Clock	24_MHz [SysClk/1]
32K_Select	Internal
PLL_Mode	Disable
Sleep_Timer	512_Hz
VC1 = SysClk/N	2
VC2 = VC1/N	10
VC3 Source	VC1
VC3 Divider	156
SysClk Source	Internal 24_MHz
SysClk*2 Disable	Yes
Analog Power	SC On/Ref High
Ref Mux	(Vdd/2)+/-BandGap
AGndBypass	Disable
Op-Amp Bias	Low
A_Buff_Power	Low
SwitchModePump	OFF
Trip Voltage [LVD (SMP)]	4.81V (5.00V)
LVDThrottleBack	Disable
Supply Voltage	3.3V
Watchdog Enable	Disable

Figure 9: Global Settings in PSoC Designer. Screenshot [3].

As can be seen in figure 9, in the global settings the user can set many global controls of the system, such as the speed of the Central Processing Unit (CPU) clock. The range of this will differ in various models. The clock divider variables VC1, VC2, and VC3 can be configured in the case that a lower clock speed is needed for one of the blocks in the program. The system can be configured to run with three volts or five volts. The user can set which level they would like the reference voltage to be, as well as several other options given to better fit the needed parameters of the project.

Once the hardware and Global Settings are prepared, the user can then add further functionality by the use of the C programming language. Additionally, included files which are written in assembly can be modified to the user's needs. Many of the hardware settings that were previously made can be programmed in the code to change while the microcontroller is in operation. For example, for this project the digital communications to the SD card needs to be below 400 KHz for initialization of the card but then sped up to a much faster speed for the data

transfer. This is handled within the body of the program code by calling the respective function and giving the required argument. Exploiting the use of the code can be beneficial to the user. If for example the user has used all the blocks available and cannot add external filtering, the implementation of a digital filter written in the C language can be used in the program. [6, 42-53.]

4 Microcontroller Interfaces

4.1 UART Communication

The UART is an older but still widely used form of digital communication. The physical connections consist of transmit, receive, and a common ground. The typical speed for UART communication has always been a baud rate around 9600 bps, although modern UART connections can be programmed to reach speeds over ten times higher.

The transmission of the data between two modules starts with making sure both have the same baud rate, as there is no common clock signal for synchronization. The organization of the data bits is what is used to control data flow. Figure 10 shows the construction of a UART data packet.

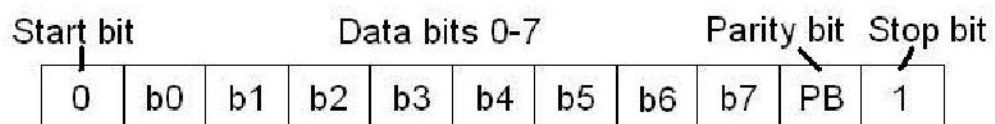


Figure 10: UART Packet Construction.

When the sending unit starts its transmission, it starts the packet with a start bit. The start bit being a logical low is noticed by the receiver as a signal that information is coming. The data is then transmitted starting with the least significant bit first. There is an optional parity bit that can be used. Then the transmission is ended by the last bit which is a logical high stop bit.

The communication can be set up to be full duplex or half duplex. There are also options that can be exercised such as using a parity bit, character length, and a stop bit. More modern UART connections, renamed Universal Synchronous/Asynchronous Receiver/Transmitter (USART), have been designed to utilize clock signals. This gives them the ability to communicate synchronously or asynchronously, eliminating the need for start and stop bits. This helps to improve efficiency and the speed of the data transmission.

4.2 SPI Communication

SPI connections are widely used as well these days though they are not as old as the UART connections. The SPI connection consists of SS, MISO, MOSI, and SCK. The speed of the SPI connection can be set for many MHz depending on the device that is being used.

The communication of the data of the SPI connection is a full duplex shift register system. The data is written to the register of the unit and then clocked out to the register of the receiving unit. As the names suggest, MOSI is for the data coming from the master to the slave and MISO is for the data coming from the slave to the master. The registers used are usually 8 bits in length. Both sides are synchronized with the same clock signal.

Several options are given for the SPI connection. One option is the clock polarity. This sets whether the system sees a logical 1 or a logical 0 as the base value for the clock signal. Also there is the clock phase. This dictates whether the register will read or write data on the raising edge or the falling edge of the clock pulse.

The SPI connection also gives the advantage of having multiple slaves. In this configuration the slaves all share the same MISO, MOSI, and SCK lines but have different SS lines. A single slave unit can be singled out by holding its slave select line to a logical 1. As the other slave's SS lines are held to a logical 0, they will not listen to the communications on the common lines.

4.3 WiFly WLAN Module

The WiFly wireless unit is an off the shelf 802.11 WLAN module made specifically to interface with embedded electronic projects. This module makes it possible to bypass the complex procedure in making custom Transmission Control Protocol/Internet Protocol (TCP/IP) connections, as well as saving the large amount of memory that it would take to implement the protocol directly on the microcontroller. Transfer speeds of the wireless communication can reach up to 4 Mbps. The unit has 8 Mbits of flash memory and 128 KB of Random Access Memory (RAM). This memory can be used to store configuration files as well as being used for buffering the incoming data, as the UART connection transfer is slower than the incoming data from the WLAN.

The WiFly module can be purchased on a breakout board called the Surf Board. The layout of the WiFly module can be seen in figure 11.



Figure 11: WiFly RN-131GSX Wireless Module. Taken from RN-134 WiFly GSX Datasheet [7].

The interface to the unit is UART, and as can be seen in figure 11 on the bottom left side of the circuit, there are power, ground, transmit, and receive pins. The unit can be configured by connecting the UART pins to a HIN232 Serial transmitter/receiver [8] and making a serial connection to the unit using Tera Term, PuTTY, or any other serial connection program. In this command mode many settings can be made.

Once the WiFly unit is setup it can be taken out of command mode. Any further system changes can be made via a TCP/IP telnet session, given that the user knows the IP address of the WiFly unit [9].

In command mode there are many options the user can configure to suit the project's needs. There are options to use User Datagram Protocol (UDP) or TCP/IP protocols. There are data transfer rates that can be changed, along with buffer size and packet terminator characters to make custom size packets. There are a lot of useful features that make this device an easy solution to embedded wireless networking.

The WiFly unit has external pins for sensor implementation. This is useful when the designer wants to have the WiFly unit broadcast data upon a sensor trigger sequence. The external pins can also be used to initiate sleep or to wake the module. Automatic commands can also be configured such as configuring the WiFly unit to obtain an IP address upon power up. Another example could be the automatic writing of bytes to the UART connection when a task is completed or a sensor has been triggered.

4.4 Capacitive Touch

Capacitive touch sensing technology works on the concept that a change in the capacity of a button type interface results in a change of a signal that is being monitored. The button type interfaces can range from simple buttons and slide bars to large touch screens that track the location of where the user's finger is on the surface. All of these examples use the same method of detection. When the capacitance change alters the signal, the change in the signal is recognized by the system and can then be used to trigger specific actions in the system.

The skin of the finger acts partially as a dielectric and partially as a conductor which interacts with surrounding electric fields. The electrolytes within the fingers also interact with the electric fields. As the finger touches the area of the capacitive touch sensor, this interaction with the electric fields is what changes the capacitance. The finger and the body physically become part of the capacitance of the system, adding to the existing capacitance of the circuit. This change in capacitance then modifies the

parameters of the oscillator circuit which change the speed at which the circuit oscillates. The oscillation comes from what is known as a Capacitive Sensor Relaxation Oscillator (CSR). Figure 12 shows the circuit layout of the CSR.

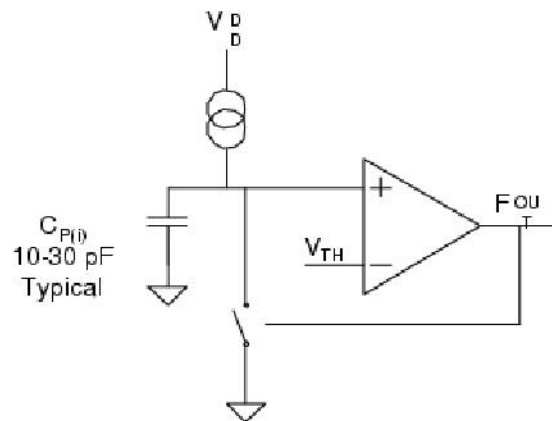


Figure 12: Capacitive Sensor Relaxation Oscillator. Taken from Leshner Todd [10].

The circuit consists of a comparator, a switch, and a capacitance that comes from the layout of the buttons. The capacitor is first charged to a voltage level defined by the comparator. When that voltage is reached the switch is closed to allow the capacitor to discharge into ground. The time that it takes to complete this cycle is noted by the use of a counter. The cycle is repeated and the counter results are compared to one another. As the capacitance changes due to a user touching the button, the charge time will grow larger due to the increase in capacitance. The larger charge time can be seen in the form of a larger counter number. The MCU is programmed in such a way that as the charge time of the capacitor passes a preset threshold, predefined actions are triggered. For example, a relay can be connected that will in turn start a motor or a large bank of lights. Several of the capacitive touch buttons can be implemented on the PSoC MCU, acting independently of each other, to perform different operations for the system [11].

Many of the capacitive touch pads designed in projects are based on printed circuit board layouts. The design is done in specific software so that proper spacing between capacitive sections of the button can be attained.

The pads are then milled out of circuit board material and connected accordingly to the circuit. This can then be hidden behind glass or thin paper to visually enhance the technology. The layout of the sensor pad can be seen in figure 13.

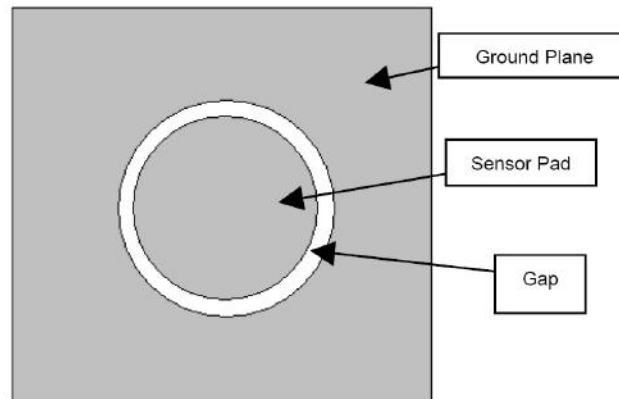


Figure 13: Capacitive Sense Button Layout. Taken from Cypress Capsense layout guidelines [12].

The button and ground plane are milled onto a printed circuit board. There is a separation gap between them, shown in figure 13. The sensor pad is taken into an input of the MCU by way of a trace, and the capacitance is read between the input and the ground plane.

The integration of capacitive touch capability into embedded systems has become a widely used form of system control. The use of capacitive touch buttons is attractive in that there are no moving parts, so necessary maintenance of the user interface is lowered. The buttons can also be adjusted to work under a pane of glass or plastic, keeping the usability while increasing the ability to keep the user interface clean and functional.

One application of the capacitive touch sensors that has become widely used is buttons on public electronic machines, for example train station ticket machines. Today the application of capacitive touch sense to things such as kitchen appliances, television remote controls, and hand held video games is also seen. As some touch pads can be designed to give multi-functions, the usability of the interfaces becomes much greater, for example the touch screen of a cell phone with press and slide controls.

5 Microcontroller Environment of the Electronic Class Schedule

5.1 Functional Division of Microcontrollers

In this project two types of PSoC MCUs were used due to the fact that the MCU needed for the capacitive touch sensing did not have enough digital blocks to manage both the capacitive touch and the communication functionality. For the duration of this thesis work they will be referred to as the Control MCU and the Communications MCU.

The PSoC microcontroller used for the Control MCU is a CY8C21534. This PSoC was chosen to take care of the capacitive touch buttons and the management of power for the digital photo frame and the Communications MCU. This processor type works with a settings wizard in the PSoC Designer software that creates capacitive touch pad settings for the user. For the management of power in the system, this model has enough I/O pins to use it to gate several transistors for power flow control in critical areas. It has a processor speed of 24 MHz and operates from 2.4 volts to 5.25 volts. It contains 8 KB of flash memory and 512 bytes of static random access memory. This module provides the normal PSoC function blocks such as Pulse Width Modulators (PWM), ADCs, counters, timers, UART, and SPI. It also has the option to utilize up to 20 of the input/output ports as capacitive sensing and proximity sensing. [13.]

The Communications MCU is a PSoC type CY8C29466. The capability of this microcontroller to have up to 16 digital blocks is why it was chosen to control the WiFly and SD card communications. It has a processor speed of 24 MHz, 32 KB of flash memory, and 2 KB of static random access memory. It can have 12 analogue inputs, four analogue outputs, or up to 44 digital input/output ports. [14.]

The system has been designed to have several sections of the unit function in a specific order. Every time the electronic class schedule is used, the unit follows the same function flow which is shown in figure 14.

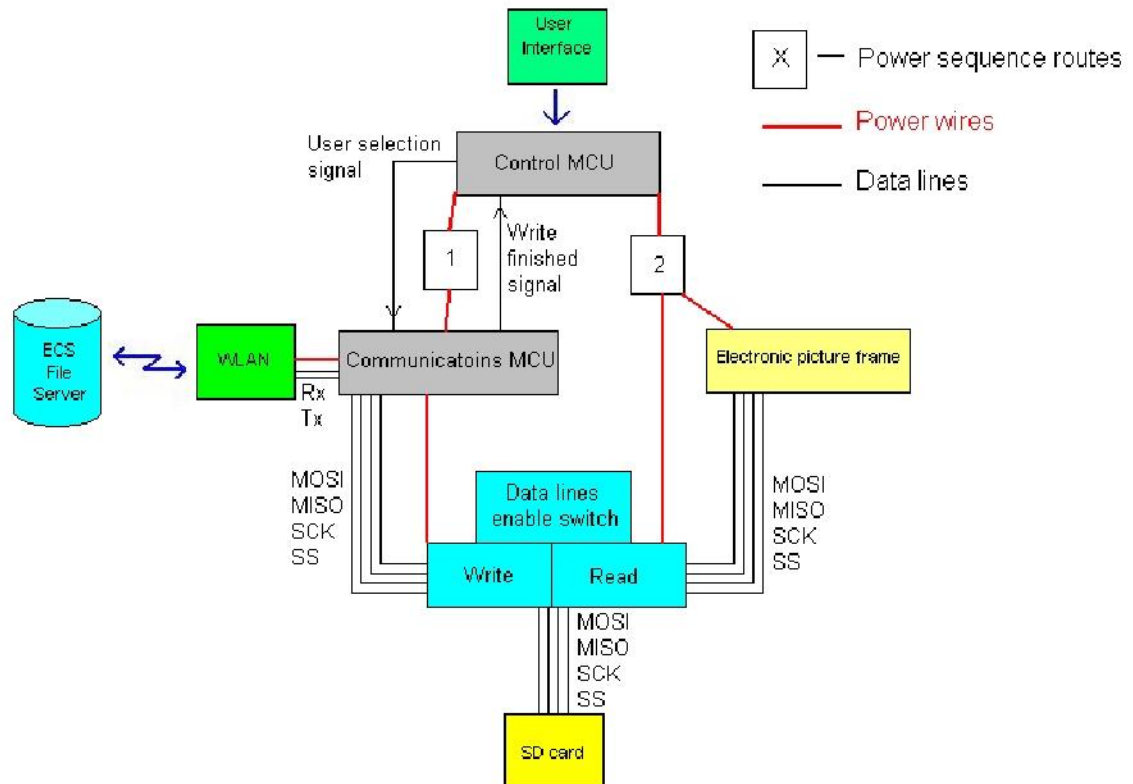


Figure 14: System Sequence Block Diagram.

As can be seen in the figure, when a user touches a button, the Control MCU sends a logic 1 on the signal line that signifies the user's button press. The Control MCU then turns on power, by way of block 1, to the Communications MCU. This is accomplished by the use of a transistor set which is designed to allow enough current for the operation. The block 2 route is held off in this phase. Once the Communications MCU is on, it turns on power to the WiFly WLAN unit and sends a logic 1 to the enable switch so that it may write to the SD card. After data is sent from the electronic class schedule's Network File Server (NFS) and written to the SD card, the Communications MCU sends a write finished signal to the Control MCU. The Control MCU then cuts power to route 1 effectively turning off the Communications MCU, the WiFly WLAN, and the enable write signal. It then gives power to route 2, by use of another transistor set, turning on the electronic picture frame and the enable read signal so

that the picture frame may access the file on the SD card. The picture is shown for a specified amount of time after which the Control MCU will cut power to route 2 effectively turning off power to the enable read signal and electronic picture frame. The process can be initiated at any time by the user by pressing one of the buttons.

The alternate enabling of the data lines is implemented due to the fact that both the electronic picture frame and the Communications MCU are both master SPI units, and they conflict with each other if connected simultaneously. The method that was found to work the best to isolate which master was to use the SD card was the use of the HEF4066 bilateral switch integrated circuit which can be seen in figure 15.

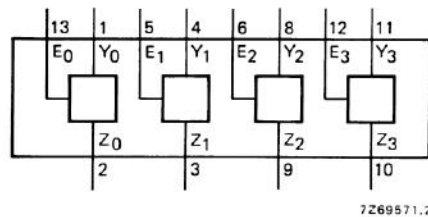


Figure 15: HEF4066 Bilateral Switch. Taken from HEF4066 Quadruple bilateral switch Datasheet [15].

The HEF4066 bilateral switch consists of four logic switches as can be seen in the figure. Each logic switch consists of an input, output, and an enable signal. For this project two HEF4066 chips were used, one for the connection of the SD card to the Communications MCU, and one for the connection of the SD card to the digital photo frame. For writing purposes, the MCU is allowed to turn on its enable signal giving it access to the SD card while the digital photo frame is held off. When the writing is complete, the Communications MCU turns off its enable signal and loses its power, effectively holding the enable signal to a logical 0 through a pull down resistor. The Control MCU then gives power to the digital photo frame as well as its enable signal allowing the photo frame to read the file. The switch requires 5 volts to operate but can switch and be enabled with 3.3 volts making it an ideal choice for the low voltage communications that are present in this project.

5.2 Design of Capacitive Touch User Interface

The capacitive touch sense interface was designed for use with the CY8C21534-24PVXI PSoC MCU. The board was designed using PADS software according to touch button layout specifications given by Cypress Semiconductor Corporation [8]. The layout of the design can be seen in figure 16.

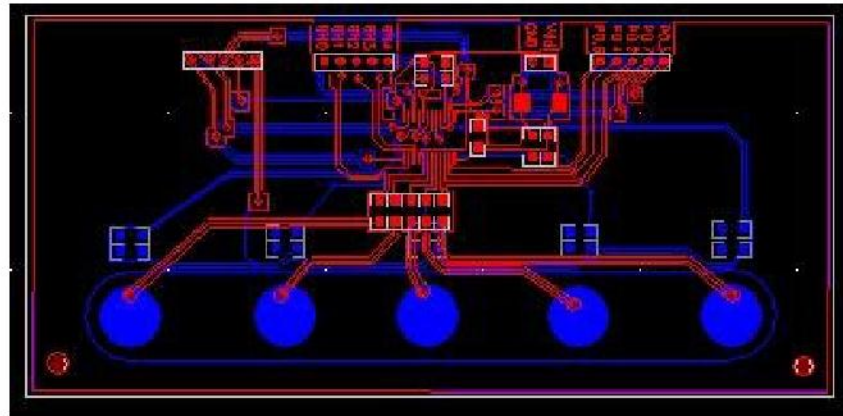


Figure 16: PADS Software Capsense Board Design. Screenshot [16].

The component layout is first designed with PADS Logic. All required components are placed and connected accordingly. This design is then taken into PADS Layout, shown in figure 16, which is where the traces and pads are added. It is in this step that the touch pads and ground plates are designed according to the PSoC specifications. The clearances are set for the milling, and the board is then milled on the machine. The components are then soldered to the board, and it is ready for programming.

In the PSoC Design software five buttons were set up in the design to represent the five days of the present week. The MCU itself was programmed using the cap sense wizard within the PSoC Designer program. The pins were then routed to the external pins of the MCU so that they could be routed to the cap sense pads on the board. The software for the capacitive touch required very little configuration, as most of the programming is done by the cap sense wizard and through the use of prewritten libraries. The only code that is necessary is a check to see if the button has been touched. This consists of one command for button scan [17, 35-36].

5.3 Interfacing WLAN Module

The interfacing of the WiFly module involved both hardware and software configuration. An external antenna was purchased for use with the Wifly unit, to give a boost of 2 decibels (dB) to the antenna system. The range of the internal antenna proved to be too weak for reliable communications. The physical connection to the WiFly unit is a common UART connection. The connections were taken to the pins of the Communications MCU via a set of manual switches providing easy system programming capabilities. Figure 17 shows the connection of the manual switches.

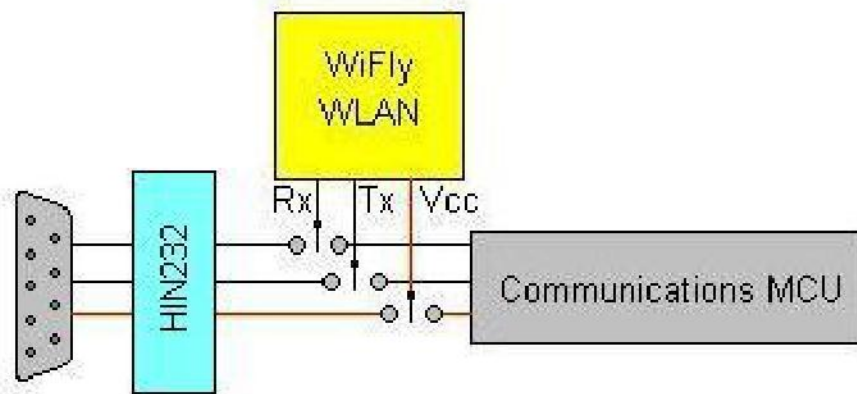


Figure 17: Manual Switching of WiFly Connections.

As can be seen in figure 17, the power and data lines can be isolated from the Communications PSoC and directed to the Serial to UART adaptor HIN232 [8]. This is to alleviate any communication problems while programming the WiFly unit via its serial connection, as a simultaneous connection of the data lines to the Communications MCU might alter the data during transfer.

The software configuration of the WiFly unit is done by establishing a connection with a serial communications program on the computer such as Putty or Tera Term. The set comm open command was set to transmit a byte representing the letter O out of the UART connection to the Communications MCU when a TCP/IP connection was established. This is to tell the MCU that the connection has been made and it can start

sending commands for delivery to the NFS. Dynamic Host Configuration Protocol (DHCP) was turned on so that the unit would automatically get any available IP address from the wireless network. The IP protocol was set to auto connect on power so that no command was needed from the MCU. The WiFly unit will be powered off when not in use so auto-connect on power up was a viable option. The UART communication parameters were set to 14400 baud rate with no parity bit. In addition, the appropriate security parameters were set so that the WiFly unit could establish a connection on the secured wireless network. There are many other parameters that can be set for use with the WiFly, but these were the only parameters which were needed for this project.

The setup of the Communications MCU required only the connection of the WiFly UART terminals to the MCU pins and internal routing and programming of the MCU. Using PSoC Designer, the pins were routed to a UART communications block. The clock for the UART block was set to use the clock divider selection of VC3. The main clock signal being 24 MHz is divided by a VC1 value of 2 and then divided by the VC3 value of 104. The UART block then again divides the clock signal by eight to find its baud rate. This was calculated to be 14423 which is within the clock tolerance to a 14400 baud rate. Clock synchronisation of the UART communications block was set to Sync to SysClk for best synchronisation at this speed.

The programming for the use of the UART was done in the C language in PSoC Designer. The code was written to read which button was pressed from the Control MCU, and then it was necessary to wait for the incoming letter O from the UART connection signalling that that WiFly has established a TCP/IP connection. When this is received, the program will send out a file name corresponding to the button that the user has pressed. For the initial project the names of the files were given as file1 to file5 representing the five days of the week. The program then waits for incoming file size and sector count data to be delivered via the UART connection. The directory entries for the FAT file system are prewritten in a character array, and the file size data is used to modify the directory entry to reflect the correct file size for the file that is being retrieved. After the array has been modified the MCU then sends out a letter S as a start byte to signal that it is ready for the raw data. The raw data is sent to the

WiFly and buffered as it is sent out of the UART connection. The MCU is programmed to enter this raw data directly to the SD card in 512 byte chunks using a FOR loop. The sector count that was received from the server program dictates the length of this loop for proper writing function. After all of the data is received from the UART connection the WiFly unit is no longer needed, and it is powered off by the Communications MCU.

5.4 Integration of SD Card

For the connection to the SD card the Communications MCU was used. The pins of the SD card can be connected to the pins of the MCU and used in SPI mode. Figure 18 shows the correct connection of the SD card to the PSoC microcontroller.

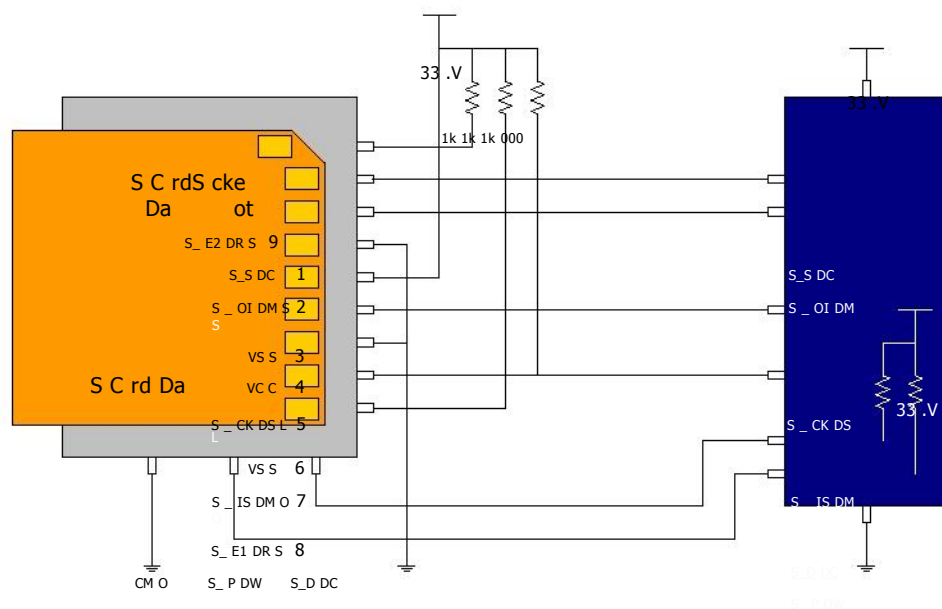


Figure 18: SD Card Interface to PSoC Microcontroller. Taken from PSoC SD Card Module Solution PPT [18, 14].

The SD card socket shown in figure 18 can be a purchased prefabricated SD card breakout board, or as in this project it can be a custom breakout board made from a Micro SD to SD card size adaptor with pin connectors soldered to the contacts. The SD_CD and SD_WP pins were not utilized in this project as they are for functions that were not needed for the operation of the electronic class schedule. The four data lines

MISO, MOSI, SCLK, and SS were not taken directly from the SD card to the MCU as shown in the figure but rather switched through the HEF4066 bilateral switch integrated circuit [15]. Only during the time of reading the file for display will the enable signal to the HEF4066 and the power to the digital photo frame be turned on. This allows the photo frame, upon power up, to read that there is a new file on the SD card, as well as saving power while the unit is not in use. The circuit board for these connections to the Communications MCU were fabricated using PADS Logic and PADS Layout in the same fashion as the Control MCU circuit board was designed.

Using PSoC designer the SPI connection was setup to communicate over the pins to which the SD card was connected. The clock of the SPI communications block was set up to run from an 8 bit Counter Block. This gives the ability to change the speed of the SPI connection in real time by changing the values of the counter within the program code. The counter clock is taken from VC1 having a divider of 2. The main clock signal is 24 MHz which is divided by the VC1 value of 2, then divided by the period value for the counter which is initialized to 60. When the SPI connection block receives the clock signal it divides this again by two to find its clock rate. This gives a calculated clock signal of 100 KHz which is used for the initialization of the SD card. Once the initialization is finished, the Counter Block is programmed to switch to a period of eight for a clock speed of 750 KHz. This is the speed that is used for data transfer.

This speed can be taken up to several MHz if needed after the card initialization is accomplished below a speed of 400 KHz. For stability issues the speed was kept relatively low for this project. Additionally, the UART baud rate limits the speed of the data flow, so higher rates on the SPI connection are not necessary.

Within the software of the MCU there are two arrays that are used in the writing of data to the SD card. The first is the FAT entry and the second is the Directory entry. The arrays can be seen in figure 19.

```

30 BYTE fat[20] = {0xFF, 0xFF, 0xFF, 0x7F, 0x03, 0x00, 0x04, 0x00, 0x05, 0x00, 0x06, 0x00, 0x07, 0x00,
31 0x08, 0x00, 0x09, 0x00, 0xFF, 0xFF};
32
33 BYTE directory[64] = {0x54, 0x48, 0x45, 0x53, 0x49, 0x53, 0x20, 0x20, 0x20, 0x20, 0x20, 0x08, 0x00,
34 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x72, 0x86, 0x9E, 0x3D, 0x00, 0x00, 0x00, 0x00,
35 0x00, 0x00, 0x46, 0x49, 0x4C, 0x45, 0x20, 0x20, 0x20, 0x20, 0x4A, 0x50, 0x47, 0x20, 0x18, 0x30, 0xA9,
36 0x86, 0x9E, 0x3D, 0x9E, 0x3D, 0x00, 0x00, 0x9A, 0x92, 0x66, 0x3D, 0x02, 0x00, 0x25, 0x03, 0x00, 0x00};
37

```

Bytes replaced with proper file size

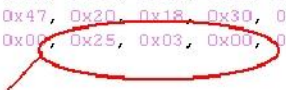


Figure 19: SD Card File Information Arrays.

Figure 19 shows the information that needs to be written to the SD card so that the file is recognized as a picture file. The only information that is modified is the size of the file when the MCU is retrieving information from the server program. It is not necessary to have a file system erase and create a new file every time, because only one file is needed for display at a time. This allows the system to use the same file space repeatedly, verses finding free space every time a write command needs to be executed. Additionally, the proper use of a filing system on the MCU would require more memory than is available. Once the file size of the Directory entry has been modified, the MCU writes the FAT entries and the Directory entries to the SD card. Two FAT entries are needed for filing system redundancy checks. For the card used on this project the first FAT entry is in the address space sector 2, the second FAT entry is in address space sector 241, and the Directory entry is made in sector 480. As the arrays for these entries are under 512 bytes, and a successful write command needs 512 bytes exactly, the remaining missing bytes are filled in with the hex value 0x00. Filling the remaining data in a sector with dummy bytes was accomplished with a FOR loop count of 512 minus the partial raw data in the sector. The Communications MCU is then ready for the raw file data.

As the raw data starts to come in from the wireless unit, a continuous write command is first issued to the SD card, and data is written directly to the card. The write command used to make the data write function is similar to the command 0 that was shown in section 2.3. Figure 20 shows the continuous write command 25 as given via the SPI to the SD card.

```
// CMD 25(59) Continuous data write

SPIM_SendTxData(0x59); // set message to transmit
while(!(SPIM_bReadStatus() & SPIM_SPI_SPI_COMPLETE)){};
SPIM_SendTxData(loc1); // set message to transmit
while(!(SPIM_bReadStatus() & SPIM_SPI_SPI_COMPLETE)){};
SPIM_SendTxData(loc2); // set message to transmit
while(!(SPIM_bReadStatus() & SPIM_SPI_SPI_COMPLETE)){};
SPIM_SendTxData(loc3); // set message to transmit
while(!(SPIM_bReadStatus() & SPIM_SPI_SPI_COMPLETE)){};
SPIM_SendTxData(loc4); // set message to transmit
while(!(SPIM_bReadStatus() & SPIM_SPI_SPI_COMPLETE)){};
SPIM_SendTxData(0x95); // set message to transmit
while(!(SPIM_bReadStatus() & SPIM_SPI_SPI_COMPLETE)){};
```

Figure 20: PSoC Designer SPI CMD 25. Screenshot [3].

As can be seen in the figure, the command starts with the command byte of 0x59 representing a continuous write function. Next is the argument which gives the memory location to be written to, shown here as variables passed to the function. The CRC is not necessary at this point as the card is initialized and in SPI mode, so once in SPI mode the hex number 0x95 is used instead as a dummy byte for the CRC.

After the continuous write command, the MCU waits for an accepted response token from the SD card. Then the MCU is free to send data beginning with the start byte of 0xFC. The SD card knows then that everything following is raw data and should be saved into the respective memory locations. This is a continuous write command and it will take data in one sector at a time until a proper stop token is received. This sector grouping is such that the SD card may perform a CRC on the data with every sector. This grouping is not avoidable even though the CRC is not being used. Furthermore, this grouping does slow down the transmission of data. When all data is sent on the

continuous write command, the host device must fill the remaining space of the last sector with dummy bytes of the hex value 0x00 and then send the stop token in order to receive a data accepted token from the SD card. The stop token is a single byte of hex 0xFD.

After the stop token is sent and the data has been correctly written to the SD card memory, the MCU will cut power to the WiFly wireless unit and send a signal back to the Control MCU that the file has been successfully written to the card and it is ready for viewing. When all sectors have been properly written, the digital photo frame can read the file as a normal picture file.

The locations of the entries on the SD card can vary with cards. The SD card utilized for this project is a Transcend 2GB Micro SD card. This card uses 64 sectors per cluster of memory. This gives a total of 32768 bytes of memory per cluster. For this project the FAT entries were written to include the space of 10 clusters for the file. This gives a usable memory space of 327680 bytes for the file. The Directory entry includes the card information, file name, size, starting sector, time, and date information. The array in the MCU only includes enough information to cover the card information and the information for one file. The file name, date of creation, starting memory sector, and other aspects of the file can remain the same every time. The only information changed is the file size. The last entry made is the volume entry where the raw data is written to. The beginning sector for the raw data is always set to sector 512, and the reserved space continues for the next 327680 bytes.

No system settings of the digital photo frame have been changed from the default values. The circuit board of the unit has been enclosed and the buttons and card slots have become inaccessible, as they are no longer needed for the operation of the schedule.

6 Client-Server Functionality of the Electronic Class Schedule

6.1 Schedule File Server Overview

The schedule file server program was designed to serve as a file server for the electronic class schedules, as well as creating the schedule picture files from data retrieved from the school schedule website. The functional block diagram can be seen in figure 21.

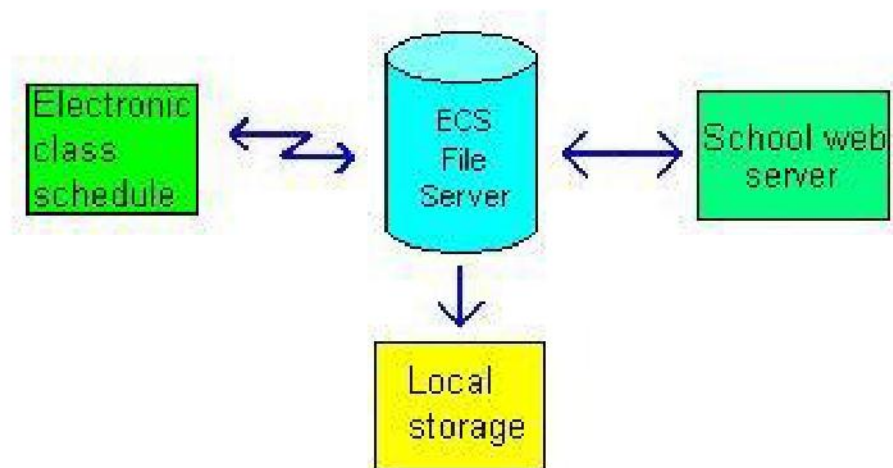


Figure 21: Schedule File Server Functional Block Diagram.

As shown in the figure, the proposed function of the NFS is to access the school's web server for information to be used in making the schedules. The schedules are then held in local storage on the NFS until they are ready to be sent. The electronic class schedules can open a wireless connection and retrieve these files when needed.

The schedule file server has been written in the higher level language C# using Microsoft Visual Studio 2010 Professional. This was chosen to take advantage of the form and list box capabilities, as well as the libraries for TCP/IP communication.

The application was kept basic as the only function at that point in time was to listen out for file requests and send the files. Figure 22 shows how the listbox looks when the application is in operation.

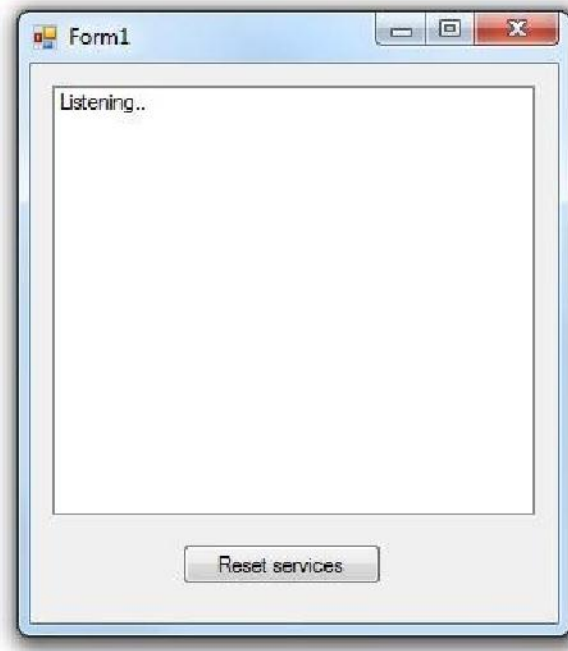


Figure 22: Server Program Application Console in Microsoft Visual Studio.
Screenshot [19].

As shown in the figure, the text box shows the status of the server program. In this example it is listening out for an incoming request. The figure also shows a reset services button on the application console. This is so that if there is any hang up of the application, the button can be used to restart all of the services used by the server program. The list box and form allow the system manager to see in real time what the program is doing and if there are any problems. [20, 33-37.]

6.2 Creation of JPG Schedule Files

The first function of the file server program is to create the schedule picture files for the electronic class schedules. It does this by periodically looking up class schedules on

the school's website and parsing information for that particular classroom. It then uses this data to create a text file version of the schedule and then converts it to a JPG picture file. Each classroom will have a separate JPG file for each day of the current week. The program can be set to create files on intervals of every 30 minutes so as to keep the schedules up to date for display. The JPG files will be stored with names corresponding to the class number so that upon a request the server program can easily find and send the correct file. The extent of development of the server program for this project was given to be delivery of the picture files. The parsing of the information from the school schedule website will be developed at a further date.

6.3 Connection and Delivery of Schedule Files

The second function of the server program is the delivery of the schedule files. The program is designed to listen on a particular port for any requests being made by the electronic class schedules. For the project development, port 2000 was utilized. When a connection is requested, it is accepted and a network stream is created [20, 172-180]. The listbox at this point will show that a connection has been made. The electronic class schedule that has made the request then sends out the name of the file it is requesting. The server program will scan incoming data and wait until it reads the letter f, as all files that will be requested will start with the letter f, for example file1. The file name that is being requested is sent without the file extension. When the file server program receives the name of the file, it is then added to a prewritten character string. This string represents the file directory for the file server's local storage where the schedule pictures are stored. The extension JPG is then added to the end of the string and the program uses the string to locate the file. Once the file is located, a file reader function is opened, and the raw file data can be accessed. [20, 134.]

When the raw data is opened for access, the size of the file is found and sent back to the electronic class schedule. The number of 512 byte sectors is then calculated and sent back. This will be used for SD card writing purposes by the MCU of the electronic class schedule, as the writing function of the SD card is accomplished in groups of 512 bytes. A note on the listbox is put up showing that the file size has been sent. The server program then waits for the electronic class schedule to send the hex byte 0x53

representing the letter S as a start byte, signifying that it is ready for the raw data. Once the start byte is received the server program then starts to send the raw data of the schedule file. When all data has been sent, the connection is terminated and a message is shown on the listbox that the file has been sent. The server then returns to the idle mode and shows that it is again listening out for a request.

7 Discussion

7.1 Implementation Issues

During this project there were several issues that needed to be overcome, which did not have simple solutions. These proved to be good learning points and areas for self development. The first issue was getting the write command to work with the SD card. The documentation for issuing commands to any SD card is difficult to find. Every SD card manufacturer has little differences in the way the cards are communicated with. Furthermore, within each manufacturer's line of cards there are different flows of communication depending on what type of card it is and what size it is. Thus, finding the correct combination of commands takes a great deal of experimentation. Six different SD cards were used in the development of this project, and only one was successfully implemented. Also, the Cypress documentation for using the SD card is rare. The company at one point in time had an SD interface with libraries that handled the file system, but it was dropped because of too many unresolved problems and size limitations of the MCUs. When searching the Cypress forums, few examples showing how to issue byte commands to an SD card can be found. The main flow of the program came from the SD manufacturer's manual, but most of the help to resolve the problems came from online forums and hobby experimenter websites.

Another issue was the fact that the system was developed as a 3.3 volt system to work with the SD card, negating the possibility to use a Liquid Crystal Display (LCD) with the microcontroller for debugging purposes. The PSoC MCU is capable of running with 5 volts, and originally it was done so. The SPI data lines to the SD card were taken to 3.3 volts using level shifters. This gave the ability to use the LCD to show the responses that the SD card was giving. The level shifters were taken out and the MCU was configured to function on 3.3 volts to help with communication problems between the MCU and the SD card. The WiFly unit also proved to work better on the lower voltage. At this voltage the LCD would not work so another temporary MCU was

implemented to show outputs on the LCD. A separate SPI connection was programmed into the Communications MCU and output to the temporary MCU which ran on 5 volts and had an LCD. This way the whole system could stay at 3.3 volts and the responses from the SD card could be forwarded and displayed for debugging.

Working with 3.3 volts resulted in problems in switching power to the individual areas of the system. The transistors used for the switching of power were PNP BC556 [21] and NPN BC546 [22] used in the Darlington setup to provide better current flow [23, 95]. The rated voltage is 5 volts on both. It was attempted to use these transistors with the system's 3.3 volts. The lower voltage did not allow for the proper current and the switching was intermittent. To solve the problem, the 5 volts from the power supply was taken into the collectors and switched using the MCUs 3.3 volts on the base. Then the output was supplied to a MIC5200 voltage regulator [24] which dropped it to 3.3 volts for use in the system.

The largest issue of the project that presented itself was how to properly isolate the two master SPI connections from each other and give alternate control over the SD card. The use of the Darlington transistor setup was attempted on each data line but that idea proved to supply too much stray capacitance and the signals were degraded so that they would not work. Logic gates were attempted, such as the SN7408, and the signal still seemed to be degraded beyond a usable amount. Several switching integrated circuits and multiplexer integrated circuits were used including SN74LS243 transceiver, HCF4053, MM5616 multiplexer, and the HEF4066 quadruple bilateral switch. All of them gave the same results. The issue was eventually resolved using the HEF4066. It was found that the problem was a combination of issues. The first issue being that Vcc on the integrated circuit needed to be 5 volts, though the enable, input, and output could all be used with the 3 volt system. The second issue was that the HEF4066 needed to be kept on while the enable pins were held low to effectively stop a signal. The original method was to cut all power to the HEF4066 and assume that the

signals would not pass. This assumption proved to be wrong as it would still degrade the signal existing in the other switching device. With the HEF4066 left powered up and the enables held to Gnd when a separation of data lines is required, the system works as it is supposed to.

7.2 Results

The electronic class schedule performs as it was designed. The user may select one of five buttons and receive the respective picture file on the screen. Designing the system to handle larger size picture files could enhance the experience for the user. Though the existing file size of 3 KB is sufficient to deliver the material, as of now files larger than 10 KB take too much time to transfer and run a greater risk of losing data. The system can provide an easy way for teachers to put their schedules to the appropriate rooms without having to travel around the school changing out paper schedules. This also includes writing extra comments. For example, if a class is cancelled or moved to another room, this information can be added to the online schedule for the electronic class schedule to parse and display for users. There are many other improvements that future students may add as well to ensure that the electronic class schedule is developed to its full potential.

7.3 Future Development

The speed of the system was limited by the read and write operations of both the UART connection to the WiFly and the SPI connection to the SD card. During development the UART connection was tested to run best at the speed of 14400 bps. The initialization of the SD card must be below 400 KHz, but it can be stepped up for data transfer. For this project the data rate was only stepped up to 700 KHz, as the files are around 3 Kb in size. The total transfer from WiFly to SD card takes a little over two seconds. Future models of the WiFly unit will include SPI connection, being several times faster than UART, which will effectively speed up the delivery of data. When these become available, the speed of the data transfer can be increased enabling the picture files to be larger and of better quality.

Another area of development involving speed is seeing if the Bus mode of the SD card can be used with the PSoC MCU. Research into using the Bus mode was not done. During the project this concept was not seen in any other similar SD card embedded projects. If this can be accomplished, then three data lines would be available for the movement of data.

The addition of extra memory to the unit could assist in enhancing the user experience. EEPROM or SRAM external memory could be used to store additional pictures such as system error messages to the user or special notices pertaining to that classroom. System messages could also be displayed to the user to show which file is being retrieve. In addition, directions on how to use the electronic class schedule could be displayed to the user. Currently the electronic class schedule is not set up to show anything on the screen until the schedule is received and written to the SD card.

The ability to send a file directly to the electronic class schedule would be a good future feature for teachers. This would allow the teachers to send messages showing that a class has been cancelled or moved to another room. The system as it is only shows what is put into the class schedules online. To add personal messages, one would need to be able to wake the unit from the power down state and send a file for display. Developing a second application that could be given to the teachers could allow the teachers to directly connect to a specific class schedule and give it a custom picture file. The addition of the external memory could assist in implementing this idea, as the message could be stored and shown when a schedule is not being requested.

One issue that could be corrected in future versions is the incompatibility of SD cards. During the experimentation there were six SD cards that were used to develop the initialization and write command. During the end phase of the project only one card was working properly. This is due to the fact that each card responds differently to the commands, so there needs to be an initialization process as discussed in section 7.2 to correctly initialize more than just one type of card. This may very well take a lot of memory, in which case the Communications MCU would need to be replaced with a model that has more memory available. With the current MCU designs that are out on the market today, this notion could be easily achieved.

The last area of development is the server program. This program could be developed further to show all files that have been parsed and turned into JPG files. It could give information such as size and the time they were created and show a list of the files in the working program window. The program could also show which electronic class schedule was connected to it and keep a small log of the communications it has done. Also the current design only handles one request at a time. The program could be structured to handle several requests when several units are placed around the school.

8 Conclusions

The goal of developing a low priced system that could retrieve class schedules over the wireless network and present them on a screen for the user was met. A server program was written that can properly listen out for file requests and return the correct file to the unit which made the request. The electronic class schedule has been developed to a point that it can retrieve the picture files over the wireless network and write them to the SD card for viewing on the electronic picture frame. The system has been designed with the minimum specifications of the project goal, and it fulfils the requirements set for it. Given the proper time and research, further development can be made to upgrade the functionality in the system making the electronic class schedule a viable option for class schedule delivery.

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Microcontroller Specifications

CY8C21534 Cypress

- Clock 24 MHz
- Operating voltage 2.4 V to 5.25 V
- Operating temperature range -40 to 85 Celsius
- 4 analogue blocks
- 4 digital blocks
- 8 KB flash memory
- 512 Bytes SRAM
- Programmable pin configurations
- Programmable multiplexing
- I2C, UART, SPI communications
- Programmable watchdog timers
- Supports Capsense buttons
- 28 analogue inputs
- 0 analogue outputs
- 28 digital I/O ports

CY8C29466 Cypress

- Clock 24 MHz
- Operating voltage 3.0 V to 5.25 V
- Operating temperature range -40 to 85 Celsius
- 12 analogue blocks
- 16 digital blocks
- 32 KB flash memory
- 2 KB SRAM
- Programmable pin configurations
- Programmable multiplexing
- I2C, UART, SPI communications
- Programmable watchdog timers
- 12 analogue inputs
- 4 analogue outputs
- 44 digital I/O ports

Program Code - Communication MCU Program

```

//-----
// Metropolia University of Applied Sciences
// Marcel Mushik 24 April 2011
// Final year project - Electronic class schedule
// Code: Control MCU program
//-----

// Include files -----
#include <m8c.h>           // part specific constants and macros
#include "PSoCAPI.h"      // PSoC API definitions for all User Modules

// Global variables -----
int i = 0;
int count = 0;
int decision = 0;

// Declarations -----
#pragma interrupt_handler Timer8_ISR           // timerISR to be handled as the interrupt code
void button_press(void);

// Function description-----
// Main function. Receives button selection from user.
// Turns on power to Communications MCU and forwards button selection.
// Waits for a signal indicating that data has been downloaded and written to SD
// card.
// Turns off WiFly, and gives power to Digital photo frame, also enables read.
// Times out, or starts again with another button press.
void main(void)
{
    M8C_EnableGInt;           // Enables Global interrupts
    ButtonSig1_Start();       // Makes ready ButtonSig1 for operation
    ButtonSig2_Start();       // Makes ready ButtonSig2 for operation
    ButtonSig3_Start();       // Makes ready ButtonSig3 for operation
    ButtonSig4_Start();       // Makes ready ButtonSig4 for operation
    ButtonSig5_Start();       // Makes ready ButtonSig5 for operation
    MCU2_pwr_Start();         // Makes ready MCU2_pwr for operation
    SD_pwr_Start();           // Makes ready SD_pwr for operation
    Read_enable_Start();      // Makes ready Read_enable for operation
    Timer8_WritePeriod(100);   // Sets timer period value
    Timer8_WriteCompareValue(0); // Sets timer compare value
    Timer8_EnableInt();        // Enables timer interrupts

    while(1)                  // Reads input from user.
    {
        if ((PRT2DR & 0x01) == 0x01) // Button 1 P2.0
        {
            decision = 1;           // Notes decision
            button_press();         // Forwards decision to function
        }
        else if ((PRT2DR & 0x04) == 0x04) // Button 1 P2.2
        {
            decision = 2;           // Notes decision
            button_press();         // Forwards decision to function
        }
        else if ((PRT2DR & 0x10) == 0x10) // Button 1 P2.4
        {
            decision = 3;           // Notes decision
            button_press();         // Forwards decision to function
        }
    }
}

```

```

    }
    else if ((PRT2DR & 0x40) == 0x40) // Button 1 P2.6
    {
        decision = 4;           // Notes decision
        button_press();         // Forwards decision to function
    }
    else if ((PRT0DR & 0x01) == 0x01) // Button 1 P0.0
    {
        decision = 5;           // Notes decision
        button_press();         // Forwards decision to function
    }

    if(count == 30)             // If timer has interrupted 30 times,
    {                           // Photo frame is turned off,
        Timer8_Stop();          // Resets
        Read_enable_Switch(0); // Resets
        SD_pwr_Switch(0);       // Resets
        count = 0;              // Resets
    }

    ButtonSig1_Switch(0);       // Button signals zeroed after forwarding
    ButtonSig2_Switch(0);       // Button signals zeroed after forwarding
    ButtonSig3_Switch(0);       // Button signals zeroed after forwarding
    ButtonSig4_Switch(0);       // Button signals zeroed after forwarding
    ButtonSig5_Switch(0);       // Button signals zeroed after forwarding
}
}
}

```

```

// Function description-----
// Function takes decision value and forwards the respective button
// signal to the communications MCU.
// All values are reset in case of a new button push.
// Delays are set to give proper warm up time of MCU
// While loop waits until the finished signal is given from the
// communications MCU, in which case it is shut off and power
// and read enable is given to the photo frame.
// The timer is also started for use of its interrupt.
// This creates the timeout before the screen turn off automatically.
void button_press(void)
{
    Timer8_Stop();              // Resets
    SD_pwr_Switch(0);           // Resets
    Read_enable_Switch(0);      // Resets
    count = 0;                  // Resets
    for(i=0; i < 21000; i++); // Delay waits for photo frame to give up control of SD
    MCU2_pwr_Switch(1);         // Communications MCU turned on
    for(i=0; i < 800; i++);     // Delay for MCU2 warmup

    if (decision == 1) ButtonSig1_Switch(1); // Sending button signal
    else if (decision == 2) ButtonSig2_Switch(1);
    else if (decision == 3) ButtonSig3_Switch(1);
    else if (decision == 4) ButtonSig4_Switch(1);
    else if (decision == 5) ButtonSig5_Switch(1);

    for(i=0; i < 800; i++); // Delay for read of signal
    while((PRT1DR & 0x08) == 0x00); // Waits for MCU2 finished signal
    MCU2_pwr_Switch(0); // Turns off Communications MCU
    Read_enable_Switch(1); // Turns on read enable
}

```

```
        SD_pwr_Switch(1);                // Turns on digital photo frame
        Timer8_Start();
    }

// Function description-----
// Timer which keeps count of timer interrupts.
// Creates time before the photo frame automatically turns off.
void Timer8_ISR(void)
{
    count++;
}
```

Program Code - Communication MCU Program

```

//-----
// Metropolia University of Applied Sciences
// Marcel Mushik 24 April 2011
// Final year project - Electronic class schedule
// Code: Communication MCU program
//-----

// Include files -----
#include <m8c.h>           // part specific constants and macros
#include "PSOCAPI.h"      // PSoC API definitions for all User Modules
#include <stdlib.h>

// Global variables -----
int i = 0; int j = 0;
int k = 0;
int size;
int file_size = 512;
int file_size_partial;
int sectors = 0;
BYTE Rdata = 0xAC;
BYTE file[5] = {0x66, 0x69, 0x6C, 0x65, 0x31};
BYTE number_of_sectors[2];
BYTE data_size[3];
BYTE fat[20] = {0xF8, 0xFF, 0xFF, 0x7F, 0x03, 0x00, 0x04, 0x00, 0x05, 0x00, 0x06, 0x00, 0x07, 0x00,
0x08, 0x00, 0x09, 0x00, 0xFF, 0xFF};
BYTE directory[64] = {0x54, 0x48, 0x45, 0x53, 0x49, 0x53, 0x20, 0x20, 0x20, 0x20, 0x20, 0x08, 0x00,
0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x72, 0x86, 0x9E, 0x3D, 0x00, 0x00, 0x00, 0x00,
0x00, 0x00, 0x46, 0x49, 0x4C, 0x45, 0x20, 0x20, 0x20, 0x20, 0x4A, 0x50, 0x47, 0x20, 0x18, 0x30, 0xA9,
0x86, 0x9E, 0x3D, 0x9E, 0x3D, 0x00, 0x00, 0x9A, 0x92, 0x66, 0x3D, 0x02, 0x00, 0x25, 0x03, 0x00,
0x00};

// Declarations -----
void card_initialize(void);
void CS_toggle(void);
void write_data_init(BYTE, BYTE, BYTE, BYTE);
void write_data_raw(BYTE);
void write_data_fill(int);
void write_CRC(void); void
stop_token(void); void
start_token(void);
void debug(BYTE);

// Function description-----
// Main function. Receives button selection from Control MCU.
// Opens connection with WiFly, sends request. //
Receives data and writes file to SD card.
void main(void)
{
    M8C_EnableGInt;           // Enables global interrupts
    SD_SS_Start();            // Makes ready SD_SS for operation
    SD_SS_Switch(1);          // Sets SD_SS high, not enabled
    Debug_SS_Start();         // Makes ready Debug_SS for operation
    Debug_SS_Switch(1);       // Sets Debug_SS high, not enabled
    MCU_fin_sig_Start();       // Makes ready MCU_fin_sig for operation
    MCU_fin_sig_Switch(0);     // Sets MCU_fin_sig low, not finished
    WiFly_pwr_Start();         // Makes ready WiFly_pwr for operation

```

```

Write_enable_Start();           // Makes ready Write_enable for operation
Loading_LED_Start();           // Makes ready Loading_LED for operation
Counter8_WritePeriod(0x60);    // Sets period to 60 clocks
Counter8_WriteCompareValue(0x30); // Generates a 50% duty cycle
Counter8_Start();              // Starts counter //
UART_Start(UART_PARITY_NONE);   Enables UART
SPIM_Start(SPIM_SPIM_MODE_0 | SPIM_SPIM_MSB_FIRST); // Sets SD SPI parameters
SPIM2_Start(SPIM2_SPIM_MODE_0 | SPIM2_SPIM_MSB_FIRST); // Sets Debug SPI parameters

```

```

while(1)
{
    // Waits for button press
    if ((PRT2DR & 0x04) == 0x04) // Button P2.2
    {
        file[4] = 0x31;          // Changes file number to 1
        k = 1;
    }
    else if ((PRT2DR & 0x10) == 0x10) // Button P2.4
    {
        file[4] = 0x32;          // Changes file number to 2
        k = 1;
    }
    else if ((PRT2DR & 0x40) == 0x40) // Button P2.6
    {
        file[4] = 0x33;          // Changes file number to 3
        k = 1;
    }
    else if ((PRT0DR & 0x01) == 0x01) // Button P0.0
    {
        file[4] = 0x34;          // Changes file number to 4
        k = 1;
    }
    else if ((PRT0DR & 0x04) == 0x04) // Button P0.2
    {
        file[4] = 0x35;          // Changes file number to 5
        k = 1;
    }

    if(k == 1)
    {
        WiFly_pwr_Switch(1);     // Turns on WiFly power
        Write_enable_Switch(1);   // Enables writing to SD card
        Loading_LED_Switch(1);    // Turns on LED to show operational status

        // Waits for incoming byte of 'O' to show WyFly has made a connection
        while(UART_cReadChar() != 0x4F);

        // Catches extra 'O' bytes that are sent by WiFly.
        while(UART_bReadRxData() == 0x4F);

        // Sends request for file
        for(i=0; i<5; i++)
        {
            UART_PutChar(file[i]);
        }
    }
}

```

```

while(UART_cReadChar() == 0x00);           // Scans for valid data

data_size[0] = UART_bReadRxData();          // Stores Lowest byte of
                                           // file size
data_size[1] = UART_cGetChar();            // Stores middle byte of file size
data_size[2] = UART_cGetChar();            // Stores highest byte of file size

// Find number of bytes left after all 512 size writes will be made
file_size_partial = ((data_size[1]<<8)|data_size[0]) + 1;
while(file_size_partial > 512) file_size_partial = file_size_partial - 512;
file_size = file_size_partial;

// Writes file size to directory entry string
directory[60] = data_size[0];
directory[61] = data_size[1];
directory[62] = data_size[2];

// Gets number of sectors for proper future loop counts
while(UART_cReadChar() == 0x00);
number_of_sectors[0] = UART_bReadRxData();
number_of_sectors[1] = UART_cGetChar();
sectors = ((number_of_sectors[1]<<8)|number_of_sectors[0]) - 1;

card_initialize();                         // SD card initialization into SPI mode

Counter8_WritePeriod(0x30);               // Sets period to 30 clocks
Counter8_WriteCompareValue(0x15);         // Generates a 50% duty cycle

write_data_init(0x00, 0x00, 0x04, 0x00);   // Writes first FAT entry
start_token();                             // Address sector 2, offset 400
for(i=0;i<sizeof(fat);i++)
{
    write_data_raw(fat[i])
;
}
write_data_fill(sizeof(fat));
write_CRC();
stop_token();

write_data_init(0x00, 0x01, 0xE2, 0x00);   // Writes second FAT entry
start_token();                             // Address sector 241, offset 1E200
for(i=0;i<sizeof(fat);i++)
{
    write_data_raw(fat[i])
;
}
write_data_fill(sizeof(fat));
write_CRC();
stop_token();

write_data_init(0x00, 0x03, 0xC0, 0x00);   // Writes DIRECTORY entry
start_token();                             // Address sector 480, offset 3C000
for(i=0;i<sizeof(directory);i++)
{
    write_data_raw(directory[i]);
}
write_data_fill(sizeof(directory));
write_CRC();
stop_token();

```



```

write_data_init(0x00, 0x04, 0x00, 0x00);    // Writes raw data
start_token();                             // Address sector 512, offset 40000

Counter8_WritePeriod(0x02);                // Sets period to 2 clocks
Counter8_WriteCompareValue(0x01);          // Generates a 50% duty cycle

UART_CPutString("S");                      // Sends 'S' to show ready for raw data

while(UART_cGetChar() == 0x00);             // Waits for raw data to start coming
write_data_raw(UART_bReadRxData());
for(i=0;i<511;i++)                          // Writes first sector of raw data
{
    // Previous line read the 512th byte
    while((UART_bReadRxStatus() & 0x08) != 0x08);
    write_data_raw(UART_cGetChar());
}
write_CRC();

for(j=0;j<(sectors-1);j++)                  // Writes additional sectors
{
    start_token();
    for(i=0;i<512;i++)
    {
        while((UART_bReadRxStatus() & 0x08) != 0x08);
        write_data_raw(UART_cGetChar());
    }
    write_CRC();
}
start_token();

// Writes remaining raw bytes after all complete sectors
for(i=0;i<(file_size_partial - 1);i++)
{
    while((UART_bReadRxStatus() & 0x08) != 0x08);
    write_data_raw(UART_cGetChar());
}

// Fill remaining empty space in sector after partial write
write_data_fill(file_size_partial - 1);
write_CRC();
stop_token();

Counter8_WritePeriod(0x30);                // Sets period to 10 clocks
Counter8_WriteCompareValue(0x15);          // Generates a 50% duty cycle

k = 0;
Loading_LED_Switch(0);                    // Turns off LED
Write_enable_Switch(0);                   // Disables write
WiFly_pwr_Switch(0);                     // Turns off WiFly
MCU_fin_sig_Switch(1);                   // Signals finish to Control MCU
}
}
}

```

```

// Function description-----
// Initializes SD card for SPI communications
void card_initialize(void)
{
    for(i=0; i < 2400; i++); // Delay
    for(i=0; i < 100; i++) // Clock train for SPI mode
    {
        SPIM_SendTxData(0xFF); // set message to transmit
        while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
    }

    SD_SS_Switch(0); // SD port low, SS on

    SPIM_SendTxData(0xFF); // set message to transmit
    while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
    SPIM_SendTxData(0x40); // set message to transmit // CMD 0, set SPI mode
    while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
    SPIM_SendTxData(0x00); // set message to transmit
    while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
    SPIM_SendTxData(0x00); // set message to transmit
    while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
    SPIM_SendTxData(0x00); // set message to transmit
    while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
    SPIM_SendTxData(0x00); // set message to transmit
    while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
    SPIM_SendTxData(0x95); // set message to transmit
    while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
    SPIM_SendTxData(0xFF); // set message to transmit
    while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
    while(Rdata != 0x01) // Waits until ready
    {
        SPIM_SendTxData(0xFF); // set message to transmit
        while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
        Rdata = SPIM_bReadRxData();
    }
    CS_toggle();

    while(Rdata != 0x00)
    {
        SPIM_SendTxData(0x77); // set message to transmit // CMD 55 (ACMD41)
        while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
        SPIM_SendTxData(0x00); // set message to transmit
        while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
        SPIM_SendTxData(0x00); // set message to transmit
        while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
        SPIM_SendTxData(0x00); // set message to transmit
        while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
        SPIM_SendTxData(0x00); // set message to transmit
        while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
        SPIM_SendTxData(0x95); // set message to transmit
        while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
        SPIM_SendTxData(0xFF); // set message to transmit
        while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
        SPIM_SendTxData(0xFF); // set message to transmit
        while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
        CS_toggle();

        SPIM_SendTxData(0x69); // set message to transmit // CMD 41 (ACMD41)
        while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
    }
}

```

```

        SPIM_SendTxData(0x00); // set message to transmit
        while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
        SPIM_SendTxData(0x00); // set message to transmit
        while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
        SPIM_SendTxData(0x00); // set message to transmit
        while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
        SPIM_SendTxData(0x00); // set message to transmit
        while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
        SPIM_SendTxData(0x95); // set message to transmit
        while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
        SPIM_SendTxData(0xFF); // set message to transmit
        while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
        SPIM_SendTxData(0xFF); // set message to transmit
        while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));

        Rdata = SPIM_bReadRxData();
        CS_toggle();
    }
    CS_toggle();
}

```

// Function description-----

// Toggles the chip select of the SD card while writing commands.

void CS_toggle(void)

```

{
    SD_SS_Switch(1); // SS port HIGH, SS off
    SPIM_SendTxData(0xFF); // set message to transmit
    while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
    SD_SS_Switch(0); // SS port LOW, SS on
}

```

// Function description-----

// Write command structure. High byte + 6 byte command + 2 high bytes.

void write_data_init(BYTE loc1, BYTE loc2, BYTE loc3, BYTE loc4)

```

{
    SPIM_SendTxData(0xFF); // set message to transmit
    while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
    SPIM_SendTxData(0x59); // set message to transmit // CMD 25(59) Continuous write
    while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
    SPIM_SendTxData(loc1); // set message to transmit
    while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
    SPIM_SendTxData(loc2); // set message to transmit
    while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
    SPIM_SendTxData(loc3); // set message to transmit
    while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
    SPIM_SendTxData(loc4); // set message to transmit
    while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
    SPIM_SendTxData(0x95); // set message to transmit
    while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
    SPIM_SendTxData(0xFF); // set message to transmit
    while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
    SPIM_SendTxData(0xFF); // set message to transmit
    while(!(SPIM_bReadStatus() & SPIM_SPIM_SPI_COMPLETE));
}

```

```

// Function description-----
// Start token for continuous write command.
void start_token(void)
{
    SPIM_SendTxData(0xFC); // set message to transmit // Sending data
    while(!(SPIM_bReadStatus() & SPIM_SPI_SPI_COMPLETE)); // FC-multiple blocks
}

// Function description-----
// Sends one byte to SD card while write command is
// open.
void write_data_raw(BYTE raw)
{
    SPIM_SendTxData(raw); // set message to transmit // Sending raw data byte
    while(!(SPIM_bReadStatus() & SPIM_SPI_SPI_COMPLETE));
}

// Function description-----
// Writes remaining bytes after raw data to complete the 512 byte
// block.
void write_data_fill(int size)
{
    for (i=0; i<(512-size); i++)
    // Fills space with 0x00 bytes
    {
        SPIM_SendTxData(0x00); // set message to transmit
        while(!(SPIM_bReadStatus() & SPIM_SPI_SPI_COMPLETE));
    }
}

// Function description----- //
// Writes CRC bytes after continuous write command.
void write_CRC(void)
{
    SPIM_SendTxData(0xFF); // set message to transmit
    while(!(SPIM_bReadStatus() & SPIM_SPI_SPI_COMPLETE));
    SPIM_SendTxData(0xFF); // set message to transmit
    while(!(SPIM_bReadStatus() & SPIM_SPI_SPI_COMPLETE));
    while(Rdata == 0x00)
    {
        SPIM_SendTxData(0xFF); // set message to transmit
        while(!(SPIM_bReadStatus() & SPIM_SPI_SPI_COMPLETE));
        Rdata = SPIM_bReadRxData();
    }

    for(i=0; i < 50; i++) // Command flush
    {
        SPIM_SendTxData(0xFF); // set message to transmit
        while(!(SPIM_bReadStatus() & SPIM_SPI_SPI_COMPLETE));
        Rdata = SPIM_bReadRxData();
    }
}

// Function description-----
// Sends stop token after continuous write command.
void stop_token(void)
{
    SPIM_SendTxData(0xFD); // set message to transmit // Stop token 0xFD
    while(!(SPIM_bReadStatus() & SPIM_SPI_SPI_COMPLETE));
    SPIM_SendTxData(0xFF); // set message to transmit
    while(!(SPIM_bReadStatus() & SPIM_SPI_SPI_COMPLETE));
    SPIM_SendTxData(0xFF); // set message to transmit

```

```

while(!(SPIM_bReadStatus() & SPIM_SPI_SPI_COMPLETE));
Rdata = SPIM_bReadRxData();

for(i=0; i < 100; i++) // Command flush
{
    SPIM_SendTxData(0xFF); // set message to transmit
    while(!(SPIM_bReadStatus() & SPIM_SPI_SPI_COMPLETE));
    Rdata = SPIM_bReadRxData();
}
CS_toggle();
while (Rdata != 0xFF) // Command flush
{
    SPIM_SendTxData(0xFF); // set message to transmit
    while(!(SPIM_bReadStatus() & SPIM_SPI_SPI_COMPLETE));
    Rdata = SPIM_bReadRxData();
}
}

// Function description----- //
Sends bytes out of the debug SPI connection, for debugging.
void debug(BYTE test)
{
    Debug_SS_Switch(0);
    SPIM2_SendTxData(test); // set message to transmit
    while(!(SPIM2_bReadStatus() & SPIM2_SPI_SPI_COMPLETE));
    Debug_SS_Switch(1);
}

```

Program Code – File Server Program

```
//-----
// Metropolia University of Applied Sciences
// Marcel Mushik 24 April 2011
// Final year project - Electronic class schedule
// Code: File server program
//-----

// Include files -----
using System;
using System.Collections.Generic;
using System.ComponentModel;
using System.Data;
using System.Drawing;
using System.Linq; using
System.Text;
using System.Windows.Forms;
using System.Threading;
using System.Net;
using System.Net.Sockets;
using System.IO;

namespace Server_App
{
    public partial class Form1 : Form
    {
        private Socket connection;
        private NetworkStream socketStream;
        private BinaryReader reader;
        private BinaryWriter writer;
        private Thread serverThread;
        TcpListener server = null;

        // Function description-----
        // This function creates a server service that listens for incoming requests.
        // As a request is received, the respective file is located and the file size is sent.
        // The number of 512 byte sectors is also sent, for loop control in the Electronic class schedule program.
        // The program then waits for a start bit signifying that it can send the raw file data.
        // When the raw data is sent, the file server program ends the connection and begins to listen again.
        public void RunServer()
        {
            try
            {
                // Fetches local IP address
                string hostname = Dns.GetHostName();
                IPAddress[] ips = Dns.GetHostAddresses(hostname);
                string ip = String.Empty;
                if (ips.Length > 0)
                {
                    ip = ips[0].ToString();
                }

                // Creates listener port 2000 local IP address
                Int32 port = 2000;
                IPAddress localAddr = IPAddress.Parse(ip); server
                = new TcpListener(localAddr, port);
```

```
// Start listening
server.Start();

// Displays information to listBox for user
listBox1.Items.Add("Local IP address:");
listBox1.Items.Add(ip);
listBox1.Items.Add("Listening on port:");
listBox1.Items.Add(port);
listBox1.Items.Add("");
listBox1.Items.Add("Listening...");

// Creates an AcceptSocket for connection
connection = server.AcceptSocket();
socketStream = new NetworkStream(connection);

// Creates writer for connection
writer = new BinaryWriter(socketStream);

// Creates reader for connection
reader = new BinaryReader(socketStream);

// Clears listBox
listBox1.Items.Clear();

// Displays status
listBox1.Items.Add("Connection made.");

// Creates message string for storage
char sendChar = new char();
char [] msgFromClient = new char[5];
string message = null;

do
{
    try
    {
        // Scans incoming bytes, waits for start byte 0x66 'f'
        while (msgFromClient[0] != 0x66)
        {
            msgFromClient[0] = reader.ReadChar();
        }

        // Reads bytes after 0x66 'f' start byte
        for (int i = 1; i < 5; i++)
        {
            // Received information is the file name
            msgFromClient[i] = reader.ReadChar();
        }
        message = new string(msgFromClient);

        // Displays request to user
        listBox1.Items.Add("Request for: ");
        listBox1.Items.Add(message);
        listBox1.Items.Add("Sending file size...");

        // Appends file name to string
        string file = "C:\\Documents and Settings\\m\\Desktop\\schedule_files\\";
        file += message;
```

```
// Adds file type to file name
file += ".jpg";

// Opens file access stream
FileStream data = new FileStream(file, FileMode.Open, FileAccess.Read);

// Opens file
FileInfo info = new FileInfo(file);
int len = (int)info.Length;

// Retrieves file size
byte[] bLen = BitConverter.GetBytes(len);

// Sends file size, bytes
writer.Write(bLen, 0, 4);
writer.Flush();

// Sends number of sectors in file
bLen = BitConverter.GetBytes((len / 512) + 1);
writer.Write(bLen);
writer.Write(0);

writer.Flush();

// Displays status
listBox1.Items.Add("    File size sent");

byte[] data2 = new byte[len];
int count = 0, total = 0;
count = data.Read(data2, 0, len);

// Scans incoming bytes, waits for byte 0x53 'S', when schedules MCU is ready for raw
// data
while (sendChar != 0x53)
{
    sendChar = reader.ReadChar();
}

// Displays status
listBox1.Items.Add("Sending file...");

// Sends raw data of file
while (total != len)
{
    writer.Write(data2, 0, count);
    total += count;
}

// Finishes sending data and closes connection, program starts over
writer.Flush();
listBox1.Items.Add(" File sent.");
reader.Close();
writer.Close();
socketStream.Close();
connection.Close();
listBox1.Items.Add("Disconnected.");
listBox1.Items.Add("");
server.Stop();
RunServer();
}
catch(Exception)
```



```

        {
            // Program is stopped if an exception is present
            server.Stop();
            RunServer();
        }
    }
    while(message != "QUIT1");
}

catch (Exception error)
{
    // error code can be added here
}
}

// Function description----- //
Initializes form.
public Form1()
{
    InitializeComponent();
}

// Function description----- //
Starts thread for communications.
private void Form1_Load(object sender, EventArgs e)
{
    serverThread = new Thread(new ThreadStart(RunServer));
    serverThread.Start();
    CheckForIllegalCrossThreadCalls = false;
}

// Function description----- //
List box option.
private void listBox1_SelectedIndexChanged(object sender, EventArgs e)
{
}

// Function description----- //
Reset button action.
private void button2_Click(object sender, EventArgs e)
{
    try
    {
        serverThread.Abort();
        server.Stop();
        Application.Restart();
    }
    catch (Exception error)
    {
        MessageBox.Show(error.ToString());
    }
}
}
}
}

```

List of Electrical Components

- (1) Digital photo frame
- (1) WiFly WLAN module
- (1) CY8C21534 PSoC microcontroller
- (1) CY8C29466 PSoC microcontroller
- (1) HIN-232 Serial to UART
- (2) HEF-4066 Bilateral switch
- (3) MIC5200 3 V voltage regulator
- (1) J380BV PNP transistor
- (4) BC556 PNP transistors
- (5) BC546B NPN transistors
- (1) 4-pole on/off switch
- (1) Single pole on/off switch
- (1) Male DB9 serial connector
- (1) Micro SD to SD adaptor
- (5) 2 μ F capacitor
- (1) 100 μ F capacitor
- (1) 10 nF capacitor
- (1) 100 nF capacitor
- (6) Surface mount LED
- (2) LED
- (4) 150 Ohm resistor
- (11) 560 Ohm resistor
- (1) 2.2 KOhm resistor
- (1) 1 KOhm resistor
- (12) 10 KOhm resistor
- (1) 14 KOhm resistor

Appendix 4: Circuit Board Diagrams

