May 15, 2006

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440 – Post-Mortem for a Wireless Cell Phone Docking Station

Dear Dr. Rawicz:

The attached document is the *Post-Mortem for a Wireless Cell Phone Docking Station* from Websa Technology Ltd, which was previously described in our project proposal. We are developing a mobile phone to home phone communication system which allows the user to dock his or her cell phone and use normal corded or cordless home phones to make and receive cellular phone calls.

The purpose of this Post-Mortem is to describe the current state of our system, the discrepancies from our original design specifications, and provide an insight to the possible future plans with the system. Outlines of our time constraints, budget, and the interpersonal and technical experience gained by each individual through this project will also be provided in this document.

Websa Technology consists of five talented, innovative, and dedicated fifth-year engineering students: Wilson Kwong (CEO), Andy Leung (CFO), Stephen Au-Yeung (COO), Edwin Wong (CTO-Hardware) and Bobby Ho (CTO-Software). If you have any questions about this document, or the project in general, please feel free to contact us at websa-ensc440@sfu.ca. Thank you.

Sincerely,

Wilson Kwong
Chief Executive Officer
Websa Technology Ltd.

Enclosure: ***Post-Mortem for a Wireless Cell Phone Docking Station***

POST MORTEM

WEBSA

WIRELESS CELLPHONE DOCKING STATION

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DATE:

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Table of Contents

List of Figures

List of Tables

Glossary

ADC	Analog to Digital Converter
AT	Attention
BSM	Base Station Module
MCU	Microcontroller Unit
QOS	Quality of Service
RSM	Receiver Station Module
TDD	Time Division Duplex
UART	Universal Asynchronous Receive Transmit
VoIP	Voice over Internet Protocols
WTM	Wireless Transmission Module

1 Introduction

For the past 20 weeks, Websa Technology has been working diligently on the proof-of-concept model for The *Wireless Mobile-Dock* (WMD) system. Throughout this stage of development, the project focused on the production of a working proof-of-concept model for our system. By breaking up our project into three modules, we were able to focus on successfully developing the individual parts. The three modules included the Base Station Module (BSM), Receiver Station Module (RSM), and Wireless Transmission Module (WTM). Even though we divided the team into sub groups for development, our constant communication allowed us to develop with the overall design in mind, which provided an easier and more efficient integration effort. The core functionality of our current system is working well and, given more time, our product can be a potential contender in today's markets.

This document will present our development outcome, deviations from our original design as stated in previous documentations, final budget and time constraints, and recommendations and future plans for the WMD system. In closing, each member of the group enrolled in ENSC305 will present their interpersonal and technical experiences gained from participating in this venture.

2 Current State of the System

The current WMD system is shown in Figure 2-1.

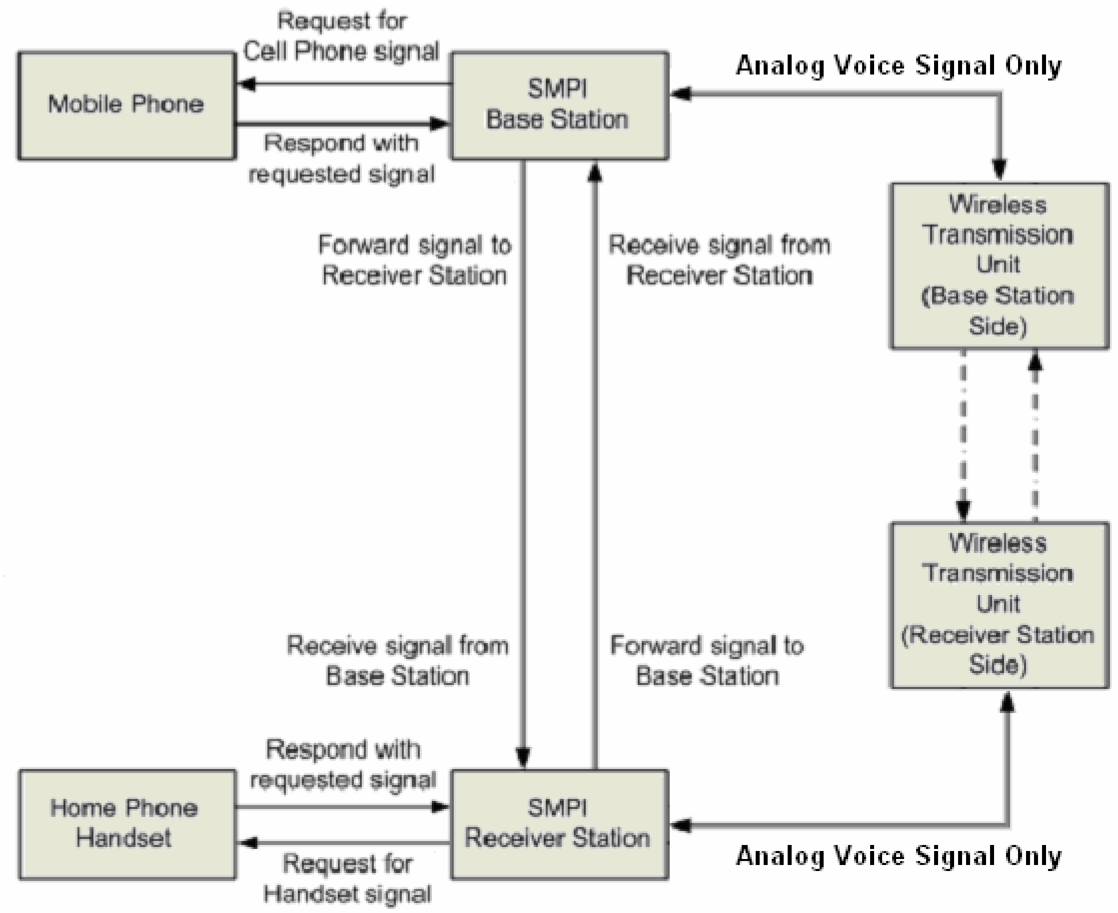


Figure 2-1: Current WMD System block diagram

2.1 Base Station Module

The operation of the base station module (BSM) closely resembles its Functional Specifications while adhering to the Design Specifications in terms of implementation. It can correctly receive incoming cell phone calls and forward the information to receiver station module (RSM). Furthermore, it can detect and dial the number received from the RSM and send that number to the cell phone via attention (AT) commands. The cell phone will terminate a conversation upon acknowledgement that the home phone has been placed on-hook. In all, the BSM was implemented successfully.

2.2 Wireless Transmission Module

The WTM currently can support two-way voice communication between the BSM and RSM. This is achieved via the time division duplex (TDD) method as proposed in Websa's Design Specifications. However, the WTM does not support data communication (i.e. commands and digit dialing) between the BSM and RSM in its current state. Thus, the RSM cannot remotely control the BSM as intended or vice versa. However, once a call is established, the WTM will allow bidirectional voice conversation between the BSM and RSM.

Moreover, the WTM sends voice packets back and forth upon full power up. Since half of the WTM is in the BSM and the other half of the WTM is in the RSM, full power up is achieved by power up of both the BSM and RSM. Upon full power up of the WTM, voice packets will be transmitted back and forth. WTM currently does not support starting and stopping of voice packet transmission, however.

2.3 Receiver Station Module

The receiver station module (RSM) provides the interface between the WTM and a normal telephone. Functionality of the RSM closely resembles the functional specifications. The module is currently able to provide dial tone and busy tone through the use of the call progress chip. Dual-tone Multi-Frequency (DTMF) signals can also be correctly encoded by the DTMF chip.

Unfortunately, in the current state of our product, the RSM cannot ring the telephone due to an unfortunate mishap with the ringing circuitry. The problem and its remedy will be explained further in the following sections.

3 Deviations from Original Functional Specifications

In comparison to the Design Specifications document, some of the hardware and software modules did not behave the way as intended. In this section, we present the functional specifications that were not met and explain the reasoning behind it.

3.1 Base Station Module

Comparing with the requirements listed in our functional specification, most of high priority features have been implemented except for the following three functions:

R33-I: The BSM will monitor the cell phone status at all time
This feature is omitted from the current phase of development due to technical complexity and timing constraints. With the current software design, mobile phone status data are received via interrupt routines and periodically sends AT commands to request for cell phone status and may potentially impact the quality of voice and data communication. However, this feature can be added in future developments by introducing additional timers to keep track of the packet relay latency. To accomplish this, better microcontroller units should be adopted.

R36-I: The BSM will communicate with the WTM
Due to design inefficiencies, the WTM is not able to handle control data packet and voice packet simultaneously. Please refer to the WTM section for additional details. Instead, the base station is connected with receive station via a wired connection. As a result, data packets are transmitted via the dedicated I/O ports between the microcontrollers in the BSM and RSM.

R41-I: Retransmission of data due to error will occur when requested
Retransmission of data introduces additional logic complexities to the current software infrastructure and will burden the microcontroller with timing constraints. Better error analysis must be done in order to implement this feature.

3.2 Wireless Station Module

R63- I: The module will monitor its connection status between BSM and RSM.
R70- I: The unit must communicate and interface with the base station.
R71- I: The unit must communicate and interface with the receiver station.
R72- I: Wireless transmission must support full duplex data communication, relaying instructions and commands between one BSM and one RSM.

Currently the module cannot support wireless data packet transfer. Hence, it is unable to monitor the connection status or interface with the BSM and RSM. A detailed explanation of this problem is presented in section 5.2.

3.3 Receiver Station Module

The Receiver Station Module behaved closely to the functional specifications for the most part. The prototype design for the RSM resembled closely what was stated in the Design Specifications. However, the following functional specifications came short in our current prototype:

R55- I: The module will ring the connected telephone when there is an incoming cell phone call.

A ringer circuit was built for the system. However, due to the high voltage and large current draw required to activate the ring signal of the telephone, it was believed that some electronic parts within the circuit suffered damage from large currents. In the end, the circuit was not implemented in our current prototype.

R58- I: The module will communicate directly with the WTM.

Only voice data is able to be transferred to the WTM directly. Any control data packets cannot be communicated directly to the WTM at this moment. Please refer to section 5.2 for further details.

4 Assessment of Project Management

4.1 Budget

Table 4-1 below shows an actual cost breakdown for the project during this prototype model development of the WMD system.

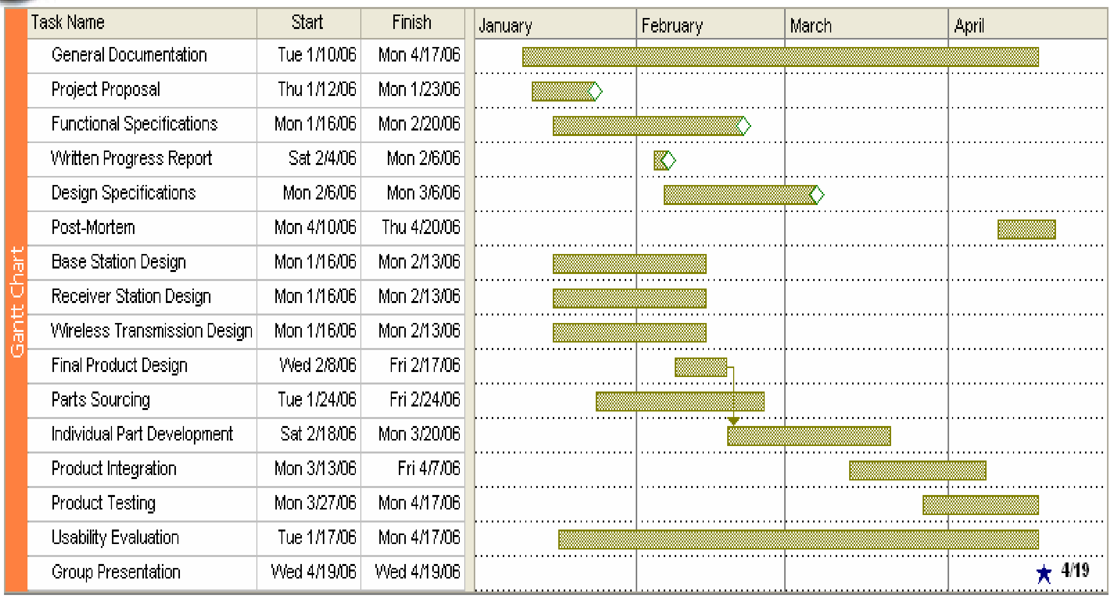
Table 4-1: Budget Summary for Websa WMD system Prototype Model Development.

Module	Component/Description	Cost
Communication Device	Sony Ericsson T68i	N/A
	Sony Ericsson T610	N/A
	Telephone Handset	N/A
Base Station	Sony Ericsson T68 Serial Data Cable	$50
	Analog-to-Digital Converter	$50
	Electronics Devices: Microcontroller, Dual EIA-232 Driver/Receiver, Hex Inverter	$30
Receiver Station	North American Data Access Arrangement	$120
	Integrated Dual Tone Multi-Frequency transceiver	$20
	Ringer Circuit	$20
	Call Progress Tone Generation & Detection	N/A
Wireless Transmission	915MHz Multi-channel RF transceiver	$400
Electronic Components	Circuit components: crystal oscillators, DACs, operational amplifiers, speakers, microphones, prototype boards, casing equipments and etc.	$220
Miscellaneous Items	Included shipping/handling fee, wireless transaction payment fee and miscellaneous items	$180
Total		**$1090 CDN**

In the previous project proposal, the initial cost is estimated to be $625 CDN. The additional cost overrun mainly derives from the unexpected wireless transmission development cost and the underestimation of prototype development, which includes the cost of casing and miscellaneous parts. In retrospect, without the unexpected cost overrun, the initial estimate summary was an accurate prediction of total cost of the development of the system. From this experience, Websa is fully confident that cost overruns will be minimal in the future.

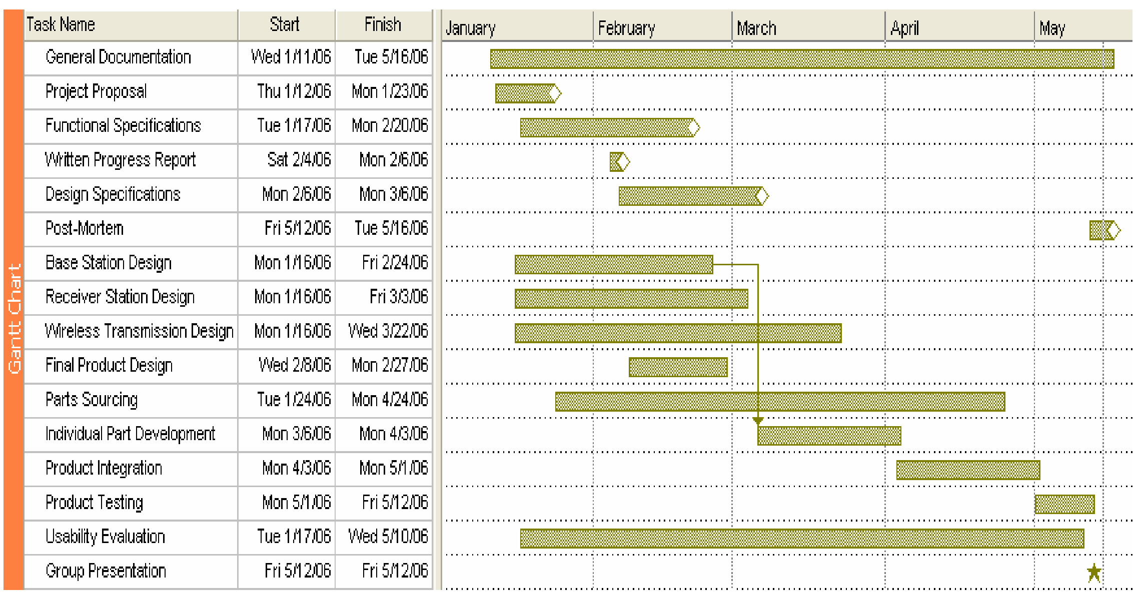
4.2 Timeline

The Original Gantt Chart and the Actual Gantt Chart followed are presented in Figure 4-1 and Figure 4-2, respectively.



Task Name	Start	Finish
General Documentation	Tue 1/10/06	Mon 4/17/06
Project Proposal	Thu 1/12/06	Mon 1/23/06
Functional Specifications	Mon 1/16/06	Mon 2/20/06
Written Progress Report	Sat 2/4/06	Mon 2/6/06
Design Specifications	Mon 2/6/06	Mon 3/6/06
Post-Mortem	Mon 4/10/06	Thu 4/20/06
Base Station Design	Mon 1/16/06	Mon 2/13/06
Receiver Station Design	Mon 1/16/06	Mon 2/13/06
Wireless Transmission Design	Mon 1/16/06	Mon 2/13/06
Final Product Design	Wed 2/8/06	Fri 2/17/06
Parts Sourcing	Tue 1/24/06	Fri 2/24/06
Individual Part Development	Sat 2/18/06	Mon 3/20/06
Product Integration	Mon 3/13/06	Fri 4/7/06
Product Testing	Mon 3/27/06	Mon 4/17/06
Usability Evaluation	Tue 1/17/06	Mon 4/17/06
Group Presentation	Wed 4/19/06	Wed 4/19/06

Figure 4-1: Original Gantt Chart



Task Name	Start	Finish
General Documentation	Wed 1/11/06	Tue 5/16/06
Project Proposal	Thu 1/12/06	Mon 1/23/06
Functional Specifications	Tue 1/17/06	Mon 2/20/06
Written Progress Report	Sat 2/4/06	Mon 2/6/06
Design Specifications	Mon 2/6/06	Mon 3/6/06
Post-Mortem	Fri 5/12/06	Tue 5/16/06
Base Station Design	Mon 1/16/06	Fri 2/24/06
Receiver Station Design	Mon 1/16/06	Fri 3/3/06
Wireless Transmission Design	Mon 1/16/06	Wed 3/22/06
Final Product Design	Wed 2/8/06	Mon 2/27/06
Parts Sourcing	Tue 1/24/06	Mon 4/24/06
Individual Part Development	Mon 3/6/06	Mon 4/3/06
Product Integration	Mon 4/3/06	Mon 5/1/06
Product Testing	Mon 5/1/06	Fri 5/12/06
Usability Evaluation	Tue 1/17/06	Wed 5/10/06
Group Presentation	Fri 5/12/06	Fri 5/12/06

Figure 4-2: Actual Gantt Chart Followed

Up until the end of March, we were able to meet all our deadlines and stay relatively on course. However, due to some part sourcing delays and design problems, our project inevitably was delayed for approximately one month. This setback ultimately affected individual part development as well as final product integration. The team also realized that having three full time coop students ultimately affected productivity to a certain extend due to time availability and physical endurance.

5 Future Design Adjustments

5.1 Base Station Module

The base station was very well implemented and stayed on track with the functional and design specifications. The single modification that Websa sees as beneficial would be to use a different microcontroller to allow for faster instruction set and implementation in C programming language.

5.2 Wireless Transmission Module

The problem with the current implementation of the Time Division Duplex (TDD) design does not allow the transmission of data packets in between voice signals due to a very short switching time period of 5 milliseconds. This design error, unfortunately, was not discovered until the end and hence a remedy to the problem could not be carried out. For the next design, reimplementation of the TDD mechanism with a longer switching time period, ideally around the range of 300 – 500 milliseconds, would remedy this problem. The voice data will also be compressed with a software base codec to allow for more voice samples to be stored within the CC1100's internal buffer, thus improving the TDD period. In addition, we would use a faster microcontroller as the current PIC microcontroller has a slow operating speed when it is powered by less than 3 volts.

Furthermore, we believe our development time will decrease dramatically had we purchase a wireless development kit. Without proper data logging tool like a development kit, it was extremely difficult when debugging data packets with a transmission rate of 250kbps. However, due to budget constraints, we were unable to afford this tool.

5.3 Receiver Station Module

In the future design, a new ringer circuit will be considered instead of the current one due to the high current draw of the current design. Figure 5-1 shows the current design while Figure 5-2 shows the future consideration, respectively.

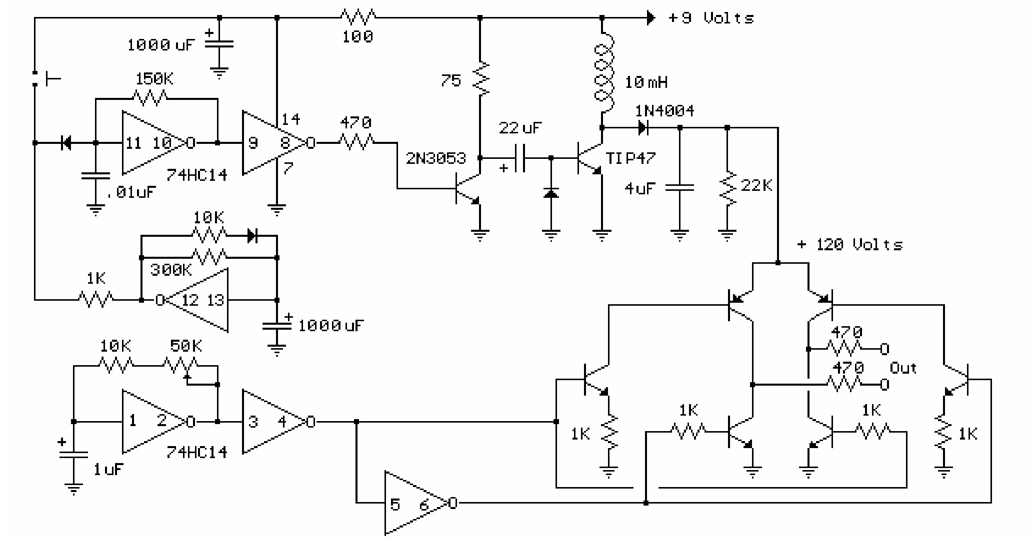


Figure 5-1: Current ringer circuit [1]

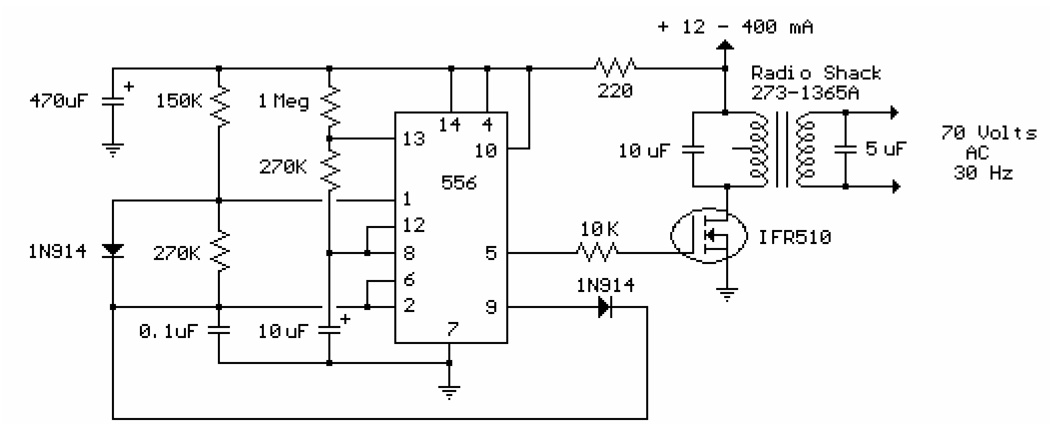


Figure 5-2: Future ringer circuit implementation [1]

Also, it was discovered that the use of the Data Access Arrangement (DAA) circuit to provide the TIP and RING was not a correct choice. Many problems arose using the DAA chip including analog voice input gain being too small and problems driving the telephone. Through communication with the manufacturer, it was recommended that a Subscriber Line Interface Circuit (SLIC) is used for telephone line emulation. The block diagram of this chip is shown in Figure 5-3.

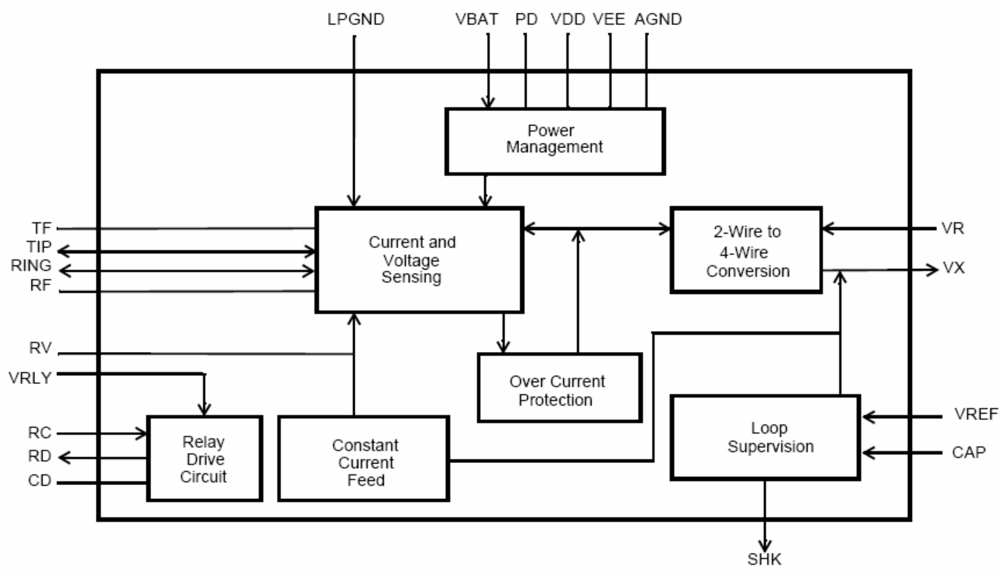


Figure 5-3: Subscriber Line Interface Circuit (SLIC) block diagram [2]

6 Future Plans and Recommendations

Once our current product has been successfully deployed to our target audience of single person households, businessmen, students and young adults, our next target market includes family households and small businesses. The new market segment can be achieved with the introduction of multiple mobile phones interfacing via central routing. The central routing unit will be able to monitor which home phone is available for communication and distinguish voice and data packets between each communication channel. This feature will greatly benefit business professionals such as sales agents who communicate with their customers via mobile phones.

Websa further foresees supporting voice over internet protocols (VoIP). VoIP technology is growing quickly and in the future, more of the VoIP mobile phone or landline phone will be used by the general public. Hence, with the introduction of VoIP, our product can fit in easily with future market needs. With VoIP, existing IP network protocol may be employed. For example, we may be able to use the IP routing protocols and add simple Quality of Service (QOS) parameters as well as congestion avoidance methods. As a result, a small home phone network can be created.

We would also like to add Bluetooth support to the base station such that Bluetooth capable mobile phones do not need to be physically connected with the docking station. This feature provides great flexibilities for placement of the user’s cell phone and the base station.

7 Interpersonal and Technical Experiences

7.1 Wilson Kwong (Chief Executive Officer)

The past four months has been an extremely challenging yet unforgettable experience; especially being the CEO of the team. To be honest, I was concerned at first about joining a group who had three members on coop as ENSC 440 had a reputation of ruining your otherwise normal life. However, having been friends with the team through the past four years, I have learned their work ethics and their hard working nature quickly put my worries to rest. We have also found great joy in starting work late in the evening rather than during the day because there are fewer distractions and we tend to get more work done.

Leading my team though the many stages of the project involved concentration and coordination. We conducted meetings once a week to once every two weeks, depending on the necessity. As a group, we would update each other on their current progress, and members contributed knowledge to help others with their problems and vice-versa. This method worked effectively because integration was a key component towards the end. Knowing where each sub group is at and the progress they're making provides incentive, motivation, and ease of integration. Communication was a key factor and our group was very good at it. I was responsible for facilitating these communications and making sure everyone was focused on the task they needed to accomplish. With such a group environment and open communication, everyone felt equally important and no person was in dominating control.

On a technical aspect, I gained a great deal of new hardware and firmware expertise that I would not have otherwise gained without ENSC440. I was responsible for the RSM and it was tough working alone at first. However, my team was able to provide feedback and help me out whenever I needed help, which made the tough times not so tough. In the end, the feeling of a full product development cycle was trying yet very rewarding when I saw the results. Furthermore, I was able to brush up on my assembly language skills, hardware design skills, and most of all, my firmware skills.

In all, there were times of discontent and lack of motivation. However, our group dynamics and various areas of expertise was such that when a member of the group hit a road block, someone else in the team would have a breakthrough and boosted team moral. Everyone had their up and down moments but by unconsciously making development breakthroughs, it boosted the energy and motivation of everyone in the team. This fortunate cycle of brilliance allowed us to push through the project. In the end, working on the *Wireless Mobile-Dock* system with my team was a very enjoyable experience.

7.2 Andy Leung (Chief Financial Officer)

Being responsible for the financial portion of the project, which included controlling the budget and monitoring the cash flow, I gained new insight to company operating expenses and the importance of correct cost/expense estimation. I was responsible for ensuring that our team members do not purchase parts that can be provided to us at no cost, such as samples. I also made sure our team bought only the parts necessary at the best price possible. Keeping the cost low was important for our project due to our limited development budget. However, I soon realized there are many unexpected cost overruns that need to be included and I will take into account these factors upon my next experience as CFO.

Through this experience, I realized that communication was a key factor and documentations, although troublesome, are worth their while in the end. At times, I realized our group was heading down the wrong path. However, a quick review of our documentations allowed us to refocus and get back onto the path that we want to travel.

Technically, I was initially responsible for researching the AT commands for controlling mobile phones. I then worked on developing the hardware of the Analog-to-Digital Converter (ADC) and Universal Asynchronous Receive Transmit (UART) interface of the Base Station Module. In addition, I contributed to the hardware and software development of call progress tone generation of the Receiver Station Module.

Upon the completion of the prototype model, Andy is responsible on the hardware on-board development of the base station module which including layout design, soldering, wiring, and casing.

7.3 Bobby Ho (Chief Technical Officer – Software)

One of the important lessons that I learned from this project was to allocate sufficient time for testing. In embedded system development, we must expect the unexpected errors, such as memory corruption or data lost due to real time constraint. We should assign sufficient testing period to cover all the cases and be able to recover from errors. Although our time for testing was on the short side in this project, we were able to pull through with the time that we had allotted.

On a more technical side, by implementing the Mobile to Phone Interface, I have gained valuable experience on firmware development; in particular, programming with assembly language. Using assembly is efficient but it is also very tricky in that programmers are directly manipulating with memories. Because of the limited file registers that are built into the microcontroller, various buffers are usually allocated in different register banks depends on modules. However, extremely careful coding is required with this approach in that memory corruption will occur if the incorrect register bank is selected.

Some development IDE have built in directive such as bank select or programming page select. Those directive words are usually very convenient but we must use them with caution. Understanding their syntax and restrictions are important to avoid unexpected errors. Also, when using indirect address reference, the programmers must make sure that the referenced memory address is valid and it is not used by other entities.

In all, this project experience with my team members was very enjoyable at times when things were working, and bearable at worst when things didn't go according to expectations.

8 Conclusion

The past semester has been an emotional roller coaster for the team members at Websa Technology Ltd. A lot of hard work, dedication, and determination was put forth to complete this project. Combined with our engineering knowledge to date, we were able to successfully create a functional proof-of-concept wireless cell phone docking station.

9 References

[1] Bowden's Hobby Circuits 15 Jan. 1999. *Telephone Ring Generator Circuits.* 12 May. 2006 <http://ourworld.compuserve.com/homepages/Bill_Bowden/page11.htm#ring2.gif>

[2] Zarlink Semiconductors 15 Jan. 2006. *Subscriber Line Interface Circuit.* 12 May. 2006 <http://www.zarlink.com/common/direct/assets/DS/zarlink_MH88612_JUN_02.pdf >

