VoIP Gateway Design Evaluation

Project Report

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Title:
VoIP Gateway Design Evaluation

Theme:
Design and Analysis

Project Period:
Fall Semester 2017

Project Group:
Patton Equipment

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Page Numbers: 11

Date of Completion:
December 14, 2017

Abstract:

This project report is intended to serve as a high level design and analysis document, pursuant to request for services issued by Patton Equipment, for the design evaluation of a IP-PBX based VoIP Gateway. Based on the design and performance requirements desired by the client, evaluation tests were carried out using the Beagle Bone Black platform, with the aid of external hardware and software components. Using these test results, which are listed as project deliverables, the suitability of the AM 3358 MPU for the IP-PBX based VoIP Gateway was evaluated, along with providing recommendations pertaining to full system design and performance.

TABLE OF CONTENTS

Executive Summary

Pursuant to the Request for Services (RFS) issued by Patton Equipment, Alvakonda, Tichkule, and Yamasani have evaluated the suitability of the AM3358 MPU for the design of their e911 IP-PBX VoIP Gateway product. Critical aspects such as operating system compatibility, computational power, I/O interfacing, development cost, adaptability and reliability were evaluated.

Hardware interface capabilities were evaluated using network interfaces (USB and Ethernet), serial ports, HDMI displays, as well as multimedia storage devices. The AM3358 also displayed ease of operation with various distributions of Windows (WINCE 2007 and WINCE 2013) and Linux (Debian, Angstrom, Asterisk) operating systems. Software development, OS customization and building, was easily facilitated by the use of standard toolchains like GNU-ARM and Microsoft Visual Studio 2008. Based on the evaluation and test results, we can affirm that the AM3358 MPU is capable of handling the interfacing and processing requirements for the e911 IP-PBX VoIP Gateway product.

Telephony and PBX functionality was implemented using a off-the-shelf softphone software (Zoiper), and the Asterisk OS. Specifically, the ability to make inter-softphone calls with SIP functionality, routed via the PBX hosted on the AM3358 MPU based Beagle Bone Black platform, was successfully tested and verified. The AM3358 MPU was also able to successfully process audio and speech signals (with a VAX DMIPS of 646) by executing standard decoding algorithms like G.711.

Based on the relative ease of system integration, we forecast that the product will be ready to market within the next 18 months. Also, our cost considerations indicate that the total price for bulk development of the product is well within the budget specifications provided by Patton Equipment. Based on these factors, our evaluation team strongly recommends the AM3358 MPU for Patton Equipment's e911 IP-PBX VoIP Gateway product.

1. Problem Statement and Objectives

The main objective of this document is to analyze the suitability of the AM3358 MPU for Pattons proposed e911 IP-PBX VoIP Gateway. This analysis has been performed in accordance with the following objectives:

- Verify the performance of the AM3358 MPU in terms of its hardware capabilities, peripherals, and network interfaces so as to meet the requirements specified in the Request for Services (RFS).
- Evaluate the compatibility of Windows Compact Embedded and Linux operating systems for the proposed VoIP Gateway.
- Analyze the capabilities of the AM3358 MPU with respect to its signal processing functionality for audio/speech encoding and decoding.
- Evaluate the IP-PBX VoIP capabilities of AM3358 MPU.
- Determine whether a AM3358 MPU based system can be realized within the provided budget, schedule, and performance constraints, and provide Patton with a recommendation accordingly.

2. Approach and Methodology for Evaluation

Taking into consideration the requirements listed in the RFS issued by Patton Equipment, the AM3358 MPU was evaluated thoroughly using hardware and software test procedures. Cost and power considerations are also made to justify the selection of this MPU.

2.1 Hardware Evaluation

The hardware components listed in the RFS for the proposed e911 IP-PBX VoIP Gateway were tested using the Beagle Bone Black (BBB) platform which features the TI AM3358 MPU. The block diagram of the composite system is shown in Fig. 1.

The AM3358 MPU was assessed to have the following hardware capabilities:

- Up to Two Industrial Gigabit Ethernet MACs (up to 1000 Mbps)

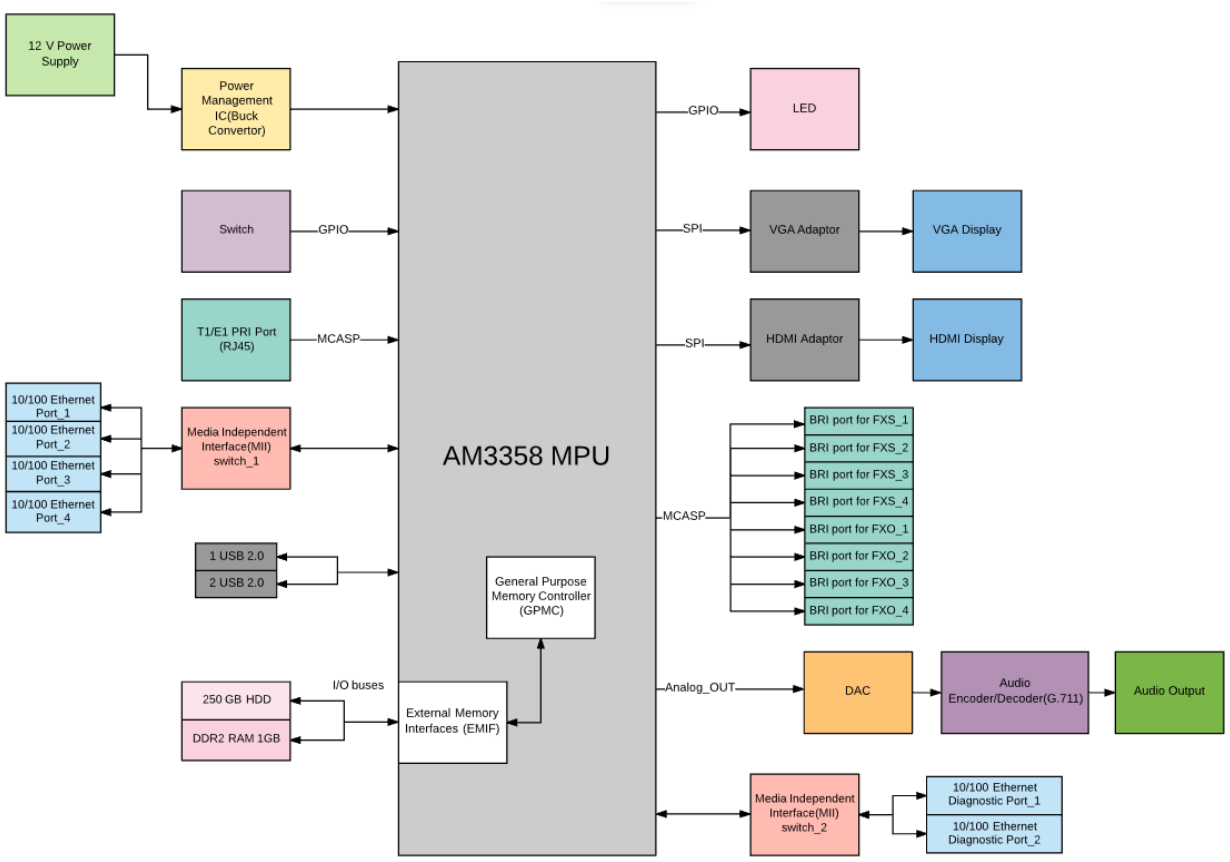

Figure 1: Block diagram of the AM3358 MPU, showing on-board components as well as peripherals that were used to conduct tests for design evaluation.

- Up to Two Multi Channel Audio Serial Ports (MCASP) which support digital audio interface transmissions (AES-3 Format) with PRI/BRI transceivers.
- Up to Three MMC, SD, and SDIO ports for interfacing multimedia devices.
- Up to four Banks of GPIO pins (32 pins per bank) for external LED interface.
- The presence of two Media Independent Interface (MII) switches allows multiplexing of four input Gigabit Ethernet MACs and two output Ethernet diagnostic ports.
- Due to the absence of internal memory, external FLASH and RAM memory need to be interfaced with the AM3358 MPU with the help of External Memory Interfaces (EMIF) and General purpose memory controllers (GPMC).
- Although an onboard 12-bit ADC is present, an external DAC is required to convert digital audio data into analog signals.
- Additional Support is required for HDMI and VGA display capability.
- Requirement of external Power Management IC to buck the input voltage of 12V to multiple output voltages like 3.3 V, 1.1 V, and 5 V.

2.2 Cost Evaluation

The list of hardware components for Patton's proposed e911 IP-PBX VoIP Gateway can be found in the attached Bill of Materials (`Project3_BOM.xlsx`). The entire prototype costs approximately $120. The major part of the cost is incurred on account of PCB fabrication and Primary Rate Interface and Basic Rate Interface transceivers. This cost can be reduced by offshore bulk manufacturing of PCB (for example in China (PCBway)) and cheaper alternatives for PRI and BRI transceivers.

2.3 Software Evaluation

A modularized approach was taken for evaluating the software capabilities of the AM3358 MPU by executing and analyzing independent software tasks as follows:

- Module 1: Using Platform Builder to create Windows Compact Embedded (WINCE) Toolchain.
- Module 2: Testing and comparing the compatibility of WINCE 2007 and WINCE 2013 with the AM3358 MPU. Implementing a G.711 decoder/encoder to process audio files for PBX I/O functionality.
- Module 3: Booting Linux on the AM3358 MPU and executing a custom diagnostic shell script at startup.
- Module 4: Building a custom PBX using Asterisk to test the VoIP Gateway.
- Module 5: Deploying a custom telecom/IOT application using the AM3358 MPU.
- Module 6: Creating a custom WINCE operating system using Platform Builder.
- Module 7: Running a Dhyrstone Benchmark for AM3358 MPU.

3. Module Test Results

This section describes test results of the evaluation as well as insights inferred for each module. Supporting material in the form of code, configuration commands, and screenshots are included with the project deliverables.

3.1 Module 1

The following software modules were installed

- Microsoft Visual Studio 2008
- .NET compact framework 3.5
- Platform Builder

The following installation guides were used to install WINCE 2007 and WINCE 2013

- https://msdn.microsoft.com/en-us/library/jj200354(v=winembedded.70).aspx
- https://msdn.microsoft.com/en-us/library/jj200354.aspx

Please refer to the included screenshot for Platform Builder (`platformbuilder.png`)

3.2 Module 2

1-2. A prebuilt image of WINCE 2007 was downloaded and used to boot up the BBB. To achieve this, the following steps were performed:

- Micro-SD card was formatted using the HPUSBFW.exe utility.
- MLO file was copied over as the first file of the FAT partition.
- The kernel (NK.bin) and Bootloader (ebootsd.nb0) files were copied to SD card.

3. A FTDI serial-to-USB cable was used to observe debug messages during the booting process of WINCE 2007. The following observations are made:

- The MLO starts the boot process by loading the ebootsd.nb0 file into RAM which has a starting address of 0x80002000.
- ROMHDR has a starting address at 0x80002044.
- The WINCE image was launched by jumping to address 0x8000bce0.

4. The kernel was observed to be of length = 0x5628f48. This translates into 90345288 bytes (86.16 MB), which is consistent with size of NK.bin file on the SD card.
5. The screenshot showing debug messages on the terminal is included in the project deliverables (`wince_2007_debugmessages.png`).
6. After connecting the HDMI output to the monitor and rebooting the operating system, the WINCE 2007 home screen was seen. A screen shot showing this is included in the project deliverables (`WINCE_2007_Screenshot.png`).

7. A G.711 encoded Audio file `A_eng_f5.wav` was decoded using the Mulaw2Lin() function to convert u-law to 16-bit PCM values. The decoded file had 16-bit precision, as compared to 8-bit precision in the encoded file, which resulted in an output WAV file of double the size (103 KB vs 206 KB). The spoken sentences audible in the decoded file were as follows:

- A rod is used to catch pink salmon.
- The source of the huge river is the clear spring
- Kick the ball straight and follow through.
- Help the woman get back to her feet.

The output wav file (`decoded_output.wav`), and the source code (`Decoder.c`) are included in the project deliverables.

8. The following differences were observed between WINCE 2007 and Linux

- The kernel size for WINCE 2007 (86.16 MB) was observed to be much smaller than that for Linux versions (Debian: 2.7 GB and Angstrom: 1.1 GB).
- Linux provided a variety of login options including GUI, Serial terminal and SSH, while WINCE 2007 allows log in without any authentication.
- WINCE 2007 has default installations of user facing applications similar to Linux but within a compact image size.

9-10. The procedure for installing WINCE 2013 was identical to that for WINCE 2007 and was repeated as listed in parts 1-2 of this module.
11. A FTDI serial-to-USB cable was used to observe debug messages during the booting process of WINCE 2013. The following observations are made

- The MLO starts the boot process by loading the ebootsd.nb0 file into RAM which has a starting address of 0x80002000.
- ROMHDR had a starting address at 0x80002044.
- The WINCE image was launched by jumping to address 0x8000d259.

12. The kernel size was observed to be of length = 0x2608f50. This translates into 39882576 bytes (38.03 MB), which is consistent with size of NK.bin file on the SD card.
13. The screenshot showing debug messages on the terminal is included in the project deliverables (`wince2013_debugmessages.png`).
14. After connecting the HDMI output to the monitor and rebooting the operating system, the WINCE 2013 home screen was seen. The screen shot is included in the project deliverables (`WINCE_2013_Screenshot.png`). The image size is much smaller (38.03 MB) as compared to WINCE 2007(86.16 MB).

3.3 Module 3

1. A bash script was created to display the following diagnostic information for the linux operating system:

- Current date & time
- Linux kernel version
- Disk partition information
- Current disk usage
- Current running process of root & debian user
- Hardware list of BBB
- Report of BBB CPU & processing units
- Current RAM usage

2. This script was made executable by changing the permissions using the command `chmod +x`. The script (`test_script.sh`) and its output can be found in the project deliverables (`Boot_results_test_script.docx`).

[Bonus] Boot time execution

The script (`test_script.sh`) was placed in the startup boot directory `/etc/init.d` of Debian on the BBB. The script was registered as a service by executing the command `update rc-d test_script defaults`. Upon rebooting, execution of this service was verified by running the command `service test_script status`.
The output verifying the execution of the service at boot up (`Startup_status.jpg`) is included in the project deliverables.

3.4 Module 4

1. A Debian image with Asterisk pre-built into it was downloaded and flashed onto the microSD card. This card was then used to boot the Asterisk based operating system on the BBB. The image size was observed to be 1.1 GB. The output can be seen in `Asterisk_Image_Size.jpg`.

2. The following steps were taken to configure Asterisk and the softphone application Zoiper Classic.
   - Edited extensions.conf file to configure extension@100 and a playback message of Hello-world under the [from-external] category.
   - Edited sip.conf to add the softphone number 6001 and its associated properties.
   - Using Zoiper Classic, a new sip account was registered with the number 6001 under the same domain as the BBB.
   - Asterisk was restarted.

3. A call was successfully made from 6001 to the extension 100 and a Hello-world message was audible (`Hello_World.jpg`).

4. [Bonus] SIP phone to SIP phone call
   - Two SIP phones were set up on two different laptop computers with the names `demo-vishnu` and `demo-shiril`, with numbers 6004 and 6005, respectively.

- On the Asterisk OS , the above two phones were added in the sip.conf file along with their respective credentials.
- Asterisk service was restarted.
- Successful phone calls were made in both directions(vishnu-shiril and shiril-vishnu) as is evidenced by the screenshots (`Asterisk_Bonus_Phone_to_Phone.jpg`) included in the project deliverables.

Relevant commands for this module are included in the project deliverables (`Asterisk_Commands.docx`).

3.5 Module 5

[Bonus] - Web Application

A web server displaying the results of the diagnostic boot up script was hosted on the beagle bone black. To accomplish this, the following steps are followed:

- The Debian repositories were updated and the packages `lighttpd` and `lighttpd-module-fastcgi` were installed.
- Services using port 80 were disabled in order to grant access of port 80 to `lighttpd`.
- After the OS was rebooted, a web browser was used to navigate to the IP Address of the BBB and observe the contents of a placeholder HTML page.
- project3.html and project3.css were created to populate the webpage with the output of the diagnostic boot script.

The output of the BBB-`ipaddress/project3.html` webpage can be found in the project deliverables (`Web_Application.png`)

3.6 Module 6

[Bonus] Custom WINCE 2007 OS

Using the Platform Builder plugin of Microsoft Visual Studio 2008, a custom WINCE 2007 image for VirtualPC was created, whose code size was observed to be 36.24 MB (`wince2007_build.png`). The following guides were used to build custom WINCE7 OS image :

- https://msdn.microsoft.com/en-us/library/jj584921(v=winembedded.70).aspx

- https://msdn.microsoft.com/en-us/library/jj200438(v=winembedded.70).aspx

Due to Windows platform compatibility issues, the custom WINCE 2007 OS could not be evaluated with the VirtualPC software as VirtualPC requires a native Windows 7 machine, while only a virtual Windows 7 machine was available to us.

3.7 Module 7

[Bonus] Dhyrstone benchmark

On the Debian OS, performing the Dhrystone benchmark for 10 runs yielded an average VAX DMIPS of 646.95 (`Dhrystone_BBB_Debian.jpg`).

4. Recommendations

The AM3358 MPU was evaluated qualitatively and quantitatively keeping in mind the design and performance requirements listed by Patton Equipment in the RFS for their e911 IP-PBX VoIP Gateway product. Based on the modular test results, we can affirm that the AM3358 MPU performs satisfactorily from both, hardware and software perspectives. The AM3358 MPU was observed to operate at well over 500 VAX DMIPS, which exceeds the processing requirement listed in the RFS. Further, from a system design standpoint, the development cost for a single prototype the was $120. Although this exceeds the price limit in the RFS, we are confident that the system can be developed at a much lower price if bulk production (to the order of 5000 units) is undertaken, in which case the price would fall well within the budget limitation of $50. Thus, development of the product is certainly feasible within the time and budget constraints specified in the RFS, and hence, the evaluation team has given the AM3358 MPU a straight GO for Patton Equipment's e911 IP-PBX VoIP Gateway product.

5. List of Project Deliverables

- Block Diagram
- Bill of Materials
- Evaluation report for TI Sitara AM3358 MPU
- Module code, commands, screenshots in individual module folders

Appendix: References

https://msdn.microsoft.com/en-us/library/jj200354(v=winembedded.70).aspx
https://msdn.microsoft.com/en-us/library/jj200354.aspx
https://opensource.apple.com/source/tcl/tcl-20/tcl˙ext/snack/snack/generic/g711.c
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https://msdn.microsoft.com/en-us/library/jj584921(v=winembedded.70).aspx
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https://www.digikey.com/
https://github.com/tonyho/ARM˙BenchMark/tree/master/dhrystone-src
http://infocenter.arm.com/help/topic/com.arm.doc.dai0273a/DAI0273A˙dhrystone˙benchmarking.pdf

Appendix: Project Team Staffing

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