Project Report on

CONTROLLNG HOME AUTOMATION USING ALEXA WITHOUT CLOUD STORAGE

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2016 – 2017.

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Project Summary:

The target audience of the home automation will be all the domestic users around the world. In today's era, there are many AVR (Automatic Voice Recognition) devices available in the market such as Lenovo Smart assistant, Amazon Echo, Google Home that are costlier and uses cloud storage which needs active internet connection.

Smart Home automation is the use of control systems and information technologies to reduce the need for human work in the production of goods and services. It involves automation of lighting, heating, security as well as home appliances like oven, refrigerators etc. Wi-fi is often used for remote monitoring and control. Modern systems generally consist of switches and sensors connected to a central hub by which the system is controlled with a user interface.

Home automation is gaining popularity among the domestic users around the world as it saves a lot of human labor and it needs internet connection to function. When internet connection is not available, we won't be able to the AVR devices to control the appliances.

We came up with the idea of using the AVR device without internet connection i.e. using local storage like external hard drive (HDD). There are many AVR devices available which are designed for home automation. We have chosen Amazon echo for our design proposal.

We are going to propose an idea of using the local storage instead of cloud storage to control home automation using "Amazon echo".

Amazon echo is a smart speaker developed by Amazon.com. This device is capable of voice interaction, making to-do lists, weather traffic, playing audio books and other real time information. It can also control several smart devices using itself as a home automation hub.

In default mode, the Amazon echo device continuously listens to all the speech, which is primarily set up as "Alexa" (derives from Alexa Internet, the Amazon owned internet indexing company). The device also comes with a manually and voice- activated remote control. Echo's microphones can be manually disabled by pressing a mute button to turn off the audio processing circuit. Echo requires a wireless internet connection to work. Echo's voice recognition capability is based on Amazon Web Services and the voice platform Amazon acquired from Yap, Evi, and IVON (a Polish-based specialist in voice technologies used in the Kindle Fire).

Echo performs well with a 'good' (low latency) Internet connection which minimizes processing time due to minimal communication round trips, streamable responses and geo-distributed service endpoints. High speed accuracy is achieved through sophisticated natural language processing (NLP) algorithms built into the echo's text to speech (TTS) engine.

Motivation:

The sole aim of this project is to modify the existing Amazon echo which operates in cloud storage to work in local storage when there is no internet connection required as the existing on requires an internet connection to operate. The local storage can be a hard drive or a SD card. It depends on the designer to choose which option or have both options also.

Approaches:

To propose our idea, we have taken the reference device as Amazon Echo and understand its hardware components and working with cloud storage. Amazon Echo consists 2.5'' woofer, 7-microphone array, remote control and has TPS53312 (step down regulator), TLV320DAC3203 (ultra-low power stereo audio codec), TPA3110D2 (amplifier), DM3725CUS100 (digital media processor), K4X2G323PD-8GB8 (Samsung 256 MB RAM), SanDisk 4 GB flash memory, Wi-Fi and Bluetooth module.

How does an Amazon echo control home automation?

The below figure 1 tell us how the Amazon echo works. In the below figure, Amazon Echo works with cloud storage. When the user speaks to the echo device, it receives the command and goes to the NLP (Natural Language Processing) which is done by the Amazon neural network and in turn replies to the user command.

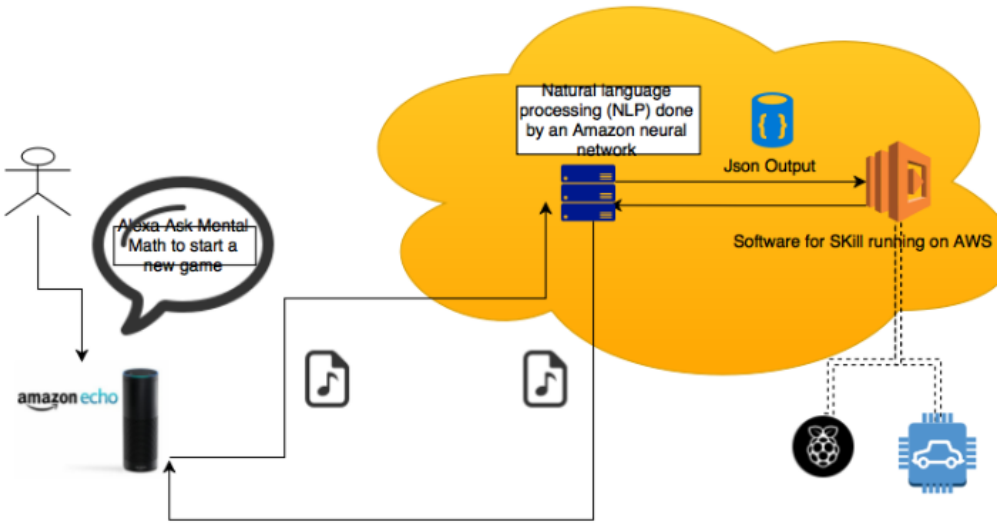


Figure 1 How Amazon Echo works

System Diagram for our proposal:

In this diagram, we are introducing the local storage option connected with the Amazon echo. There are lots of options available for local storage such as HDD, NUC computer, SD cards etc. Here, we are connecting the external hard drive with a USB port.

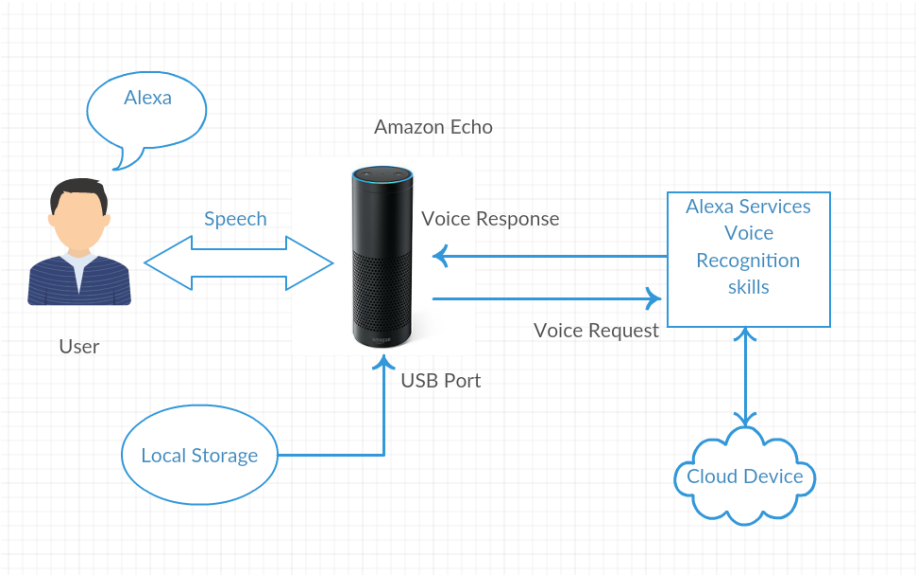


Figure 2 System diagram

Storage details:

For storage purpose, we are using portable SSD Drive which has a capacity of 375 GB. This drive consumes low power and its cost is around 30$. Its size will be 7mm. Data will be stored in this drive for recognition purpose and whenever device goes offline. Apart from that we can also save data for controlling home automation.

Critical Components used in our proposal:

The main critical components in our design proposal are the processor (CPU) used inside the Amazon echo and the local storage (RAM) for storing all the data.

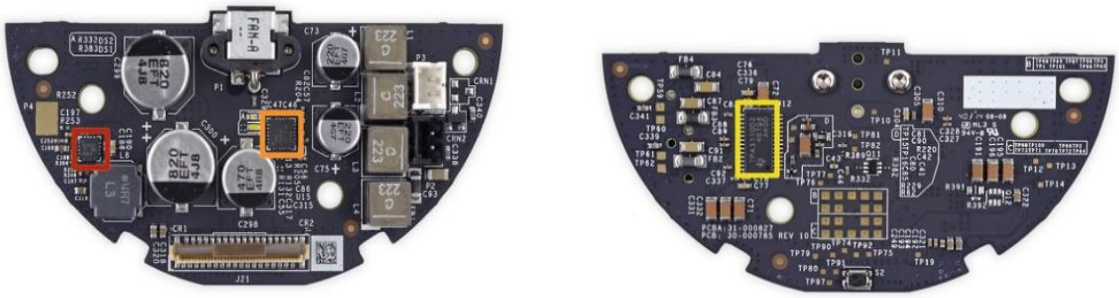
1. **CPU (Processor)**
2. **Memory (Local storage).**

Let us see about the processor used in Amazon echo in detail.

CPU (Central Processing unit) performs all the basic arithmetic, logical, control and input/output operations specified by the instructions. The principal components of a CPU include the arithmetic logic unit (ALU) that performs arithmetic and logic operations, processor registers that supply operands to the ALU and store the results of ALU operations, and a control unit that orchestrates the fetching (from memory) and execution of instructions by directing the coordinated operations of the ALU, registers and other components.

Let’s have a look at the processor used in the Amazon echo.

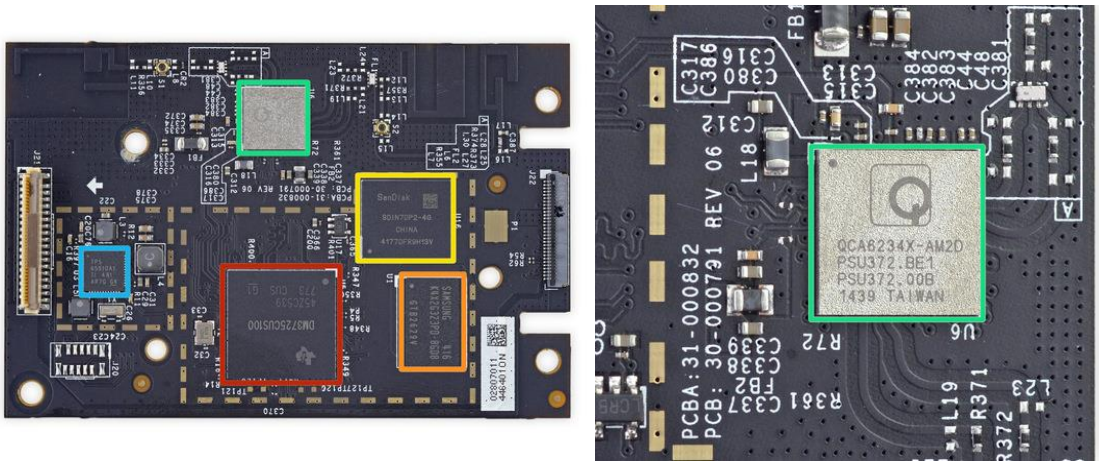
Amazon Echo is world’s smartest speaker, which includes lots of hardware including 2.5” woofer, with reflex port to drop extra bass, 2.0” tweeter, and 7 microphone array. The power and speaker driver board lives on the bottom of stack.



In the above figure, the red box is Texas Instruments TPS53312, likely an updated version of the TPS53311 3A Step-Down Regulator with Integrated Switcher, next to this orange box is Texas Instruments TLV320DAC3203 Ultra Low Power Stereo Audio Codec. And in next figure yellow box is Texas Instruments TPA3110D2 15W Filter-Free Class D Stereo Amplifier.

After that there are some vibration-dampening fabric swaddling the speakers as shown in below figure.

After that the main part of amazon echo is shown below,



Here, as shown in above figure, this hardware component is powering amazon echo. The first figure blue box is Texas Instruments TPS65910A1 Integrated Power Management IC. Next to that red box is Texas Instruments DM3725CUS100 Digital Media Processor which is most critical component of amazon echo. Above the red box there is green box is Qualcomm Atheros QCA6234X-AM2D Wi-Fi and Bluetooth Module. There is yellow box which is SanDisk SDIN7DP2-4G 4 GB iNAND Ultra Flash Memory. The last component is orange box, which is Samsung K4X2G323PD-8GD8 256 MB LPDDR1 RAM.

The top of amazon echo consists of 7 microphone array. In the next figure, green box is S1053 0090 V6 Microphone (x7), Yellow box is Texas Instruments SN74LVC74A Dual Positive-Edge-Triggered D-Type Flip-Flops. The red box is Texas Instruments LP55231 Programmable 9-Output LED Driver (x4). Last is orange box Texas Instruments TLV320ADC3101 92dB SNR Low-Power Stereo ADC (x4).

The most critical component in our system is processor and second most critical component is memory.

Processor: (CPU)

We see many processor and among them we conclude two processors which can be best suitable for our system which are **Texas Instruments OMAP4460** and **Texas Instruments DM3725CUS100 Digital Media Processor.**

Starting with Texas instruments OMAP4460 is Cortex A9MP core type processor.

The below diagram gives us an idea how the internal structure of a Cortex A9MP core type processor looks like.

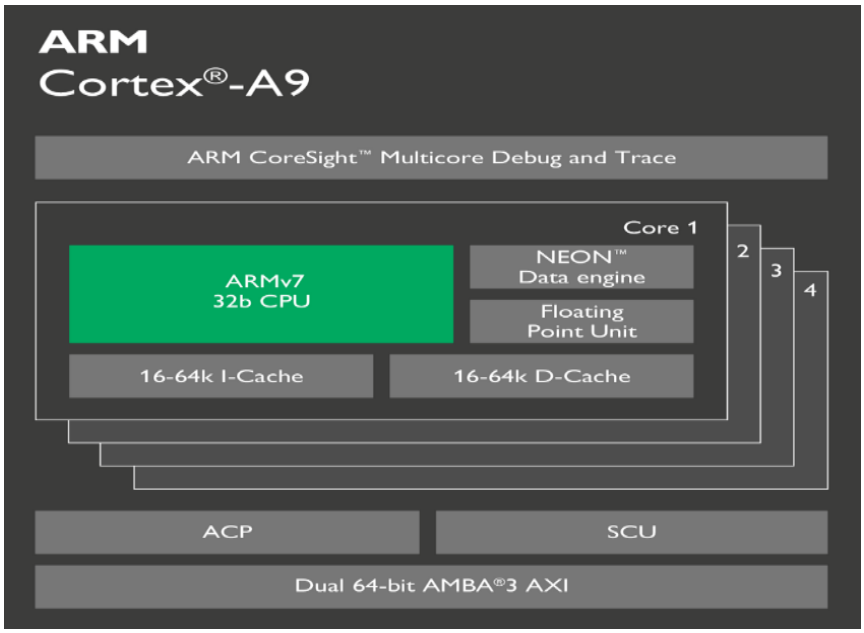


Figure 3 Architecture of ARM Cortex- A9

The key benefit of using Cortex A9 processor is its scalable performance and power efficiency for a broad range of 32-bit consumer, networking, enterprise and mobile applications support the wide ARMv7-A 32-bit software eco-system mature and silicon proven in multiple process technologies. Its RISC processor. This processor works on SIMD engine. The cost of this processor is cheap. Its clock speed is 1.5GHz. It has 2 core. Its ram is 512-1024MB LP-DDR2 and it has flash drive up to 8GB. This processor also support display of RGB, HDMI, and DSI. Regarding networking, this processor also support Wi-Fi 802.11 b/g/n, and Bluetooth 4.0. Regarding connectivity, it supports 2 SD card, 1 OTG and 1 USB 2.0. It also supports UART, I2c, and SPI communication. Regarding OS, this processor also support to Linux and Android. The next is power source and it consumes only 3.3-4.5 V.

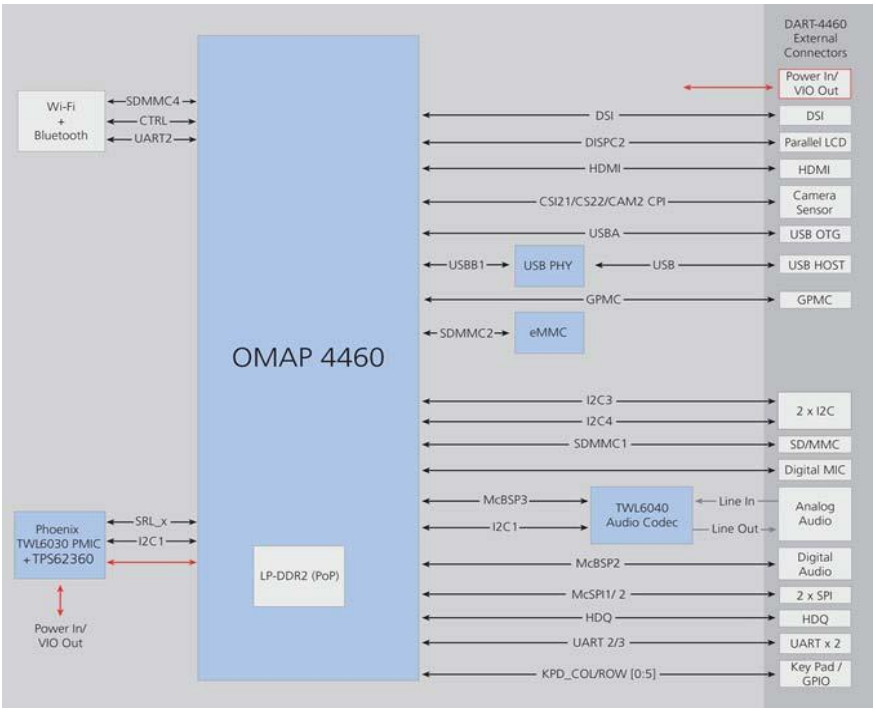


Figure 4 Architecture of OMAP 4460

The cortex A9 is highly reliable and 25% higher performance than cortex A8. The Cortex-A9 processor is suitable for low-power, cost-sensitive 32-bit devices which require competitive power efficiency. This processor use Trust Zone security extension for security purpose.

The next processor is Texas Instrument DM3725CUS100 which is currently using in amazon echo. Texas Instrument DM3725CUS100 is cortex A8 core type processor.

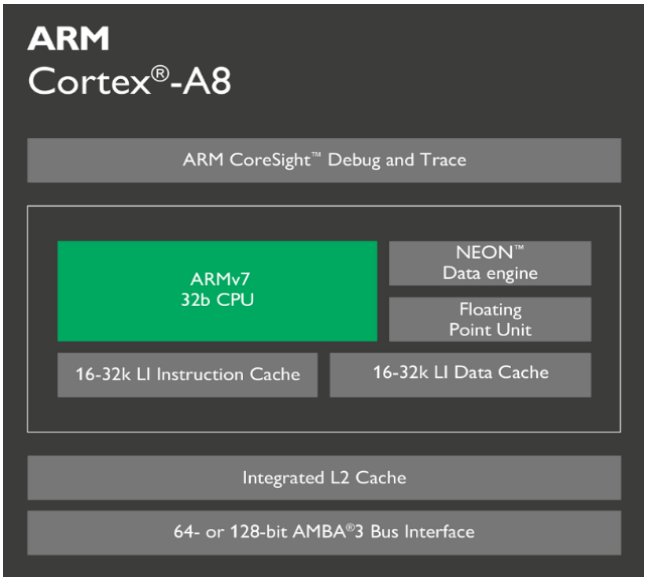


Figure 5 Architecture of ARM Cortex- A8

Significant benefit of ARM cortex A8 processor is large increase in single thread performance over its predecessor, the ARM11.ARMv7-A support including NEON and Trust Zone. Widely deployed in mobile and embedded, with numerous low-cost 3rd party development platforms. A great processor on which to learn the ARM architecture. This processor incorporates the ARM NEON single instruction multiple data (SIMD) engine, ARM Trust Zone security extension. The clock cycle is 1GHz.

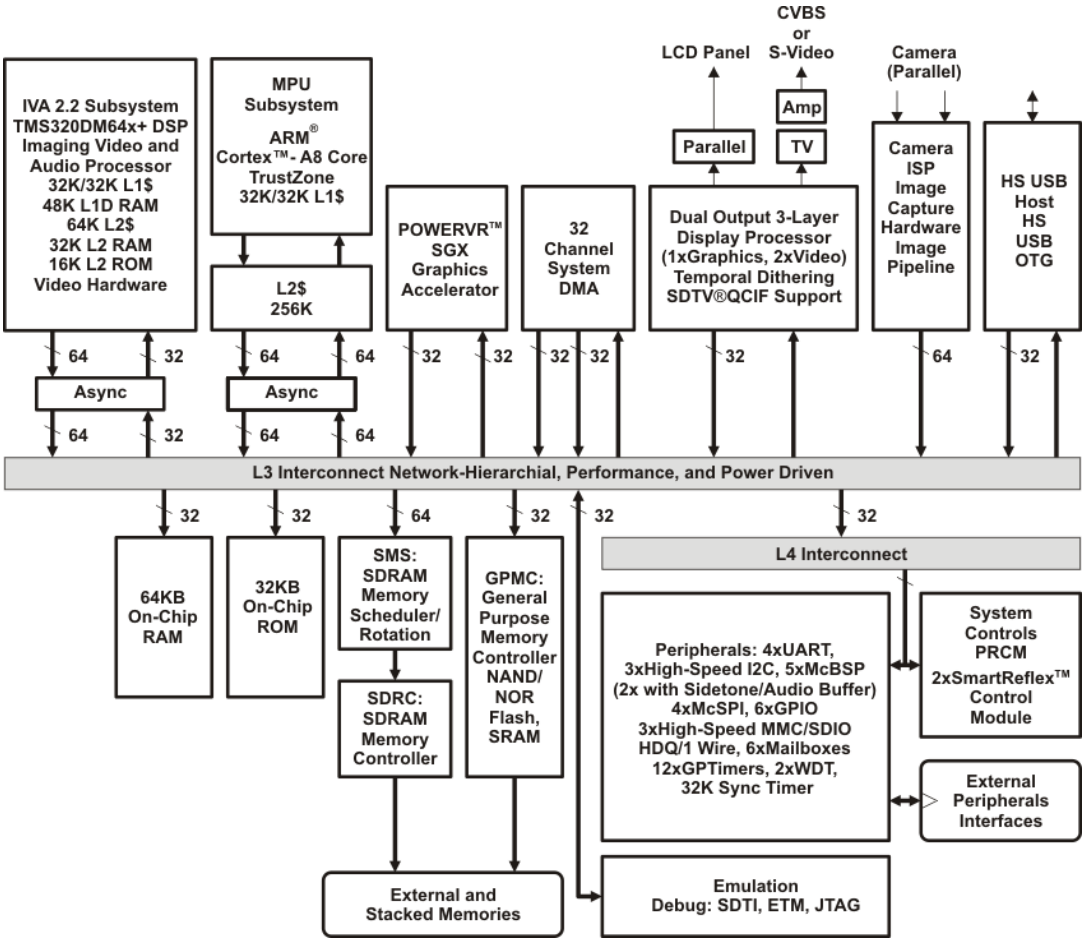


Figure 6 Block Diagram for DM3725CUS100

It has single core processor. It has 4 UART, 4 I2C, 6 GIPO peripheral communication. It also supports OTG and 4 USB port too. Regarding OS, this processor also support to Linux, DSP/BIOS, Neutrino, Integrity, Windows Embedded CE, VxWorks, and Android. It works on 256MB LPDDR1 ram. It works with 4 GB flash storage. The cost of this processor is comparably less than another processor. Regarding networking this processor also support Wi-Fi 802.11 b/g/n, and Bluetooth 4.0. The next is power source it consumes only 4-4.5 V.

Comparison between the Cortex-A8 and A-9 processors is given below.

Specifications	Cortex-A8	Cortex-A9
Architecture Version	V7	V7
Pipeline Type	in order, dual issue, superscalar	out-of-order, variable length, superscalar
Pipeline Stages	13	8
ISA Efficiency (DMIPS/MHz)	2.01	2.5
MMU	Yes	Yes
TLB	2x32 full associativity	4 element fully associative + 2x32 two-way associative
Core to L1 Interface	64 bit -- NEON 128 bit	64 bit -- NEON 128 bit
L1 $ Set associativity	4	4
Line Length	64 Bytes	32 Bytes
Tightly coupled memory	No	No
Integrated L2	Yes	Yes
Cache Model	L1 – VIPT L2 - PIPT	Instruction – VIPT Data -PIPT
Branch Prediction	512 Entry BTB	2 way x 256 BTAC
General Coprocessor Interface	No	No
External Interfaces	1 AXI – 64/128	2 AXI 64 bit
Trust zone support	Yes	Yes

Non Cacheable Fill Buffer	16 word	2 - 8 word
Java support	Jazelle RCT	Jazelle DBX
Floating Point Media	VFP Lite and NEON SIMD	VFPv3 and NEON SIMD
Per-Cycle Multiply-accumulate throughput (fixed point)	2 x 32 bit 4 x16 bit 8 x 8 bit	2 x 32 bit 8 x 8 bit

The epitome of above discussion is comparison between Texas Instruments OMAP4460 and Texas Instruments DM3725CUS100, we conclude that Texas Instrument OMAP 4460 is better than current processor Texas Instruments DM3725CUS100.

Memory (Local storage)

Memory is the second most critical component used in our modified design.

The existing Amazon echo available in the market works with an internet connection using cloud storage. We have planned to modify the existing Amazon echo which works in cloud storage (Internet) to work in local storage too. We came up with this idea because, when there is no internet connection, we will not be able to use Amazon echo as it is connected to the internet. So, when amazon echo is connected to the local storage like RAM, hard disk it doesn't require any internet connection and all the data required for the echo to function is stored in the local storage as backup and can be used when there is no internet connection.

Computer memory is a physical device capable of storing information temporarily or permanently. Memory can be volatile or non-volatile. Volatile memory means the contents are lost, when the hardware device loses power. eg. RAM. RAM (Random Access Memory) is a volatile memory that stores information on an integrated circuit used by the software or hardware. Non-volatile memory keeps the contents even if the power is lost. EEPROM is an example of NVRAM.

It is very common for people to get confused by what parts are referred as memory. Although both the hard drive and RAM are memory, RAM is the main memory of the processor and hard drive is the storage or secondary storage.

When an Amazon echo works in local storage, it is first loaded from the hard drive and placed into RAM, which allows the program to communicate with the processor at high speeds. Any data saved is sent to the hard drive for storage. Storage for most processors in use today consists of a hard disk drive. Hard drives can provide hundreds or thousands of gigabytes of space that can be used to store applications, documents, data used by Amazon echo to function.

The below figures gives us an idea of the storage options available in the market.

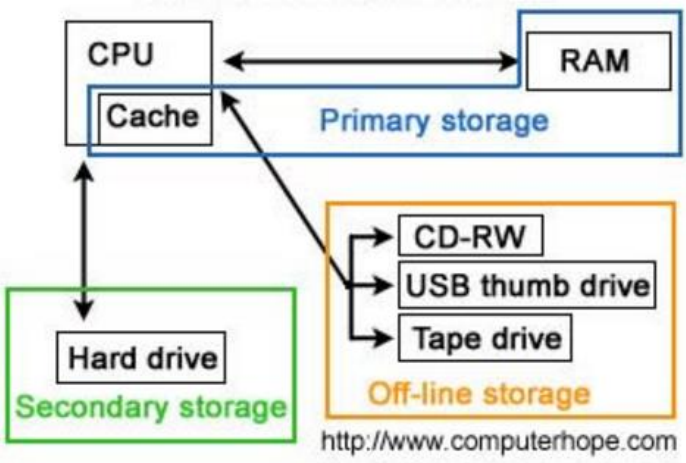


Figure 7 Storage options available

Today's processors have minimum RAM size of 2GB and the memory can be extended to 8GB or more.

Selection of RAM and storage is a vital task as it might affect the performance of the Amazon echo. As we are planning to use the echo for more specialized task like controlling the home light and fan, more RAM can benefit the purpose. It all depends on the processor that we use in echo and we must make sure that the RAM is upgradeable or comes equipped with as much RAM.

External storage or external hard drive are used to fulfill the large storage requirements. The primary characteristics of an HDD is its capacity and performance. Capacity of a HDD available varies from 250 GB to 12 TB. Some of the manufacturing companies of these HDD's are Seagate, Toshiba and Western Digital.

The main advantage of using these external hard drives are

- Data can be transported easily from one place to another.
- External storage also works as data backup. This back up may prove useful at times such theft because important data is not lost.

External hard drives are typically connected via USB (Universal Serial bus) for data transfer.

The present Amazon echo doesn't have a USB port to connect to the external hard drive. As we can see in the below construction part, we don't have a slot for USB or SD card.

Figure 8 Amazon Echo tear down/Construction

This figure above tells us the components present in the existing Amazon Echo and how the device is constructed and designed.

Our idea is to modify the construction of the Amazon echo by adding an USB port to the device.

The above figure gives us an idea of how an amazon echo is constructed and the components used. It has a 7- microphone array, action button, woofer, tweeter and a volume ring. It does not have a USB port to connect to other external devices as it is based on cloud storage.

To work using local storage, we need to change the design by inserting a USB connection anywhere between the volume ring and reflex port. It is up to the designer to decide where to have the USB port connection.

By modifying the design as shown below, we can connect an external local storage device to the Amazon echo and this allows it to work when there is no internet connection. The USB cable come along with the storage device, so that it can relate to the port and the data is stored and can be used whenever needed.

We can also have a slot for SD (Secure Digital) cards. It is also a non-volatile memory card used in portable devices. They are available in three different sizes namely mini, micro and the original size. SD cards offer greater capacity from 2GB to 2TB. SD cards can also be used for storing back up data like external hard drives.

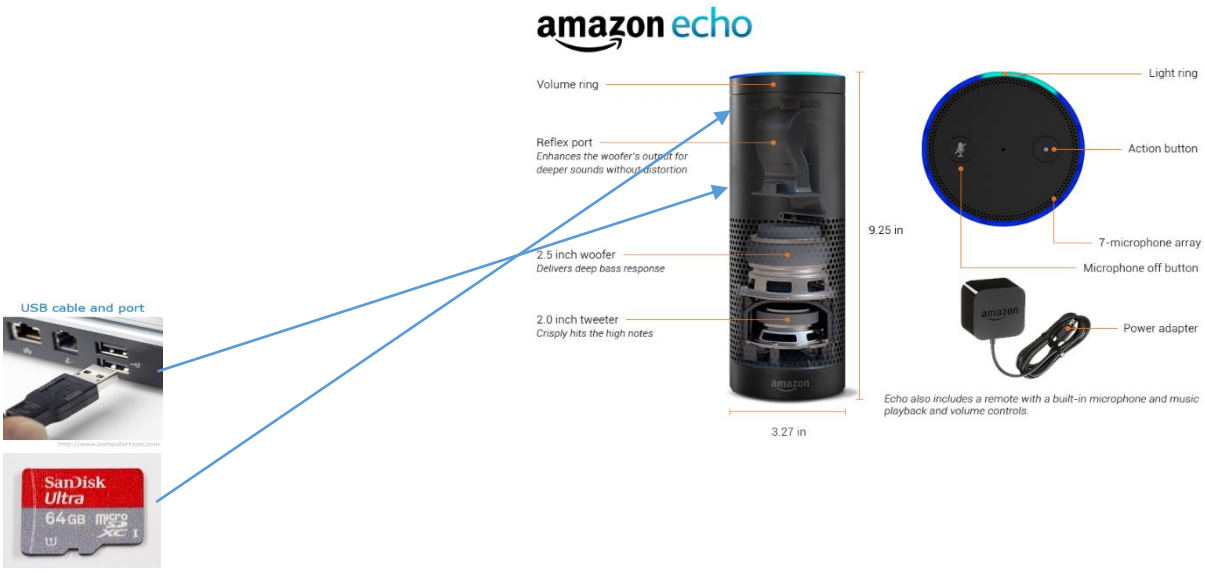


Figure 9 Amazon Echo modification in the design for local storage

The above figure gives us an idea how a SD card and an external device can be connected to store the saved data and allows the device to operate in local storage without using the internet connection. It is left to the designer to choose which option to use either the SD card or external drive or both for using the local storage.

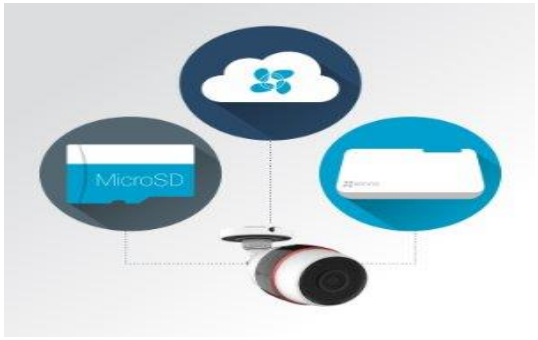


Figure 10 Echo connected to cloud, SD card and HDD

Design Verification and Validation

Making sure that the implementation is correct is a critical part of the design. A variety of techniques are used in practice to ensure that the final system operates correctly.

The three different types of activities are:

a) **Testing**
b) **Validation**
c) **Verification**

Testing: It exercises an implementation by providing stimuli and evaluating the implementation's outputs.

Validation: It refers to comparing the implementation to the initial requirements or specifications

Verification: This can be performed at any stage of the design process and compares the design at one level of abstraction to another.

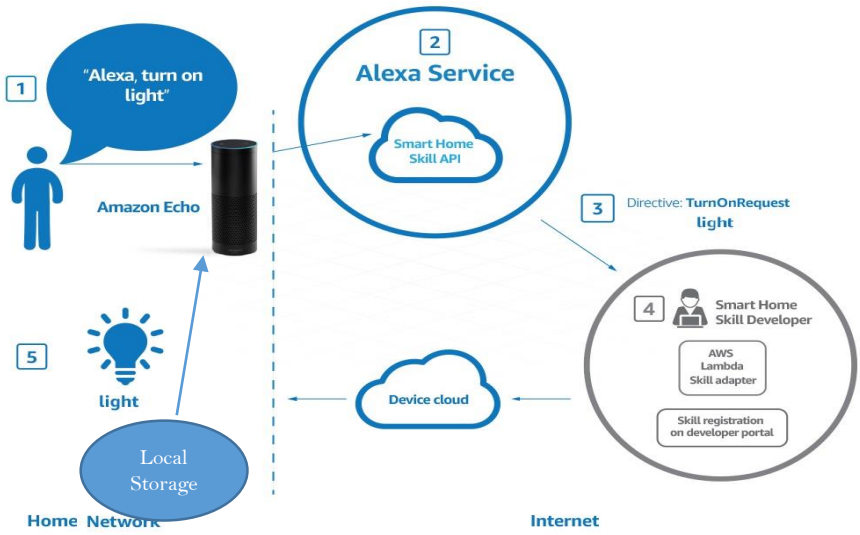
Verification and design: Verification and validation should not be performed at the final step to check the complete implementation. The design must be repeatedly verified at each level of abstraction. Design errors become more expensive to fix as they propagate through the design allowing a bug to be carried to a more detailed level of implementation requires more engineering effort to fix the bug.

Testing of Amazon echo when working in local storage.:

As we are focused on developing the new design for Amazon echo which is used to control home automation. We have decided to test the device with the following criteria as given below.

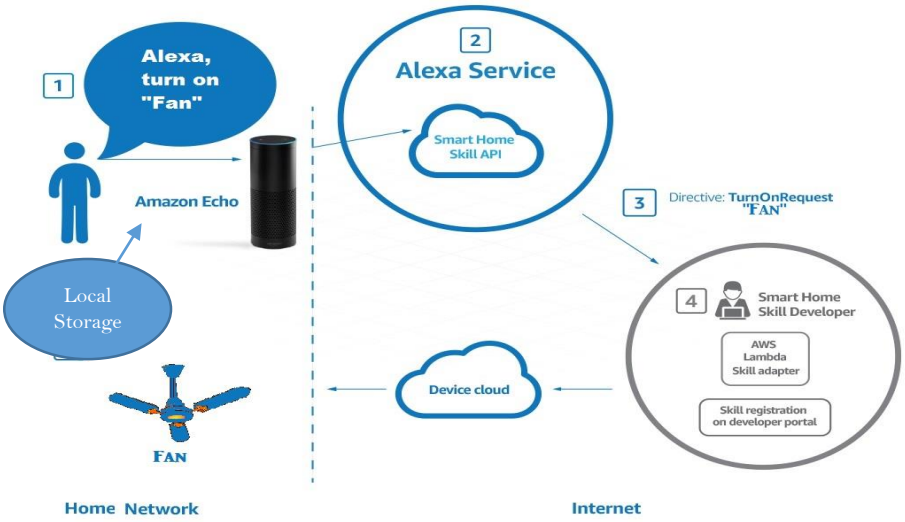
1. Controlling Lights using Amazon echo
2. Controlling Fan using Amazon echo
3. Controlling Car using Amazon echo.

Controlling Lights:



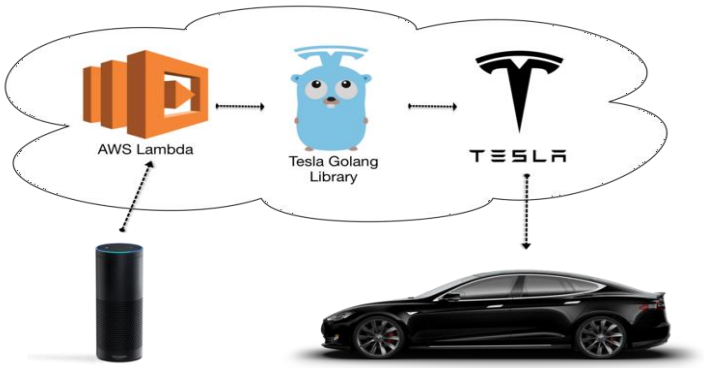
When User speaks "Alexa, turn on light", Amazon Echo recognizes the word spoken and then goes to Alexa service which is developed by smart home skill developer and executes as per the command given and this data is stored in cloud storage as well as local storage and it will control lighting of house.

2. Controlling Fan using Amazon echo



When User speaks “Alexa turn on Fan”, amazon echo distinguishes the word spoken by user, and it will go to Alexa service and call API for “turn on the Fan”, developed by smart home developer. This data is stored in local as well as in cloud storage.

3. Controlling Car using Amazon echo



Here in Tesla electric car, using tesla Golang library, Tesla car can be control using amazon echo. The technology behind this is all based in the cloud. We are using the Amazon Echo’s Alex Skill Kit to trigger on a keyword (‘ask KITT’) and send the resulting event to AWS Lambda. Lambda then executes my code (We built our Lambda function with Apex, which we highly recommend for anyone working with Lambda) where we use the Tesla Golang library recently published. The Golang code on Lambda then calls the unofficial Tesla API which in turns triggers the car to move. We can also use this technique to open the garage door via Home link and drive on out using the summon capability.

Design Phase:

Our main motive is to change the existing Amazon echo design which works on cloud storage to the one which works in local storage. To change the design of the existing device, extreme challenge was required to collect all the details related to the types of processors suitable and storage options available. It is also in our greatest welfares to talk with a few faculty members of the ECE department and take their feedback. For instant, for speech related questions we acquired advice from **Dr. Kepuska.** For network, related queries, we asked help from **Dr. Lee** and for microcontroller related questions we took help from **Dr. Otero.** We got depth information related to our project. Second major source for our information is ProQuest, which is provided by FIT library resources. And lastly, we considered numerous websites to collect all datasheet and information.

After collecting the information required for modifying the design, we had to change the construction of the current device. The current device does not have a slot for USB port. We had to recreate the entire device by adding a slot for USB port, so that external storage device can be connected to the device with the help of the USB port.

We had to consult a lot of designers, who have dealt with this kind of design alteration as it requires a lot of engineering. We took the opinion of the designers and asked whether this kind of modification can be done and there should not be any design error as they are very expensive.

Design Tasks:

We had to perform several design tasks to implement the design as per the standards of the implementer.

- The unspecified parts of the implementation must be designed. In our design, the USB port must be designed which are not specified in the current design of Amazon echo.
- An initial round of platform- independent optimization must be used to improve the chosen reference implementation.
- The reference implementation must be profiled analyzed.
- The hardware platform must be designed based on the initial characterization.
- The design must be verified to conformance to the standard as well as nonfunctional parameters such as performance and energy consumption.
- Amazon network software must be evaluated for functional correctness. The processors architectures can be tuned and optimized for the application.
- The designer should implement the design based on the parameters like performance, power, cost and quality or ease of implementation.
- Design space exploration evaluates hardware alternatives. We had to check for the design space to add the USB port or the SD card slot.

The below figure tells us about the design modification suitable for working in local storage.

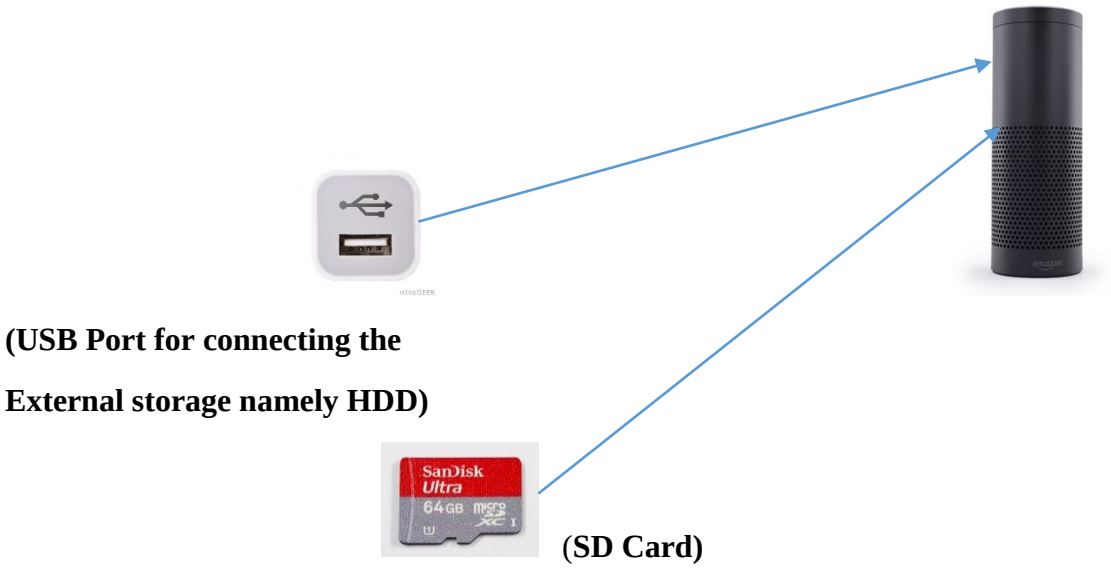
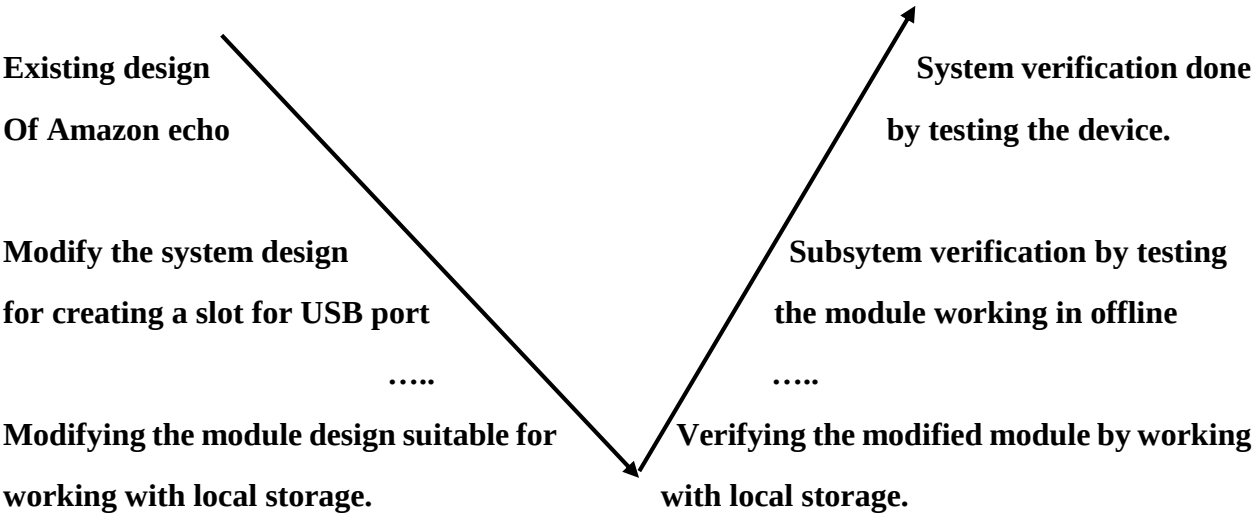


Figure 7 Design Modification in the Amazon echo device

The design alteration is nothing but creating a slot for USB port or SD card depending upon the user choice, so that with the help of USB port, one can connect the external storage of any capacity and the saved data is stored in the local storage and it works offline too. SD cards can also be used as external devices and are available in various capacities and they are easier to carry and use.

V- Chart for system design and verification of Amazon echo with the modified design



Cost and Schedule:

Our project cost will be around 400$. Amazon echo is available in the market at a price of $179.9. As we are modifying the current Amazon echo design by inserting a USB port, an external hard drive or SD card as per the user choice, these components need to be included in the design as well. The external hard drive cost ranges from 40$ to 150$. The price varies depending on the capacity we are using for local storage. The cost of ARM Cortex A-8 will cost around $13.75 depending upon the speed and the internal memory.

To amend the existing Amazon echo by adding a USB port, it requires designers to work on the modifications necessary for making the device work in local storage too. The time taken to complete the alterations may take 3 days depending on the time taken by the designer.

The labor cost for one day may cost around 40$. If the designer takes 3 days to complete the design, then the total labor cost will be 120$.

On adding up all the costs needed for modification, the total budget comes to 400$.

Benefits of the Modified Amazon Echo:

- Our system is 100% ecofriendly.
- Our design will not affect any other AVR device as it is based on open source data.
- Our system is completely safe as it does not affect any person or animal.
- As our system is open source, any person can upgrade or change as per their requirements.
- This design helps people to use Amazon echo even when there is no internet connection.
- Our system has good sustainability and provides a good performance like the current Amazon echo which works using cloud storage.

The epitome of above discussion tells that, right now our project is conceptual, so we are not sure about the problems to be faced in the future. But we are sure that we will design an efficient and ecofriendly modified Amazon echo system.

Executive Summary:

Amazon echo developed by Amazon.com was initially limited to Amazon Prime members, but it became widely available in the United States from June 23, 2015. This device gets connected to the voice controlled intelligent personal assistant service named Alexa. Alexa is a virtual assistant that can perform tasks or services for an individual.

With the development of these AVR devices , home automation has been made easy .It includes controlling and automation of lighting, heating (such as smart thermostats), ventilation, air conditioning (HVAC), and security, as well as home appliances such as washer/dryers, ovens or refrigerators/freezers.

We have taken Amazon echo as the sample device to implement our design by working in local storage as the current AVR Devices work on cloud storage.

We had come up with this idea, so that the Amazon echo device which works only with internet connection, can be used even when there is no internet connection, so that it can be used anywhere.

To work using local storage, we have used the external hard drive. When the echo device is connected to the external hard drive, all the data used by the echo device is backed-up in the external storage. When the device operates during offline mode, the saved data is used for its functioning. In this way, we can use the echo device in offline mode.

We have decided to modify the current design of the echo device, as the current echo device does not have a USB port to connect the external hard drive (HDD). By having a USB port, we can operate the device in local storage.

There have been some design tasks involved in changing the design and design engineering is required to alter the current design and design space also has been considered as it changes the hardware.

By implementing the above design change as discussed above, we will be able to use the Amazon echo device for home automation using local storage.

The current Amazon echo has been popular among the domestic users around the world and it uses the internet connection for remote controlling and monitoring and are an important constituent of Internet of Things.

Thus, by connecting the Amazon echo device with the local storage using USB port or SD card, we will be able to use the device in offline mode too.

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