

# COVER

## - From Past to Present:

### Harnessing Matter to Integrate Legacy Devices into the Next-Gen Smart Home Ecosystem

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**Abstract**—In recent times, the global smart home market has seen remarkable expansion, projected to cross \$164 billion by 2028. Driven by the desire for convenience, security, and energy savings, we're witnessing sophisticated device integrations in our homes. However, this growth isn't without its challenges. The array of smart home devices from different brands has fragmented the user experience, leading to a maze of applications for device control. Many third-party apps, despite their intentions, often don't mesh seamlessly with central control devices like smartphones, a challenge evident in platforms such as Apple Home and Google Home App . Additionally, a significant number of devices still lack IoT integration, which challenges expanding smart home market.[1]

Addressing these challenges, we introduce the LG Cover, an innovative solution designed to bridge gaps in the smart home ecosystem. We suggest specialized integration for all LG devices, resurrecting legacy devices through the Matter protocol, and ensuring consistent user experience across various brands. This system supports the integration of both Matter and ThinQ devices, and also supports older devices based on IR technology, revitalizing its utility within modern smart home setups.

To facilitate seamless integration, the LG Cover adopt a structured setup process involving the registration of the hub to the ThinQ app and the Matter API device. ThinQ supporting or IR supporting devices are connected to LG Cover with proprietary protocols, and LG Cover mediates the connected devices to Matter enabled controllers. Users are enabled to communicate with non-Matter-supporting devices through LG Cover using Matter API. With LG Cover's comprehensive approach, users can experience the convenience of a unified smart home ecosystem, irrespective of the device's age or brand.

#### Role Assignments

Roles	Name	Description
User/Customer	SONG WOJUNG	User/Customer plays the role of a various ages who needs support with an old LG devices that doesn't support matter api. Despite the advancements in tech and the ubiquity of smart homes, not every device owned is compatible with the latest standards. This poses a challenge in achieving a cohesive experience, especially when most contemporary hubs primarily cater to the latest models and technologies. Therefore, the LG Cover plays an instrumental role in bridging this gap. While it is equipped to support the Matter API, its design philosophy is to be inclusive. The goal is to serve users like Alex, ensuring that their older, reliable LG devices don't become obsolete. This includes even those devices that don't support LG ThinQ.
Product Designer	KWON KITAE	A Product Designer is responsible for understanding user needs and business objectives to conceptualize and design products that provide effective solutions; they engage in user research to gather insights, sketch initial design ideas, create wireframes and interactive prototypes, collaborate with cross-functional teams like product managers, engineers, and marketers to refine designs, ensure consistency in brand aesthetics and user experience across products, gather and act on feedback from user testing sessions. Also works with documentation that helps other roles communicate with each other more effectively.

Software developer	KIM JINA	A software developer is responsible for collaborating with development manager, product owners, and product designer to understand software requirements, converting these into functional specifications, designing the software architecture based on these requirements, writing clean and maintainable code, ensuring software is scalable and robust, testing the software for bugs and inconsistencies, deploying software to production environments, maintaining and updating software as necessary, and documenting development processes and software functionalities to ensure continuity and ease of future modifications. Also works with connection between the matter API and ThinQ devices to maintain connectivity.
Development manager	YEO DAKYUM	A Development Manager oversees the software development process, coordinating with cross-functional teams to ensure projects are completed on time and within budget, establishing and implementing development methodologies, setting objectives and deliverables for the development team, mentoring and providing guidance to developers, ensuring code quality and adherence to standards. Also works with the actual hardware chip that will be used in Cover.

## I. INTRODUCTION

### A. Motivation

- **Growth of Smart Home Systems**  
The smart home market has experienced remarkable growth over the last few years. According to Statista, the global smart home market is projected to surpass \$141 billion by 2023, up from \$76.6 billion in 2018.[2] This exponential growth is driven by consumers' increasing desire for convenience, security, and energy efficiency. As homes integrate more devices, the need for a cohesive control system becomes critical.
- **The Challenge of Diverse Devices from Different Companies**  
As smart home devices proliferate, a significant challenge arises due to the sheer variety of brands and products available. Different companies offer their distinct range of smart

devices, each with its dedicated application for control. This leads to an overflow of applications on users' smartphones or tablets, complicating what should be a simplified process.[3][4] The fragmentation of control interfaces creates inefficiency and reduces the user-friendly nature of the smart home system. There's a clear need for a centralized platform, like Matter, that can consolidate control, ensuring that users can manage their entire smart home ecosystem without juggling multiple applications.

Additionally, there is a potential risk of user's personal information being exposed when remotely controlling products of diverse companies through IoT. Currently, when a user issues a command to turn on the lights from a mobile phone, it often goes through a cloud-based connection between the phone and the hub, and then the operation is executed via an API.[5] With Matter, all operations can be performed locally without passing through external servers, ensuring that personal information is not exposed.

- **Bridging the IoT Gap with LG Cover**

While many modern devices are equipped with IoT capabilities, a substantial portion remains without this integration. The disparity between IoT-enabled devices and those lacking this feature can result in gaps within the smart home ecosystem. Matter, a unifying protocol for smart home devices, can introduce IoT capabilities to previously incompatible devices. LG Cover, supporting Matter, acts as a bridge, allowing even non-IoT devices to join the integrated smart home network. This inclusivity ensures that no device is left out, offering users a comprehensive smart home experience.

### B. Problem Statement

- **Gap in Dedicated Support for LG Devices**  
The landscape of smart home devices is increasingly complex and fragmented, with a myriad of brands and protocols available in the market. Within this expansive ecosystem,

while there are many generic hubs available, there is a conspicuous absence of a dedicated hub designed specifically for LG's vast array of devices. Owners of LG products, both modern and legacy, find themselves in need of a hub that is acutely attuned to the nuances of LG's electronic architecture. Generic solutions often fall short in leveraging the full potential of LG devices, leaving users with a less-than-optimal experience.

- **Neglect of Legacy IR Devices and Old ThinQ Products**

The tech industry's rapid advancement has led to a situation where many older, yet perfectly functional devices, especially those based on infrared (IR) technology and earlier versions of LG's ThinQ products, are left out of the modern smart home narrative. Most current hubs are squarely focused on the latest communication protocols, sidelining these older devices. This presents a challenge for many households that still rely heavily on these devices and are looking for ways to integrate them into a unified smart home ecosystem.

- **Diverse Brand Environment Leading to Fragmented User Experiences**

The average household's smart device portfolio often comprises products from a variety of brands. Current IoT hubs, while claiming broad compatibility, tend to offer a disjointed user experience due to inconsistencies in how different brands' devices are integrated and managed. Users are thus left longing for a singular platform that can offer a seamless and harmonious experience across all their devices.

### *C. Solution*

- **Tailored Integration for LG's Spectrum of Devices**

The LG Cover stands out with its commitment to providing a seamless experience specifically for LG device owners. Whether it's the latest smart TV or a legacy LG appliance, the LG Cover ensures perfect harmony and optimized performance, something that can only be

achieved with a deep understanding of LG's technological DNA.

- **Inclusivity for Legacy Devices**

One of LG Cover's hallmark features is its pioneering capability to revitalize older devices using the Matter protocol. Whether it's an IR-based remote-controlled device or an older iteration of the ThinQ product line, the LG Cover, through its integration with Matter, ensures that these devices are not only recognized but also seamlessly incorporated into the modern smart home ecosystem. By leveraging the universal nature of Matter, LG Cover effectively bridges the gap between past and present, preserving the utility and value of legacy devices in today's interconnected world.

- **Consistent Experience Across a Multitude of Brands**

Beyond its specialization in integrating LG products, the LG Cover showcases its prowess in providing a consistent and intuitive interface, even when dealing with devices from multiple manufacturers. This focus on providing a unified user experience ensures that managing a diverse smart home setup is no longer a daunting task, but a delightful experience utilizing Matter, it would enable us to incorporate our device to many readily available, existing home management application, such as Apple HomeKit or Google Home App, which is much well suited for corresponding mobile OS.

### *D. Related Software*

- **Google Nest Hub 2 Gen.**

Nest Hub is the device to use to manage your smart home since it is compatible with so many different things.

We can watch a range of movies, music, and TV shows using Nest Hub, and we can use voice commands or a single tap to operate connected smart devices. A sleep sensor function can also promote restful sleep.

Many Nest Hub functionalities are accessible through Quick Gestures. Quick Gestures uses

Motion Sense instead of a camera to identify when our hand moves.

- **Samsung SmartThings Station**

Samsung SmartThings Station combines a smart home hub and wireless phone charger while supporting up to three separate programmed automation routines.

It works with a broad selection of Matter and other Samsung smart home products, and its accompanying app makes it simple to set up routines you can activate from the Station with a tap.

It is incapable of playing music or supporting voice control because it lacks a speaker and microphone. Instead, this hub serves as a wireless charging station for devices that are Qi compliant.

Both the Android and iOS platforms currently support Samsung SmartThings Station.

- **SwitchBot Hub 2**

SwitchBot Hub 2 supports old infrared appliances, we can link additional SwitchBot goods through Bluetooth and Wi-Fi to create a smart home environment.

We can integrate Hub 2 into our smart home ecosystem to deploy Matter over Wi-Fi in the future for current Bluetooth-only products like SwitchBot Curtain, SwitchBot Lock, and SwitchBot Blind Tilt, eliminating the need to purchase additional hardware to make them Matter compatible.

- **Ikea Dirigera Hub**

DIRIGERA hub is the central control hub for a smart home in the IKEA Home smart app.

It enables us to connect and control a variety of smart gadgets, including speakers, blinds, and lighting. These devices allow for remote control, the creation of personalized settings for various situations and emotions, and the scheduling of automated chores.

We can operate your smart home using the app, remotes, voice commands, or motion thanks to the hub's flawless integration into our house's design. It is made to be user-friendly for everyone, including visitors, of all ages.

IKEA offers a growing selection of smart items to expand our setup over time and updates the app often to improve the smart home experience.

- **Bosch Smart Home Controller 2nd Gen.**

Bosch Smart Home Controller II is a crucial part of the Bosch Smart Home ecosystem, serving as both hardware and software hub. It connects to various smart devices like thermostats and cameras and can integrate with third-party products. Users control it through a user-friendly app, web interface, or voice commands via popular voice assistants. It communicates using Wi-Fi, Zigbee, and Z-Wave.

Security and privacy are a priority with strong encryption. Regular updates enhance performance and security. It's energy-efficient and scales easily, making it the central unit for smart homes, providing control, security, and efficiency.

Smart Home Controller II ensures the security of our data, even when accessed remotely while we're on the go. We have the flexibility to either control our system exclusively within our home network or remotely to monitor its status.

- **Homebridge**

Homebridge is a lightweight NodeJS server that emulates the iOS HomeKit API. It allows users to integrate various smart home devices that do not natively support Apple's HomeKit into the HomeKit ecosystem. Homebridge facilitates a broad array of plugins from various developers, which enables the connection and control of non-HomeKit devices via your iOS devices.

Being open-source software, Homebridge allows for transparency, community input, and modification. Users can delve into the code, understand how it works, and even contribute to its development. This openness fosters innovation and enables continuous improvement of the platform.

Its open-source nature, extensive plugin support, and active community make it a unique and invaluable tool for smart home

enthusiasts, especially those invested in the Apple ecosystem.

c. Read the QR code on LG Cover's screen and click "Add to Home Assistant".

d. LG Cover is set to the user's Matter API devices.

## II. REQUIREMENTS

### A. Installing Hub

#### 1. Register LG Cover to ThinQ

To use non-Matter-supportive devices on home assistants as if they were Matter devices, LG Cover is to be registered to ThinQ app. The information regarding the device control function will be given to LG Cover to generate Matter-supportive QR code.

Registration procedure is as follows:

- a. In the ThinQ app, press '+' to add new devices. A camera screen that reads QR codes appears.
- b. Above the square frame for QR codes, click 'matter' button to add the LG Cover hub.
- c. Read the QR code on LG Cover's screen to register the hub to ThinQ app.
- d. LG Cover is set to ThinQ app.

#### 2. Register LG Cover to Matter API device

LG Cover needs to be connected to user's Matter API device to provide information from ThinQ app to home assistants such as Google Home, Apple Home, Alexa, and more. Matter API devices will recognize LG Cover as a Matter device and send or receive signals upon Matter protocols.

Registration procedure is as follows:

- a. In the home assistant application of the user's device, execute menu for adding new devices.
- b. Among the various ways and brands of devices, select 'Matter' or 'Add Matter device'. A camera screen that reads QR codes appears.

### B. Register device to LG Cover

Devices registered to ThinQ app can be operated from user's home assistant just like Matter devices via LG Cover. ThinQ and LG Cover is connected, and LG Cover, the bridge hub, mediates ThinQ and Matter API home assistants. Therefore, as users register their devices to Register devices to LG Cover using one of the following three methods according to the supported module for the device.

#### 1. Matter device

All matter devices use setup code, which is provided on the device, in the packaging, or in an app. Register the Matter device to ThinQ to control device through LG Cover. Matter devices can be registered to the Matter API device through ThinQ or directly to home assistants.

Registration procedure is as follows:

- a. In the ThinQ app, press '+' to add new devices. A camera screen that reads QR codes appears.
- b. Above the square frame for QR codes, click 'matter' button to add device.
- c. Read the QR code on the device to register the device to ThinQ app.
- d. Click "Connect through NFC" or "Connect through Pin" to connect the device by tapping on the NFC tag or manually entering the setup digits.
- e. Device is registered to ThinQ.

Registration procedure to home assistant is as follows:

- a. Read the QR code on the device.
- b. Page will be redirected to registration page for home assistant app.
- c. Click “Add to Home Assistant”.
- d. Device is registered to Matter API home assistant.

## 2. ThinQ device

LG appliances that support ThinQ can be registered easily on the app. Devices connected to ThinQ are automatically added to Matter devices via LG Cover acting as a bridge. Register the device to ThinQ to manage the device from home assistants through LG Cover. Registration procedure is as follows:

- a. In the ThinQ app, press ‘+’ to add new devices. A camera screen that reads QR codes appears.
- b. Read the QR code of the device or find the device from the list of products provided.
- c. Device is registered to ThinQ app.

## 3. Legacy Infrared(IR) device

Infrared supporting devices could or could not be LG’s products. If the device is not in LG’s database, IR signals should be recorded with IR receiver. If the device is LG’s product, IR signals would be listed in LG’s database. In this context, LG Cover must possess the capability to access the database of infrared signals associated with a particular device.

Devices that supports only infrared remote control can be registered to ThinQ and be managed by LG Cover.

Registration procedure is as follows:

- a. In the ThinQ app, click ”Add device by IR”.
- b. ThinQ requests for IR signals.
- c. User sends signals to LG Cover through

remote controllers or any kind of IR controllers.

- d. The name of the device will be set by smart matching or manually by user.
- e. The device is registered to ThinQ.

## C. Integration

LG cover is able to access ThinQ API via RESTful API. As new devices that do not support Matter protocol are registered to ThinQ app, LG Cover pulls users’s devices from ThinQ. The information can hold the name of the device and list of signals for device operation to be managed in Cover.

LG Cover receives information about the newly registered device. LG Cover is already linked to Matter API devices, or home assistants. Therefore, LG Cover mediates the newly registered device to home assistants and lets Matter API devices to recognize the device as a Matter-supporting device and communicate with the device using matter signals.

The user’s actions to trigger these operations and the corresponding signal flow are as follows:

### 1. Matter device

Devices that support Matter can be controlled directly from home assistants using Matter API.

### 2. ThinQ device

Communication from user to device can be processed as following:

- a. User sends a Matter signal through home assistant.
- b. LG Cover receives the Matter signal.
- c. LG Cover delivers the command to ThinQ API by network.
- d. ThinQ app receives the command from LG Cover and executes the command.

Communication from device to user can be processed as following:

- a. Device sends a signal to ThinQ through network.
- b. ThinQ receives the signal from device and LG Cover acquires the data from ThinQ API.
- c. LG Cover translates the signal and delivers the data to home assistant by Matter signal.
- d. Matter API device, home assistant, receives the data and conveys information.

### 3. IR device

Communication from user to device can be processed as following:

- a. User sends a Matter signal through home assistant.
- b. LG Cover receives signal via Matter.
- c. LG Cover indicates the Matter signal and transmits the corresponding IR signal for IR device to receive.

## D. Control device using LG Cover

### 1. Matter device

Matter devices provide simple and complicated control options available by Cover and home assistants.

Cluster is a group of functions, such as On/Off Cluster or Level Control Cluster. In general, user should be able to use a variety of clusters supported by home assistant, along with manufacturer-specified functions. Among the clusters supported by home assistant, some of the most common ones include On/Off, Open/Close, Color Control, Level Control, Temperature Measurement, and more.

Node encapsulates the full product and controls all endpoints of the particular device. Each endpoint includes clusters, and each cluster holds attributes and events.

Consider a device that belongs to On/Off Light

Switch Device Type, and holds two endpoints. Endpoint 1 includes the Server On/Off Cluster, and Endpoint 2 includes the Client On/Off Cluster.

The flow of an On/Off control is as follows:

- a. User clicks the On/Off button from home assistant.
- b. The Client Cluster controls the Server Cluster.
- c. Server Cluster triggers the command to turn on or turn off the switch.
  - i. If the OnOff attribute of the Node is “On”, the switch would be turned off.
  - ii. If the OnOff attribute of the Node is “Off”, the switch would be turned on.

### 2. ThinQ device

Complicated control functions of appliances can also be added to Matter API device in forms of shortcuts. Cover enables user selected commands be registered as shortcuts in the device, and user is able to execute the command by just one click.

Simple Control:

#### a. Turn On / Turn Off

User can turn on and turn off the matter device from home assistants by clicking “On/Off” button from the home assistant app or from user defined shortcuts.

Complicated Control:

#### a. Refrigerator Temperature

User can check the temperature of each section through home assistants.

User can set the temperature to personal preference through home assistants.

#### b. Washing Machine

Washing mode, water temperature, number of rinse, and other control functions can be set with home assistants.

### 3. IR device

#### a. LG product

LG holds information of all LG products. Therefore, all commands of IR devices are available even if the device does not support ThinQ. When LG IR device is registered to ThinQ through LG Cover, ThinQ can manage several commands of the device with LG Cover for Matter controls.

Simple Control:

##### i. Turn On / Turn Off

User can turn on and turn off the matter device from home assistants by clicking “On/Off” button from the home assistant app or from user defined shortcuts.

Complicated Control:

##### i. Air conditioner

###### A) Wind direction

Direction of the be wind, from top to bottom, left to right, can set through home assistants.

###### B) Wind temperature

Increase and decrease in wind temperature can be set through home assistants.

###### C) Operation Mode

Operation mode such as Air-conditioning, dehumidification, and heating can be set through home assistants.

##### ii. TV

###### A) Remote Controller

Sound, channels, and other control functions can be set with home assistants.

#### b. Non-LG product

Information of IR devices of other

manufacturers is not available by LG. Therefore, when the device is registered to ThinQ through LG Cover, information to be sent is very limited. Only simple control functions can be registered to Cover.

##### i. Turn On / Turn Off

User can turn on and turn off the matter device from home assistants by clicking “On/Off” button from the home assistant app or from user defined shortcuts.

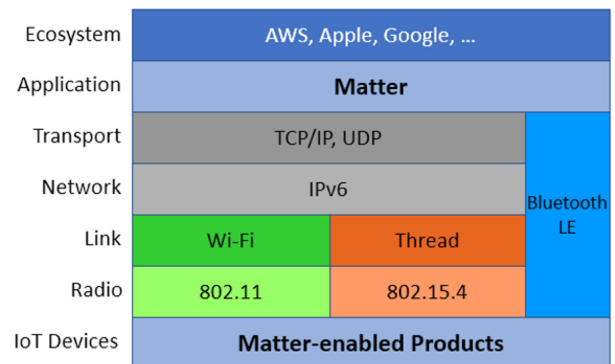
### E. Default display of LG Cover

When the LG Cover is not in progress of connecting devices, LG Cover displays date and time, temperature, and humidity on the screen.

## III. DEVELOPMENT ENVIRONMENT

### A. Choice of hardware development environment

#### • Consideratoins for Matter



#### • Requirements for Matter

As you can see from Matter’s formal name CHIP (Connected home IP) it runs on existing IP. However, there is bit of difference in PHY layer that it could use Thread running on IEEE 802.15.4 radio instead of WiFi on IEEE 802.11 radio.

For Matter enabled devices and especially a Matter hub that connects with various devices, most likely it would require 802.11, 802.15.4 and BLE connectivity. It would be very cost prohibitive and detrimental to implement various radios one by one with generic off



the shelf 8 bit microcontroller such as AVR or PIC, and workload required for matter is questionable for it to run on old, almost deprecated 8bit MCUs of past. While we could use 32 bit microcontroller such as ARM cortex lineup to solve the processor performance issue, it would still leave the issue of having to implement such radios.

It would be much better off with dedicated SoC with everything needed implemented, ready to go. While designing customized chip is completely outside of this scope, thankfully there already exists a MCU supporting Wifi, Thread, and BLE in one single convenient package; ESP32 series.

- ESP32

ESP32 is a series of low-cost, low-power system on a chip microcontrollers with integrated Wi-Fi and dual-mode Bluetooth. The ESP32 series employs either a Tensilica Xtensa LX6 microprocessor in both dual-core and single-core variations, Xtensa LX7 dual-core microprocessor or a single-core RISC-V microprocessor and includes built-in antenna switches, RF balun, power amplifier, low-noise receive amplifier, filters, and power-management modules. ESP32 is created and developed by Espressif Systems, a Chinese company based in Shanghai, and is manufactured by TSMC using their 40 nm process. It is a successor to the ESP8266 microcontroller.

Since the release of the original ESP32, a number of variants have been introduced and announced. They form the ESP32 family of microcontrollers. These chips have different CPUs and capabilities, but all share the same SDK and are largely code-compatible.

A minimal table to compare the Espressif's MCU families.

While ESP32-C6 seems like a best choice since it has 802.15.4 capability, It is currently logistically difficult to get a development board. So we had to opt for ESP32-S3, while lacking 802.15.4 support, as current state of 802.15.4 Thread have long way to go before going mainstream we concluded it was not vital.

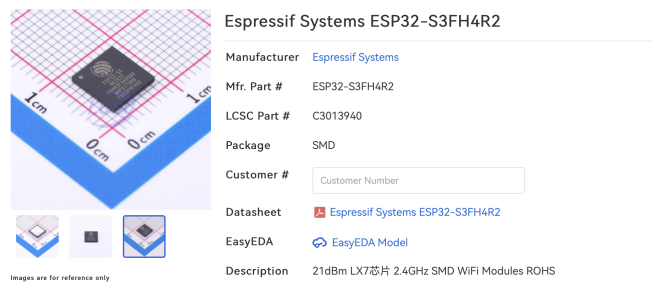
**ESP32-S3** is a dual-core Xtensa LX7 MCU, capable of running at 240 MHz. Apart from its 512 KB of internal SRAM, it also comes with integrated 2.4 GHz, 802.11 b/g/n Wi-Fi and Bluetooth 5 (LE) connectivity that provides long-range support. It has 45 programmable GPIOs and supports a rich set of peripherals. ESP32-S3 supports larger, high-speed octal SPI flash, and PSRAM with configurable data and instruction cache.

As we are not just building a virtual docker image, there is some considerations that have to be made.

- ESP32-S3 module

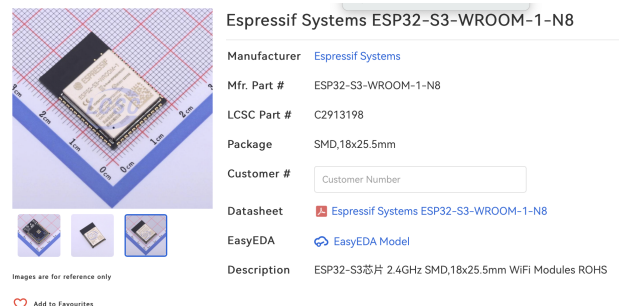
ESP32-S3 comes in different form factors, but there is mainly two. One being just a bare chip in QFN56 package, and another being with basic components laid out in PCB with antenna and RF shield.

## 1. ESP32-S3



- very difficult to design RF PCB
- could lead to sub-optimal design
- not FCC certified

## 2. ESP32-S3-WROOM-1



- Easier to implement
- have ready made pcb / rf shield
- FCC certified
- easier to meet local RF regulation laws

Ordering Code	Flash	PSRAM
ESP32-S3-WROOM-1-N4	4 MB (Quad SPI)	-
ESP32-S3-WROOM-1-N8	8 MB (Quad SPI)	-
ESP32-S3-WROOM-1-N16	16 MB (Quad SPI)	-
ESP32-S3-WROOM-1-H4	4 MB (Quad SPI)	-
ESP32-S3-WROOM-1-N4R2	4 MB (Quad SPI)	2 MB (Quad SPI)
ESP32-S3-WROOM-1-N8R2	8 MB (Quad SPI)	2 MB (Quad SPI)
ESP32-S3-WROOM-1-N16R2	16 MB (Quad SPI)	2 MB (Quad SPI)
ESP32-S3-WROOM-1-N4R8	4 MB (Quad SPI)	8 MB (Octal SPI)
ESP32-S3-WROOM-1-N8R8	8 MB (Quad SPI)	8 MB (Octal SPI)
ESP32-S3-WROOM-1-N16R8	16 MB (Quad SPI)	8 MB (Octal SPI)

- **Wi-Fi + Bluetooth 5 (LE)**  
ESP32-S3 supports a 2.4 GHz Wi-Fi (802.11 b/g/n) with 40 MHz of bandwidth support. The Bluetooth Low Energy subsystem supports long range through Coded PHY and advertisement extension. It also supports higher transmission speed and data throughput, with 2 Mbps PHY. Both Wi-Fi and Bluetooth LE have superior RF performance that is maintained even at high temperatures.
- **Mature Software Support**  
ESP32-S3 is supported through Espressif's popular ESP-IDF platform that already powers millions of devices on the market. ESP-IDF comes with rigorous testing, regular updates and an unparalleled support policy. Based on ESP-IDF's mature software architecture, developers can easily build applications anew or migrate their own applications to the ESP32-S3 platform, and continue working with the trusted ESP-IDF tools and APIs.
- **Security**  
ESP32-S3 provides all the necessary security requirements for building securely connected devices, without requiring any external components. It supports AES-XTS-based flash encryption, RSA-based secure boot, digital signature and HMAC. ESP32-S3 also has a

“World Controller” peripheral that provides two fully-isolated execution environments, which enables the implementation of a trusted-execution environment or a privilege-separation scheme.

## B. Choice of software development platform

### 1. Development Platform

#### a. Linux

Linux is based on the Unix operating system which supports a wide range of programming languages, tools, and frameworks. The operating system is used for server environments, desktop applications, and embedded systems development, among others. Linux's command-line utilities are particularly well-suited for working with development boards and IoT devices. Linux is apt for IoT development due to its performance and the extensive community support available for troubleshooting and enhancements.

#### b. macOS Monterey

macOS Monterey is Apple Inc.'s desktop operating system for Macintosh computers. It is compatible with many development tools, languages, and frameworks essential for different kinds of software development, including web development, mobile app development, and hardware programming.

### 2. Language and Framework

#### a. Espressif ESP-IDF

ESP-IDF is Espressif's official IoT Development Framework for the ESP32, ESP32-S, ESP32-C and ESP32-H series of SoCs. It provides a self-sufficient SDK for any generic application development on these platforms. ESP-IDF currently powers millions of devices in the field, and empowers building a variety of network-connected products, ranging from simple light bulbs to big appliances and industrial devices. ESP-IDF runs on the FreeRTOS operating system,

with modifications to better support the SoC's features and capabilities. It uses C as the programming language and provides a suite of development tools for flashing the SoC, monitoring output, and debugging. Various components, component level configuration, and command line support of ESP-IDF enables developers to build their projects at ease.

b. C/C++

C is a procedural high-level programming language that is designed to provide efficient access to memory and language constructs that map efficiently to machine instructions. C++ supports both procedural and object-oriented programming paradigms, and provides features such as overloading, templates, and exceptions, which are not available in C. The core components of ESP-IDF and the APIs provided for interacting with the ESP32 hardware are written in C. This allows for efficient interaction with the hardware and is suitable for the resource-constrained environments typically associated with embedded systems. The framework provides support for C++ exceptions and other features, allowing developers to leverage the object-oriented aspects of C++ in their ESP32 projects.

c. xtensa-esp-elf

xtensa-esp-elf is a toolchain for 32-bit Xtensa microcontrollers, based on GCC. It provides all the necessary tools to transform high-level code into a binary form that the microcontroller can execute, handling the specifics of the Xtensa architecture, including its custom instructions and configurations. xtensa-esp-elf includes a collection of binaries such as an assembler, linker, and archiver that prepare the code for execution on the microcontroller. The compiler, xtensa-esp-elf-gcc, is the customized version of GCC provided by Espressif, tailored specifically for the Xtensa architecture of ESP32 and ESP32-S series. It allows developers to compile C and C++ code into efficient

machine language that can run directly on the low-level hardware. This version of GCC has been optimized to harness the unique features and capabilities of the ESP32's processor, ensuring that developers can maximize performance for a variety of applications, from simple IoT devices to complex networking systems, while leveraging the rich set of features and the robust development framework provided by ESP-IDF. Since the Xtensa cores are different from the architecture of a typical development computer (x86\_64 or arm), the xtensa-esp-elf-gcc performs cross-compilation, generating executable code for a different architecture than that of the build host. The xtensa-esp-elf toolchain is versatile and supports development across multiple operating systems, including Linux, macOS, and Windows, thus enabling a wide range of developers to create applications for Espressif's hardware platforms regardless of their preferred development OS.

d. React Native

React Native is an open-source framework developed by Facebook for creating native-style mobile apps using React and JavaScript. It enables developers to build applications for multiple platforms, including iOS and Android, with a single codebase, leveraging a rich ecosystem of libraries and tools. Its component-based structure allows for the reuse of code across different platforms, while maintaining the ability to integrate with native functionality and third-party libraries. The framework's live and hot reloading capabilities significantly enhance developer productivity, and its large community provides strong support, with contributions extending its reach to platforms like Windows and macOS. Given these benefits, a significant number of developers opt for React Native to create mobile applications that deliver a native user experience with the agility of web app development.

e. Go

Go, often referred to as Golang, is a programming language created at Google and derived from the syntax of the C language, aiming to make development simple, efficient, and readable. The language supports a wide array of programming paradigms, including concurrent, functional, and object-oriented styles. Go is used for backend systems, cloud computing, and DevOps tools, and others. Go's built-in concurrency support, along with its powerful standard library and garbage collection, makes it particularly well-suited for building fast, scalable network servers and distributed systems. Owing to Go's supporting features, Go has become a preferred choice among developers for managing backend systems.

### *C. Software in use*

#### 1. LG ThinQ, LG SmartHome Application

The LG ThinQ app is a smart application designed to connect, manage, and communicate with LG smart appliances, providing users with a seamless and intuitive way to ensure their devices operate smoothly. It allows for remote monitoring and control of LG appliances, offering features such as laundry cycle tracking, refrigerator management, and the ability to send cooking instructions to ovens. Integration with voice assistants like Google Assistant and Alexa further enhances the user experience, enabling voice commands for convenience. The app's Smart Diagnosis and proactive alerts system aid in maintaining appliance health, alerting users to potential issues and facilitating troubleshooting. Additionally, ThinQ UP feature keeps appliances up-to-date with the latest software, allowing for personalization and enhanced functionality tailored to users' lifestyles and preferences, underscoring LG's commitment to smart home innovation and user-centric design.

#### 2. VSCode (Visual Studio Code)

Visual Studio Code (VSCode) is a free, open-source code editor developed by Microsoft, renowned for its performance, extensibility,

and support for a wide range of programming languages and tools. It combines simplicity with powerful developer tooling, like built-in Git commands, a robust debugging suite, and IntelliSense for smart code completion. Its lightweight design ensures smooth operation, while extensions available through its marketplace allow developers to customize and enhance their coding environment to suit a multitude of workflows. This flexibility, coupled with features like live share for collaborative coding and a built-in terminal, has made VSCode a popular choice among developers across disciplines, from web development to data science and beyond.

#### 3. GitHub

GitHub is a web-based platform that provides hosting for software development version control using Git, facilitating collaborative coding from contributors worldwide. It acts as a repository hosting service, allowing developers to share their code, track changes, and manage versions with robust version control and collaboration features. GitHub extends Git's functionality with its own features, such as issue tracking, feature requests, task management, continuous integration, and wikis for project documentation. It has become an essential tool for both open-source and private software projects, creating a community that fosters learning, sharing, and collaboration on a global scale. GitHub's impact is substantial, providing a nexus for software development and a repository for a vast array of projects across different fields and technologies.

#### 4. Figma

Figma is a cloud-based design tool that specializes in user interface and user experience design with real-time collaboration. It stands out for its intuitive interface and vector-based graphics, which are pivotal in modern web and mobile application design. As a browser-based tool, it allows designers to work on projects from anywhere, share their work instantly, and receive feedback dynamically. Teams can simultaneously edit projects, significantly

streamlining the design process. Figma supports the entire design journey—from wireframing to prototyping to delivering final assets—all within the same environment. Its component system and design libraries enable consistency across designs, while plugins and integrations enhance its functionality. This all-encompassing solution has made Figma a go-to tool for designers, product teams, and organizations looking to create and iterate on designs efficiently.

## 5. LaTeX

LaTeX is a high-quality typesetting system; it includes features designed for the production of technical and scientific documentation. It is the de facto standard for the communication and publication of scientific documents in many fields, including mathematics, computer science, engineering, physics, chemistry, and economics. LaTeX is based on the TeX typesetting system, and it excels at complex documents that contain a lot of mathematics, references, citations, and cross-referencing. Rather than focusing on the appearance of the document directly, it encourages authors to concentrate on its structure by defining commands that describe the logical structure of a document. These commands are compiled to produce a beautifully formatted document in PDF or other formats, with high typographical quality, suitable for academic and professional publication. LaTeX is widely used in academia for the submission of scientific papers and is available as free software.

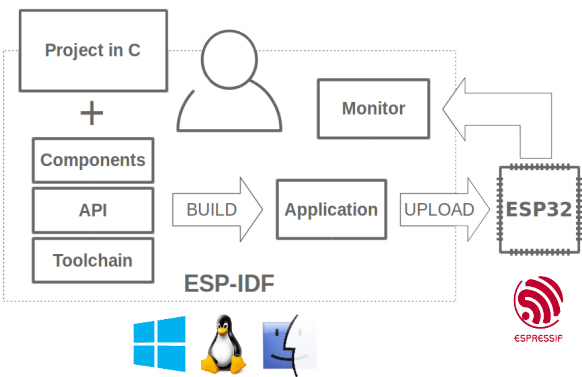
## 6. Notion

Notion is an all-in-one workspace application designed to integrate notes, tasks, wikis, and databases into a single, user-friendly interface, promoting productivity and organization for both personal and professional use. It offers a highly flexible environment where users can create custom pages and databases with rich content types, such as text, images, checklists, and links, and connect these elements in a modular way. Notion's powerful organizational tools, including nested pages, tagging, and sorting, allow for detailed

knowledge management and project tracking. Its collaborative features enable real-time teamwork and sharing, making it popular among remote teams, students, and individuals seeking a centralized platform to manage their work and studies. With its sleek design and versatile functionality, Notion stands out as a multifaceted tool that adapts to various workflows and simplifies the integration of diverse information and task management.

## D. Specification

### • ESP-IDF



## E. Cost

Name	Price	Quantity
ESP32-S3	3 dollars	1
Laptop	1000 dollars	1
Apple TV 4k	150 dollars	1

## IV. SPECIFICATION

### A. System Requirements

#### 1. Installation and Registration of LG Cover to ThinQ App

##### a. ThinQ App Registration

- User opens ThinQ app and taps the '+' to add a new device.
- User selects the 'matter' button to add the LG Cover hub.

- iii. User scans the QR code on LG Cover's screen to register the device.

#### b. Matter API Device Registration

- i. User opens the home assistant app and navigates to add a new device section.
- ii. User selects 'Matter' or 'Add Matter device'.
- iii. User scans the QR code on LG Cover's screen and confirms the addition to the home assistant.

### 2. Registration of LG Cover to Matter API Device

#### a. Matter Devices

- i. Added via the ThinQ app using the device's QR code or setup code.
- ii. Can also be registered directly to home assistants.

#### b. ThinQ Devices

- i. Devices supporting ThinQ are automatically registered to LG Cover through the ThinQ app by scanning the QR code or selecting from a list.

#### c. Legacy IR Devices

- i. Added by sending IR signals to LG Cover via remote controllers, which are matched to the device or manually set by the user.

### 3. Device Registration Procedures

- i. LG Cover pulls device information from ThinQ and relays it to the home assistants.
- ii. Matter devices communicate directly using Matter API.

- iii. ThinQ devices send and receive commands via the ThinQ app and LG Cover.

- iv. IR devices are controlled by converting Matter signals to IR signals via LG Cover.

### 4. Control Device Using LG Cover

#### a. Matter Devices

- i. Controlled by clusters and nodes for various functions through the home assistant.

#### b. ThinQ Devices

- i. Simple and complicated controls are supported, with shortcuts for frequently used commands.

#### c. IR Devices

- i. **LG products:** Full range of commands available for control via LG Cover.
- ii. **Non-LG products:** Limited to simple controls such as power on/off.

### 5. Default Display for LG Cover

- i. Displays date, time, temperature, and humidity when not in device connection mode.

### B. Technical Specifications

1. **Connectivity:** Wi-Fi, NFC, Infrared (IR), and Matter protocol support.
2. **Compatibility:** Works with LG and non-LG devices that support ThinQ, Matter, or IR.
3. **Security:** Must use secure connections and encrypted communications.
4. **APIs:** RESTful API for ThinQ for backend integration; Matter API for device

communication.

5. **User Interface:** ThinQ app for setup and control; home assistant interfaces for ongoing interaction.
6. **Power:** Must support standard household power requirements and include power-saving modes.

#### *C. User Documentation*

1. Compliance with Matter standards.
2. Secure QR code generation and scanning.
3. Robust error handling for failed device additions or communications.
4. Thorough testing with various brands and types of devices to ensure compatibility.

#### *D. Quality Assurance*

1. Detailed setup guide for LG Cover and device registration.
2. Troubleshooting tips for common issues during setup or use.
3. Contact information for support.

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