# Analog Portable Graphic Equalizer

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# CONCEPT OF OPERATIONS

REVISION – 1
10 October 2022

# CONCEPT OF OPERATIONS
# FOR
# Analog Portable Graphic Equalizer

Team GrAPE

APPROVED BY:

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Project Leader Date

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Prof. Kalafatis Date

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T/A Date

# Change Record

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# 1. Executive Summary

During events or large gatherings, the use of audio processing devices such as equalizers is typically used to provide quality audio entertainment. Frequently, equalizers have installed applications and often receive and deliver audio signals through wired connections. The graphic analog portable equalizer (GrAPE) differs from typical analog equalizers by the main features being audio signal processing via Bluetooth and its portability. The GrAPE will be a graphic analog portable equalizer that will consist of at least ten frequency bands between 0Hz to 20kHz. The gain of these frequency bands will be adjusted with the help of sliders physically on the device. The input and outputs for the GrAPE will operate via Bluetooth with the additional ability to use an auxiliary connection at the output. The size of the GrAPE will be designed to be small enough to fit into small carriers, such as backpacks. The goal of the GrAPE is to provide its users with a low-budget quality audio processor that provides portability and accessibility.

# 2. Introduction

This document is an introduction to the GrAPE, a graphic analog portable equalizer, that will provide its users with a low-budget quality audio processing system. The graphic equalizer will serve as a tool to enhance the performance of an audio system by controlling the gain of various frequency bands, which are physically displayed on the device with sliders. The input and outputs of the graphic equalizer will function via Bluetooth with the additional feature of having an auxiliary connection at the output stage of the device.

## *2.1. Background*

Equalizers are audio processing devices that are widely used in audio systems. The use of equalizers has become standard in modern audio applications; whereas before, equalizers were used mostly in telephones to enhance the intelligibility of the speech signal in the 1930s by flattening out the audio response [1]. However, equalizers are used today to enhance the performance of the system by allowing one to choose whether to increase or decrease chosen frequency gains, rather than just flattening.

There are two main types of equalizers: parametric and graphic. Parametric equalizers allow the user to control the gain, center frequency, and bandwidth of the equalizer filters separately. These equalizers are known for being flexible due to the number of factors a user can control. However, the knowledge level needed to efficiently utilize parametric equalizers is high, therefore experts and engineers mostly utilize these types of equalizers. Graphic equalizers, on the other hand, allow the user to control the gain of various frequency bands, while the center frequency and the bandwidth are fixed, leaving the user to only control the gain of a specific frequency band. Since graphic equalizers are less intricate and require less training than parametric equalizers, they are used more frequently by the general public.

Graphic equalizers are generally built to be used through installed applications and typically are not portable. In addition, the input and output of the most common graphic equalizers are completely analog instead of wireless. This is where the GrAPE differs from typical equalizers; as the GrAPE will be built to be portable, and the input/output will operate via Bluetooth with the option of an auxiliary connection at the output. The GrAPE is set to provide its users with a relatively low-budget quality audio processing device that is portable and accessible.

## 2.2. Overview

The system for the analog portable graphic equalizer will operate with a single input from a smartphone device via Bluetooth receiver and a dual output: Bluetooth transmitter and auxiliary. The GrAPE will require two microcontrollers: digital-to-analog (DAC) and analog-to-digital (ADC). The GrAPE user interface includes a set of at least ten sliders on the housing. The main signal processor, as seen in Figure 1, will set the frequency bandwidths; then, for each bandwidth, it will alter the gain to the desired level and fix each frequency center.

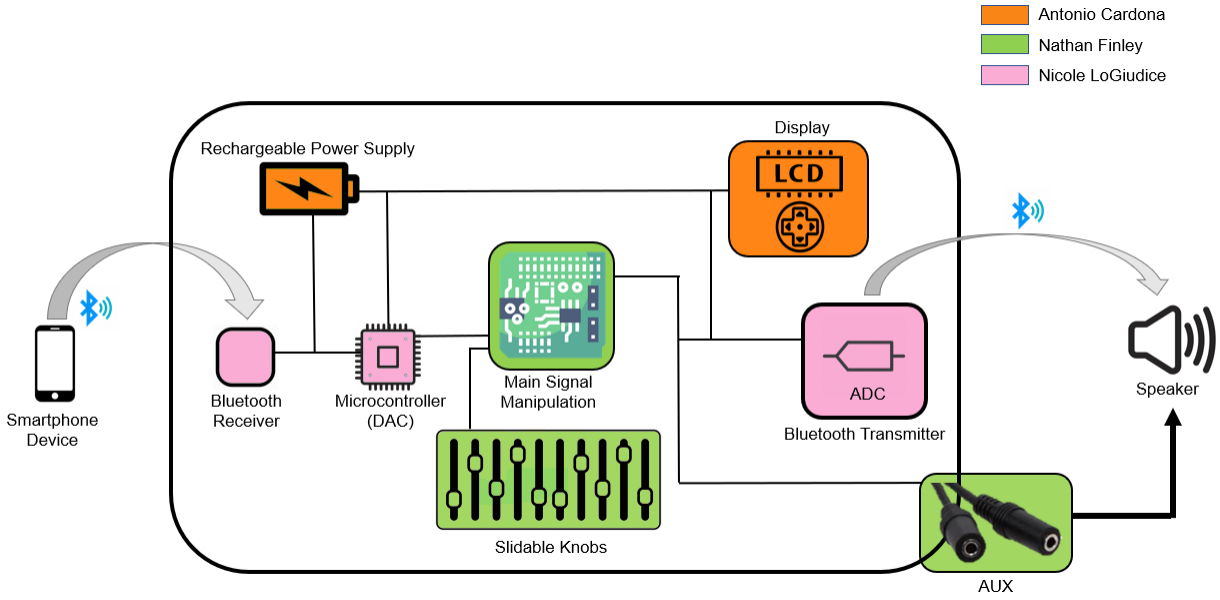


***Figure 1:*** *Analog Portable Graphic Equalizer Diagram*

## 2.3. Referenced Documents and Standards

[1] J. Rämö, V. Välimäki and B. Bank, "High-Precision Parallel Graphic Equalizer," in IEEE/ACM Transactions on Audio, Speech, and Language Processing, vol. 22, no. 12, pp. 1894-1904, Dec. 2014, doi: 10.1109/TASLP.2014.2354241.

# 3. Operating Concept

## *3.1. Scope*

The graphic analog portable equalizer will operate as a standard analog equalizer with at least ten frequency-tuning sliders, an attached LCD to visualize frequency strengths, Bluetooth input, and output connectivity, and an internal power source. The above functionality will fit inside an enclosure no larger than the capacity of a backpack. A continuous phone-transmitted Bluetooth signal containing audio data will be received, manipulated as per the settings of the frequency sliders, and then transmitted to any device for playback (via Bluetooth or auxiliary). Signal processing and transmission will be designed to occur concurrently with signal reception and latency will be minimized so that the GrAPE can tune “live” music and a user needn’t wait a significant time for playback. Though the current market has plenty of analog equalizer equipment to choose from, the additional LCD and Bluetooth features distinguish the GrAPE as a device that could benefit users who desire frequency-tuned audio but require wireless transmission.

## *3.2. Operational Description and Constraints*

The GrAPE is purely an audio modification and transmission device. The Bluetooth connectivity allows for one transmission device, a phone; and two reception devices, any speaker that has Bluetooth or auxiliary input capabilities. When a song is played on a device through a Bluetooth connection to the equalizer, a powered-on speaker that is also connected to the GrAPE will begin to produce the audio that has been altered to desired specifications. When using Bluetooth output connectivity, for the system to operate correctly, the user must ensure two connections:

1. A Bluetooth connection from the phone to the GrAPE
2. A Bluetooth connection from the GrAPE to the desired speaker.

For Bluetooth output, the equalizer will first search for available receivers, then the user will be able to select the desired output receiver. Ultimately, the equalizer will be able to transmit its audio signal directly to any speaker that has Bluetooth or auxiliary input.

The constraints of our proposed design are as follows:

- The Bluetooth connectivity features will prohibit long-distance signal transmission; any devices connected via Bluetooth to the equalizer will need to maintain close proximity in order to ensure the stability of said connection.
- Since the original signal needs to be transmitted *at least once,* via Bluetooth input and if Bluetooth output is utilized, as well as processed within the GrAPE, through filters, higher-than-normal latency is to be expected.

Since the original signal might need to be transmitted *twice*, higher-than-normal interference/noise is likely to make the signal more muddy. The ultimate audio quality will not likely compare to optimized devices with line-in connections.

## *3.3. System Description*

The architecture of the system is as follows:

- Signals
  - Bluetooth receiver
    - Accepts the received Bluetooth signal and sends to the input microcontroller.
  - Input microcontroller
    - Receives data from: sliders, on/off button, Bluetooth receiver
    - Converts signal from digital to analog.
    - Sends data to: main signal processor
  - Main signal processor
    - Receives data from: input microcontroller
    - Frequency bands' gain altered to desired level, specified by sliders.
    - Sends data to: output microcontroller
  - Output microcontroller
    - Receives data from: main signal processor
    - Converts signal from analog to digital (only if output is via Bluetooth)
    - Sends data to: LCD, Bluetooth transmitter, auxiliary port
  - Bluetooth transmitter (optional)
    - Sends the digital signal from the output microcontroller to the desired output device.
- Power
  - Battery
    - Connects to all internal components that require their own power source

## *3.4. Modes of Operations*

There are only two modes of operation of the GrAPE: on and off. When off, no power is delivered to the internal components by the battery and there is no flow of data within the device. When on, the GrAPE operates in the fashion described by "Operation description and constraints."

## *3.5. Users*

The GrAPE's capabilities are designed to fit the needs of people who want to experience the performance of a standard equalizer, but desire wireless and wired output connection for widespread usability. The equalizer will have the capability to be used in settings that require a Bluetooth and/or auxiliary connection to speakers. Settings of potential use include:

- Amateur DJs
- Small-scale events that require a low budget and simple usability

## *3.6. Support*

A user manual will be provided as a component of each GrAPE. The manual will describe the basic operations of the GrAPE so that any minor malfunctions can be repaired by the user or a third party. Additionally, the user manual will explain the process to connect the phone to the GrAPE and the GrAPE to the speaker via Bluetooth or auxiliary.

# 4. Scenarios

## *4.1. Power Sourcing and User Interface*

The GrAPE's power supply will be battery-powered to allow for portability. The power supply will consist of any necessary buck and boost converters to match the required input power/voltage levels of subsystems. The user interface will include, but may not be limited to, a LCD illustrating the gain alterations pertaining to each frequency bandwidth.

## *4.2. Main Signal Processing*

The main signal processor will alter the input analog signal from the input microcontroller as per the settings of the sliders and send this altered signal to the 1) output microcontroller to be transmitted via Bluetooth, or 2) output through auxiliary. The main signal processor's purpose is primarily to interface the inputs of the sliders with the audio signal. The sliders will determine what gain will be executed on the audio signal via the main signal processor.

## *4.3. Housing and Bluetooth Input/Output Connectivity*

The analog graphic equalizer will be portable, therefore small enough to carry in a backpack because of its potential to be used in many different settings and make for easy transportation. Furthermore, because the device could be used in a wide variety of locations, it needs to be easily adaptable to the technology that is available in each setting. Therefore, the equalizer will be Bluetooth-compatible for input and output while also having an auxiliary output option for wired sound systems.

# 5. Analysis

## *5.1. Summary of Proposed Improvements*

- The equalizer will be portable, therefore small enough to carry inside a backpack, and will have its own power supply.
- The different frequencies will be identified through at least 10 different groupings from 0Hz-20kHz.
- The adjustments of each frequency group's gain will be manually set by the person using the equalizer.
- The user will be able to connect the equalizer to their phone and any sound equipment through Bluetooth.
- The equalizer will also allow for an auxiliary connection for wired output to allow for a greater range of sound equipment capabilities and less noise in the music.
- The selection of desired output connection type, Bluetooth or auxiliary, will be a manual input from the user.

## 5.2. Disadvantages and Limitations

- Due to budget constraints, the equalizer will not be designed to be waterproof.
- With the only input signal to the equalizer being digital (Bluetooth) the output sound quality through the auxiliary connection will never be as clean as a completely analog design.
- The devices connected to the equalizer need to be in close proximity when connected by Bluetooth in order to preserve sound quality and connection.
- Because data needs to be received *and* transmitted, latency will be higher than an auxiliary connection.

## 5.3. Alternatives

- Store-bought analog equalizers.
- Input to the equalizer could also include auxiliary input to allow for a completely analog design and better sound quality.
- The non-wired connection between devices could be achieved through Wi-Fi connection.
- Digital equalizers through computers or phones.

## 5.4. Impact

- Batteries are used to power the equalizer and create landfill waste when they are thrown away.
- The device will not track/record what frequencies are being altered or what songs are played.
- Bluetooth connectivity is wireless and therefore has a risk of being hacked.

# Audio Portable Graphic Analog Equalizer

Antonio Cardona
Nathan Finley
Nicole LoGiudice

# FUNCTIONAL SYSTEM REQUIREMENTS

REVISION - Draft
02 October 2022

# FUNCTIONAL SYSTEM REQUIREMENTS
FOR
# Audio Portable Graphic Analog Equalizer

PREPARED BY:

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Author Date

APPROVED BY:

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Project Leader Date

_____
John Lusher, P.E. Date

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T/A Date

# Change Record

| Rev. | Date | Originator | Approvals | Description |
|---|---|---|---|---|
| Draft | 10/02/2022 | Antonio Cardona<br>Nathan Finley<br>Nicole LoGiudice | | Draft Release |

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# 1. Introduction

## *1.1. Purpose and Scope*

Music is used for many purposes: parties, socials, education, emotion, skill. Since music is used in such a wide range of areas, many people prefer to alter the gain of certain frequencies to make the audio sound better in the setting they intend to use it in with an equalizer. However, many equalizers are expensive and digital. The Graphic Analog Portable Equalizer, GrAPE, will be a low priced, quality analog audio equalizer. The low price will allow a wider range of buyers to use the product while still allowing for good audio quality as an analog device. What sets the GrAPE apart from other equalizers is that it will allow for Bluetooth input and output. On the other hand, if the user wants to have a completely analog equalizer, the GrAPE should have an auxiliary input and will have an auxiliary output. Overall, the GrAPE will adjust the gain of each frequency band pertaining to what is input. The user also may have the ability to adjust the left and right channels' gains and the overall gain.

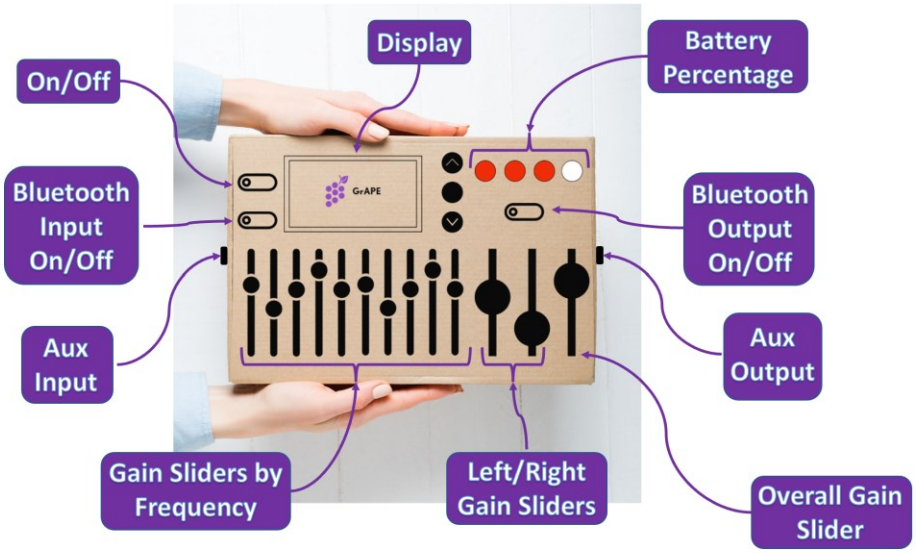


**Figure 1. Conceptual Image of the GrAPE**

## *1.2. Responsibility and Change Authority*

Our team leader, Antonio Miguel Cardona Pena, will be responsible for ensuring the responsibilities for the project are completed on time and correctly. If any responsibilities are to be changed, the approval of the team leader and sponsor, Max Lesser, are needed.

**Table 1: Subsystem Breakdown**

| Subsystem | Team Member Responsible |
|---|---|
| **Power Supply** | Antonio Cardona |
| **Main Signal Manipulation** | Nathan Finley |
| **Auxiliary** | Nathan Finley |
| **Bluetooth Input/Output** | Nicole LoGiudice |
| **User Interface** | Antonio Cardona |

# 2. Applicable and Reference Documents

## *2.1. Applicable Documents*

The following documents, of the exact issue and revision shown, form a part of this specification to the extent specified herein:

| Document Number | Revision/Release Date | Document Title |
|---|---|---|
| N/A | 7/20/2022 | ESP32-WROVER-E & ESP32-WROVER-IE |

## *2.2. Reference Documents*

The following documents are reference documents utilized in the development of this specification. These documents do not form a part of this specification and are not controlled by their reference herein.

| Document Number | Revision/Release Date | Document Title |
|---|---|---|
| IEEE 1241-2010 | June 22, 2001 | IEEE Standard for Terminology and Test Methods for Analog-to-Digital Converters |
| IEEE 370-2020 | January 8, 2021 | IEEE Standard for Electrical Characterization of Printed Circuit Board and Related Interconnects at Frequencies up to 50 GHz |

## *2.3. Order of Precedence*

In the event of a conflict between the text of this specification and an applicable document cited herein, the text of this specification takes precedence without any exceptions.

All specifications, standards, exhibits, drawings or other documents that are invoked as “applicable” in this specification are incorporated as cited. All documents that are referred to within an applicable report are considered to be for guidance and information only, except ICDs that have their relevant documents considered to be incorporated as cited.

# 3. Requirements

## *3.1. System Definition*

The GrAPE, a graphic analog portable equalizer, is a Bluetooth-based graphic equalizer that provides portability and ease of use to its users. The GrAPE has 3 subsystems: Power Supply and User Interface, Main Signal Manipulation and Auxiliary, and Bluetooth Input/Output Connectivity. Figure 2 shows a block diagram of the GrAPE and how these subsystems will interact with each other.

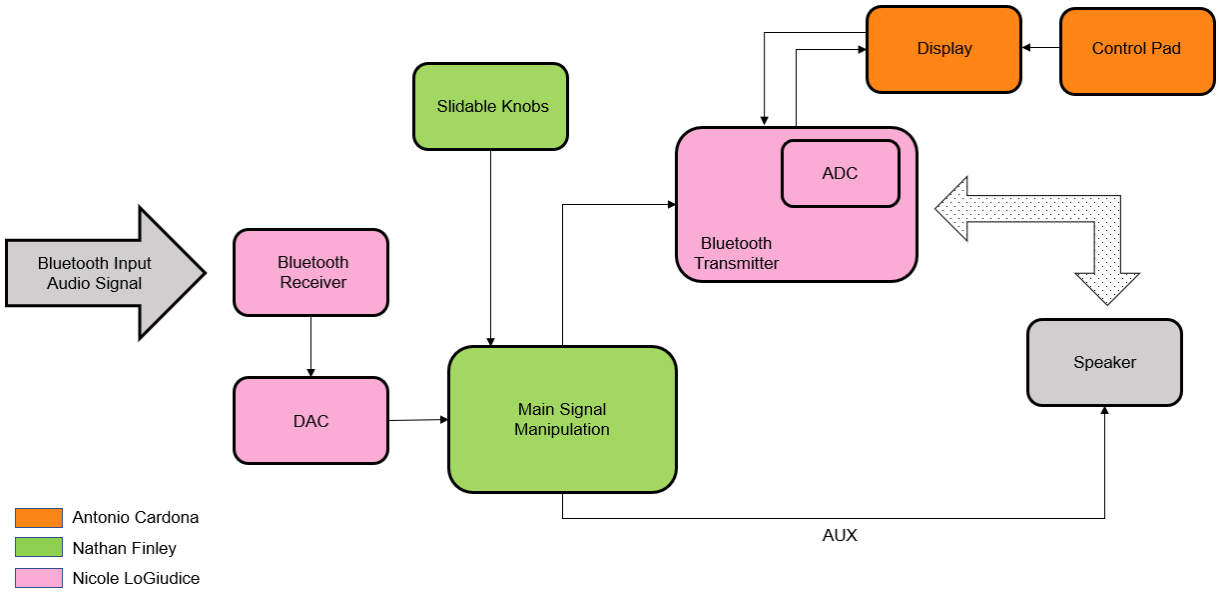


**Figure 2. Block Diagram of System**

The GrAPE will receive a Bluetooth input signal via a smartphone device, and it will output a manipulated audio signal to a speaker either via Bluetooth or Aux. The input audio signal will be received by a Bluetooth receiver and passed by a DAC. The analog signal from the DAC will then pass by the main signal manipulation system. The main signal manipulation system will have 10 frequency channels for each left and right signal. The slidable knobs will alter the frequency gain of a specific channel pair. The signal from the main signal manipulation system will then pass through either an Aux (for analog purposes) or an ADC (for Bluetooth purposes) depending on the user's preference for output.

If Bluetooth output is desired, the signal will pass through the ADC. The ADC will work concurrently with the display to effectively connect to a Bluetooth speaker. First, the available receivers (i.e., a speaker) will be shown on the display, then the user will select via the control pad a receiver to which they wish to connect to, then the ADC will output the Bluetooth audio signal to the selected receiver. On the other hand, if analog output is desired, the signal from the main signal manipulation system will deliver the output audio signal to the speaker via an auxiliary connection.

## *3.2. Characteristics*

### 3.2.1. Functional / Performance Requirements

#### 3.2.1.1. Bluetooth Connectivity Range

Bluetooth connectivity to the GrAPE for input and output will be at least 10 meters.

*Rationale: The connectivity range for the GrAPE must be far enough for its users to comfortably use the GrAPE without having to worry about the distance between their phone (input) and speaker (output) to the GrAPE. Note this is solely for the Bluetooth output of the GrAPE. The analog output to the speaker will be limited by the length of the Aux cord connected between devices.*

#### 3.2.1.2. Wireless Connection Stability

Bluetooth connectivity to the GrAPE will not drop more than 1 time per 5 minutes.

*Rationale: Since the GrAPE is an audio processing device, wireless connection stability is important for its users. The output audio signal must be continuous with as little to no connectivity issues.*

#### 3.2.1.3. Bluetooth Receiver & DAC

Bluetooth receiver receives the audio signal from an external transmitter.

*Rationale: The Bluetooth receiver is needed to receive the audio signal from a smartphone device. Then, the signal passes through a DAC to prepare the signal for future manipulation. Since the GrAPE is an analog equalizer, the signal received from the smartphone (digital) needs to be converted to analog to be able to alter frequency gains in the equalizer.*

#### 3.2.1.4. ADC & Bluetooth Transmitter

Bluetooth transmitter transmits the audio signal to a specified external receiver, and it plays.

*Rationale: If the user opts for the output to be played via Bluetooth, then the signal from the main signal manipulation system must pass through the Bluetooth transmitter which includes an ADC for the signal to be played on the speaker.*

#### 3.2.1.5. Frequency Channel Selection

Each channel is able to manipulate its frequency and nearby frequencies without excessive disruption of neighboring channels. The channels can work in combination with each other and with multi-tone signals. The slider frequency gain effects are uniform in nature across all 10 bands.

*Rationale: This requirement is set to distinguish frequency changes in gains, especially in neighboring channels.*

#### 3.2.1.6. Bandwidth

The full range of the tunable frequencies is 0-20kHz. A single channel has a standard deviation from the base frequency in which frequencies outside of said standard deviation are not amplified past a certain gain.

*Rationale: This requirement, similar to Section 3.2.1.5, prevents frequency gain changes from disrupting neighboring channels.*

#### 3.2.1.7. Display Integration

The display shows a menu on a screen (potentially an LCD) and works concurrently with the Bluetooth module on the GrAPE.

*Rationale: For the users to connect the GrAPE to a specific Bluetooth speaker, a display is needed to show available Bluetooth devices nearby. The display will work along with the Bluetooth module to be able to read the data from the receivers and display them onto the screen.*

#### 3.2.1.8. Control Pad for Display

The control pad allows its users to select and connect to a Bluetooth speaker. The interface of the control pad will consist of a minimum of 3 buttons: up, down (or left or right), and an enter button.

*Rationale: The control pad will work with the display on the GrAPE. The display will show a menu with the available Bluetooth devices nearby and the user will be able to select and connect to their desired device via the control pad on the GrAPE.*

#### 3.2.1.9. Slidable Knobs

The GrAPE will have 10 slidable knobs which will be used to alter the gain frequency of the 10 frequency bands.

*Rationale: The slidable knobs will allow the user to physically move them up and down to directly alter the gain frequency. Sliding the knobs upwards will increase then gain frequency and similarly, sliding the knobs downwards will decrease the gain frequency of that specific frequency band.*

#### 3.2.1.10. Battery Percentage

The GrAPE will have an indicator (potentially a set of LEDs) to display the level of charge.

*Rationale: A battery percentage indicator is beneficial, as it will display how much battery the GrAPE has before, during, and after use.*

#### 3.2.1.11. Battery Operating Time

The battery operating time of the GrAPE should last between 2-4 hours.

*Rationale: The GrAPE is a portable equalizer; therefore, the battery must last a reasonable amount of time for its users to utilize the device. For audio processing purposes, the battery should last enough to play multiple songs (i.e., 2-4 hours).*

### 3.2.2. Physical Characteristics

#### 3.2.2.1. Size/Dimensions

The GrAPE fits within an average-sized backpack with pockets that completely zip.

*Rationale: This requirement set is set to allow users to easily transport the GrAPE in average-sized carriers such as a backpack.*

#### 3.2.2.2. Housing

The material of the housing will not interfere with the Bluetooth's connection to meet the 10 meters requirement listed in *Section 3.2.1.1*.

*Rationale: This requirement is set to allow full Bluetooth connectivity between the GrAPE and its input and output devices.*

### 3.2.3. Electrical Characteristics

#### 3.2.3.1. Inputs

a. The presence or absence of any combination of the input signals in accordance with ICD specifications applied in any sequence shall not damage the GrAPE, reduce its life expectancy, or cause any malfunction, either when the unit is powered or when it is not.

b. No sequence of command shall damage the GrAPE, reduce its life expectancy, or cause any malfunction.

*Rationale: By design, should limit the chance of damage or malfunction by user/technician error.*

##### 3.2.3.1.1 Power Consumption

The maximum peak power for the system shall not exceed 5 watts.

*Rationale: This requirement is to ensure continuous operation of the GrAPE while turned on.*

##### 3.2.3.1.2 Input Voltage Level

The input voltage level for the GrAPE shall be 3.3V.

*Rationale: All of the subsystems are designed to run off of 3.3V.*

#### 3.2.3.2. Outputs

##### 3.2.3.2.1 Bluetooth Audio Signal

The GrAPE will output an audio signal via Bluetooth to a speaker.

*Rationale: The GrAPE will provide the user the option of selecting their preferred output method either digital (Bluetooth) or analog (Aux).*

##### 3.2.3.2.2 Analog Audio Signal

The GrAPE will output an audio signal via Aux to a speaker.

*Rationale: The GrAPE will provide the user the option of selecting their preferred output method either digital (Bluetooth) or analog (Aux).*

### 3.2.4. Environmental Requirements

#### 3.2.4.1. Thermal Resistance

The GrAPE will operate under room temperature conditions (59°-77°F).

*Rationale: This requirement is needed as audio processing devices such as the GrAPE will be under room temperature conditions. No additional temperature testing will be performed.*

# 4. Support Requirements

## *4.1. User Expectations for Intended Operability*

It is expected of the user to have the following hardware for the GrAPE to operate as intended:

- A device that has compatible Bluetooth technology with a means to source a connection to the GrAPE and at least one available audio file to transmit.
    - In this context, “compatible” means that said device’s Bluetooth transmission technology can connect to the specific on-board microcontroller of the GrAPE; A device that has Bluetooth capabilities but cannot make this connection does not meet the above expectation.

- A device that has an auxiliary output port with the functionality required to send the contents of an audio file as an audio signal.
    - This device can be used as an alternative to the first Bluetooth device listed above, or it can be a secondary feature. Note that the GrAPE is not designed to accept both signal types simultaneously.

- A compatible Bluetooth transmission receiver with a means to source a connection from the GrAPE and to a speaker.
    - In this context, “compatible” means that said device’s Bluetooth reception technology can connect to the specific on-board microcontroller of the GrAPE.
    - The above is generally a standard feature of Bluetooth speakers. In the case that the user does not use a Bluetooth-enabled speaker, it is possible to use Bluetooth-receiving devices that subsequently connect to a speaker via auxiliary cable.

- A speaker with compatible Bluetooth technology or a speaker without Bluetooth technology or a speaker with auxiliary connection capabilities or any combination of the preceding requirements.
    - In the first scenario, “compatible” means that the speaker’s on-board technology allows for connection to the GrAPE’s output Bluetooth signal.
    - A speaker without Bluetooth capabilities is expected to have auxiliary capabilities.
    - Most commercial speakers with Bluetooth capabilities also have auxiliary capabilities.

## *4.2. Provided with the GrAPE*

The GrAPE will include all functionality required to meet the feature specifications of this document excluding the “user expectations for intended operability.” For a high-level scope of what hardware features this functionality entails, please see the Table 1 listing of subsystem divisions.

The team should provide a manual with directions detailing general steps to ensure desired Bluetooth connections or port connections for intended use. This manual should also include basic operation guidelines such as an overview of all buttons, sliders, indicator light meanings, and user interface details.

## *4.3. In-Field Resolution Plan*

The expectations set by this document are such that the system should not need an in-field resolution plan. This is not to suggest that the system could be without flaws but communicates that any error that is worth diagnosing for an individual instance of this product will either be a flaw in design, a flaw in manufacturing, or a flaw in customer usage. The responsibility of this team is only to address the first of these, as the others are the responsibility of the manufacturers or customers, respectively. Flaws in design will be decided by the specifications of the intended functionality in this document, which is why no in-field resolution plan is necessary.

If the device was not designed to meet the functionality requirements of this document, then it is the responsibility of this team to correct the design so that newly manufactured models do.

# Appendix A: Acronyms and Abbreviations

| | |
|---|---|
| ADC | Analog to Digital Converter |
| AUX | Auxiliary |
| DAC | Digital to Analog Converter |
| GrAPE | Graphic Analog Portable Equalizer |
| GUI | Graphical User Interface |
| Hz | Hertz |
| ICD | Interface Control Document |
| kHz | Kilohertz (1,000 Hz) |
| LCD | Liquid Crystal Display |
| mA | Milliamp |
| MHz | Megahertz (1,000,000 Hz) |
| mW | Milliwatt |
| PCB | Printed Circuit Board |
| TBD | To Be Determined |
| USB | Universal Serial Bus |

# Appendix B: Definition of Terms

# Analog Portable Graphic Equalizer

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# INTERFACE CONTROL DOCUMENT

REVISION – Draft
02 October 2022

# INTERFACE CONTROL DOCUMENT
FOR
# Analog Portable Graphic Equalizer

PREPARED BY:

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APPROVED BY:

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Project Leader Date

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John Lusher II, P.E. Date

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# 1. Overview

This document will cover the input and output interfaces for the planned design of the GrAPE, a graphic portable analog equalizer.

Exterior interfaces are those inputs that the user of the device interacts with. The external interfaces are as follows: A main power on/off switch, an input auxiliary connection location, an output auxiliary connection location, a wireless Bluetooth input connection, a wireless Bluetooth output connection, 10 frequency gain sliders, 2 stereo-audio gain sliders, 1 main gain slider, a Bluetooth input on/off switch, a Bluetooth output on/off switch, an output LCD, an input selection panel corresponding to the LCD, 4 output battery indicator LEDs, and a charger input connection port.

Internal interfaces are those involved in the exchange of data/information or power in a way that the user does not immediately interact with. The internal interfaces are as follows: a battery that provides power to all internal systems, a Bluetooth receiver, a Bluetooth transmitter, and a main signal PCB for left and right audio. Note that interfaces that the user interacts with are excluded from the internal interfaces because they are considered external interfaces.

# 2. References and Definitions

## *2.1. References*

**ANSI S1.11-2004**
**Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters**
15 June 2009

## *2.2. Definitions*

| | |
|---|---|
| A | Ampere |
| ADC | Analog-to-Digital Converter |
| mAh | Milli-Amps per Hour |
| DAC | Digital-to-Analog Converter |
| LCD | Liquid Crystal Display |
| mA | Milliamp |
| mm | Millimeter |
| kHz | Kilohertz (1,000 Hz) |
| TBD | To Be Determined |
| V | Voltage |
| W | Watt |

# 3. Physical Interface

## *3.1. Weight*

### 3.1.1. GrAPE

**Table 1: Main Console Weight**

| Component | Weight | Number of Items | Total Weight |
|---|---|---|---|
| ESP32-WROVER-E Bluetooth module | Estimated 7.74g | 2 | 15.5g |
| NHD-C12832A1Z-FSW-FBW-3V LCD | Estimated 1.2g | 1 | 1.2g |
| L37A26-1-0-3WA3 Rechargeable Battery | 56.7g | 1 | 56.7g |
| Main Signal PCB | TBD | 1 | TBD |
| SAM4S Series DAC | Estimated 800mg | 1 | 800mg |

### 3.1.2. Externals

**Table 2: External Weight**

| Component | Weight | Number of Items | Total Weight |
|---|---|---|---|
| USB to TBD charger | TBD | 1 | TBD |

## *3.2. Dimensions*

### 3.2.1. Main Signal Manipulations

**Table 3: Main Signal Manipulation Dimensions**

| Component | Length | Width | Height |
|---|---|---|---|
| Main Signal PCB | TBD | TBD | TBD |

### 3.2.2. Display and Power Supply

**Table 4: Display and Power Supply Dimensions**

| Component | Diameter | Length | Width | Height |
|---|---|---|---|---|
| NHD-C12832A1Z-FSW-FBW-3V LCD | N/A | 41.4mm | 4.9mm | 24.3mm |
| L37A26-1-0-3WA3 Rechargeable Battery | 17.8mm | N/A | N/A | 68.6mm |

### 3.2.3. Bluetooth Input/Output

**Table 5: Bluetooth Input/Output Dimensions**

| Component | Length | Width | Height |
|---|---|---|---|
| ESP32-WROVER-E Bluetooth Module | TBD | TBD | TBD |
| SAM4S Series DAC | TBD | TBD | TBD |

## *3.3. Mounting Locations*

The GrAPE will be portable and also contain a battery that will be chargeable. Therefore, the equalizer will be able to be used anywhere and will not require a mount of any kind. The GrAPE will sit on a flat surface and work from any location.

# 4. Thermal Interface

The GrAPE may not use a heat sink as most of its devices will not perform complex computations. However, the GrAPE will be designed to have wiggle room for its lithium-ion rechargeable battery. This is to prevent the battery from compressing and potentially breaking inside the device.

# 5. Electrical Interface

## *5.1. Primary Input Power*

### 5.1.1. Primary Power for Subsystems

The GrAPE will be powered by a 3.7V and 2700mAh rechargeable lithium-ion battery. The battery will supply power to both Bluetooth modules, the DAC, the main signal manipulation system, as well as the display of the GrAPE. The voltage will be regulated by a buck converter to provide supply acceptable voltages for devices in the GrAPE which cannot use 3.7V.

## *5.2. Voltage and Current Levels*

The values on Table 6 show the voltage, current and power levels of the main components of the GrAPE. As seen from the table the total power consumption from our current voltage and current levels yields 5W. Note that the main signal manipulation currently does not have voltage or current values therefore it is expected that the power consumption of the GrAPE might be larger than 5W.

**Table 6: Maximum Values**

| Component | Voltage [V] | Current [mA] | Power [W] |
|---|---|---|---|
| ESP32-WROVER-E (x2)<br>Bluetooth Module | 3.6 (3.3 TYP) | 1000 | 3.6W |
| SAM4S Series<br>DAC | 3.6 (3.3 TYP) | 400 | 1.44W |
| NHD-C12832A1Z-FSW-FBW-3V<br>LCD | 3.3 (3.0 TYP) | 1 | 0.0033W |
| Main Signal Manipulation | TBD | TBD | TBD |

## *5.3. Signal Interfaces*

### 5.3.1. Bluetooth Modules

The GrAPE will utilize two Bluetooth modules to receive and transmit Bluetooth signals to a specific device. The Bluetooth module selected, the ESP32-WROVER-E, it utilizes its

integrated ADC to communicate to the desired receiver and effectively transmit the Bluetooth audio signal to said receiver.

### *5.4. User Interface*

The user control interface will consist of a display and a control pad. The display will show on an LCD a menu with all the available Bluetooth devices nearby. The user will then be able to use the control pad to select the Bluetooth device they want to connect to.

## 6. Communications / Device Interface Protocols

### *6.1. Bluetooth*

The GrAPE has two built-in Bluetooth modules using IEEE 802.11 ac standards. This Bluetooth will allow for wireless transfer of an audio signal to and from the GrAPE.

### *6.2. Auxiliary*

The audio signal will have the ability to come out of an auxiliary output and should have the ability to go into an auxiliary input connection.

### *6.3. Wired Battery Charging*

The battery will be charged by wire using IEEE Std 946 standards. This battery will supply power to all subsystems throughout the GrAPE.

# Audio Portable Graphic Analog Equalizer

Antonio Cardona
Nathan Finley
Nicole LoGiudice

# EXECUTION PLAN

REVISION - Draft
10 October 2022

# Execution Plan for GrAPE

| Task | Begin date | End date | Duration | Resources | Status |
|---|---|---|---|---|---|
| Research | 8/29/2022 | 10/24/2022 | 41 | | Current |
| Receive Project | 8/29/2022 | 8/29/2022 | 0 | | Complete |
| Status Update 1 | 8/31/2022 | 8/31/2022 | 0 | | Complete |
| Divide Subgroups | 8/29/2022 | 9/2/2022 | 5 | | Current |
| Research Subgroups | 9/2/2022 | 10/24/2022 | 37 | | Current |
| Status Update 2 | 9/14/2022 | 9/14/2022 | 0 | | Complete |
| Determining Design | 9/19/2022 | 11/4/2022 | 35 | | Current |
| Order Parts | 9/19/2022 | 11/4/2022 | 35 | | Current |
| Status Update 3 | 9/28/2022 | 9/28/2022 | 0 | | Complete |
| Rechargeable battery & display type selected and ordered | 10/3/2022 | 10/3/2022 | 0 | Antonio | Current |
| Status Update 4 | 10/12/2022 | 10/12/2022 | 0 | | |
| Complete Any Calculations | 10/17/2022 | 10/17/2022 | 0 | Nathan | |
| Charging circuit design complete | 10/17/2022 | 10/17/2022 | 0 | | |
| Provide Power Requirements for Subsystems | 10/17/2022 | 10/17/2022 | 0 | | |
| Putting Desing into Action | 10/10/2022 | 11/11/2022 | 25 | | |
| Troubleshoot on Breadboard | 10/10/2022 | 11/11/2022 | 25 | | |
| Ensure Concept of Integration of Display and Bluetooth | 10/19/2022 | 10/19/2022 | 0 | Nicole LoGiudice;Antonio | |
| Have working circuit of singular filter and slider network | 10/21/2022 | 10/21/2022 | 0 | Nathan | |
| Bluetooth Module on Breadboard | 10/21/2022 | 10/21/2022 | 0 | Nicole LoGiudice | |
| Design Blitz | 10/21/2022 | 10/21/2022 | 1 | | |
| Charging circuit test | 10/21/2022 | 10/21/2022 | 0 | Antonio | |
| Designing Board | 10/21/2022 | 11/18/2022 | 21 | | |
| Design Board | 10/21/2022 | 11/18/2022 | 21 | | |
| Status Update 5 | 10/26/2022 | 10/26/2022 | 0 | | |
| Code for Bluetooth Receiver Complete | 10/28/2022 | 10/28/2022 | 0 | Nicole LoGiudice | |
| Validating/Troubleshooting Board | 10/28/2022 | 12/2/2022 | 26 | | |
| Testing/Validating Board Designs | 10/28/2022 | 12/2/2022 | 26 | | |
| Status Update 6 | 11/9/2022 | 11/9/2022 | 0 | | |
| Display programming complete | 11/11/2022 | 11/11/2022 | 0 | Antonio | |
| Code for Bluetooth Transmitter Complete | 11/11/2022 | 11/11/2022 | 0 | Nicole LoGiudice | |
| Passing final frequency test system | 11/16/2022 | 11/16/2022 | 0 | Nathan | |
| Integration of Display for Bluetooth Complete | 11/16/2022 | 11/16/2022 | 0 | Nicole LoGiudice;Antonio | |
| User Controlled Menu Complete | 11/16/2022 | 11/16/2022 | 0 | Antonio | |
| Status Update 7 (Before Thanksgiving) | 11/22/2022 | 11/22/2022 | 0 | | |
| Final Demo | 12/2/2022 | 12/2/2022 | 0 | | |

# Audio Portable Graphic Analog Equalizer

Antonio Cardona
Nathan Finley
Nicole LoGiudice

# VALIDATION PLAN

REVISION - Draft
10 October 2022

# Validation Plan for GrAPE

| FSR Reference | Test Name | Success Criteria |
|---|---|---|
| 3.2.1.1 | Connectivity range | Bluetooth connectivity for input and output is at least 10 meters. |
| 3.2.1.2 | Wireless connection stability | Bluetooth connectivity does not drop more than 1 time per 5 minutes. |
| 3.2.1.3 | Bluetooth receiver & DAC | Bluetooth receiver receives the audio signal from an external transmitter. |
| 3.2.1.4 | ADC & Bluetooth transmitter | Bluetooth transmitter transmits the audio signal to a specified external receiver and it plays. |
| 3.2.1.5 | Frequency channel selection | Each channel is able to manipulate its frequency and nearby frequencies without excessive disruption of neighboring channels. The channels can work in combination with each other and with multi-tone signals. The sliders frequency gain effects are uniform in nature across all 10 bands. |
| 3.2.1.6 | Bandwidth | The full range of the tunable frequencies is 0-20kHz. A single channel has a standard deviation from base frequency in which frequencies outside of said standard deviation are not amplified past a certain gain. |
| 3.2.1.7 | Display Integration | The display shows a menu on a screen (potentially a LCD) and works concurrently with the bluetooth module on the GrAPE. |
| 3.2.1.8 | Control Pad for Display | The user-controlled menu allows the user to select and connect to a Bluetooth speaker. The interface has a minimum of 3 buttons: up, down (or left and right) and an enter button. |
| 3.2.1.9 | Slidable Knobs | The GrAPE will have 10 slidable knobs which alters the gain frequency of the 10 frequency bands. |
| 3.2.1.10 | Battery Percentage | The GrAPE will include a battery percetange indicator (potentially a set of LEDs). |
| 3.2.1.11 | Battery Operating Time | The battery operating time of the GrAPE shall last between 2-4 hours. |
| 3.2.2.1 | Size/dimensions | The GrAPE fits within an average sized backpack with pockets that completely zip. |
| 3.2.2.2 | Housing material | The material does not interfere with the bluetooths' connection to meet the 10 meters requirement. |
| 3.2.3.1.1 | Power Consumption | Rechargeable battery power supplies expected voltage levels according to its specifications. |
| 3.2.3.1.2 | Input voltage (subsystems) | The required voltage levels for all subsystems is met. |
| 3.2.4.1 | Thermal Resistance | The GrAPE operates under room temperature conditions (59°-77°F). |
| N/A | Full system demo | The GrAPE accepts audio input from a smartphone device via Bluetooth and is able to connect to a speaker via Bluetooth and Aux. The equalizer has at least 10 frequency channels that can be adjusted by slidable knobs and the audio processing and filtering is analog. The GrAPE's design is small enough to fit into a backpack. |

| FSR Reference | Methodology | Status | Responsible Engineer(s) |
|---|---|---|---|
| **3.2.1.1** | The GrAPE will be in the center of the input and output bluetooth devices. The two devices will start off right next to the GrAPE, but will be drawn farther away until they reach 10 meters. | *UNTESTED* | Full Team |
| **3.2.1.2** | Bluetooth will be tested 5 times. Each time, the GrAPE will be equally distanced in the middle from the phone and speaker. | *UNTESTED* | Full Team |
| **3.2.1.3** | Bluetooth receiver will receive an input via bluetooth from a phone. The receiver output will be connected to a DAC to then output to a speaker. | *UNTESTED* | Nicole LoGiudice |
| **3.2.1.4** | An ADC will have an analog signal input and an output connected to the bluetooth transmitter. The transmitter will be put into search mode to find all available receivers in the area. The specified receiver will be selected as the desired receiver. | *UNTESTED* | Nicole LoGiudice |
| **3.2.1.5** | Each channel will be tested individually against its control frequency. If every channel responds with the ability to adjust its set frequency to a consistent gain magnitude higher and lower than feed amplitude, then the signals will be tested with mixed frequencies with the same expectation of results. | *UNTESTED* | Nathan Finley |
| **3.2.1.6** | The top and bottom channels will be tested in their gain manipulation of the top and bottom frequencies (0 and 20 kHz) to meet the specified amplitude requirements. Intermediate frequencies will also be tested in the bandwidth of their frequency manipulation. | *UNTESTED* | Nathan Finley |
| **3.2.1.7** | The display integration will be tested by checking if the display successfully shows a select menu where it displays the available Bluetooth devices to be connected to. | *UNTESTED* | Antonio Cardona & Nicole LoGiudice |
| **3.2.1.8** | The menu will be tested by selecting a Bluetooth device on the display and checking if the GrAPE successfully connects to the selected Bluetooth speaker. | *UNTESTED* | Antonio Cardona |
| **3.2.1.9** | Individual and group testing of the set of slidable knobs are tested against an expected gain level from the design. | *UNTESTED* | Nathan Finley |
| **3.2.1.10** | Charging and discharging the battery. | *UNTESTED* | Antonio Cardona |
| **3.2.1.11** | Operating the GrAPE and recording battery life while in use. | *UNTESTED* | Antonio Cardona |
| **3.2.2.1** | The GrAPE will be placed within a backpack along with any external parts. | *UNTESTED* | Full Team |
| **3.2.2.2** | The GrAPE will be tested first through the ‘Connectivity range’ test without the housing. Once passed, the ‘Connectivity range’ test will be performed with the housing. | *UNTESTED* | Full Team |
| **3.2.3.1.1** | User multimeter and oscilloscope to validate voltage and current levels. | *UNTESTED* | Antonio Cardona |
| **3.2.3.1.2** | Use multimeter to validate input voltage levels. | *UNTESTED* | Antonio Cardona |
| **3.2.4.1** | Operating the GrAPE under room temperature conditions. | *UNTESTED* | Full Team |
| **N/A** | Team members will test the GrAPE with a smartphone device and play an audio signal (i.e a song) via Bluetooth through the equalizer onto a speaker via Bluetooth and Aux. | *UNTESTED* | Full Team |