RF Waveform Generator

Brian Chau

Daniel Hickl

Eugene Asare

Khoi Le

**Functional System Requirements**

Functional System Requirements

for

RF Waveform Generator

Prepared by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Author Date

Approved by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Project Leader Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

John Lusher, P.E. Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

T/A Date

**Change Record**

| **Rev.** | **Date** | **Originator** | **Approvals** | **Description** |
| --- | --- | --- | --- | --- |
| **-** | 02/22/24 | RF Waveform Generator |  | Draft Release |
| **1** | 04/24/24 | RF Waveform Generator |  | Revision 1 |
| **2** | 04/27/24 | RF Waveform Generator |  | Final Report |

**Table of Contents**

[**Table of Contents III**](https://docs.google.com/document/d/1mWBIA_Oa1ZBRBI4hyHL5FGaYiQXWECAY/edit#heading=h.30j0zll)

[**List of Tables IV**](https://docs.google.com/document/d/1mWBIA_Oa1ZBRBI4hyHL5FGaYiQXWECAY/edit#heading=h.3znysh7)

Table [1. Subsystem Assignments](#_1t3h5sf) 7

Table 2. Applicable Documents8

Table 3. Reference Documents8

[**List of Figures V**](https://docs.google.com/document/d/1mWBIA_Oa1ZBRBI4hyHL5FGaYiQXWECAY/edit#heading=h.tyjcwt)

[Figure 1. Project Conceptual Image 1](#_1t3h5sf)

[Figure 2. System Block Diagram 9](#_44sinio)

[**1. Introduction 6**](#_tyjcwt)

[1.1. Purpose and Scope 6](#_3dy6vkm)

[1.2. Responsibility and Change Authority 7](#_4d34og8)

[**2. Applicable and Reference Documents 8**](#_2s8eyo1)

[2.1. Applicable Documents 8](#_17dp8vu)

[2.2. Reference Documents 8](#_3rdcrjn)

[Electromagnetic Compatibility Testing And Measurement Package 8](#_v5w19tgewn5j)

[2.3. Order of Precedence 8](#_26in1rg)

[**3. Requirements 9**](#_35nkun2)

[3.1. System Definition 9](#_1ksv4uv)

[3.2. Characteristics 10](#_2jxsxqh)

[3.2.1. Functional / Performance Requirements 10](#_z337ya)

[3.2.2. Physical Characteristics 11](#_3j2qqm3)

[3.2.3. Electrical Characteristics 11](#_1y810tw)

[3.2.4. Environmental Requirements 13](#_mvy61fev7o8f)

[3.2.5. Failure Propagation 13](#_3w33vdmoipxe)

[**4. Support Requirements 13**](#_2bn6wsx)

[4.1. Necessary Technology 13](#_94n6tix8nctl)

[**Appendix A: Acronyms and Abbreviations 14**](#_qsh70q)

[**Appendix B: Definition of Terms 15**](#_1pxezwc)

[**Appendix C: Interface Control Documents 15**](#_79hzgepy8kuh)

**List of Tables**

**Table** [**1. Subsystem Assignments**](#_1t3h5sf) **7**

**Table 2. Applicable Documents****8**

**Table 3. Reference Documents****8**

**Table 4. Target Voltage/ Currents for Each Component 11**

**List of Figures**

[**Figure 1. Project Conceptual Image………………………………………………………. 1**](#_1t3h5sf)

[**Figure 2. System Block Diagram…………………………………………………………...9**](#_44sinio)

# 

# Introduction

## Purpose and Scope

Especially in the high RF domain, components for frequency synthesis are expensive and complicated which leads to increased resources in manufacturing even the most basic RF devices. Therefore, this project is entirely exploratory research and development, aiming to generate a sawtooth RF signal from 1.6-3.2 GHz with the lowest SWAP-C possible. Because this is R&D with no restrictions or restraints, our primary focus will be meeting the frequency specifications with a budget of $500 and the ideal size on a 2 x 2-inch PCB (excluding the user interface and battery power supplies). Our system will provide a baseline for simplifying RF waveform generation, which could then be implemented to cut costs and materials in mass production.



**Figure 1. Project Conceptual Image**

## 

## Responsibility and Change Authority

The team leader, Daniel Hickl, will be responsible for making sure all project requirements are met. Those requirements can only be changed with the approval of the team

leader and Professor Stavros Kalafatis.

| Subsystem | Responsibility |
| --- | --- |
| DC Power Regulation | Eugene Asare |
| Analog Drive | Daniel Hickl |
| VCO and RF Amplifier | Brian Chau |
| GUI/Monitor Design | Khoi Le |

**Table 1. Subsystem Assignments**

# Applicable and Reference Documents

## 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** |
| --- | --- | --- |
| IEEE PC95.1-2345 | 05/21/2019 | Force Health Protection Regarding Personnel Exposure to Electric, Magnetic, and Electromagnetic Fields, 0Hz to 300 GHz |
| ANSI C63.10-2013 | 12/10/2013 | American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices |
| IEEE 1057-2007 | 12/05/2007 | IEEE Standard for Digitizing Waveform Recorders |

**Table 2. Applicable Documents**

## 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 C95.7 | 11/08/2010 | IEEE Recommended Practice for Radio Frequency Safety Programs, 3kHz to 300 GHz |
| IEC 610004-4 | 06/06/2023 | Electromagnetic Compatibility Testing And Measurement Package |

**Table 3. Reference Documents**

## 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.

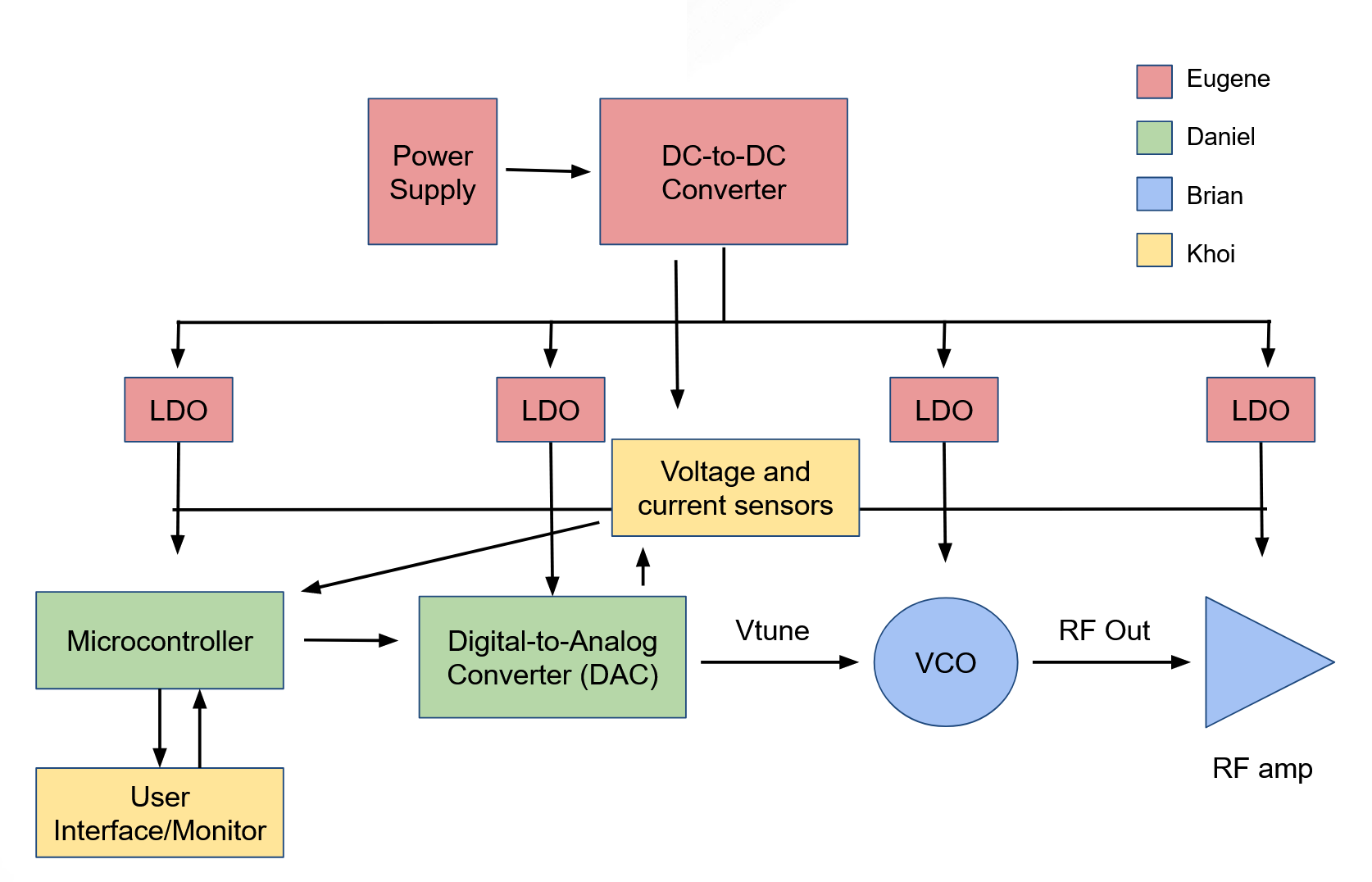
All specifications, standards, exhibits, drawings, or other documents that are invoked as “applicable” in this specification are incorporated as cited. All documents that are referred to within an applicable report are considered to be for guidance and information only, except ICDs that have their relevant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

# Requirements

In developing the RF waveform generator, an RF signal will be produced that has a frequency range from 1.6 to 3.2 GH (1.6 GHz bandwidth). Despite the changing frequency, the signal should still be robust and not degrade with an increasing chirp rate. Its input, the tuning voltage, must be a periodic signal that oscillates between 0-20 volts as specified by the VCO component. The RF waveform generator has four subsystems: Analog Drive, VCO/ RF, GUI/Monitor Interface, and DC Power Distribution.

## System Definition

An Analog Drive consisting of a microcontroller and DAC will first create a sawtooth voltage signal. That will then be taken as an input for the VCO, Which will convert that tuning voltage into a sawtooth signal in the RF domain. An RF amplifier will increase the magnitude of the RF signal for adequate testing. A GUI/user interface will also measure and display the tuning Voltage and power specifications to ensure that the system functions properly. Lastly, a power distribution subsystem will supply power to each component, stepping up/down with a series of LDOs.



**Figure 2. System Block Diagram**

In the block diagram, a power supply will consist of two or three AA batteries. Using a series of DC-DC boost converters and LDOs, that battery voltage will be stepped down to the specific needs of each component. A microcontroller will be used in conjunction with the DAC to create a tuning voltage signal digitally. That tuning voltage will be the direct input for the VCO, generating an RF waveform. Because the VCO produces a higher output power than what the RF amplifier can produce, a power attenuator will be installed between the VCO and the amplifier. As for the user interface, several voltage and current sensors will be placed on each LDO and the tuning voltage to ensure all components are receiving their intended power supply and display those values on the interface.

## Characteristics

### Functional / Performance Requirements

#### User Interface

The RF Waveform Generator shall be controlled by a GUI which shall be capable of displaying and controlling all the modes of operation. The GUI shall display the status of the RF Waveform Generator: The frequency, amplitude, and power.

*Rationale: This is the core system performance requirement. This is a requirement by our sponsor. This will allow us to have different functions for the RF generator, as well as monitor the status.*

#### Modes of Operation

The RF Waveform Generator shall have three main modes of operation which include an on-state, off-state, and modulation mode.

*Rationale: This is the core system performance requirement. This is a requirement by our sponsor to perform optimally.*

#### Range of RF Frequencies

The RF Waveform Generator shall have a range of 1.6GHz - 3.2GHz. The modulation mode shall span across this range. The “On” state shall choose constant frequencies in this range.

*Rationale: This is the core system performance requirement. This is a requirement by our sponsor to perform optimally.*

#### Accuracy of Measurements

The RF Waveform Generator shall provide voltage and currents of certain components through the user interface and collected from the microcontroller. While frequency is variable in modulation mode, the output power should be 20 dBm +/- 3 dBm. Voltage and current readings of components are as follows in the table below:

| Part | Description | Target Voltage | Target Current |
| --- | --- | --- | --- |
| PE1V14003 | VCO | 4.5 - 5V | 16 mA |
| TQL9093 | RF Amplifier | 7 V | 120 mA |
| PIC32MK | MCU with DAC | 3.3 V | 200mA |
| LM358DR | Power Op Amp | 22 V | 20 mA |

Table 4. Target Voltage/ Currents for Each Component

*Rationale: This is a requirement specified by our sponsor due to the low SWAP-C constraints of their system in which the RF Waveform Generator is integrating. Also, this is for checking the performance of the RF Waveform Generator.*

The modulation mode and “On” state shall span across this range within a tolerance of 3%.

### Physical Characteristics

#### Mass

The mass of the RF waveform generator will be no more than 200g.

*Rationale: This is a requirement specified by our sponsor due to the low SWAP-C constraints in which the RF Waveform Generator is integrated.*

#### Volume Envelope

The volume envelope of the Search and Rescue System shall be less than or equal to 2 inches in height, 2 inches in width, and 2 inches in length.

*Rationale: This is a requirement specified by our sponsor due to the low SWAP-C constraints in which the RF Waveform Generator is integrated.*

#### Mounting

THe RF Waveform Generator will have no mounting but instead it will be on a PCB.

*Rationale: The RF Waveform Generator has no mounting capabilities or functions.*

### Electrical Characteristics

#### Inputs

The only inputs the RF Waveform Generator is designed to handle are the power from the AA batteries and the tuning voltage to the VCO. The tuning voltage of the VCO will be controlled by the microcontroller. The DIP Switch connected to the microcontroller will control the state of the system in tandem with the GUI app. The switch is used as a hardware connection to control the RF waveform generator.

*Rationale: This is a requirement specified by our sponsor due to the low SWAP-C constraints in which the RF Waveform Generator is integrated.*

##### Power Consumption

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

*Rationale: This is a requirement specified by our sponsor due to the low SWAP-C constraints in which the RF Waveform Generator is integrated.*

##### Input Voltage Level

The input voltage level for the RF waveform generator shall be +2.8 VDC to +3.6 VDC. This will be stepped up with a DC-DC boost converter that will give input voltages of 22 VDC, 6 VDC, and 4.3 VDC to individual LDOs. Those LDO will drop the voltage to the voltage input required for certain components. All voltage values will have an appropriate tolerance within +/- 5%.

*Rationale: This is a requirement specified by our sponsor due to the low SWAP-C constraints in which the RF Waveform Generator is integrated.*

##### Input Noise

The input noise for the RF Waveform Generation shall operate at the lowest possible with our design due to operating at high frequency. Operating at these high frequencies any additional noise that is generated from the voltages will disrupt the RF signal produced. The LDOs in the system are used to lower the noise generated by the DC-DC boost converters.

*Rationale: This is the core system performance requirement. This is a requirement by our sponsor to perform optimally.*

#### Outputs

Essentially, there will be two outputs. One is voltage output of all monitored components. The other output will be the RF output that came out from the VCO.

##### User Interface Data Output

The RF Waveform Generator shall include an interface to indicate the status of voltage and currents over components.

*Rationale: The data will help to ensure all components are supplied with proper power and to help debug the system during testing.*

##### RF Signal Output

The primary output of the system, which will be measured using an oscilloscope and spectrum analyzer provided in the lab. The maximum range of the RF output will be 1.6 GHz.

*Rationale: Primary purpose/result of the project. This is a requirement by our sponsor to indicate project functionality.*

### Environmental Requirements

The RF Waveform Generation shall be designed to withstand laboratory tests and be used in various R&D tests.

*Rationale: Since this project is R&D oriented there isn’t much need to have our system withstand any other environmental situations.*

### Failure Propagation

The RF Waveform Generator shall not allow propagation of faults beyond the RF Waveform Generator user interface.

* + - 1. **Fault Detection**

The sensors are going to give inputs to the microcontroller with data on the voltages and currents and will be connected to the GUI and this user interface will display any errors in the power system distribution.

*Rationale: The data will help to ensure all components are supplied with proper power*

# Support Requirements

Due to the nature of this project being R&D there is no technical support service or warranty that is needed.

## Necessary Technology

**4.1.1 Computer Terminal with USB**

To view the data and use the user interface as designed, the user must use a computer terminal with a USB connection.

*Rationale: Other forms of accessing the information from the RF Waveform Generator are outside the scope of this project.*

# Appendix A: Acronyms and Abbreviations

RF Radio Frequency

GHz Gigahertz (1,000,000,000 Hz)

SWAP-C Size Weight and Power - Cost

R&D Research and Development

VCO Voltage-Controlled Oscillator

DAC Digital to Analog Converter

µC Microcontroller

GUI Graphical User Interface

LDO Low Dropout Regulator

PCB Printed Circuit Board

VDC Volts Direct Current

DIP Dual In-Line Package

USB Universal Service Bus

# Appendix B: Definition of Terms

| DC-DC Boost Converter | A device with a higher output voltage than input voltage. AKA a step-up converter because it “steps up” the voltage. |
| --- | --- |
| Digital to Analog Converter | A device that translates digitally stored information from a computer or phone into an analog sound that we can hear. |
| DIP Switch | Consists of a small block of switches mounted on a dual in-line package. Each switch corresponds to a specific binary digit. Using the switch on the PCB provides flexibility in configuration. |
| Graphical User Interface | A type of user interface that allows users to interact with a device or software via graphical components such as buttons, menus, windows, or text-based interfaces. |
| Low Dropout Regulator | A device that takes an input voltage from a power supply and uses that input to output a steady voltage. |
| Voltage-Controlled Oscillator | An RF oscillator circuit whose frequency can be controlled by a DC input voltage. |