



MICROCHIP

**HV56020/22
Evaluation Board
User's Guide**

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NOTES:

Preface

NOTICE TO CUSTOMERS

All documentation becomes dated, and this manual is no exception. Microchip tools and documentation are constantly evolving to meet customer needs. Some actual dialog and/or tool descriptions may differ from those in this document. Please refer to our website (www.microchip.com) to obtain the latest documentation available.

Documents are identified with a “DS” number. This number is located on the bottom of each page and in front of the page number. The numbering convention for the DS number is “DSXXXXXXXXA”, where “XXXXXXXX” is the document number and “A” is the revision level of the document.

For the most up-to-date information on development tools, see the MPLAB® IDE online help. Select the Help menu and then Topics to open a list of available online help files.

INTRODUCTION

This chapter contains general information that will be useful to know before using the HV56020/22 Evaluation Board. Items discussed in this chapter include:

- [Document Layout](#)
- [Conventions Used in this Guide](#)
- [Recommended Reading](#)
- [The Microchip Website](#)
- [Customer Support](#)
- [Document Revision History](#)

DOCUMENT LAYOUT

This document describes how to use the HV56020/22 Evaluation Board as a development tool to emulate and debug firmware on a target board.

The manual layout is as follows:

- **Chapter 1. “Product Overview”** – Important information about the HV56020/22 Evaluation Board.
- **Chapter 2. “Installation and Operation”** – Includes a detailed description of each function of the evaluation board and instructions on how to use the board.
- **Appendix A. “Schematic and Layouts”** – Shows the schematic and layout diagrams for the HV56020/22 Evaluation Board.
- **Appendix B. “Bill of Materials (BOM)”** – Lists the parts used to build the HV56020/22 Evaluation Board.
- **Appendix C. “Waveforms”** – Describes the waveforms for the HV56020/22 Evaluation Board.

CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

DOCUMENTATION CONVENTIONS

Description	Represents	Examples
Arial font:		
Italic characters	Referenced books	<i>MPLAB[®] IDE User's Guide</i>
	Emphasized text	...is the <i>only</i> compiler...
Initial caps	A window	the Output window
	A dialog	the Settings dialog
	A menu selection	select Enable Programmer
Quotes	A field name in a window or dialog	"Save project before build"
Underlined, italic text with right angle bracket	A menu path	<u><i>File>Save</i></u>
Bold characters	A dialog button	Click OK
	A tab	Click the Power tab
N'Rnnnn	A number in verilog format, where N is the total number of digits, R is the radix and n is a digit.	4'b0010, 2'hF1
Text in angle brackets < >	A key on the keyboard	Press <Enter>, <F1>
Courier New font:		
Plain Courier New	Sample source code	#define START
	Filenames	autoexec.bat
	File paths	c:\mcc18\h
	Keywords	_asm, _endasm, static
	Command-line options	-Opa+, -Opa-
	Bit values	0, 1
	Constants	0xFF, 'A'
Italic Courier New	A variable argument	<i>file.o</i> , where <i>file</i> can be any valid filename
Square brackets []	Optional arguments	mcc18 [options] <i>file</i> [options]
Curly brackets and pipe character: { }	Choice of mutually exclusive arguments; an OR selection	errorlevel {0 1}
Ellipses...	Replaces repeated text	var_name [, var_name...]
	Represents code supplied by user	void main (void) { ... }

RECOMMENDED READING

This user's guide describes how to use the HV56020/22 Evaluation Board. Other useful documents are listed below. The following Microchip documents are available and recommended as supplemental reference resources:

- **HV56020 Data Sheet – “Dual High-Voltage Operational Amplifier with Setup Converter and Power MOSFET” (DS200006335).**
- **HV56022 Data Sheet – “Dual High-Voltage Operational Amplifier” (DS50006326).**
- **“MPLAB® X IDE User's Guide” (DS50006326).**

THE MICROCHIP WEBSITE

Microchip provides online support via our website at www.microchip.com. This website is used as a means to make files and information easily available to customers. Accessible by using your favorite Internet browser, the website contains the following information:

- **Product Support** – Data sheets and errata, application notes and sample programs, design resources, user's guides and hardware support documents, latest software releases and archived software
- **General Technical Support** – Frequently Asked Questions (FAQs), technical support requests, online discussion groups and Microchip consultant program member listing
- **Business of Microchip** – Product selector and ordering guides, latest Microchip press releases, listing of seminars and events, listing of Microchip sales offices, distributors and factory representatives

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Users of Microchip products can receive assistance through several channels:

- Distributor or Representative
- Local Sales Office
- Field Application Engineer (FAE)
- Technical Support

Customers should contact their distributor, representative or field application engineer (FAE) for support. Local sales offices are also available to help customers. A listing of sales offices and locations is included on the last page of this document.

Technical support is available through the website at:

<http://www.microchip.com/support>

DOCUMENT REVISION HISTORY

Revision B (December 2022)

- Updated [Section 1.5 “Contents of the HV56020/22 Evaluation Board”](#).
- Updated [Appendix A. “Schematic and Layouts”](#).
- Updated [Appendix B. “Bill of Materials \(BOM\)”](#).
- Minor text and format changes throughout.

Revision A (November 2020)

- Initial release of this document.

NOTES:

Chapter 1. Product Overview

1.1 INTRODUCTION

This chapter provides an overview of the HV56020/22 Evaluation Board and covers the following topics:

- [HV56020/22 Device Overview](#)
- [HV56020/22 Device Features](#)
- [HV56020/22 Evaluation Board Overview](#)
- [Contents of the HV56020/22 Evaluation Board](#)

1.2 HV56020/22 DEVICE OVERVIEW

The HV56020 is a multi-chip module (MCM) consisting of three devices: dual high-voltage operational amplifiers, DC-to-DC converter controller and power MOSFET. The operational amplifiers are designed to drive haptic (piezo) actuators at 225V, with a 40 mA minimum peak source/sink current. The DC-to-DC controller and the power MOSFET, along with an external transformer, generate the required voltage supply for the high-voltage operational amplifiers using a non-isolated flyback configuration.

In addition, the HV56020 includes protection circuitry to provide a reliable solution, such as: over/undervoltage protection, short-circuit protection (DC-to-DC), temperature sensor and output voltage comparators for short-circuit detection on the high-voltage operational amplifiers outputs.

The HV56022 consists of dual high-voltage operational amplifiers with a 40 mA minimum peak current and a 225V maximum voltage drive. The device is designed to be used along with the HV56020 or stand alone to increase the channel count.

1.3 HV56020/22 DEVICE FEATURES

- Windows® 10 PC GUI
- Android™ BLE Application
- Connector for Three Capacitive Touch Buttons
- Single Li-Ion Battery Operation
- Battery Charging Circuit
- Four High-Voltage Operational Amplifiers
- 4 Mbit SPI Serial Flash Memory
- 225V Maximum Voltage Operation

1.4 HV56020/22 EVALUATION BOARD OVERVIEW

The HV56020/22 Evaluation Board represents a 4-channel haptic driver solution. The Evaluation Board contains: HV56020 (1), HV56022 (1), 32-bit MCU (1), 12-bit dual DACs (2), low quiescent current LDO (1), Bluetooth® BLE module (1), LDO Ripple Blocker (1), and Battery Charger Controller Management IC (1).

1.4.1 Evaluation Board Block Diagram

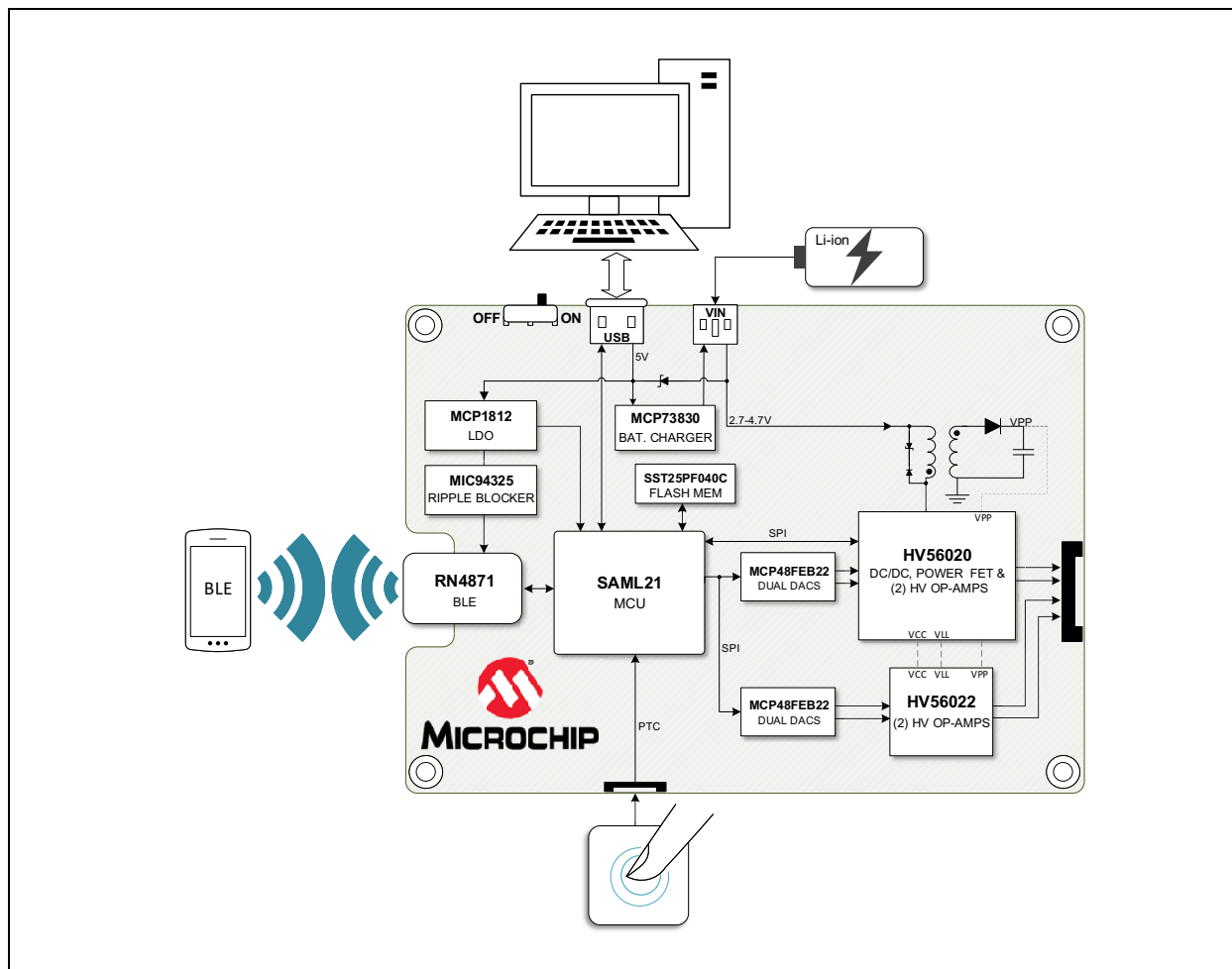


FIGURE 1-1: HV56020/22 Evaluation Board Block Diagram.

Figure 1-1 presents the Microchip components used in the HV56020/22 Evaluation Board:

HV56020	Dual high-voltage operational amplifier with boost converter and power MOSFET
HV56022	Dual high-voltage operational amplifier
SAML21J18B	32-bit microcontroller with an ARM Cortex-M0 CPU
MCP48FEB22	12-bit dual digital-to-analog converter with SPI interface
RN4871	Bluetooth Low Energy Module
MCP73830	Single-Cell Li-Ion charge management controller with soft start
SST25PF040C	4 Mbit 2.3-3.6V SPI serial flash
MCP1812	300 mA ultra-low IQ LDO linear regulator
MIC94325	500 mA low-frequency ripple attenuation LDO

1.5 CONTENTS OF THE HV56020/22 EVALUATION BOARD

The HV56020/22 Evaluation Board kit includes:

- HV56020/22 Evaluation Board (ADM00924)
- Important Information Sheet

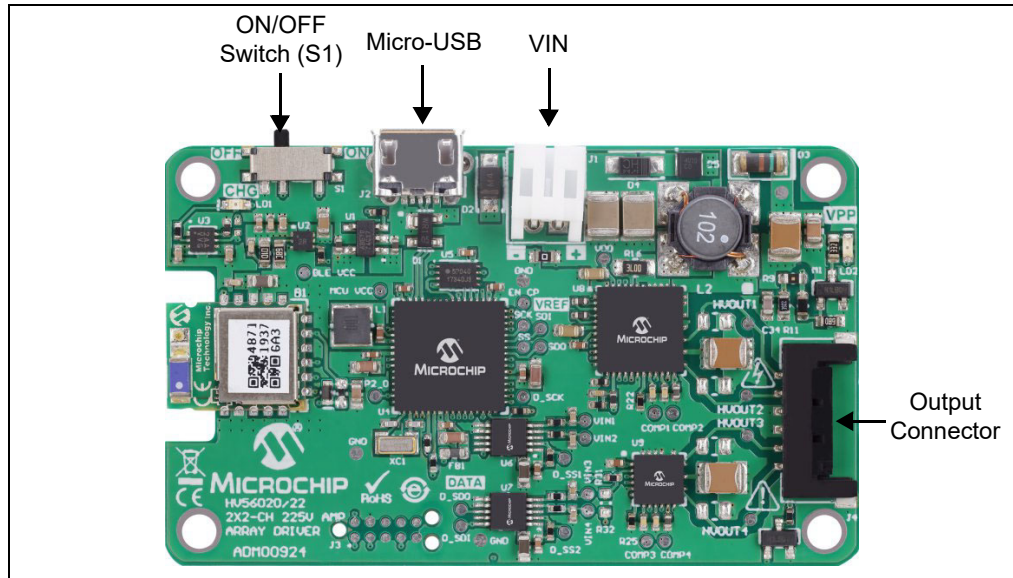


FIGURE 1-2: HV56020/22 Evaluation Board.

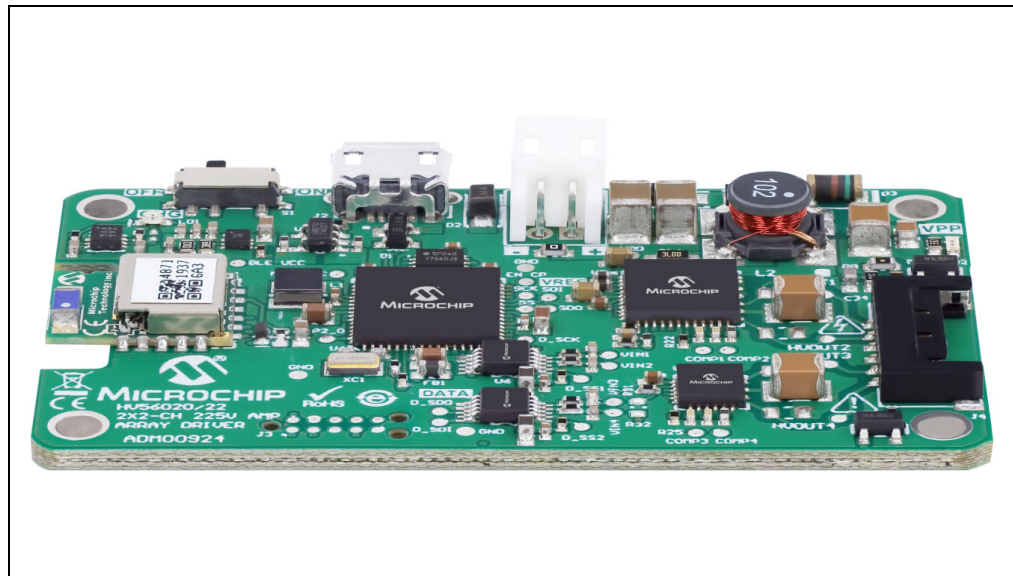


FIGURE 1-3: HV56020/22 Evaluation Board Side View.

NOTES:

Chapter 2. Installation and Operation

2.1 GETTING STARTED

The HV56020/22 Evaluation Board is fully assembled and tested. The board requires an external voltage source.

2.1.1 Tools Required for Operation

- A single-cell Li-Ion battery (500 mAh or greater, battery male connector must be compatible with P/N: S2B-PH-K-S(LF)(SN) or 440055-2)
- A personal computer with Windows® 10 or a phone/tablet with an Android™ system supporting BLE
- An oscilloscope to observe the waveforms and measure electrical parameters
- Haptic loads or equivalent capacitance loads: 0.22 µF
- Refer to the product's website for recommended actuators

2.2 SETUP PROCEDURE

To operate the HV56020/22 Evaluation Board, follow the steps below. Before using the Evaluation Board, complete the Windows® 10 initial driver installation.

WARNING

Read the HV56020/22 Evaluation Board User's Guide (this document) fully before proceeding to board setup and usage.

2.2.1 Windows® 10 Setup

Note: This is a one-time setup for the Windows® 10 PC.

1. Open the `setup.exe` application for the Windows® GUI setup.

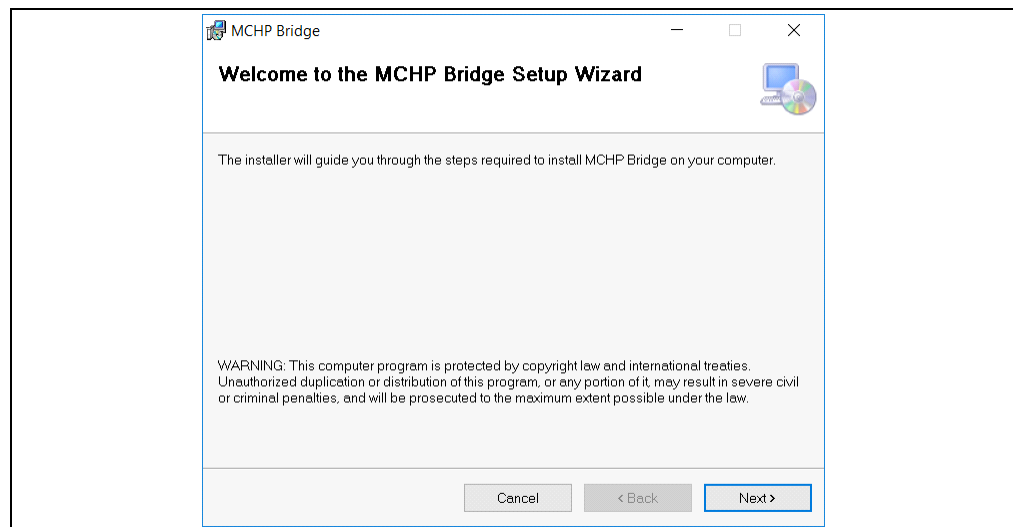


FIGURE 2-1: MCHP Bridge Setup.

2. Click **Next** in all the installation prompt windows.
3. Close the Installation Complete window, the **MCHP Bridge** logo should be visible in the Start menu.

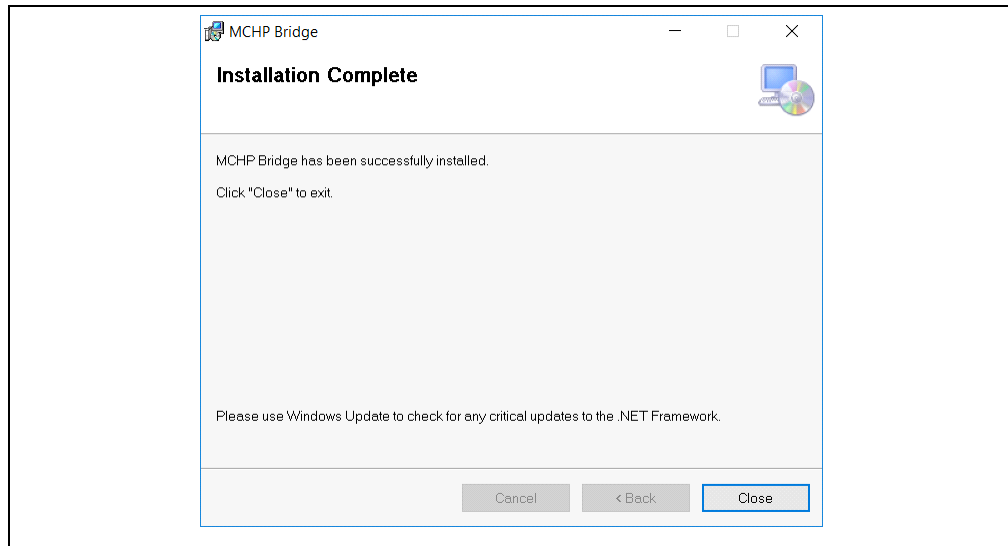


FIGURE 2-2: MCHP Bridge Installation.

2.2.1.1 WINDOWS® 10 INITIAL DRIVER INSTALLATION

1. Connect a single-cell Li-Ion battery to the J1 connector.
2. Connect the HV56020/22 Evaluation Board's Micro-USB port to the PC's USB port using a Micro-USB to USB Type A cable.
3. Launch the MCHP Haptic Bridge GUI. Turn on the HV56020/22 Evaluation Board using switch S1 (see [Figure 1-2](#)).

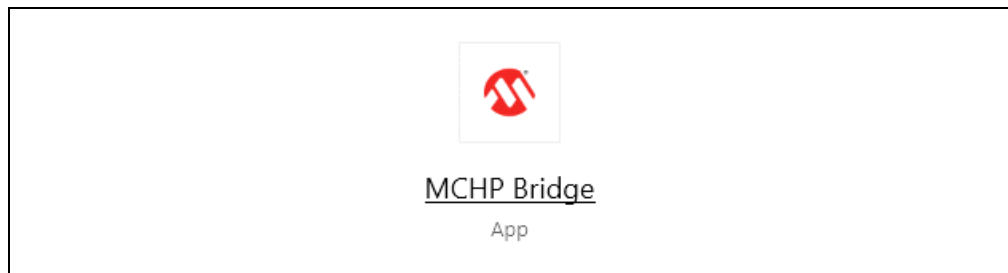


FIGURE 2-3: MCHP Bridge.

4. The following windows will appear, click **OK** and reboot the board.

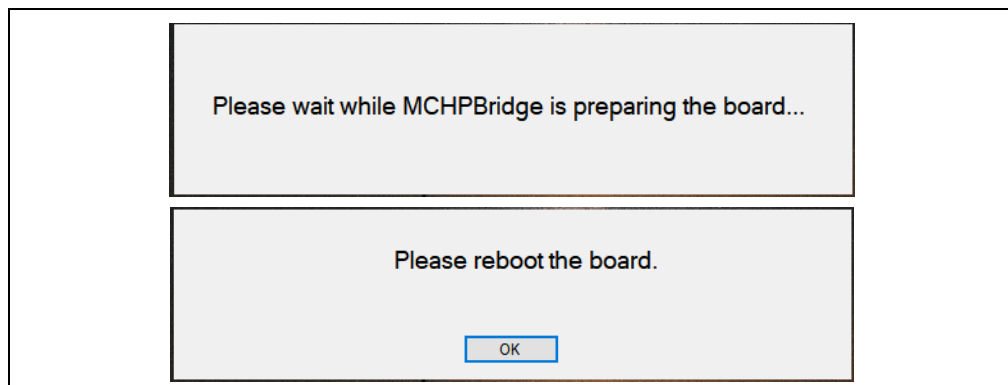


FIGURE 2-4: MCHP Bridge Start-Up and Reboot.

5. The MCHP Haptic Bridge GUI is active and recognizes the connected board as shown below:

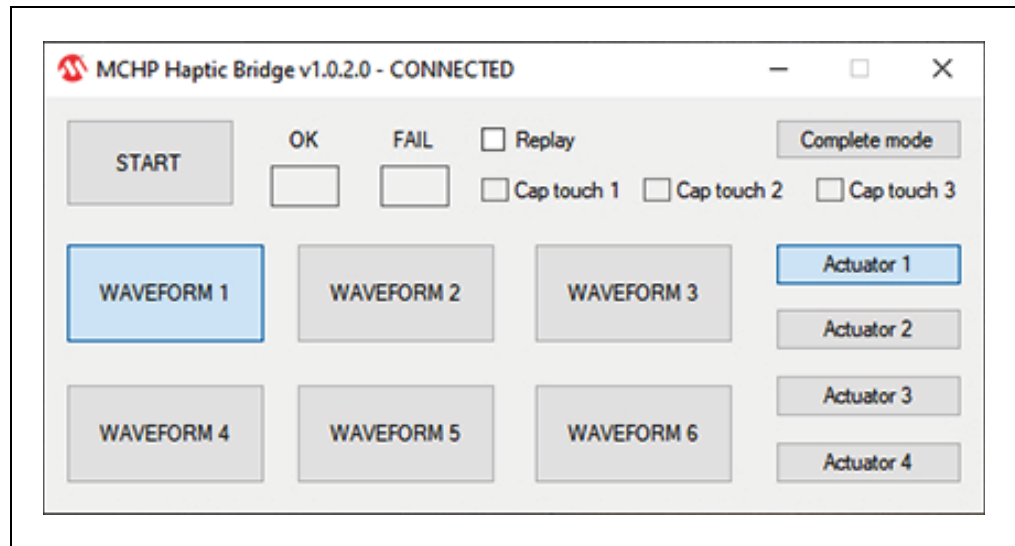


FIGURE 2-5: HV56020/22 Evaluation Board Connection.

2.2.2 Android™ Setup

1. Download the MCHP Haptic BLE App for Android™ from the product's website.
2. Install the application on an Android™ phone/tablet supporting BLE.
3. Connect a Li-Ion battery to the J1 connector and turn on the board.
4. Launch the MCHP Haptic BLE App as shown below:



FIGURE 2-6: MCHP Haptic Application.

5. Select the *Pair and Connect* option.

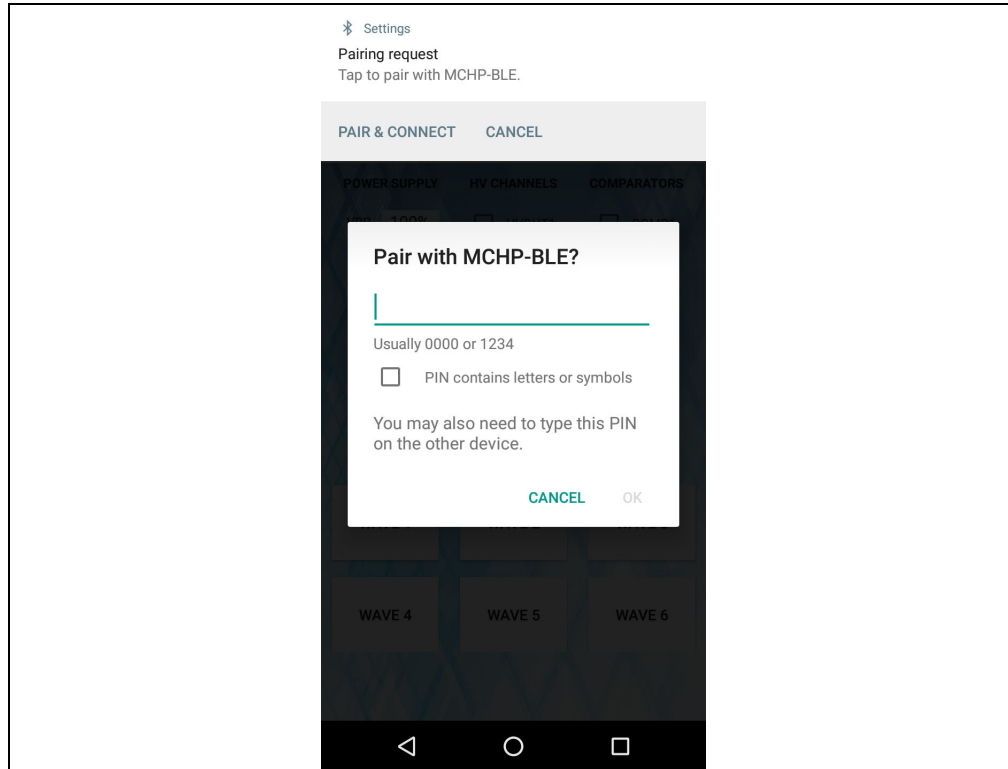


FIGURE 2-7: *Pair and Connect.*

6. Enter "123456" as PIN code.

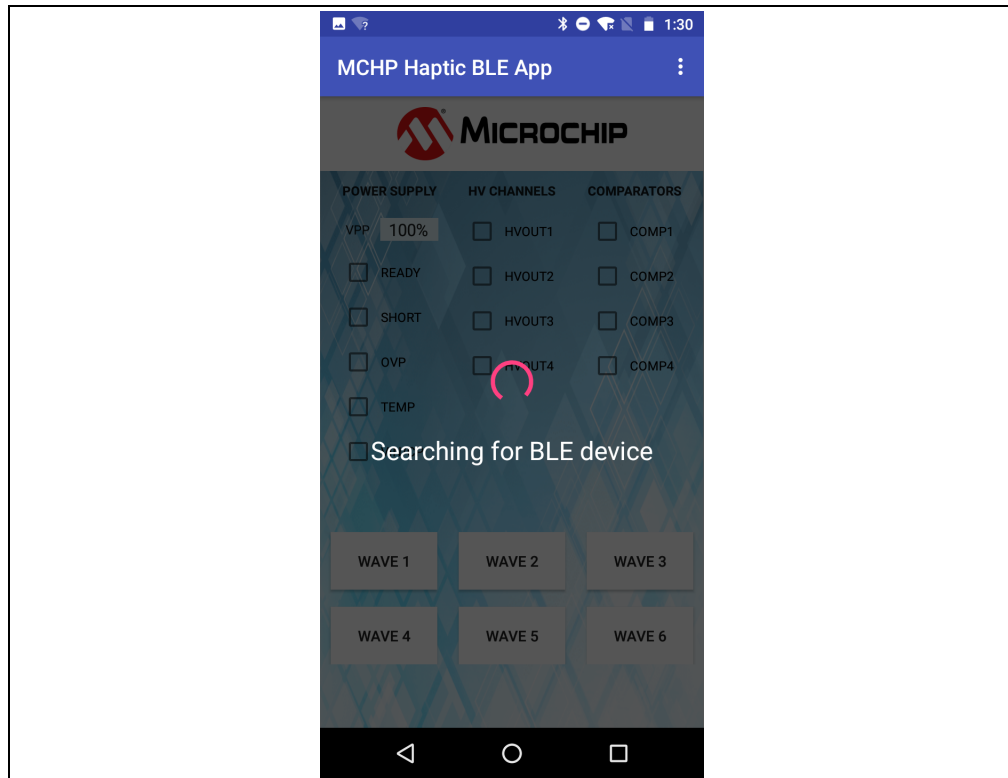


FIGURE 2-8: *Connecting the Device.*

7. Once paired successfully, the MCHP Haptic BLE App becomes active.



FIGURE 2-9: Application Activated.

2.3 WINDOWS[®] PC OPERATION

2.3.1 Introduction

The MCHP Haptic Bridge GUI operates with two different data file formats: CSV (Comma Separated Value) and WAV (Waveform Audio File).

2.3.1.1 CSV FILE FORMAT

The CSV file format consists of two components: time and voltage. The time scale is defined by the data sampling rate, where a column with 8000 data points corresponds to a single waveform with 8 kS/s. Vertical columns correspond to the sampling data points of the waveforms. The total number of cells divided by one second sets the sampling rate of the waveforms. All waveforms (columns) must have the same sampling rate (length) to avoid a program malfunction. The supported sampling frequency range of the MCHP Haptic Bridge GUI is 8 kS/s to 20 kS/s.

The default sampling frequency of the MCHP Haptic Bridge GUI is 8 kS/s. If a file contains 16 kS/s, it will be interpreted as a waveform with 8 kS/s, with a 2s duration. The sampling rate can be adjusted for any CSV file by selecting a different sampling rate option available in the GUI. See [Section 2.3.2 “Operation - Simple Mode”](#) for more details.

Waveform voltage amplitude is defined by an 8-bit code word format, where 0 corresponds to 0% and 255 to 100% of the VPP voltage selected. There are 8 voltage levels available in the MCHP Haptic Bridge: 225V, 202.5V, 180V, 157.5V, 135V, 112.5V, 90V, and 67.5V. [Figure 2-10](#) shows a CSV sample file of four channels, with an 8 kS/s format.

	A	B	C	D	E
1	204	78	1	141	
2	204	76	2	141	
3	204	75	5	142	
4	142	76	10	142	
5	144	81	18	144	
6	144	90	50	144	
...
7998	4	10	55	4	
7999	2	5	4	2	
8000	1	0	3	1	

Waveform: 1 2 3 4

FIGURE 2-10: CSV File Sample with 4-8 kS/s Waveforms.

Column A corresponds to waveform 1 and it is transmitted by default to HVOUT1. Column B is transmitted to HVOUT2, column C to HVOUT3 and column D to HVOUT4. The GUI allows a remapping of the waveforms to any HVOUT channels. See [Section 2.3.2 “Operation - Simple Mode”](#).

2.3.1.2 WAV FILE FORMAT

WAV files are used and generated by an audio processing software and most of the time consist of two channels. For the MCHP Haptic Bridge GUI, WAV files must contain four audio channels with the allowable sampling frequency range of 8 kS/s to 20 kS/s. Sampling frequency is determined and adjusted by the audio processing software. WAV files with sampling frequencies out of the allowable range will cause the GUI to malfunction.

The amplitude defined in a WAV file ranges from -1 to 1 in dB scale. That corresponds to 0-255 when compared to the CSV file data format. [Figure 2-11](#) shows a diagram of a WAV file with four audio channels. Waveforms represented in full audio scale of -1 dB to 1 dB correspond to a 100% voltage amplitude when transmitted to the HVOUTs channels.

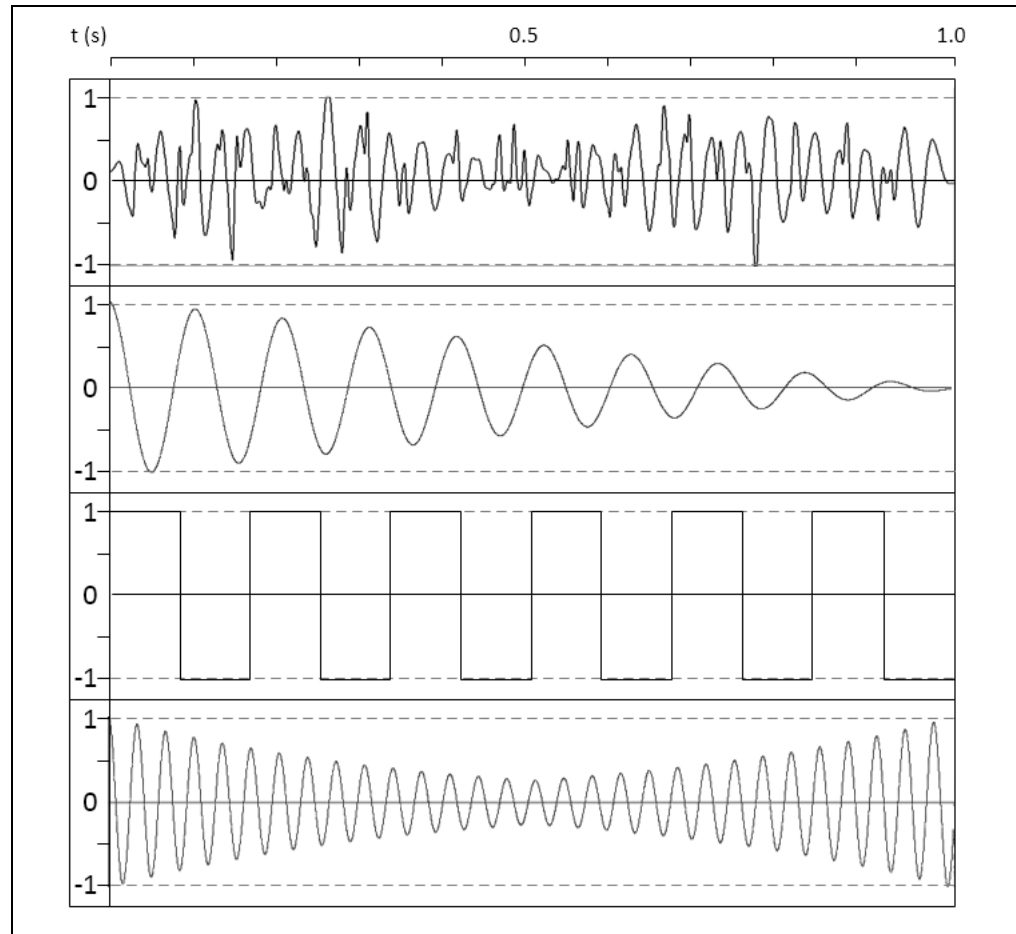


FIGURE 2-11: 4-Channel WAV File Format Diagram.

2.3.2 Operation - Simple Mode

The setup procedure must be successfully completed.

1. Connect a Li-Ion battery to the J1 connector.
2. Connect the HV56020/22 Evaluation Board's Micro-USB cable to the PC USB connector.
3. Launch the MCHP Haptic Bridge GUI.

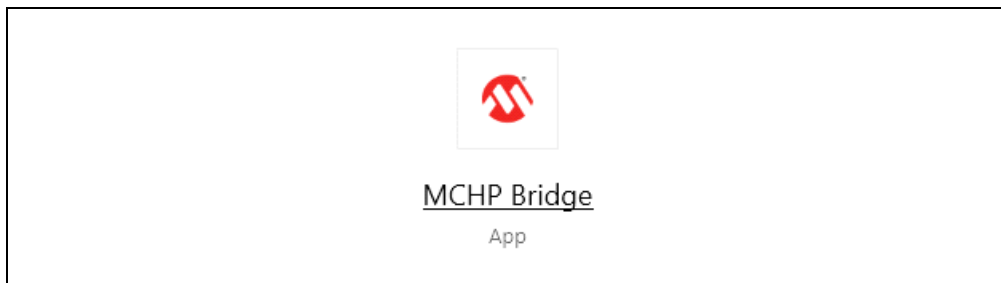


FIGURE 2-12: MCHP Bridge.

4. Turn on the HV56020/22 Evaluation Board (S1).
5. The evaluation board will be recognized by the GUI as shown in [Figure 2-13](#).
6. Select a channel, Actuator, to transmit.
7. Select a Waveform and press START.
 - OK box will turn green for a successful transmission.
 - If FAIL box lights up, select the Complete Mode and see the flags that cause the error.

Note: For Cap touch operation, refer to [Section 2.5 “Capacitive Touch Operation”](#). For waveform types, see Appendix C.

WARNING

Do not use the PC Windows® GUI along with the Android™ phone BLE application.

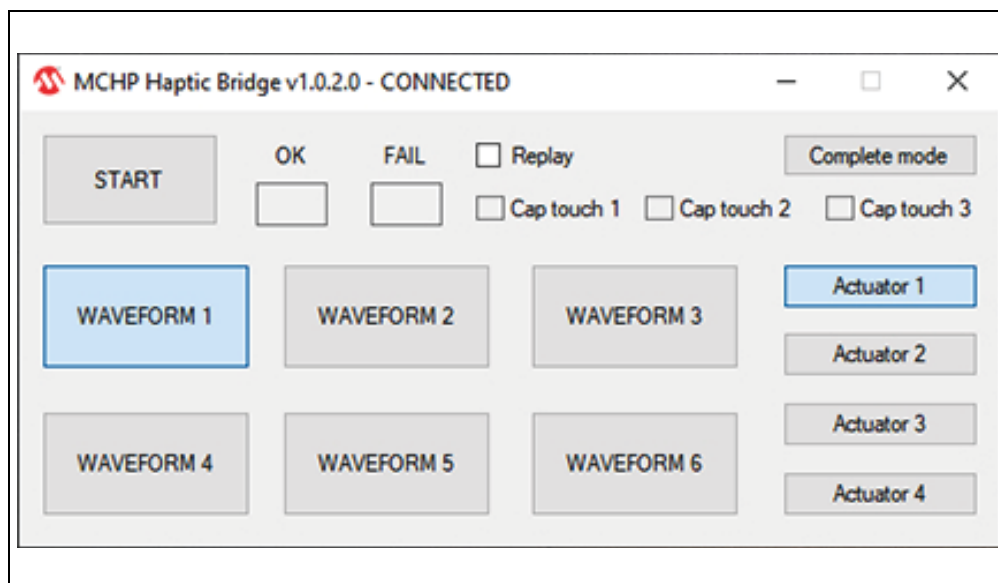


FIGURE 2-13: The GUI Recognizes the Evaluation Board.

2.3.3 Operation - Complete Mode

1. Click in the **Complete mode** tab.

2.3.3.1 WAVEFORM SELECTION

1. Click the **Add** button to include the WAV or CSV file.
 - WAV files automatically display the sampling rate.
 - The CSV files sampling rate is set to 8000 Hz by default. The sampling rate can be adjusted if desired. The maximum rate is 20 kS/s.
2. For continuous transmission of waveforms (optional), activate the Replay Effects check box.

Note: Power dissipation must be taken into account when the Replay Effects option is used.

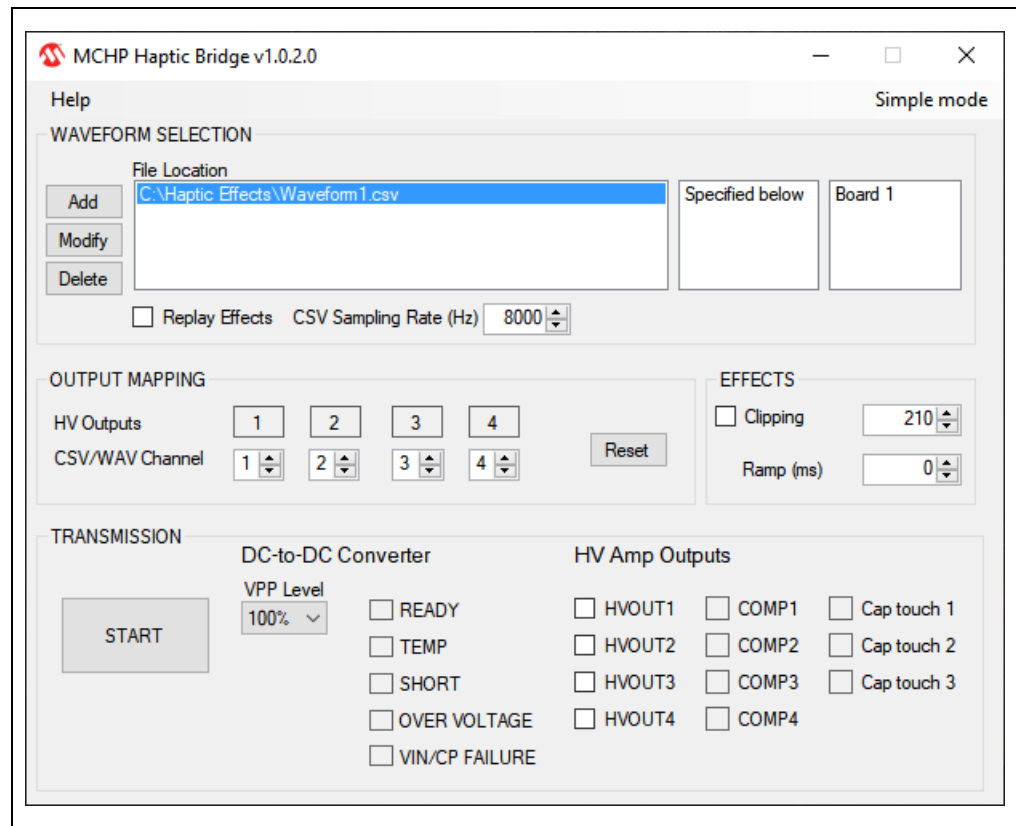


FIGURE 2-14: Waveform Selection.

2.3.3.2 CHANNEL MAPPING

The channel mapping option allows the user to redirect waveforms to the desired HVOUTs.

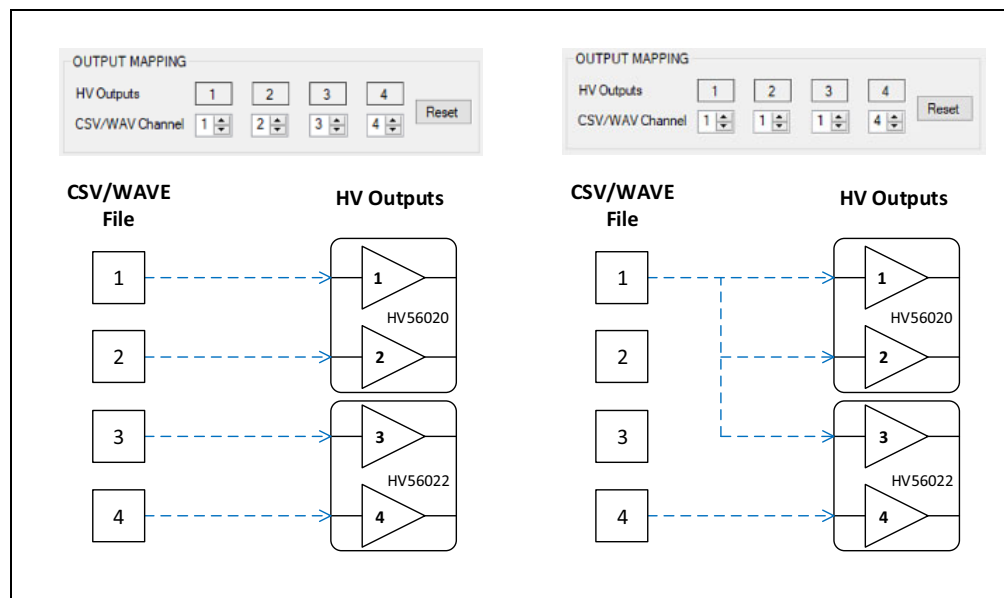


FIGURE 2-15: Channel Mapping.

2.3.3.3 EFFECTS

There are two available effects, Clipping and Ramp. Effects apply to all waveforms (from 1 to 4) in the WAV or CSV files.

- The Ramp effect is in terms of milliseconds (ms). The effect is applied by default to all waveforms with a 0 ms start time.
- Clipping is enabled when the check box is activated. Clipping limits can be modified accordingly.

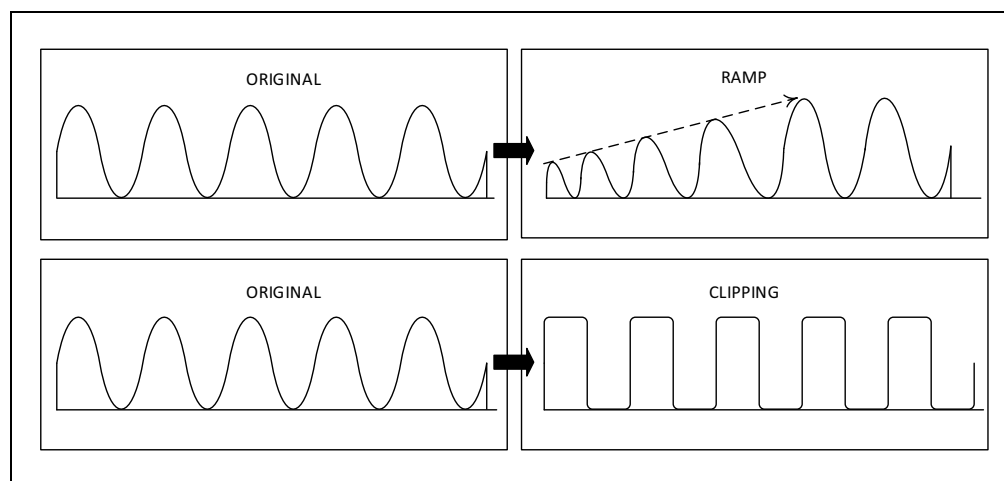


FIGURE 2-16: Clipping and Ramp Effects.

2.3.3.4 TRANSMISSION

Once waveform files and effects are selected and specified in the “WAVEFORM SELECTION”, “OUTPUT MAPPING” and “EFFECTS” sections, the user can proceed to the “TRANSMISSION” section. There are two subsections: “DC-to-DC Converter” and “HV Amp Outputs”.

DC-to-DC Converter

1. Select the desired VPP Level.

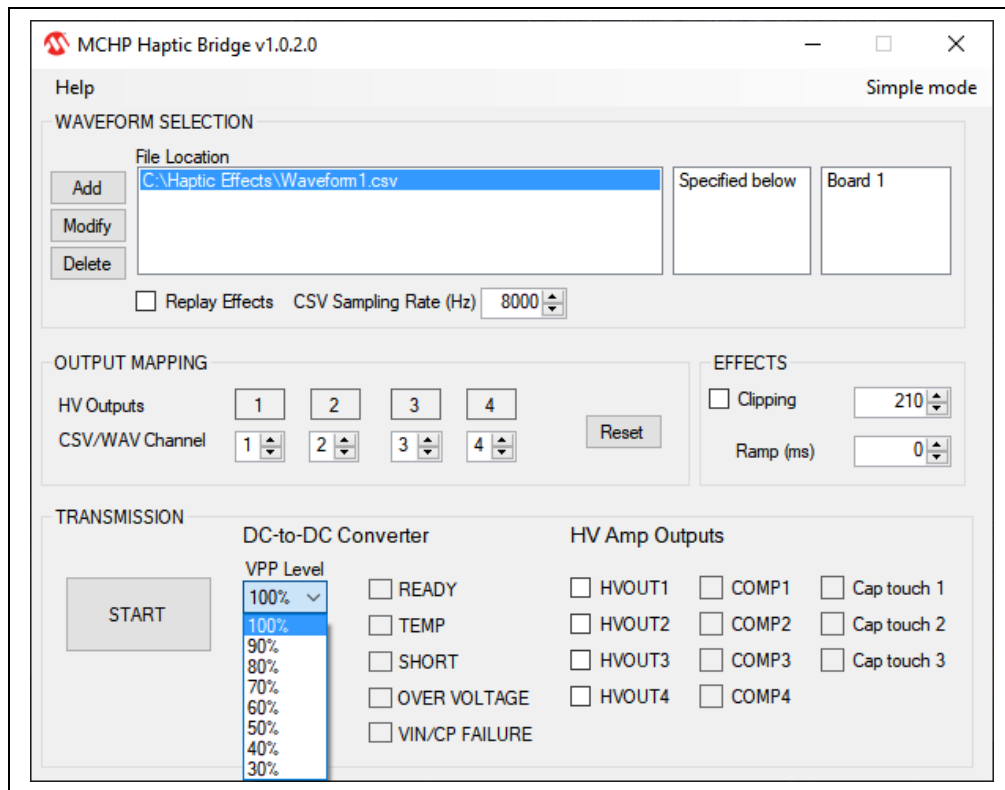


FIGURE 2-17: DC-to-DC Converter VPP Selection.

TABLE 2-1: VPP LEVEL

Level (%)	VPP (V)
100	225
90	202.5
80	180
70	157.5
60	135
50	112.5
40	90
30	67.5

READY, TEMP, SHORT, OVER VOLTAGE, VIN/CP FAILURE are status flags for the converter. They are displayed by the GUI to indicate the current status of the power supply.

- **READY** indicates that the VPP voltage has reached the set value and the GUI will send data waveforms to the high-voltage amplifiers.
- **TEMP** indicates that the HV56020 IC has reached its maximum recommended operating temperature of +125°C to +150°C. A TEMP flag will cause the GUI to deactivate VPP and stop sending data to the high-voltage amplifiers to avoid damage. When TEMP flag occurs, the GUI will block the **START** button for one minute to let the board cool off and avoid sending data.
- **SHORT** indicates there is a short-circuit condition in the DC-to-DC Converter VPP. A SHORT flag will cause the GUI to stop any operation.
- **OVER VOLTAGE** indicates that VPP is higher than its maximum recommended operating voltage of 225V. The flag will cause the GUI to stop any operation.
- **VIN/CP FAILURE** indicates two possible scenarios: VIN or Charge Pump failures, when VIN drops below the minimum operating voltage of 2.7V. A battery discharged below 2.7V will cause the failure. If the internal Charge Pump of the HV56020 drops below the minimum operating voltage, it will cause the device to malfunction.

HV Amp Outputs

2. Select the HVOUT to transmit to. Only two channels allow a simultaneous transmission.

COMP1 to COMP4 are the comparator output flags that monitor short circuits on the HVOUTs. They are indicator flags. In case of a short circuit, they will turn red momentarily. A short-circuit condition in the outputs disables the data transmission and deactivates the power supply, VPP.

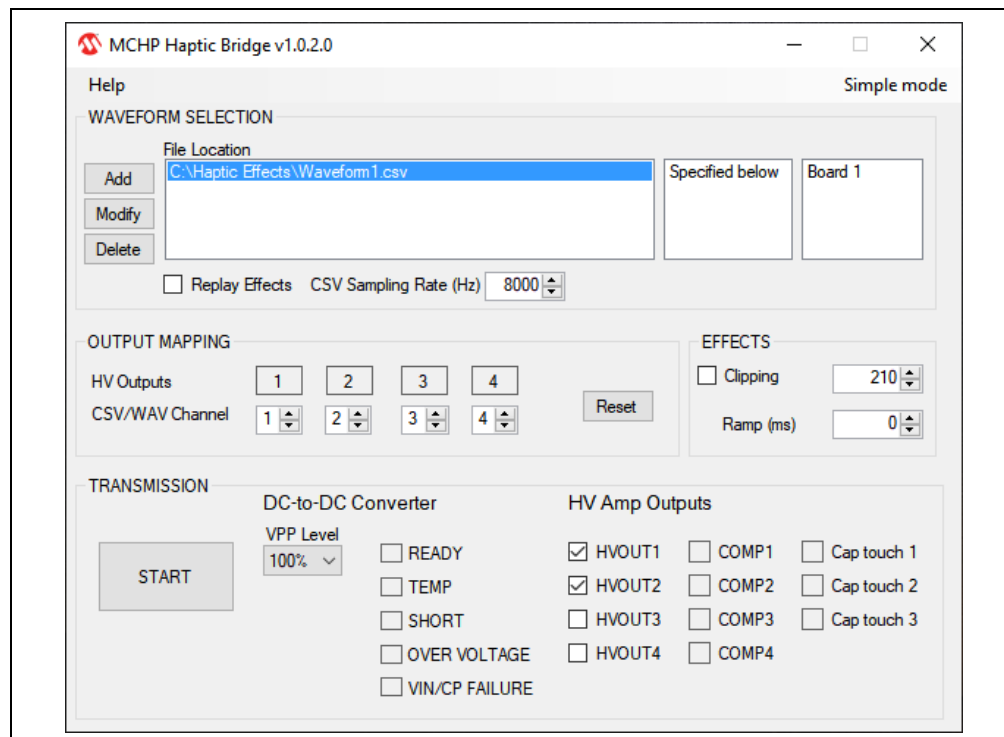


FIGURE 2-18: HV Amp Outputs Selection.

- Click **START** to transmit data to the HV Amp Outputs. A successful transmission only displays a READY flag.

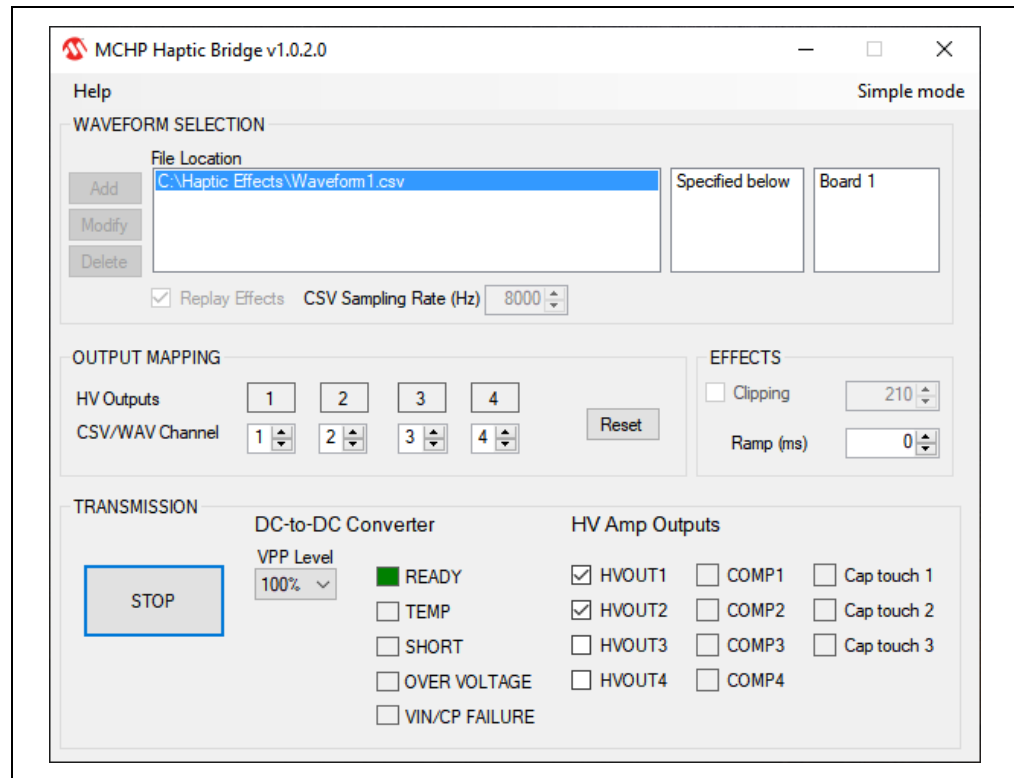


FIGURE 2-19: Successful Transmission.

- The GUI will stop sending data after the CSV/WAV file is transmitted (it depends on the file's size).

- Note 1:** If the Replay Effects option is selected, the GUI will play the file in an infinite loop. Continuous transmission must be monitored carefully. High-power dissipation might lead to thermal runaway and damage the device components in the HV56020/22 Evaluation Board.
- 2:** The Li-Ion battery will be charged by the MCP73830 when the MCU does not send data and when the USB cable is connected to the evaluation board. During charging, the CHG-LD1 will light.

2.4 ANDROID™ PHONE OPERATION

2.4.1 Introduction

The MCHP Haptic BLE App includes six waveform patterns stored in the evaluation board's memory.

2.4.2 Operation

1. Connect a Li-Ion battery to the J1 connector and turn on the board (S1).
2. Launch the MCHP Haptic BLE App.
3. The HV56020/22 Evaluation Board will be recognized and become active as shown below:



FIGURE 2-20: MCHP Haptic BLE App.

4. Select the desired VPP level.



FIGURE 2-21: *Selecting the VPP Level.*

5. Select the HV CHANNELS for data transmission.



FIGURE 2-22: *HV CHANNELS Selection.*

6. Select a **Waveform** button for transmission. The READY flag will turn green during transmission.



FIGURE 2-23: Waveform Transmission.

The Power Supply (DC-to-DC Converter) and Comparators flags have the same functionality as described in [Section 2.3.2 “Operation - Simple Mode”](#).

2.5 CAPACITIVE TOUCH OPERATION

2.5.1 Introduction

The SAML21J18 Microcontroller has the Peripheral Touch Controller, PTC, module that allows for mutual and self-capacitance sensing modes. The HV56020 Evaluation Board implements the self-capacitance mode using MCU pins: 5 (PB04), 6 (PB05), and 15 (PA06) for button touch implementation. The three touch sensor connections are available at the J5 connector, see MCU schematic page. The J5 connector has connections for an LED: anode and cathode. The anode is connected to 3.3V potential and the cathode to a series resistor followed by n-channel transistor. A 20 mA (forward current) LED is recommended to be used.

2.5.2 Operation

1. Connect the Li-ion battery to J1 connector
2. Connect the 6-position flat flex cable (e.g P/N: 0151670219) to J5 and to touch sensor load with the 3 touch sensor buttons and LED
3. Turn-On the Evaluation Board (S1)
4. Press any of the three touch sensors: TS1, TS2 or TS3. Waveforms stored in memory will be played
 - TS1 transmits WAVE 1 into HVOUT1 (Appendix C: [Figure C-5](#))
 - TS2 transmits WAVE 2 into HVOUT2 (Appendix C: [Figure C-6](#))
 - TS3 transmits WAVE 3 into HVOUT3 (Appendix C: [Figure C-7](#))
5. During transmission, the LED will light up when any of the three sensors is touched

□

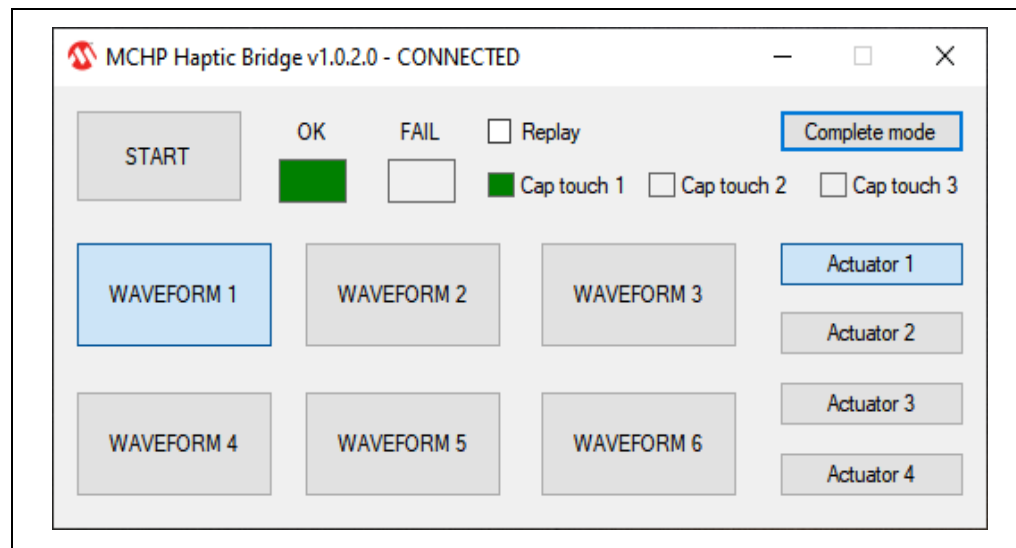


FIGURE 2-24: *Capacitive Touch Operation.*

NOTES:

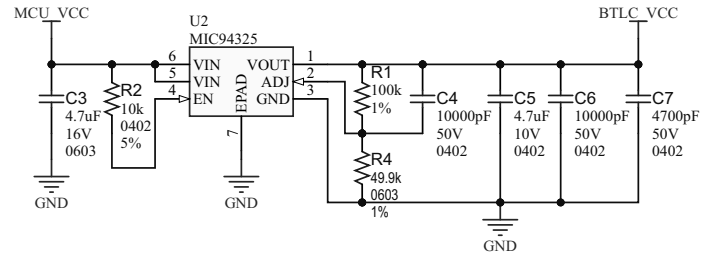
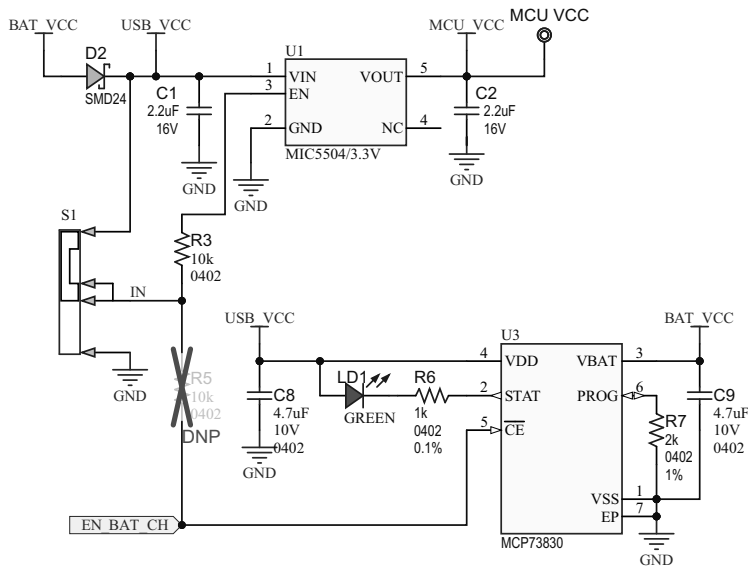
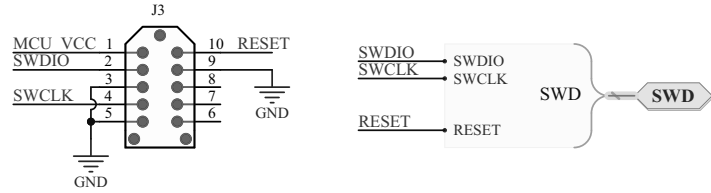
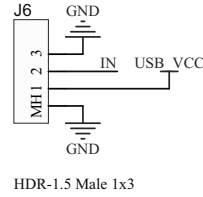
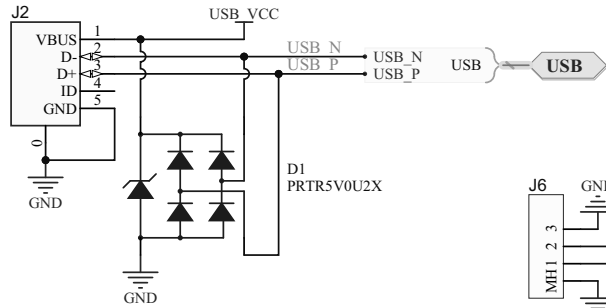
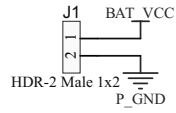
Appendix A. Schematic and Layouts

A.1 INTRODUCTION

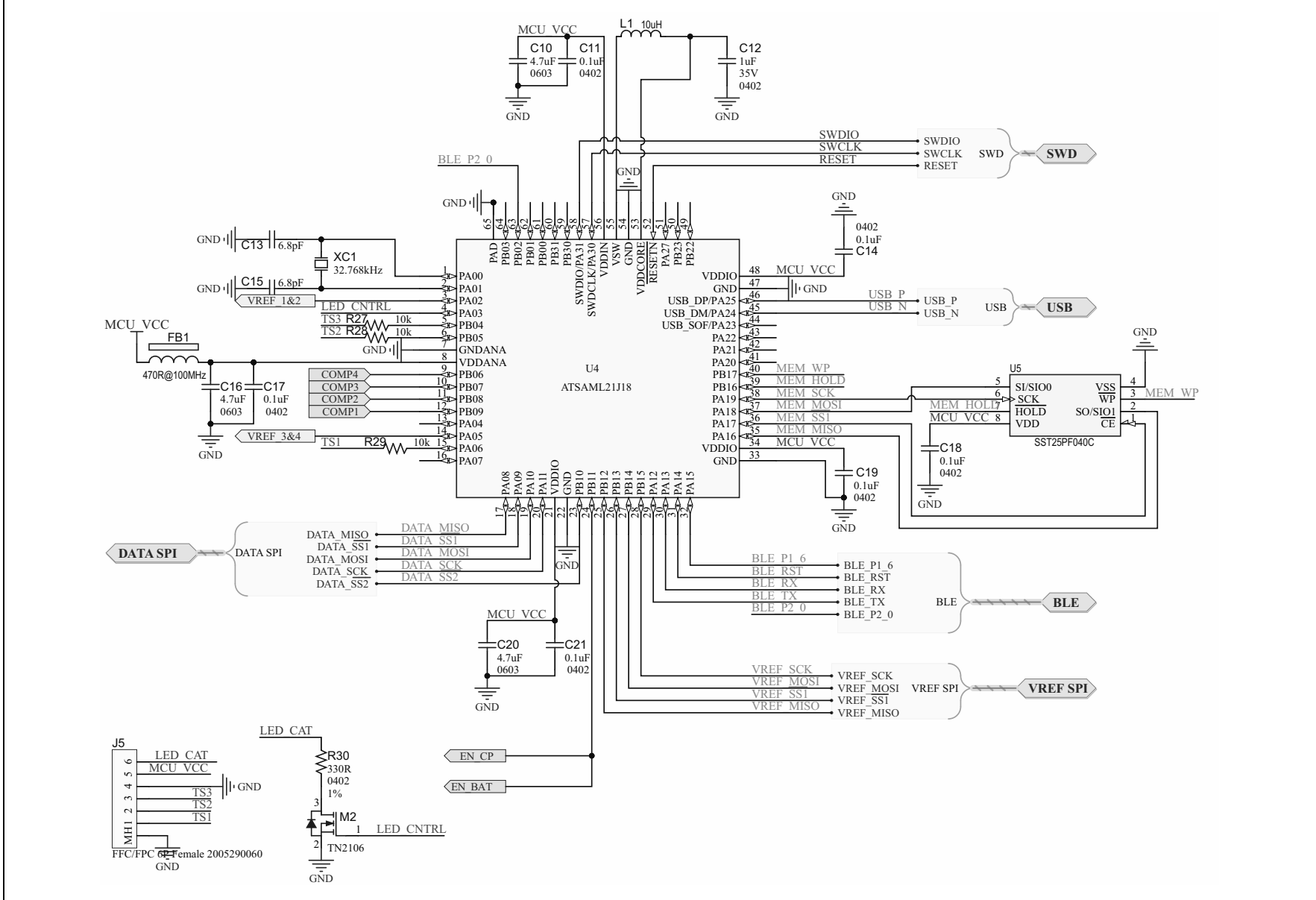
This appendix contains the following schematics and layouts for the HV56020/22 Evaluation Board:

- [Board – Schematic Top Level](#)
- [Board – Schematic Connectors](#)
- [Board – Schematic MCU](#)
- [Board – Schematic HV Drivers](#)
- [Board – Schematic BLE](#)
- [Board – Top Layer and Silk](#)
- [Board – Mid-Layer 1](#)
- [Board – Ground Plane](#)
- [Board – Power Plane](#)
- [Board – Mid-Layer 2](#)
- [Board – Bottom Layer and Silk](#)

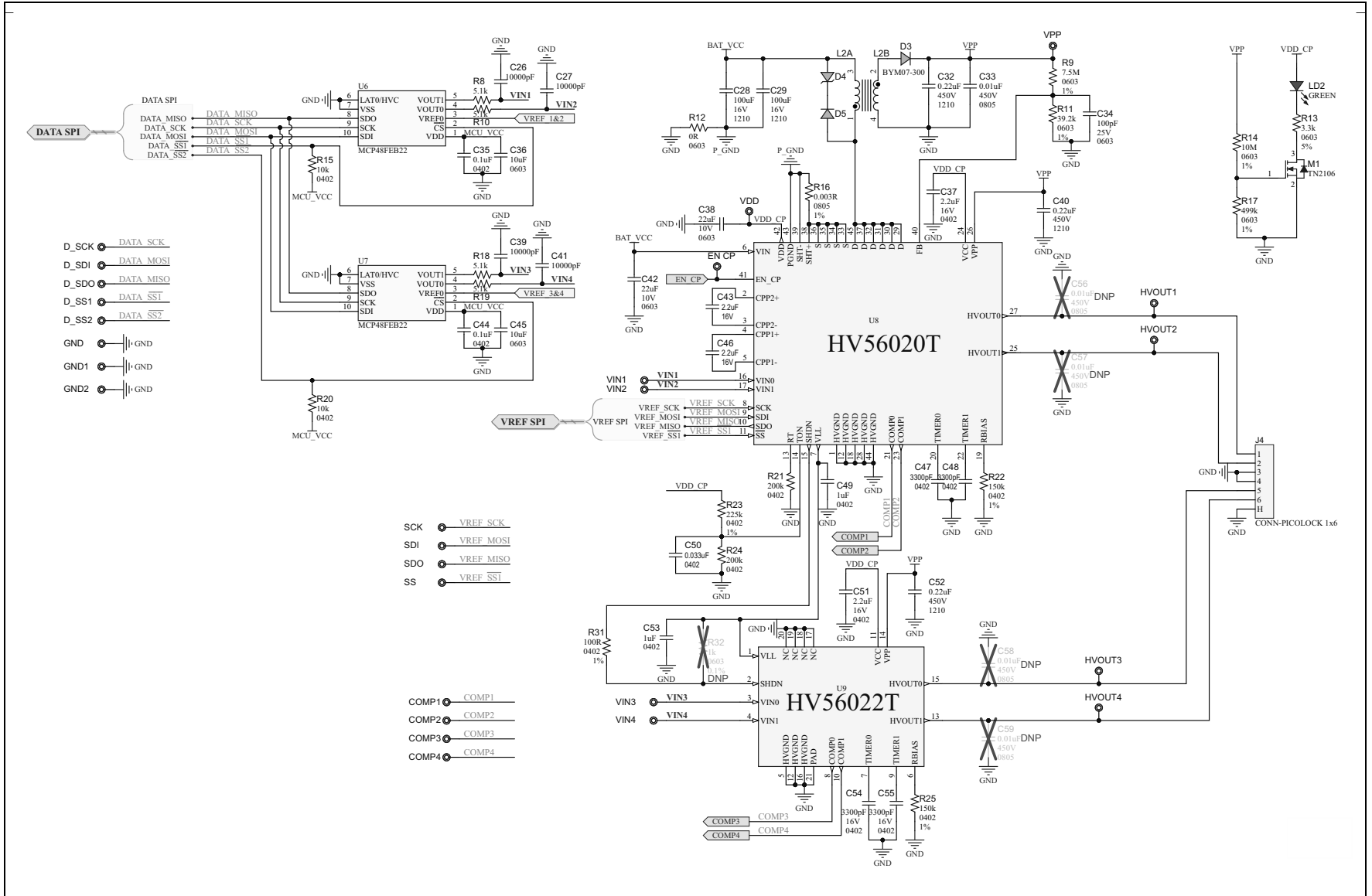
A.3 BOARD – SCHEMATIC CONNECTORS



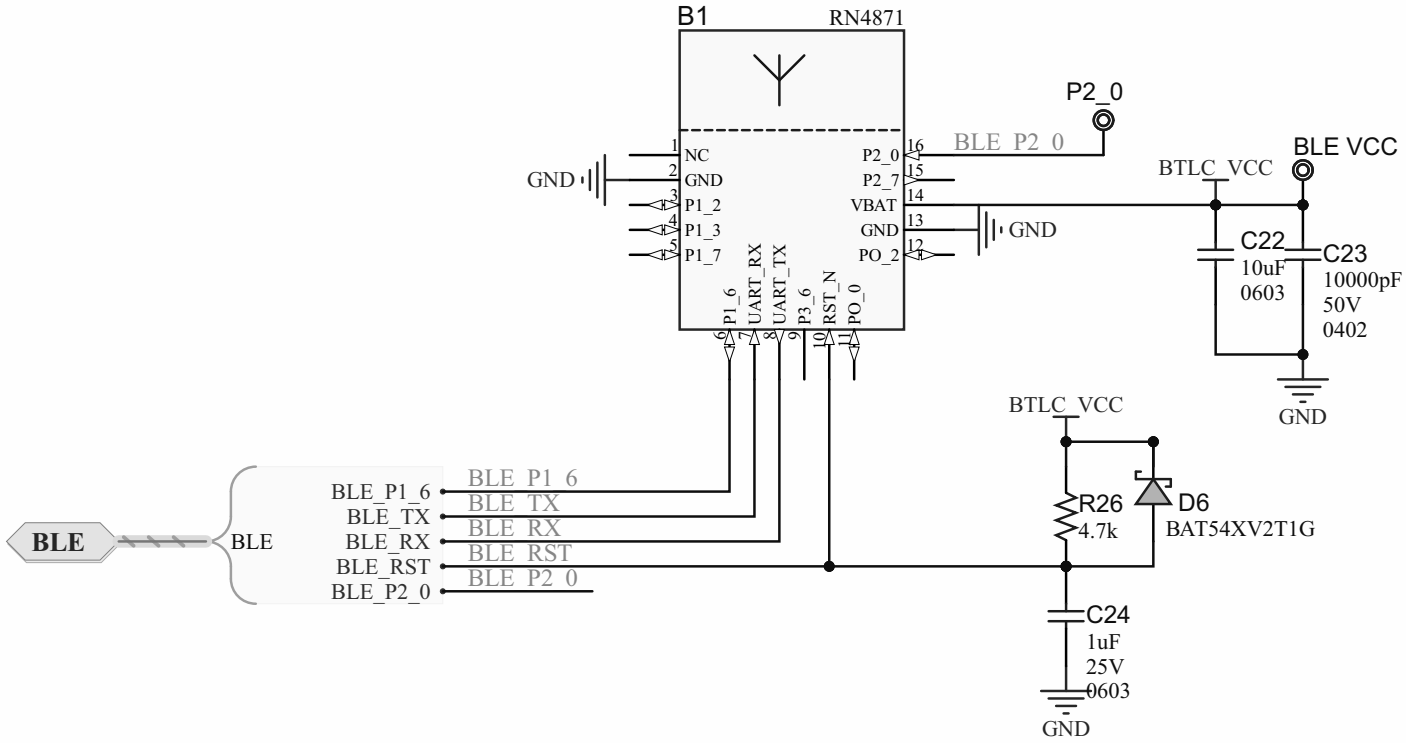
A.4 BOARD – SCHEMATIC MCU



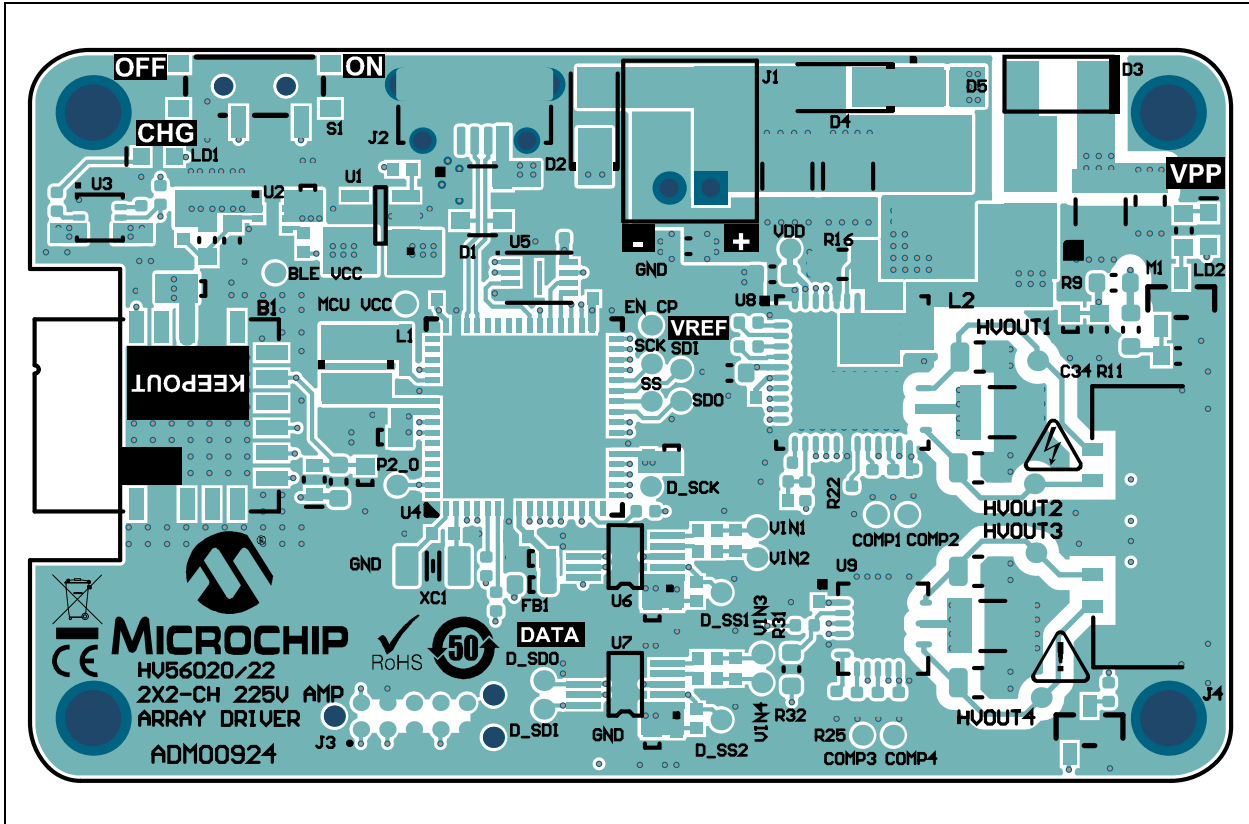
A.5 BOARD – SCHEMATIC HV DRIVERS



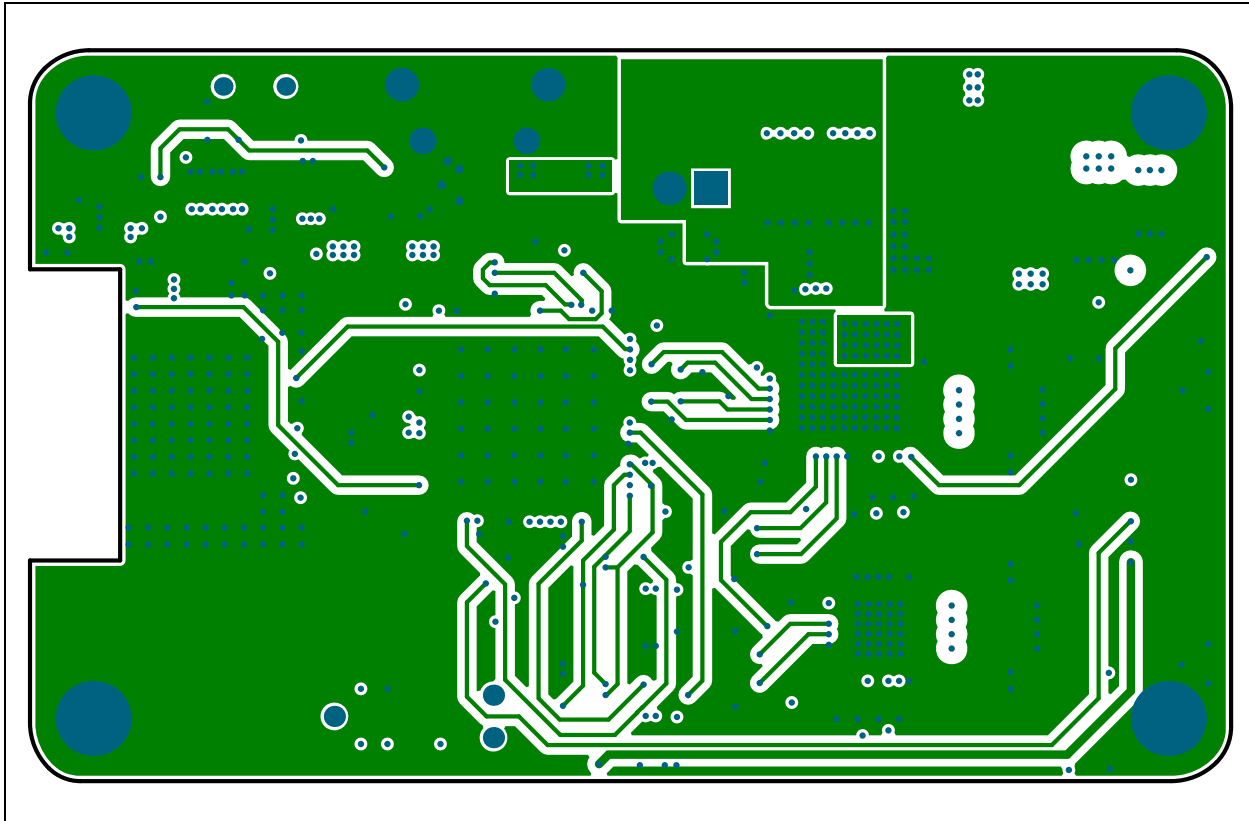
A.6 BOARD – SCHEMATIC BLE



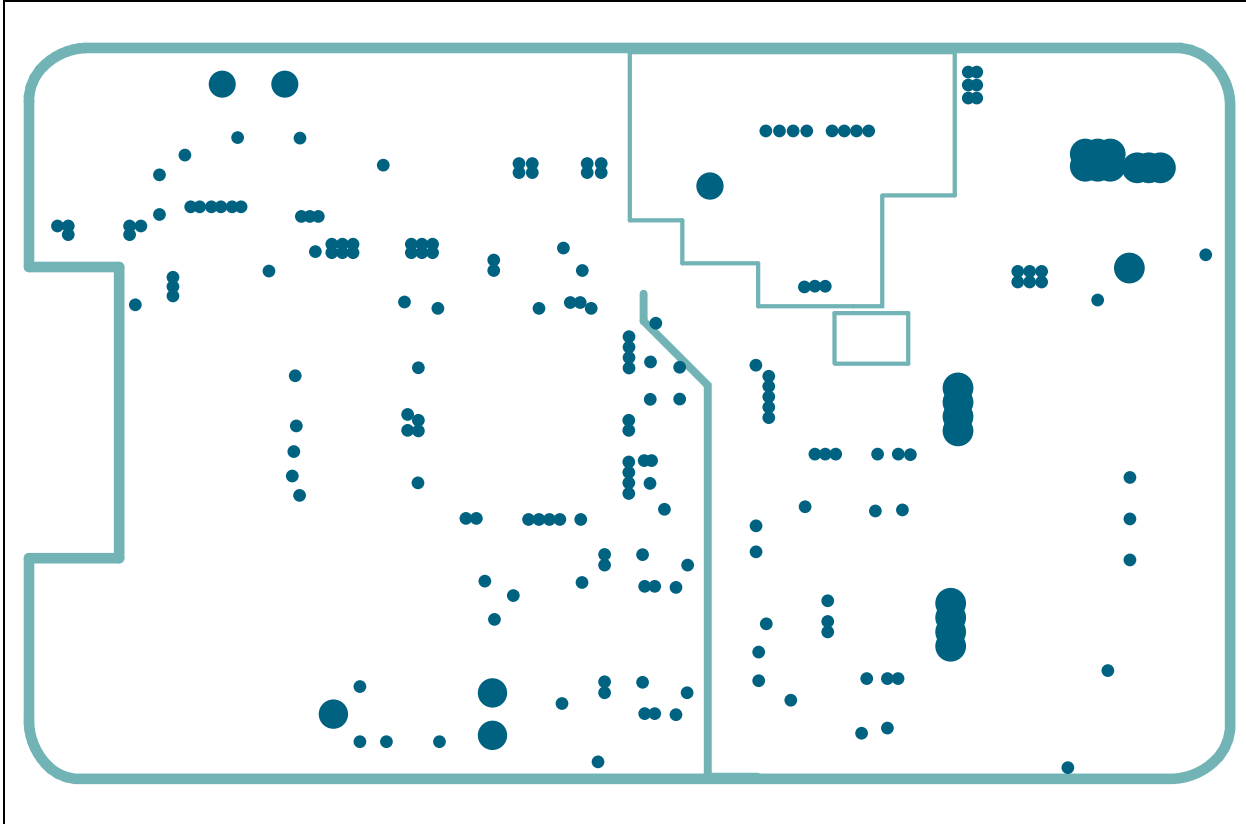
A.7 BOARD – TOP LAYER AND SILK



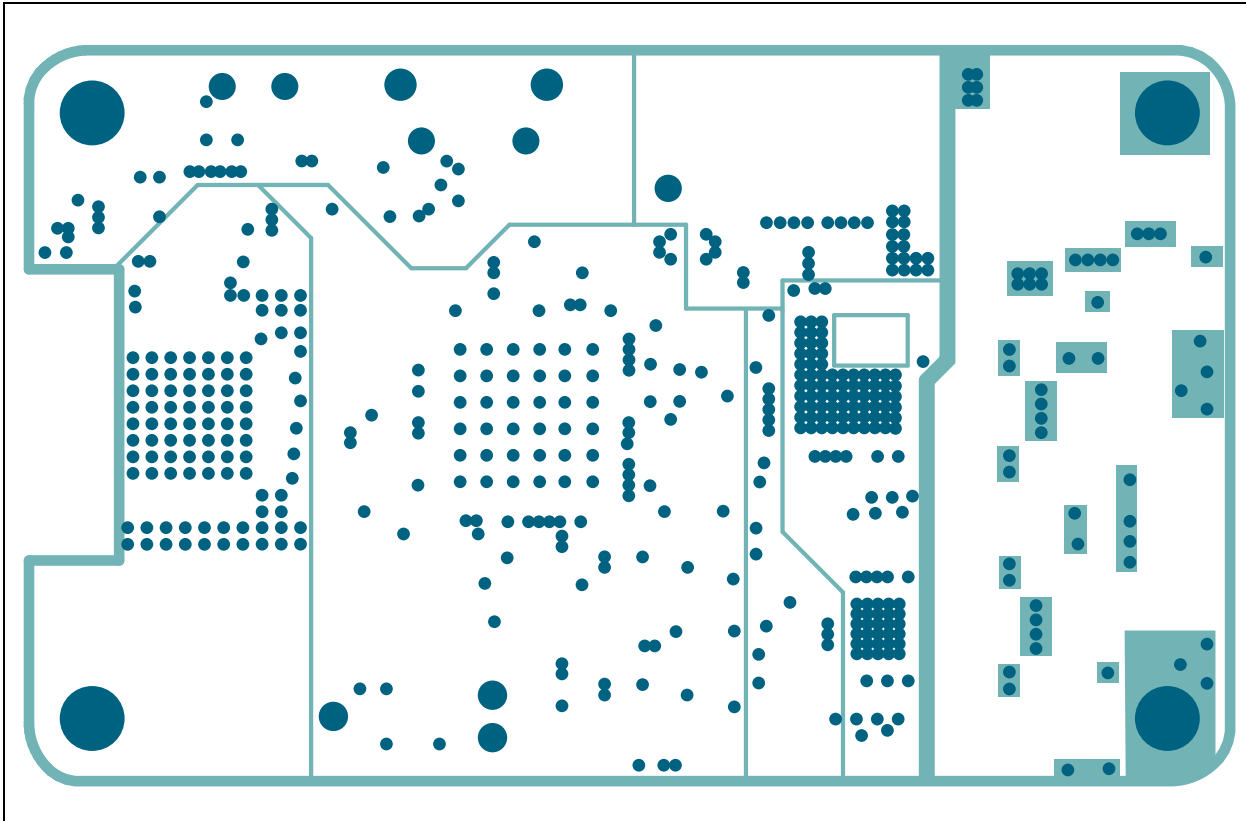
A.8 BOARD – MID-LAYER 1



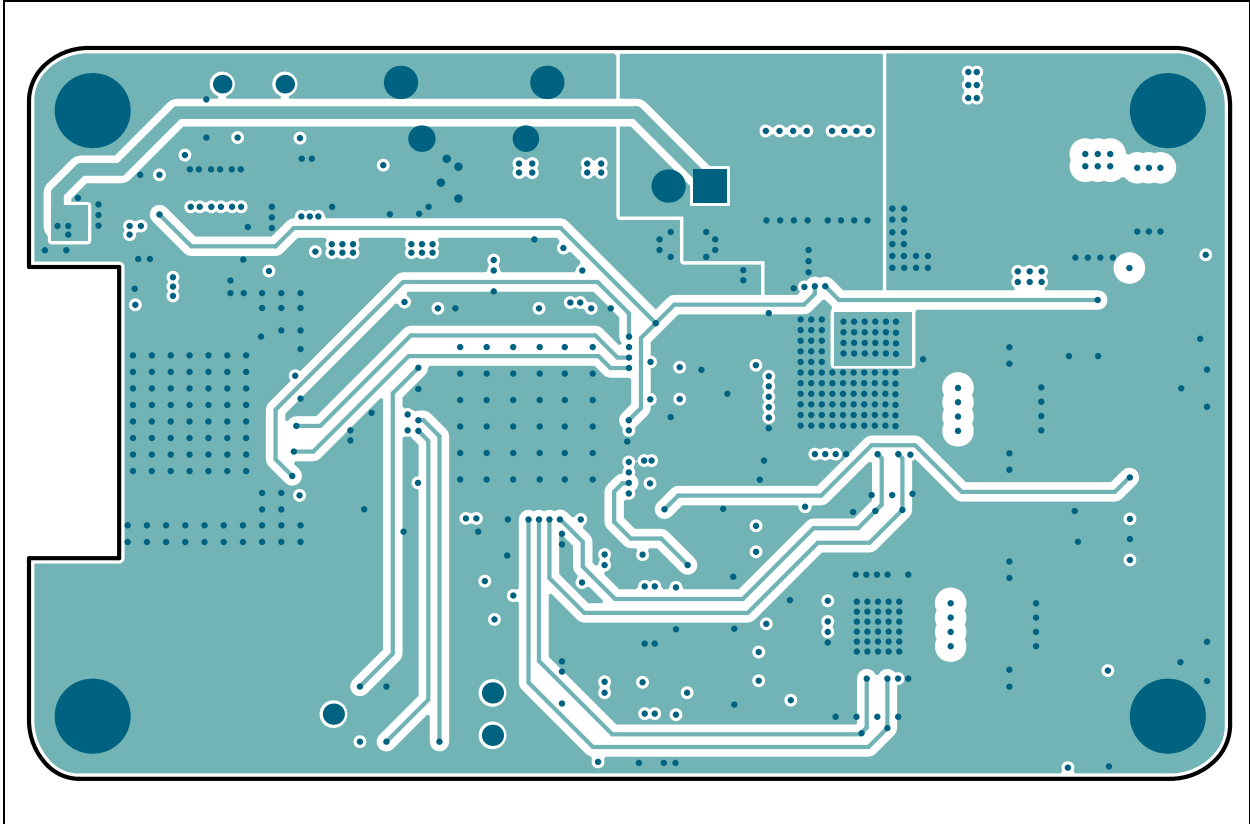
A.9 BOARD – GROUND PLANE



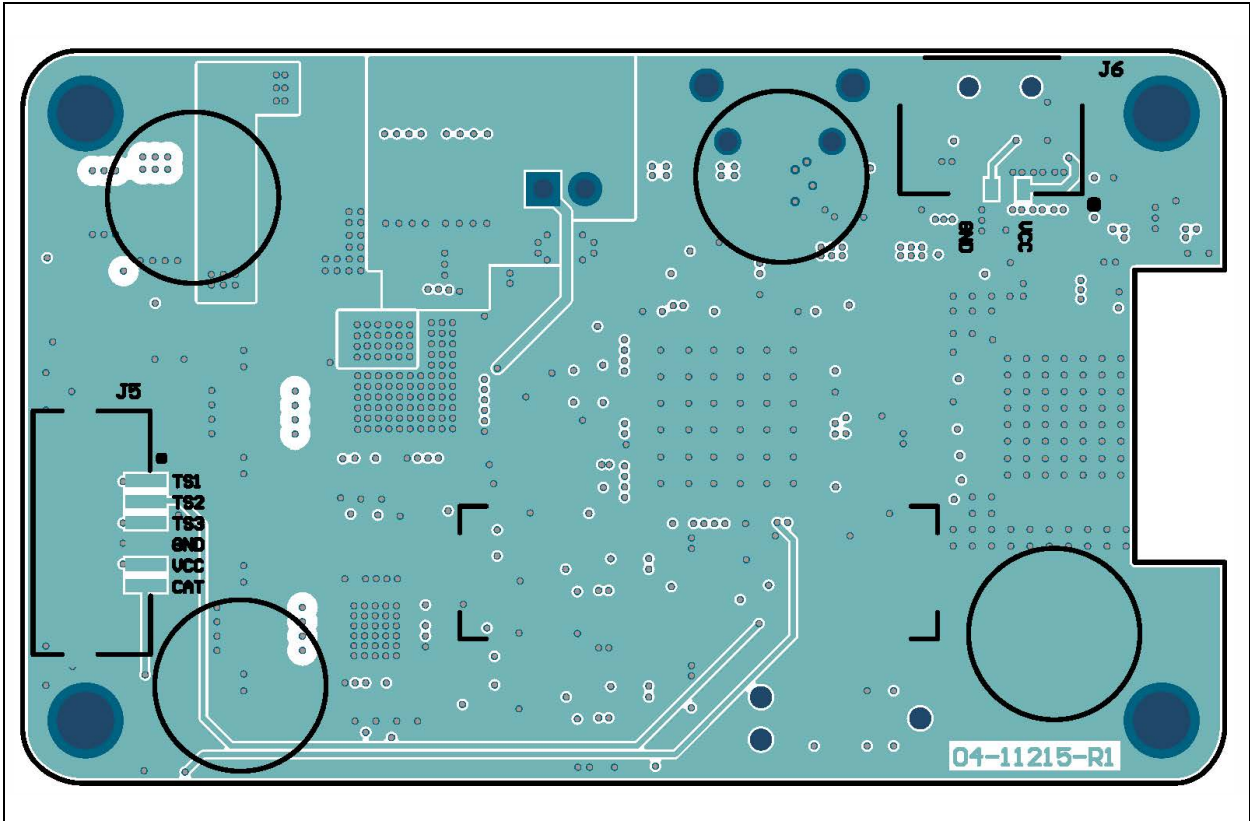
A.10 BOARD – POWER PLANE



A.11 BOARD – MID-LAYER 2



A.12 BOARD – BOTTOM LAYER AND SILK



NOTES:

Appendix B. Bill of Materials (BOM)

TABLE B-1: BILL OF MATERIAL (BOM)

Qty.	Reference	Description	Manufacturer	Part Number
6	C1, C2, C37, C43, C46, C51	Capacitor, Ceramic, 2.2 μ F, 16V, 10%, X5R, SMD, 0402	TDK Corporation	C1005X5R1C225K050BC
1	C3	Capacitor, Ceramic, 4.7 μ F, 16V, 10%, X5R, SMD, 0603	TDK Corporation	C1608X5R1C475K080AC
3	C4, C6, C23	Capacitor, Ceramic, 10000 pF, 50V, 10%, X7R, SMD, 0402	Yageo Corporation	CC0402KRX7R9BB103
3	C5, C8, C9	Capacitor, Ceramic, 4.7 μ F, 10V, 10%, X5R, SMD, 0402	TDK Corporation	C1005X5R1A475K050BC
1	C7	Capacitor, Ceramic, 4700 pF, 50V, 10%, X7R, SMD, 0402	Murata Electronics North America, Inc.	GRM155R71H472KA01J
3	C10, C16, C20	Capacitor, Ceramic, 4.7 μ F, 35V, 10%, X5R, SMD, 0603	Murata Electronics North America, Inc.	GRM188R6YA475KE15D
8	C11, C14, C17, C18, C19, C21, C35, C44	Capacitor, Ceramic, 0.1 μ F, 25V, 10%, X7R, SMD, 0402	TDK Corporation	C1005X7R1E104K050BB
3	C12, C49, C53	Capacitor, Ceramic, 1 μ F, 35V, 10%, X5R, SMD, 0402	Murata Electronics North America, Inc.	GRM155R6YA105KE11D
2	C13, C15	Capacitor, Ceramic, 6.8 pF, 50V, 0.1 pF, NP0, SMD, 0402	Murata Electronics North America, Inc.	GRM1555C1H6R8BA01D
1	C22	Capacitor, Ceramic, 10 μ F, 25V, 20%, X5R, SMD, 0603	TDK Corporation	C1608X5R1E106M080AC
1	C24	Capacitor, Ceramic, 1 μ F, 25V, 10%, X7R, SMD, 0603, AEC-Q200	Samsung Electro-Mechanics America, Inc.	CL10B105KA8VPNC
4	C26, C27, C39, C41	Capacitor, Ceramic, 10000 pF, 16V, 10%, X7R, SMD, 0402	KEMET	C0402C103K4RACTU
2	C28, C29	Capacitor, Ceramic, 100 μ F, 16V, 20%, X5R, SMD, 1210	Yageo Corporation	CC1210MKX5R7BB107
3	C32, C40, C52	Capacitor, Ceramic, 0.22 μ F, 450V, 10%, X7T, SMD, 1210	TDK Corporation	C3225X7T2W224K200AA
1	C33	Capacitor, Ceramic, 0.01 μ F, 450V, 10%, X7T, SMD, 0805, AEC-Q200	TDK Corporation	CGA4F4X7T2W103M085AE
1	C34	Capacitor, Ceramic, 100 pF, 25V, 10%, NP0, SMD, 0603	AVX Corporation	06033A101KAT2A
2	C36, C45	Capacitor, Ceramic, 10 μ F, 25V, 20%, X5R, SMD, 0603	Murata Electronics North America, Inc.	GRM188R61E106MA73D
2	C38, C42	Capacitor, Ceramic, 22 μ F, 10V, 20%, X5R, SMD, 0603	Samsung Electro-Mechanics America, Inc.	CL10A226MPCNUBE

Note 1: The components listed in this Bill of Materials are representative of the PCB assembly. The released BOM used in manufacturing uses all RoHS-compliant components.

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TABLE B-1: BILL OF MATERIAL (BOM) (CONTINUED)

Qty.	Reference	Description	Manufacturer	Part Number
4	C47, C48, C54, C55	Capacitor, Ceramic, 3300 pF, 16V, 10%, X7R, SMD, 0402	Murata Electronics North America, Inc.	GRM15XR71C332KA86D
1	C50	Capacitor, Ceramic, 0.033 μ F, 16V, 10%, X7R, SMD, 0402	TDK Corporation	CGA2B2X7R1C333K050BA
1	D1	Diode, TVS, PRTR5V0U2X, 5.5V, SMD, SOT-143	Nexperia	PRTR5V0U2X,215
1	D2	Diode, Schottky, SMD24, 500 mV, 2A, 40V, SOD-123FL	Micro Commercial Components Corp. (MCC)	SMD24PL-TP
1	D3	Diode, Rectifier, BYM07-300, 0.5A, 300V, DO213-AA, AEC-Q101	Vishay Semiconductor Diodes Division	BYM07-300-E3/98
1	D4	Diode, ZENER, KDZVTR39A, 39V, 1W, SMD, SOD-123F	ROHM Semiconductor	KDZVTR39A
1	D5	Diode, Rectifier, SBRT4U10LP-7, 0.5V, 4A, 10V, SMD, U-DFN2020-2, AEC-Q101	Diodes Incorporated [®]	SBRT4U10LP-7
1	D6	Diode, Schottky, BAT54XV2T1G, 30V, 200 mA, 40V, SOD-523	ON Semiconductor [®]	BAT54XV2T1G
1	FB1	Ferrite, 470R@,100 MHz, 1A, SMD, 0603	Murata Electronics North America, Inc.	BLM18PG471SN1D
1	J1	Connector, HDR-2, Male, 1x2 SHROUD, 2 mm, MH, THT, R/A	JST Sales America, Inc.	S2B-PH-K-S(LF)(SN)
1	J2	Connector, USB2.0, Micro-B, Female, TH/SMD, R/A	Amphenol ICC (FCI)	10118194-0001LF
1	J4	Connector, HDR 1.5, Female, Gold, 1x6, RA, SMD	Molex [®]	504050-0691
1	J5	Connector, FFC/FPC, 1 mm, 6P, Female, 2005290060, SMD, R/A	Molex [®]	200529-0060
1	J6	Connector, HDR-1.5, Male, 1x3, Gold, SMD, R/A	Molex [®]	504050-0391
1	L1	Fixed, Inductor, 10 μ H, 1.2A, 240 m Ω , SMD	Murata Electronics North America, Inc.	LQH3NPN100MJRL
1	L2	Inductor, 1 μ H:100 μ H, 1:10, 8A, SMD, ZA9735-AE	Coilcraft	ZA9735-AE
2	LD1, LD2	Diode LED Green, 1.7V, 20 mA, 3.92 mcd, Diffuse, SMD, 0603	OSRAM Opto Semiconductors GmbH	LGL29K-G2J1-24-Z
1	PCB	HV56020/22 Evaluation Board – Printed Circuit Board	—	04-11215-R1
1	R1	Resistor, TKF, 100k, 1%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ3EKF1003V
4	R2, R3, R15, R20	Resistor, TKF, 10k, 5%, 1/16W, SMD, 0402	Vishay/Dale	CRCW040210K0JNED
1	R4	Resistor, TKF, 49.9k, 1%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3EKF4992V
1	R6	Resistor, TF, 1k, 0.1%, 1/16W, SMD, 0402	Yageo Corporation	RT0402BRD071KL
1	R7	Resistor, TKF, 2k, 1%, 1/10W, SMD, 0402	Panasonic - ECG	ERJ-2RKF2001X

Note 1: The components listed in this Bill of Materials are representative of the PCB assembly. The released BOM used in manufacturing uses all RoHS-compliant components.

TABLE B-1: BILL OF MATERIAL (BOM) (CONTINUED)

Qty.	Reference	Description	Manufacturer	Part Number
4	R8, R10, R18, R19	Resistor, TKF, 5.1k, 1%, 1/10W, SMD, 0402	Panasonic - ECG	ERJ-2RKF5101X
1	R9	Resistor, TKF, 7.5M, 1%, 1/10W, SMD, 0603	ROHM Semiconductor	KTR03EZPF7504
1	R11	Resistor, TKF, 39.2k, 1%, 1/10W SMD, 0603	Stackpole Electronics, Inc.	RMCF0603FT39K2
1	R12	Resistor, TKF, 0R, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3GEY0R00V
1	R13	Resistor, TKF, 3.3k, 5%, 1/10W SMD, 0603	Panasonic - ECG	ERJ-3GEYJ332V
1	R14	Resistor, TKF, 10M, 1%, 1/10W, SMD, 0603 HV, AEC-Q200	ROHM Semiconductor	KTR03EZPF1005
1	R16	Resistor, Shunt, 0.003R, 1%, 1/2W, 0805, AEC-Q200	ROHM Semiconductor	PMR10EZPFV3L00
1	R17	Resistor, TKF, 499k, 1%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3EKF4993V
2	R21, R24	Resistor, TKF, 200k, 1%, 1/10W, SMD, 0402	Panasonic - ECG	ERJ-2RKF2003X
2	R22, R25	Resistor, TKF, 150k, 1%, 1/10W, SMD, 0402	Panasonic - ECG	ERJ-2RKF1503X
1	R23	Resistor, TKF, 225k, 1%, 1/16W, SMD, 0402	Stackpole Electronics, Inc.	RMCF0402FT255K
1	R26	Resistor, TKF, 4.7k, 5%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3GEYJ472V
3	R27, R28, R29	Resistor, TKF, 10k, 5%, 1/10W, SMD, 0402	Panasonic - ECG	ERJ-2GEJ103X
1	R30	Resistor, TKF, 330R, 1%, 1/10W, SMD, 0402	KOA Speer Electronics, Inc.	RK73H1ETTP3300F
1	R31	Resistor, TKF, 100R, 1%, 1/10W, SMD, 0402	Panasonic - ECG	ERJ-2RKF1000X
1	S1	Switch Slide, SPDT, 4V, 0.3A, MLL1200S	TE Connectivity Alcoswitch	MLL1200S
1	XC1	Crystal, 32.768 kHz, 7 pF, SMD CM7V-T1A	Micro Crystal	CM7V-T1A 32.768 kHz 7.0 pf +/- 20 ppm

Note 1: The components listed in this Bill of Materials are representative of the PCB assembly. The released BOM used in manufacturing uses all RoHS-compliant components.

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TABLE B-2: BILL OF MATERIALS (BOM) – MICROCHIP PARTS

Qty	Reference	Description	Manufacturer	Part Number
1	B1	RF Bluetooth, RN4871-I/RM130	Microchip Technology Inc.	RN4871-I/RM130
2	M1, M2	Analog MOSFET, N-CH, TN2106, 60V, 280 mA, 360 mW, 2.5R, SOT23-3	Microchip Technology Inc.	TN2106K1-G
1	U1	Analog LDO, 3.3V, 300 mA, MIC5504-3.3YM5-TR, SOT23-5	Microchip Technology Inc.	MIC5504-3.3YM5-TR
1	U2	Analog LDO, ADJ, MIC94325YMT-TR, TDFN-6	Microchip Technology Inc.	MIC94325YMT-TR
1	U3	Analog Battery Charger, MCP73830T-2AAI/MYY, TDFN-6	Microchip Technology Inc.	MCP73830T-2AAI/MYY
1	U4	MCU 32-bit, 48 MHz, 256 kB, 32 kB, ATSAML21J18B-MNT, QFN-64	Microchip Technology Inc.	ATSAML21J18B-MNT
1	U5	Memory Serial Flash, 4 Mb, 40 MHz, SST25PF040CT-40I/NP, 8-UDFN (2x3)	Microchip Technology Inc.	SST25PF040CT-40I/NP
2	U6, U7	Analog DAC, 2-Ch, 12-Bit, MCP48FEB22-E/UN, MSOP-10	Microchip Technology Inc.	MCP48FEB22-E/UN
1	U8	Analog HV Driver, 2-Ch, HV56020T-V/KXX, QFN-43	Microchip Technology Inc.	HV56020T-V/KXX
1	U9	Analog HV Driver, 2-Ch, HV56022T-V/KNX, QFN-20	Microchip Technology Inc.	HV56022T-V/KNX

Note 1: The components listed in this Bill of Materials are representative of the PCB assembly. The released BOM used in manufacturing uses all RoHS-compliant components.

TABLE B-3: BILL OF MATERIALS (BOM) – MECHANICAL PARTS

Qty	Reference	Description	Manufacturer	Part Number
1	LABEL1	Label PCBA, 18x6 mm, Bar-Code-AssyID-Rev-Serno	—	—
4	PAD1, PAD2, PAD3, PAD4	Hardware Rubber Pad, Cylindrical, D7.9, H5.3, Black	3M	SJ61A11

Note 1: The components listed in this Bill of Materials are representative of the PCB assembly. The released BOM used in manufacturing uses all RoHS-compliant components.

TABLE B-4: BILL OF MATERIALS (BOM) – DO NOT POPULATE PARTS

Qty	Reference	Description	Manufacturer	Part Number
4	C56, C57, C58, C59	Capacitor, Ceramic, 0.01 µF, 450V, 10%, X7T, SMD, 0805, AEC-Q200	TDK Corporation	CGA4F4X7T2W103M085AE
1	J3	Connector Tag, 10P, TC2050, SMT, No legs	Tag-Connect LLC	TC2050-IDC-NL
1	R5	Resistor, TKF, 10k, 5%, 1/16W, SMD, 0402	Vishay/Dale	CRCW040210K0JNED
1	R32	Resistor, TF, 1k, 0.1%, 1/10W, SMD, 0603	Panasonic - ECG	ERA-3AEB102V

Note 1: The components listed in this Bill of Materials are representative of the PCB assembly. The released BOM used in manufacturing uses all RoHS-compliant components.

Appendix C. Waveforms

C.1 INTRODUCTION

This appendix contains the waveforms obtained from the HV56020/22 Evaluation Board. DataFile.wav was used for the first four waveforms, using Windows® 10 Haptic Bridge Application. Waveforms 1 to 6 are generated using the Android™ BLE Application.

- [DataFile HVOUT1.](#)
- [DataFile HVOUT2.](#)
- [DataFile HVOUT3.](#)
- [DataFile HVOUT4.](#)
- [Waveform 1, HVOUT1.](#)
- [Waveform 2, HVOUT1.](#)
- [Waveform 3, HVOUT1.](#)
- [Waveform 4, HVOUT1.](#)
- [Waveform 5, HVOUT1.](#)
- [Waveform 6, HVOUT1.](#)

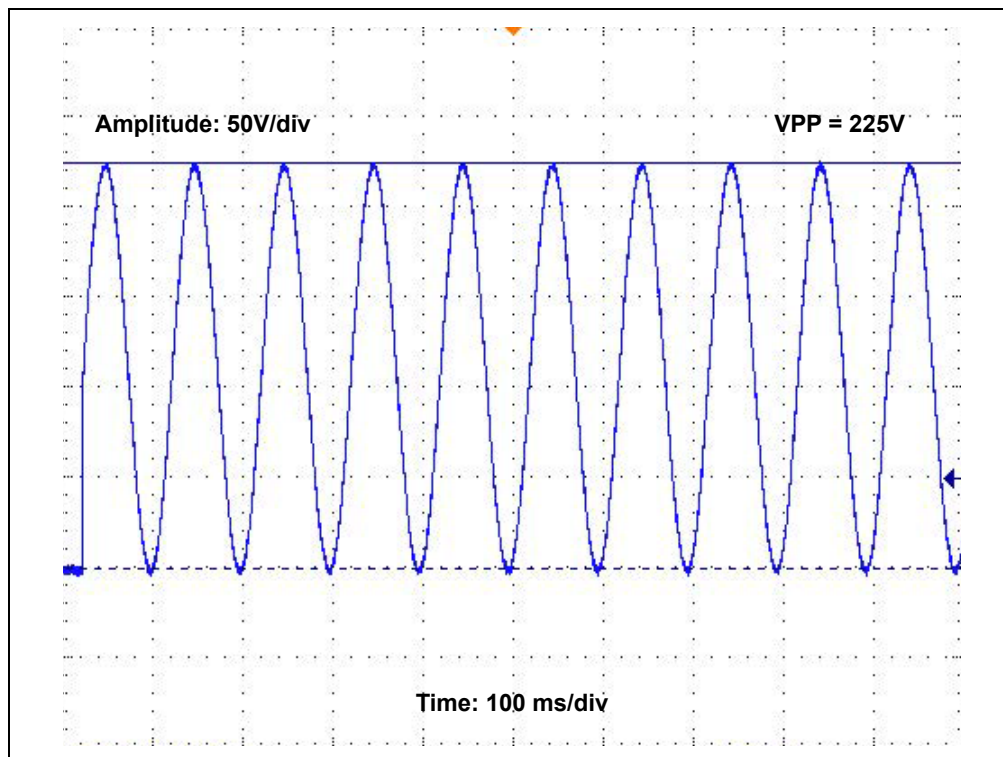


FIGURE C-1: DataFile HVOUT1.

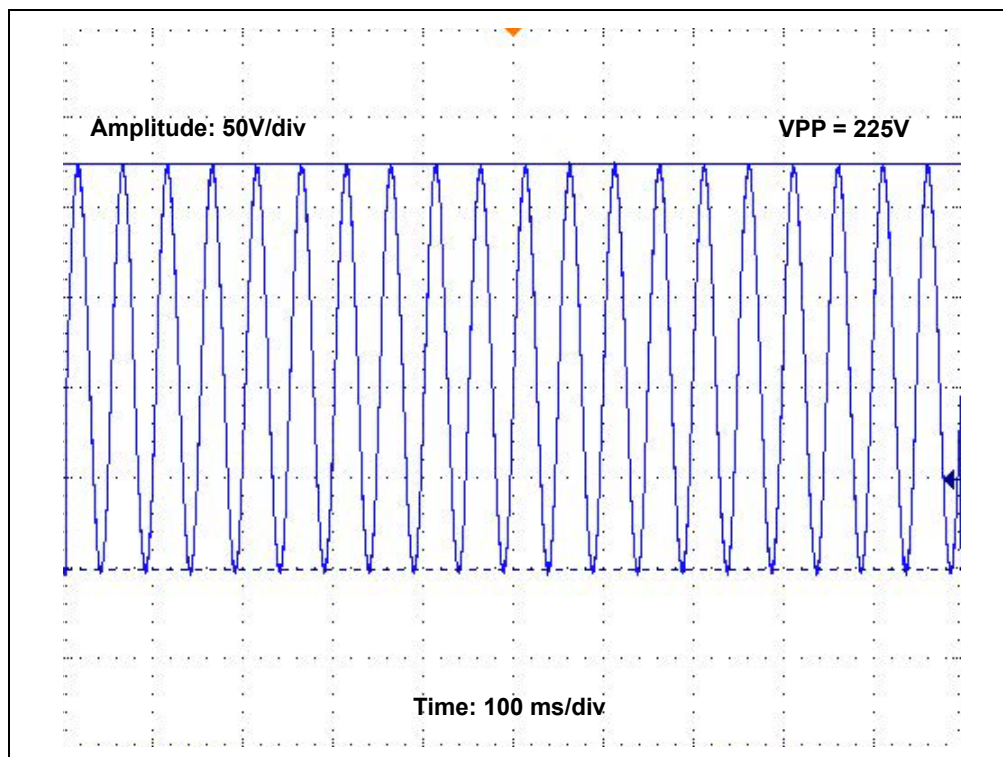


FIGURE C-2: DataFile HVOUT2.

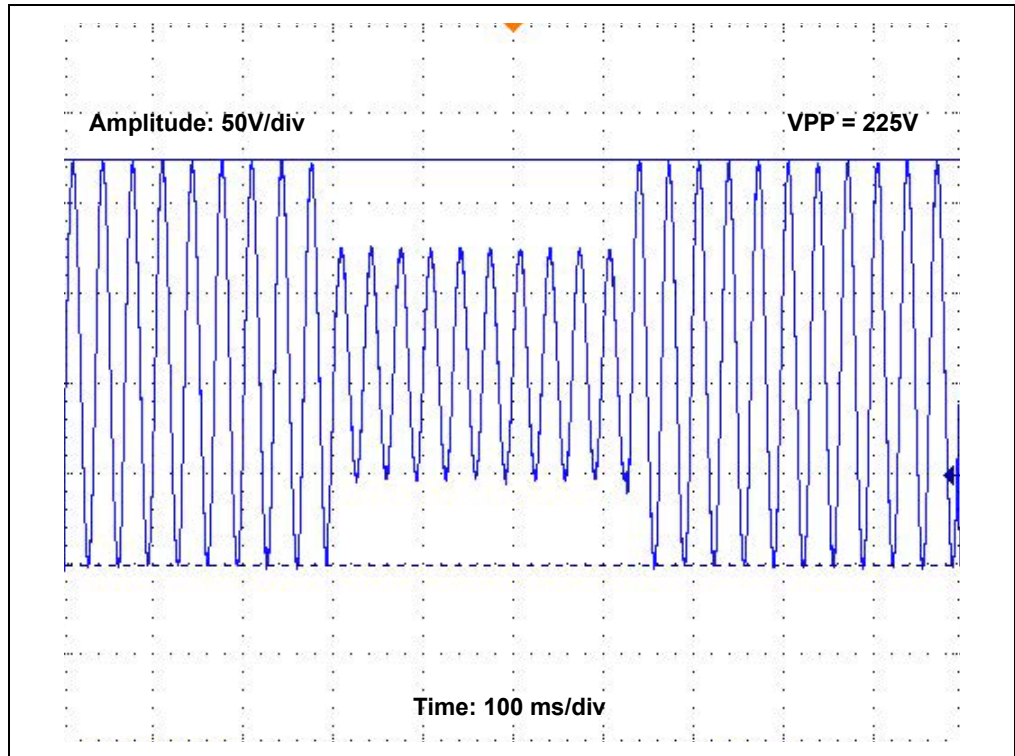


FIGURE C-3: DataFile HVOUT3.

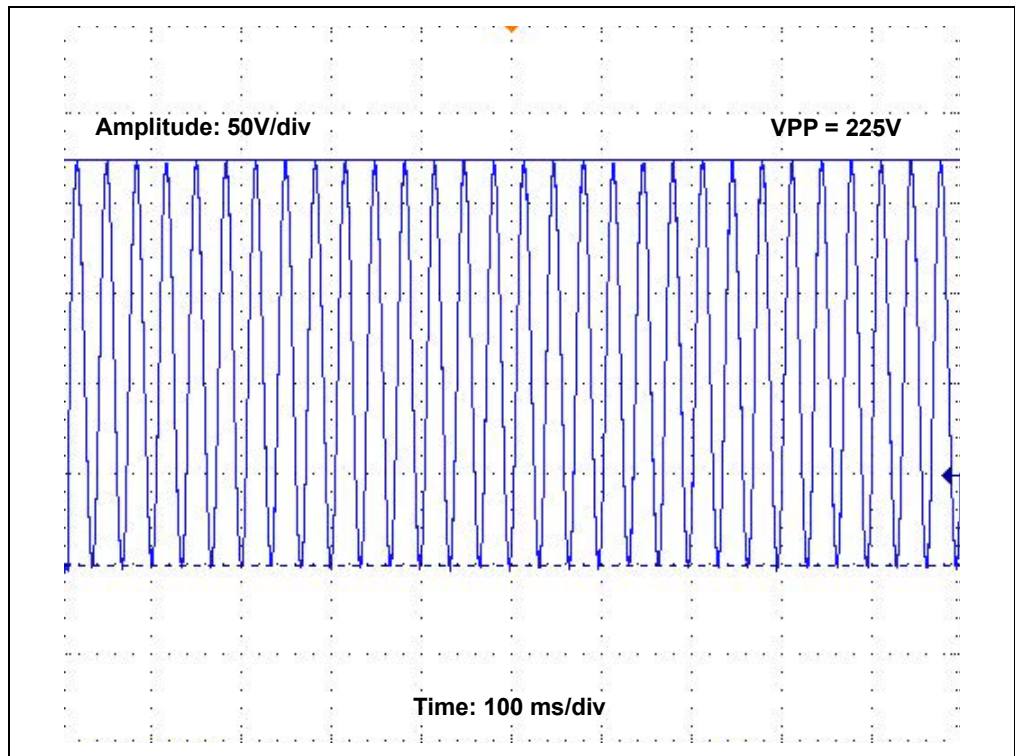


FIGURE C-4: DataFile HVOUT4.

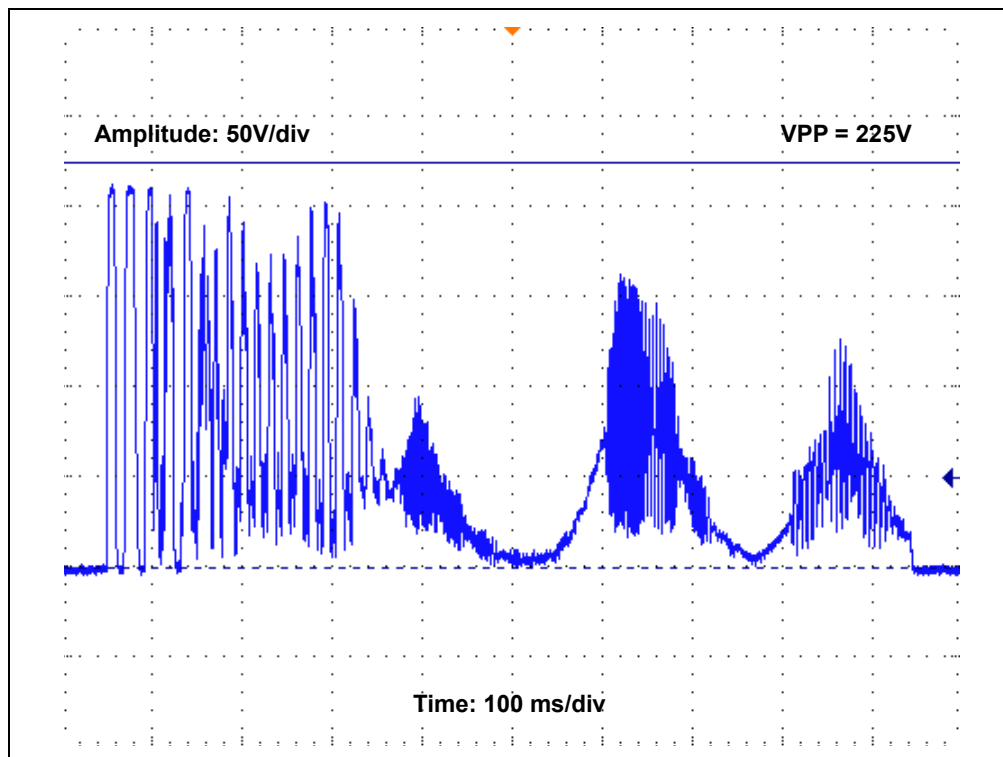


FIGURE C-5: Waveform 1, HVOUT1.

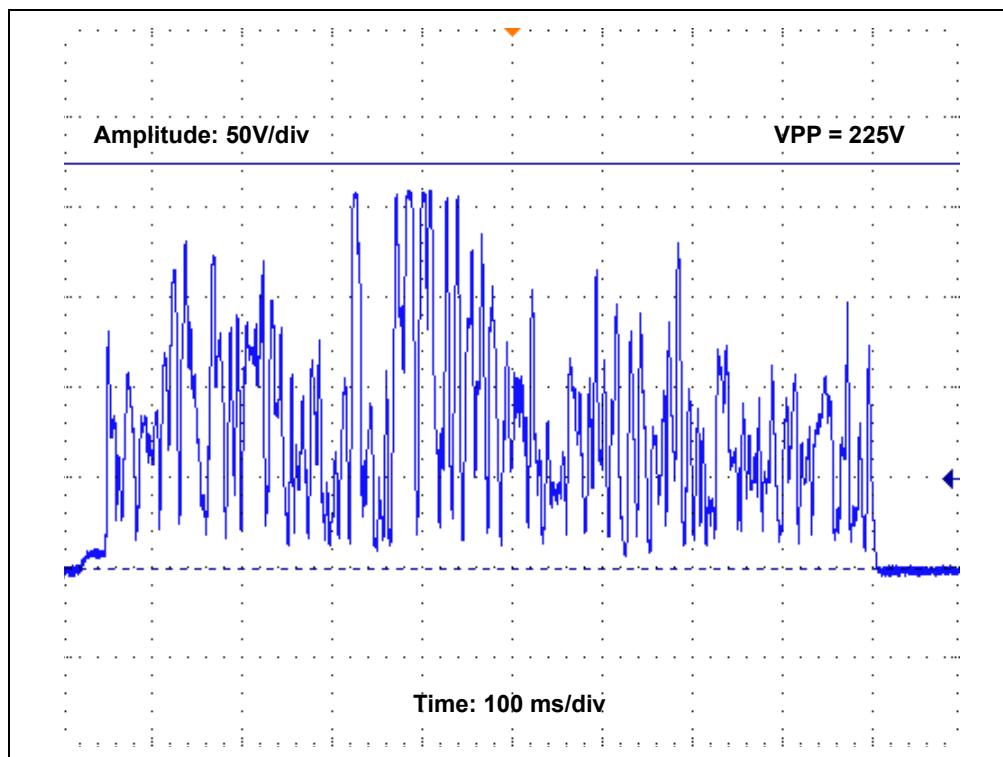


FIGURE C-6: Waveform 2, HVOUT1.

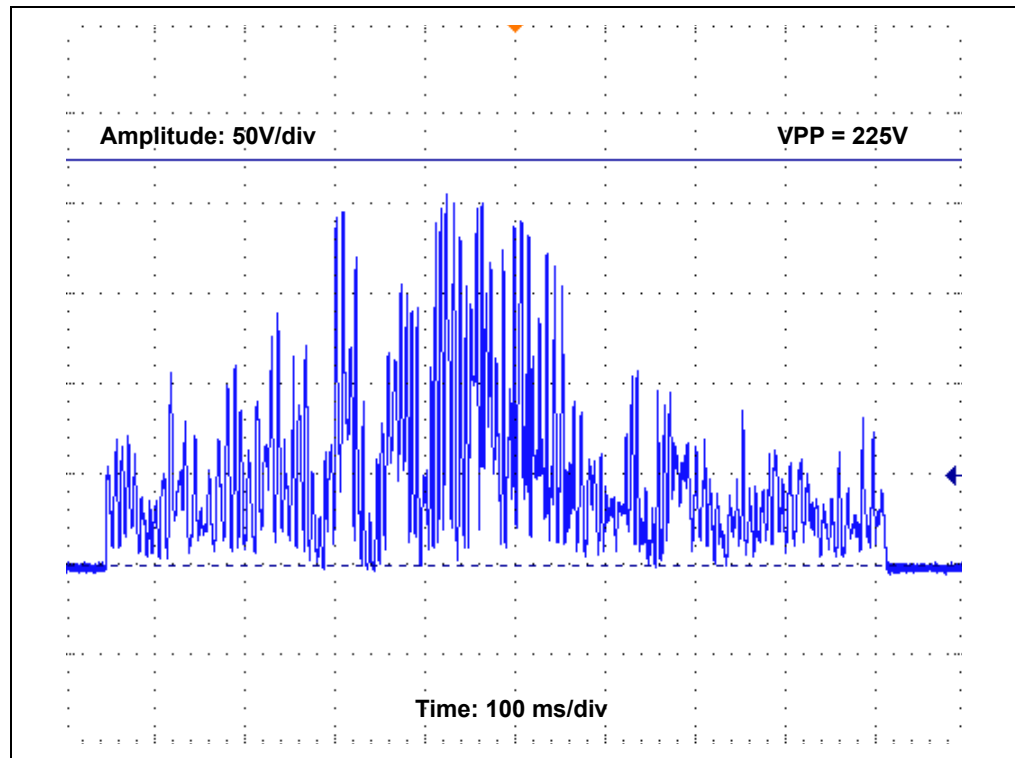


FIGURE C-7: Waveform 3, HVOUT1.

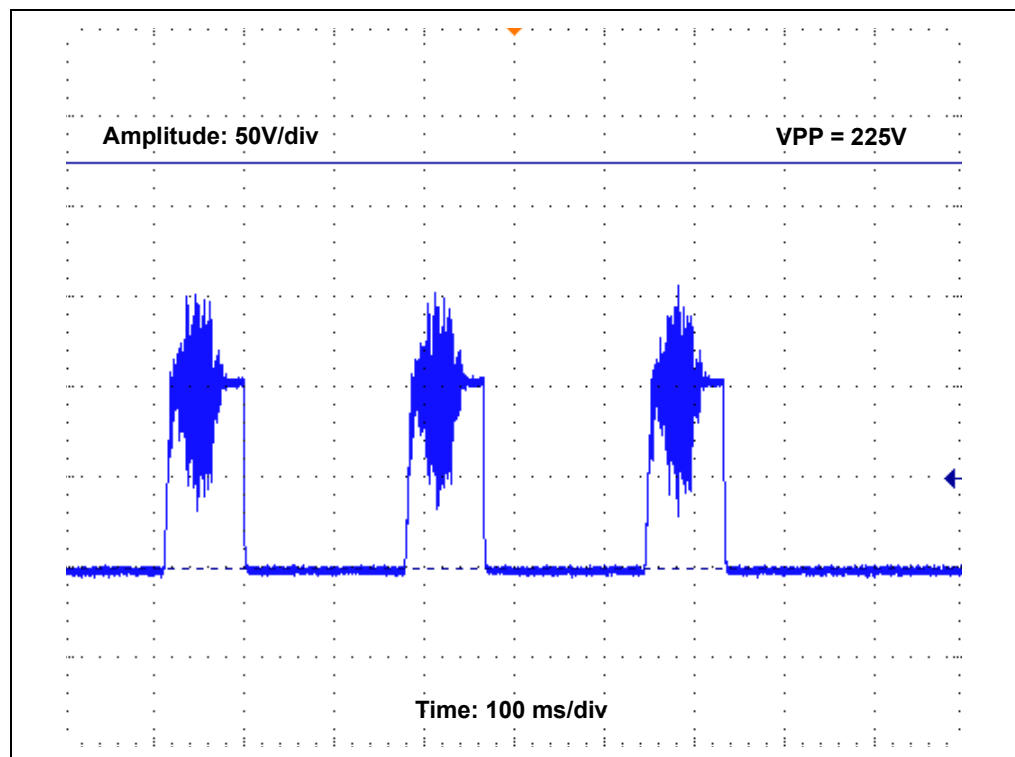


FIGURE C-8: Waveform 4, HVOUT1.

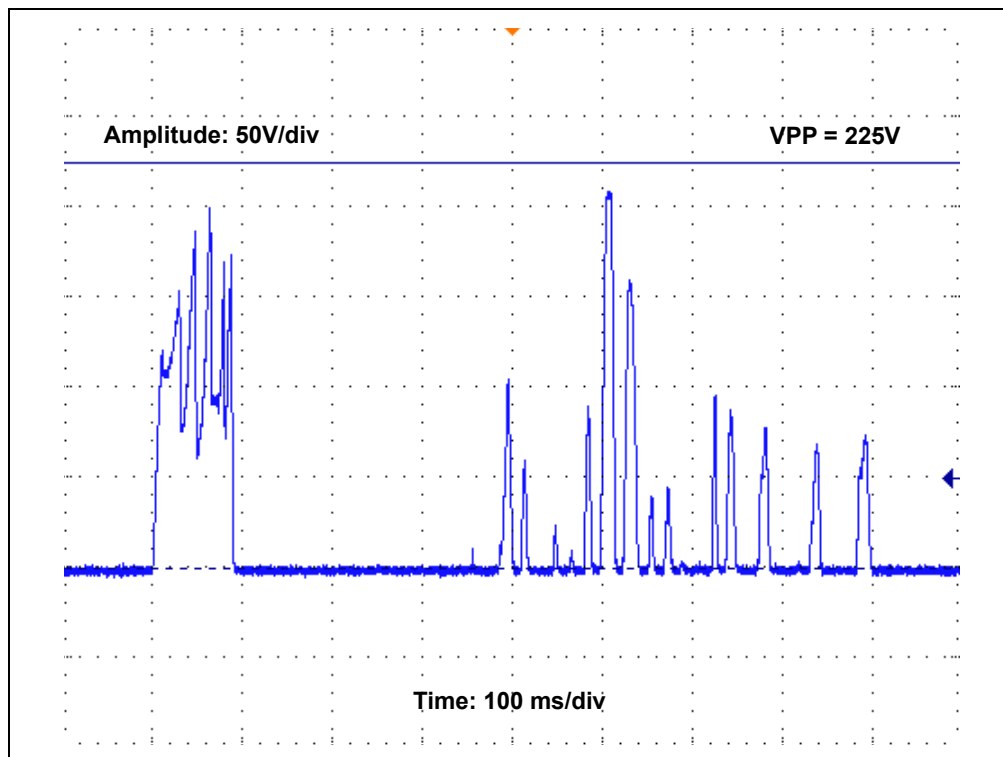


FIGURE C-9: Waveform 5, HVOUT1.

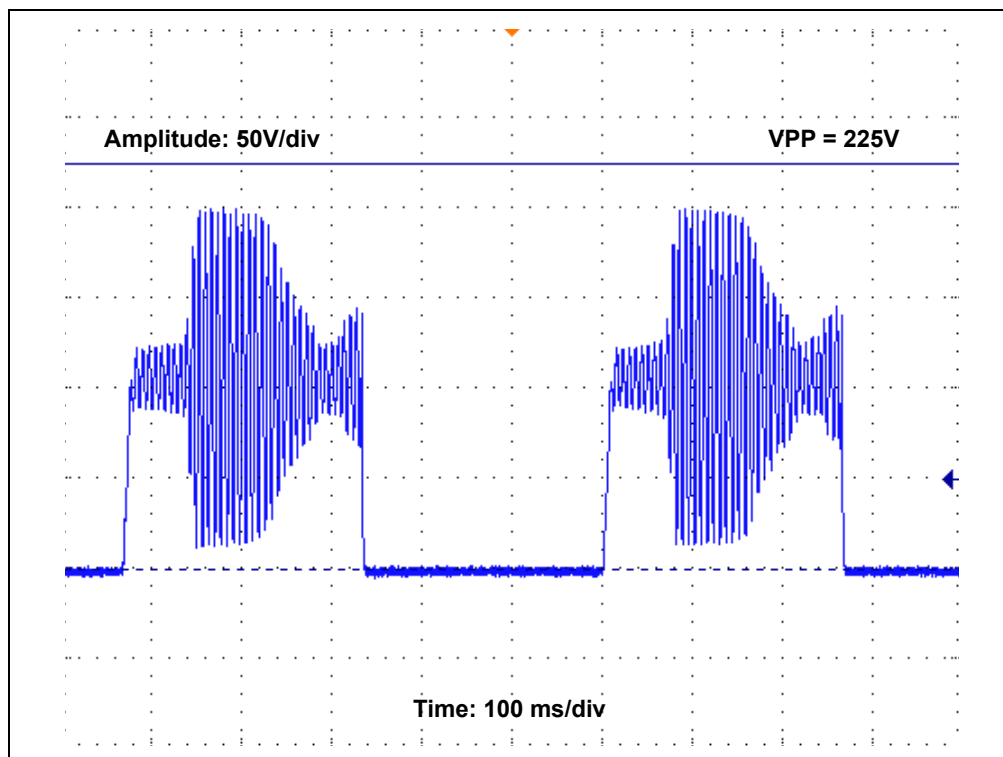


FIGURE C-10: Waveform 6, HVOUT1.



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