HV56020/22 Evaluation Board User's Guide

ISBN: 978-1-5224-7171-4

Table of Contents

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

<table>
<tr><th>Description</th><th>Represents</th><th>Examples</th></tr>
<tr><td colspan="3">Arial font:</td></tr>
<tr><td rowspan="2">Italic characters</td><td>Referenced books</td><td>MPLAB® IDE User’s Guide</td></tr>
<tr><td>Emphasized text</td><td>...is the only compiler...</td></tr>
<tr><td rowspan="3">Initial caps</td><td>A window</td><td>the Output window</td></tr>
<tr><td>A dialog</td><td>the Settings dialog</td></tr>
<tr><td>A menu selection</td><td>select Enable Programmer</td></tr>
<tr><td>Quotes</td><td>A field name in a window or dialog</td><td>“Save project before build”</td></tr>
<tr><td>Underlined, italic text with right angle bracket</td><td>A menu path</td><td><u>File>Save</u></td></tr>
<tr><td rowspan="2">Bold characters</td><td>A dialog button</td><td>Click OK</td></tr>
<tr><td>A tab</td><td>Click the Power tab</td></tr>
<tr><td>N‘Rnnnn</td><td>A number in verilog format, where N is the total number of digits, R is the radix and n is a digit.</td><td>4‘b0010, 2‘hF1</td></tr>
<tr><td>Text in angle brackets < ></td><td>A key on the keyboard</td><td>Press <Enter>, <F1></td></tr>
<tr><td colspan="3">Courier New font:</td></tr>
<tr><td rowspan="7">Plain Courier New</td><td>Sample source code</td><td><code>#define START</code></td></tr>
<tr><td>Filenames</td><td><code>autoexec.bat</code></td></tr>
<tr><td>File paths</td><td><code>c:\mcc18\h</code></td></tr>
<tr><td>Keywords</td><td><code>_asm, _endasm, static</code></td></tr>
<tr><td>Command-line options</td><td><code>-Opa+, -Opa-</code></td></tr>
<tr><td>Bit values</td><td><code>0, 1</code></td></tr>
<tr><td>Constants</td><td><code>0xFF, ‘A’</code></td></tr>
<tr><td>Italic Courier New</td><td>A variable argument</td><td><code>file.o</code>, where <code>file</code> can be any valid filename</td></tr>
<tr><td>Square brackets [ ]</td><td>Optional arguments</td><td><code>mcc18 [options] file [options]</code></td></tr>
<tr><td>Curly brackets and pipe character: { | }</td><td>Choice of mutually exclusive arguments; an OR selection</td><td><code>errorlevel {0|1}</code></td></tr>
<tr><td rowspan="2">Ellipses...</td><td>Replaces repeated text</td><td><code>var_name [,
var_name...]</code></td></tr>
<tr><td>Represents code supplied by user</td><td><code>void main (void)
{ ...
}</code></td></tr>
</table>

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

CUSTOMER SUPPORT

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 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
- 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 FEATURES

- Windows® 10 PC GUI
- Android™ BLE Application
- Connector for 3 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

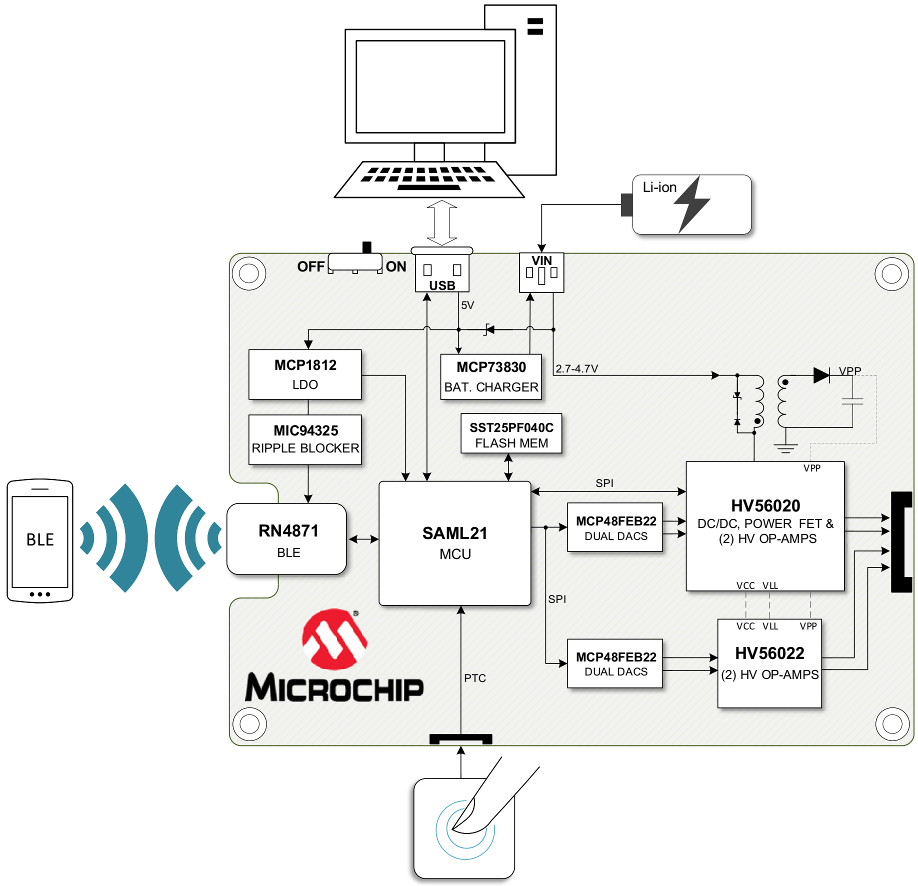


FIGURE 1-1: *HV56020/22 Evaluation Board Block Diagram.*

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

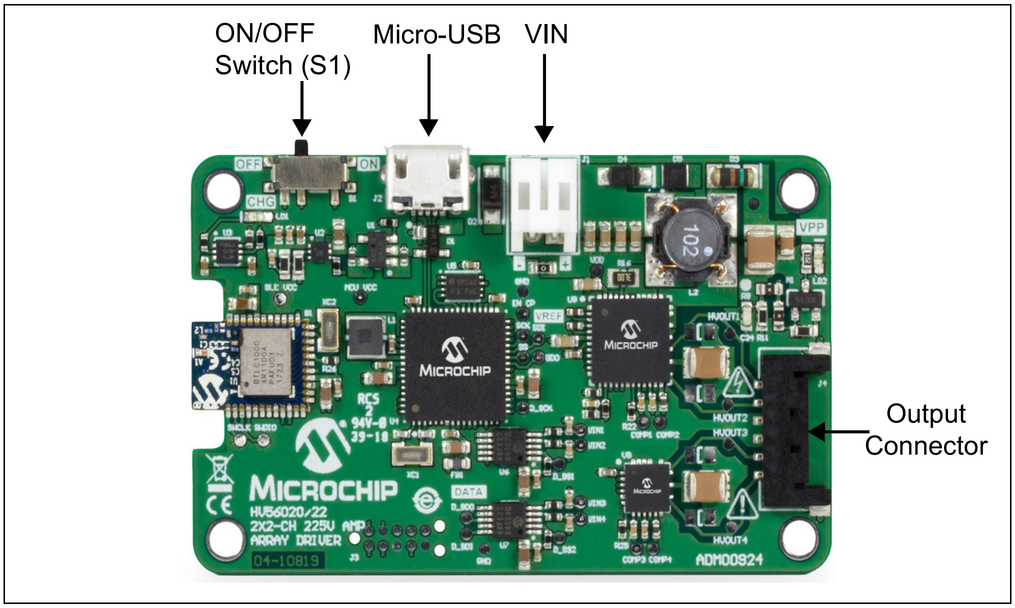


FIGURE 1-2: *HV56020/22 Evaluation Board.*

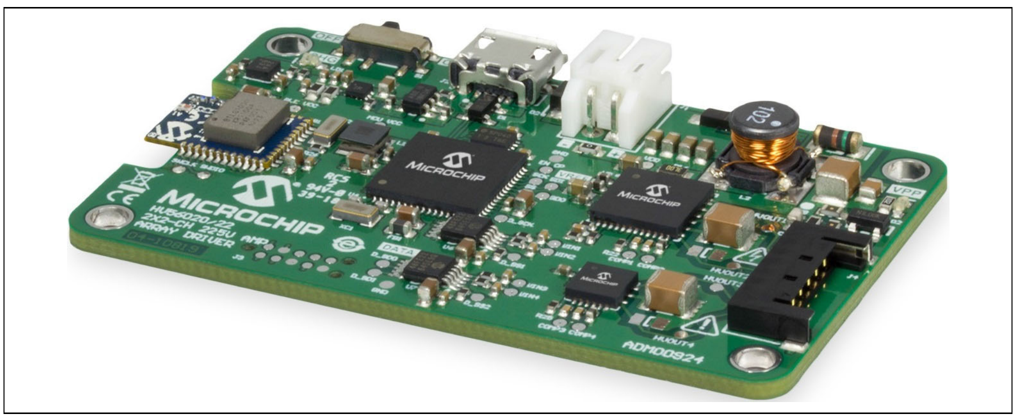


FIGURE 1-3: *HV56020/22 Evaluation Board Side View.*

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)
- 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.

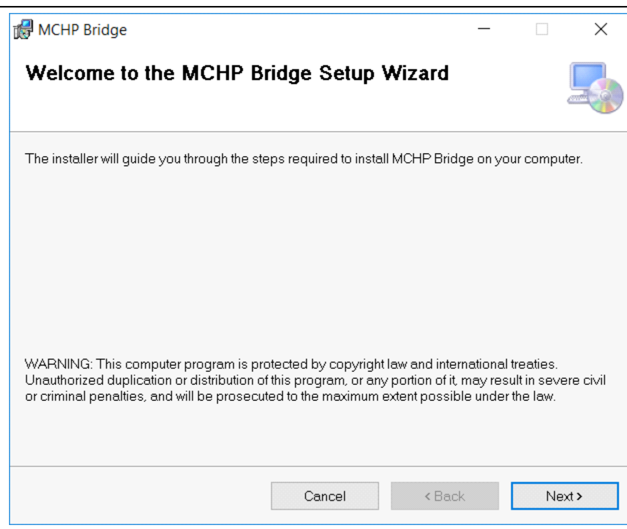


FIGURE 2-1: MCHP Bridge Setup.

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.

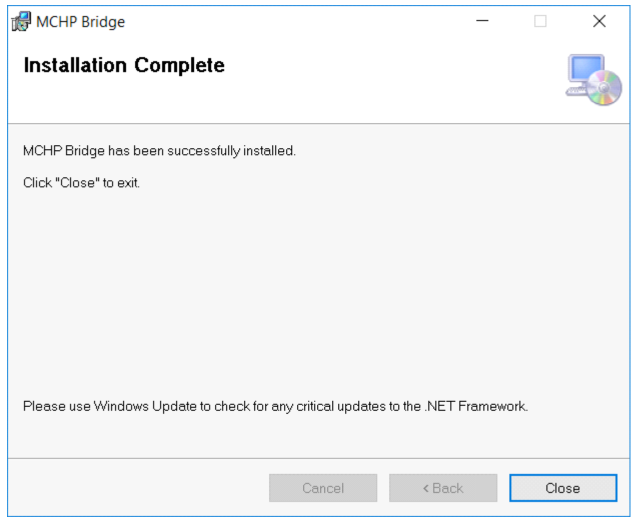


FIGURE 2-2: MCHP Bridge Installation.

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).

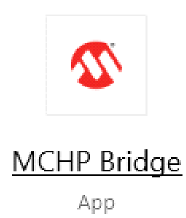


FIGURE 2-3: MCHP Bridge.

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

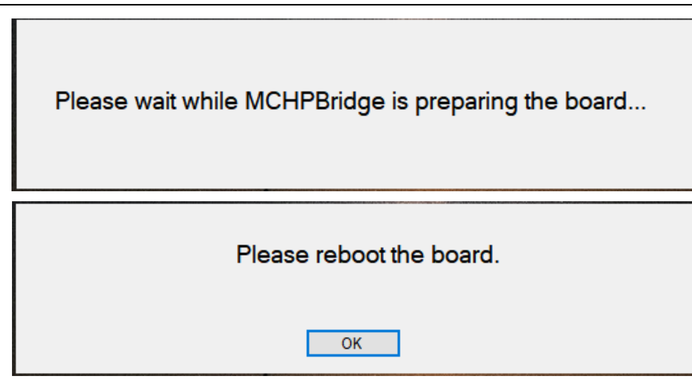


FIGURE 2-4: MCHP Bridge Start-Up and Reboot.

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

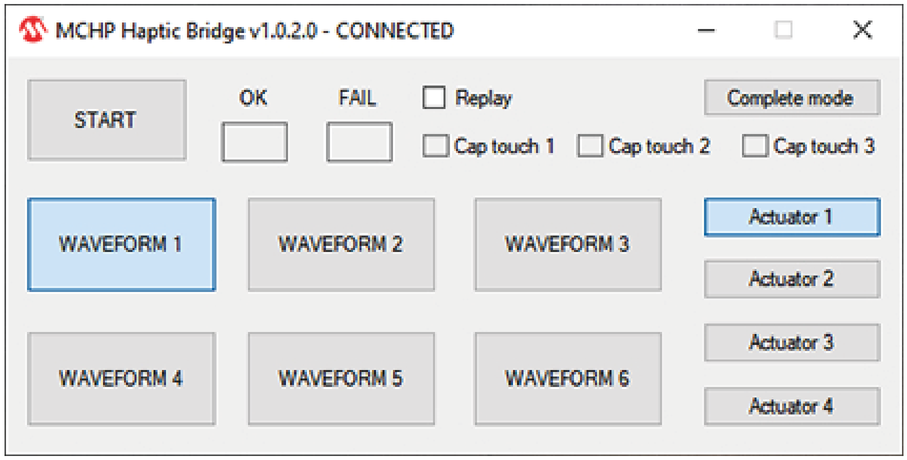


FIGURE 2-5: *HV56020/22 Evaluation Board Connection.*

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.

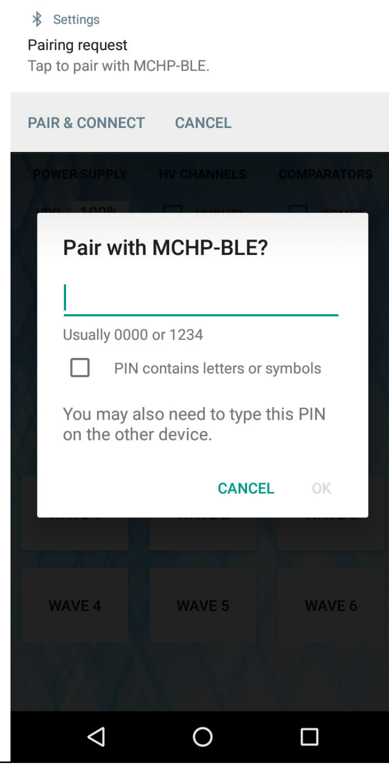


FIGURE 2-7: *Pair and Connect.*

6. Enter "123456" as PIN code.

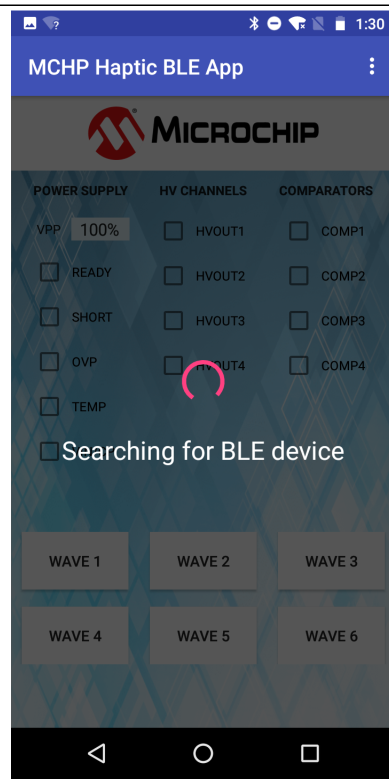


FIGURE 2-8: *Connecting the Device.*

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

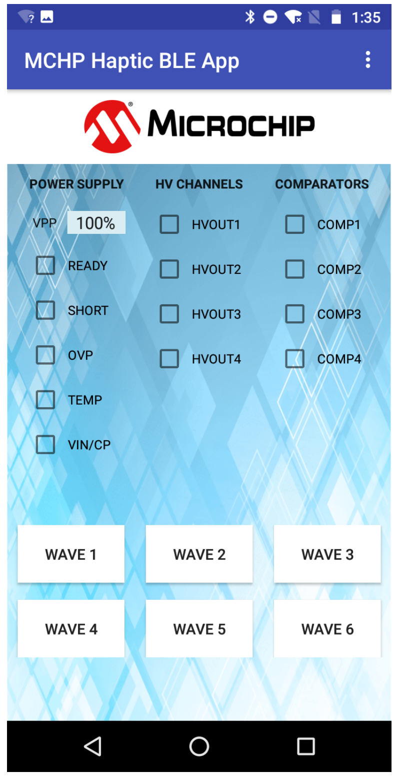


FIGURE 2-9: *Application Activated.*

2.3 WINDOWS PC OPERATION

2.3.1 Introduction

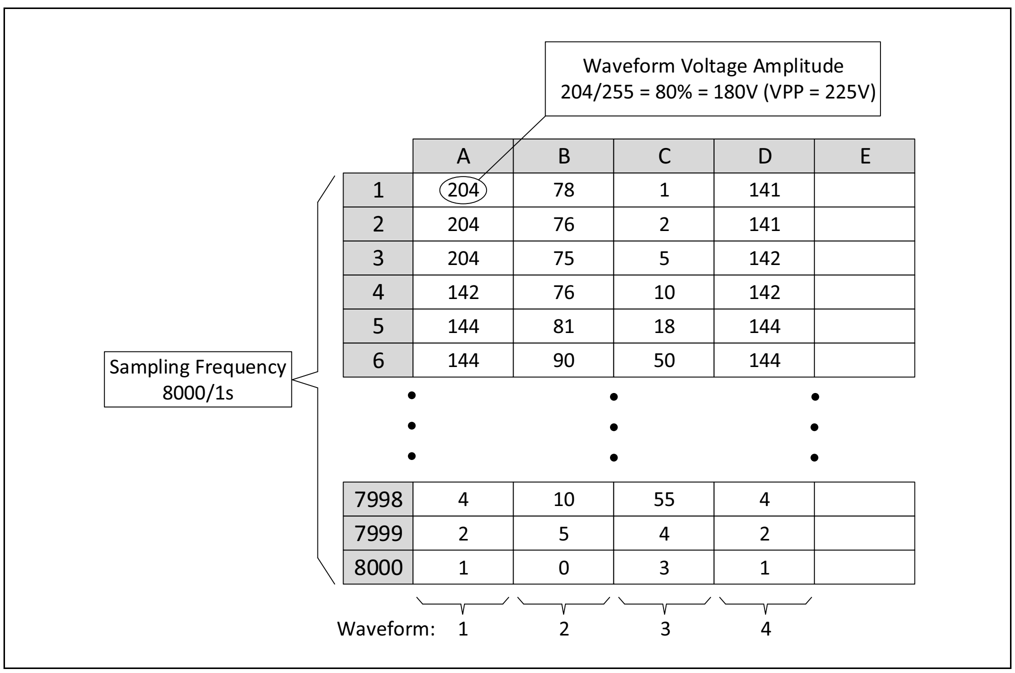
The MCHP Haptic Bridge GUI operates with two different data file formats: CSV (Comma Separated Value) and WAV (Waveform Audio File).

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, 135, 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	

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.

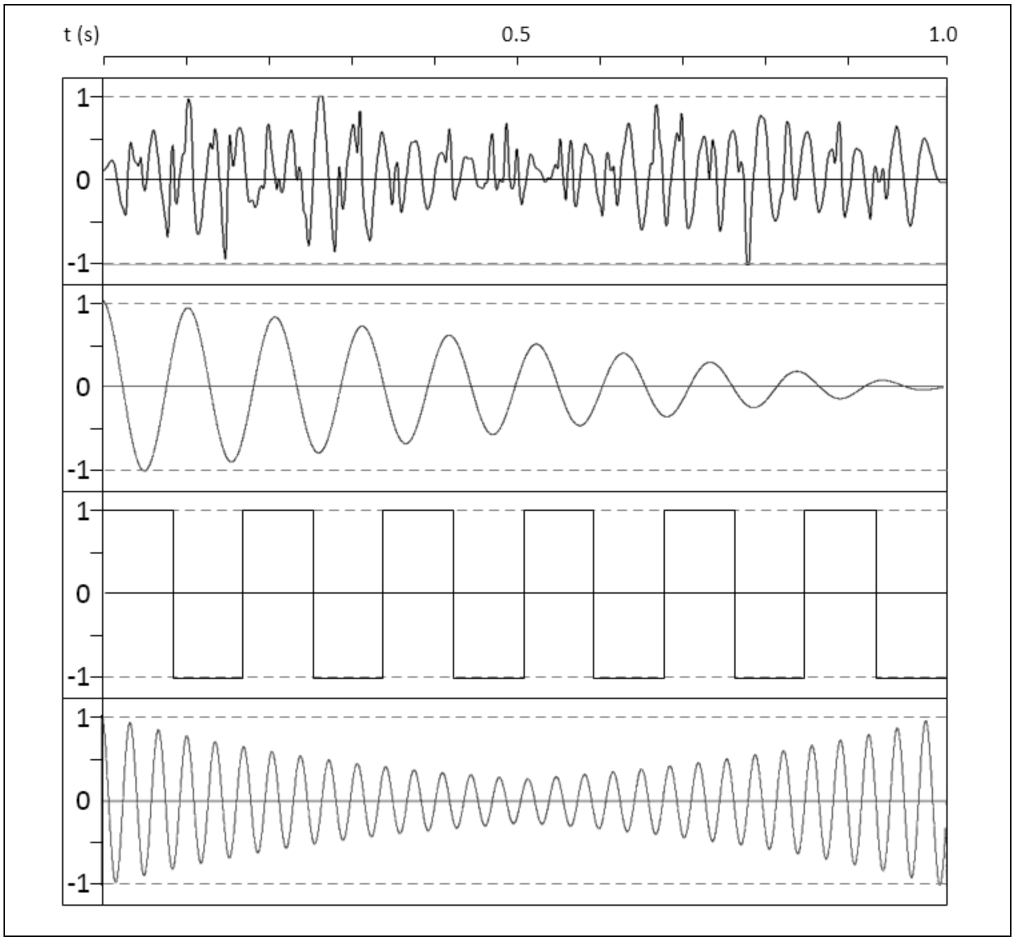


FIGURE 2-11: *4-Channel WAV File Format Diagram.*

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.

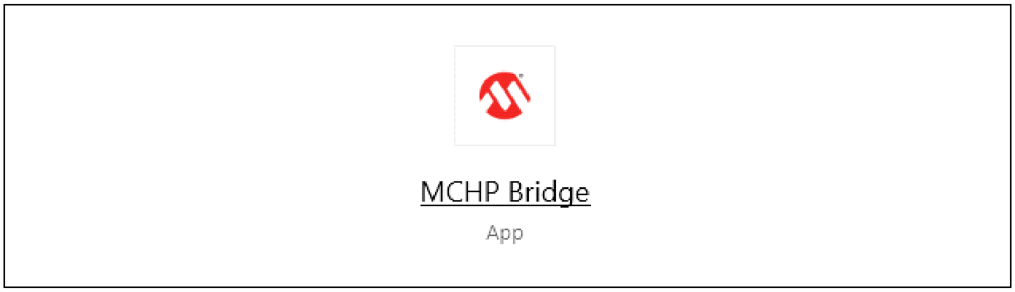


FIGURE 2-12: *MCHP Bridge.*

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.

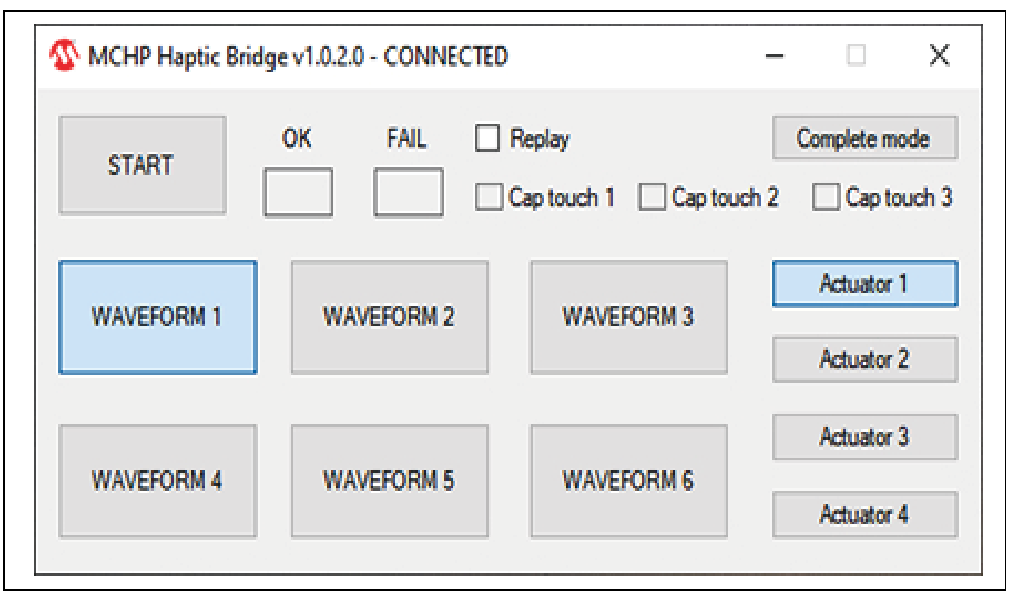


FIGURE 2-13: *The GUI Recognizes the Evaluation Board.*

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.

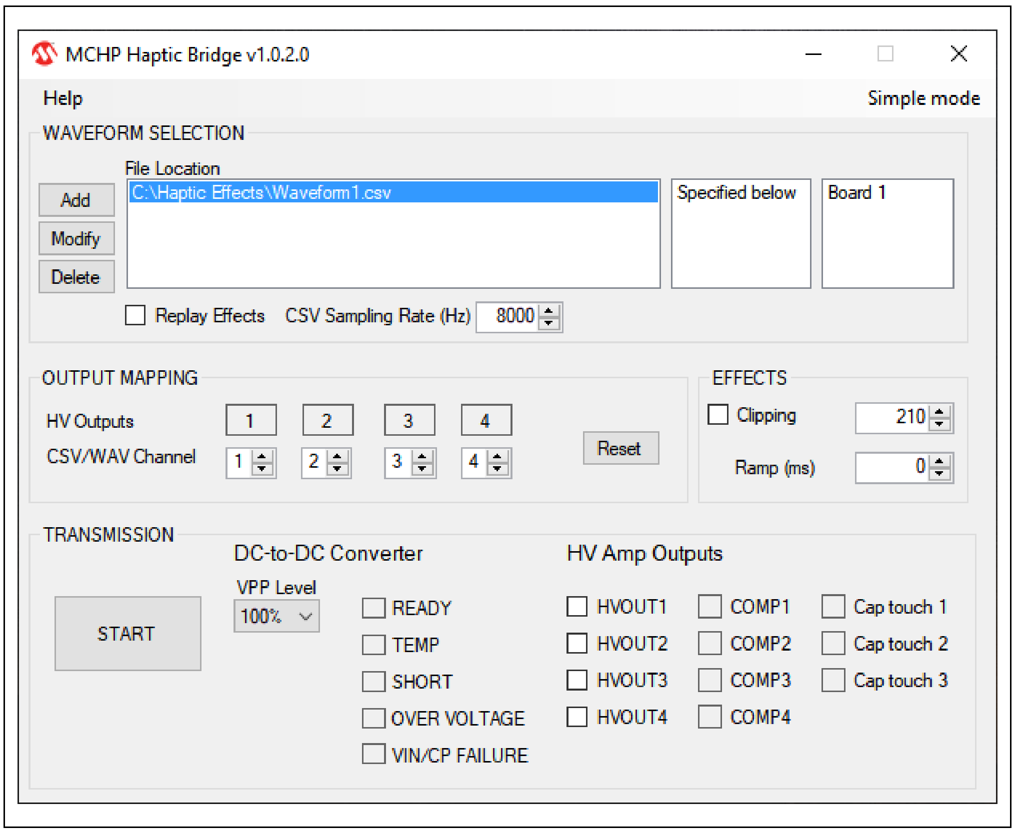


FIGURE 2-14: *Waveform Selection.*

2.3.3.2 CHANNEL MAPPING

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

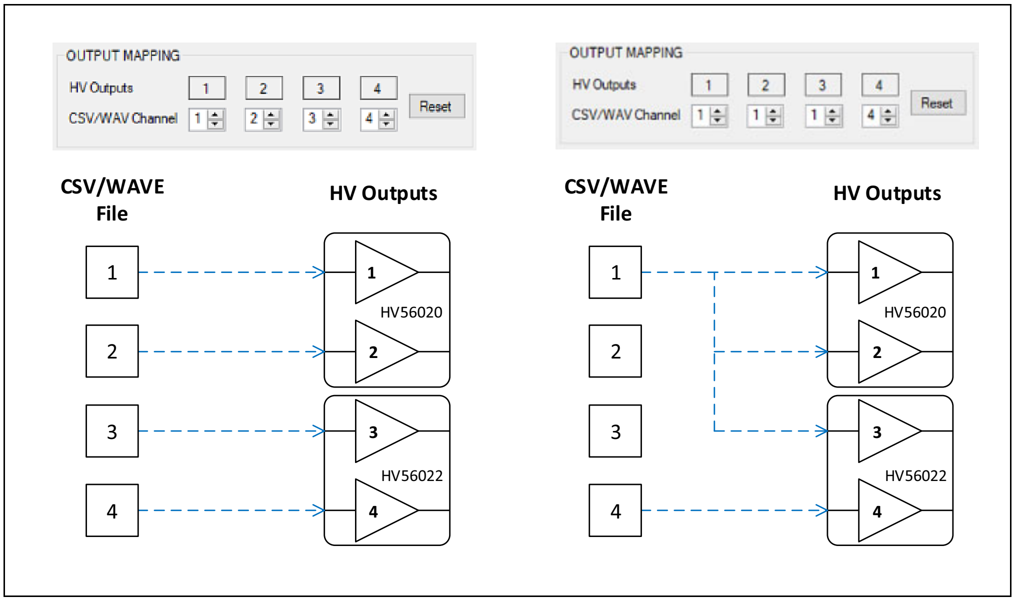


FIGURE 2-15: *Channel Mapping.*

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.

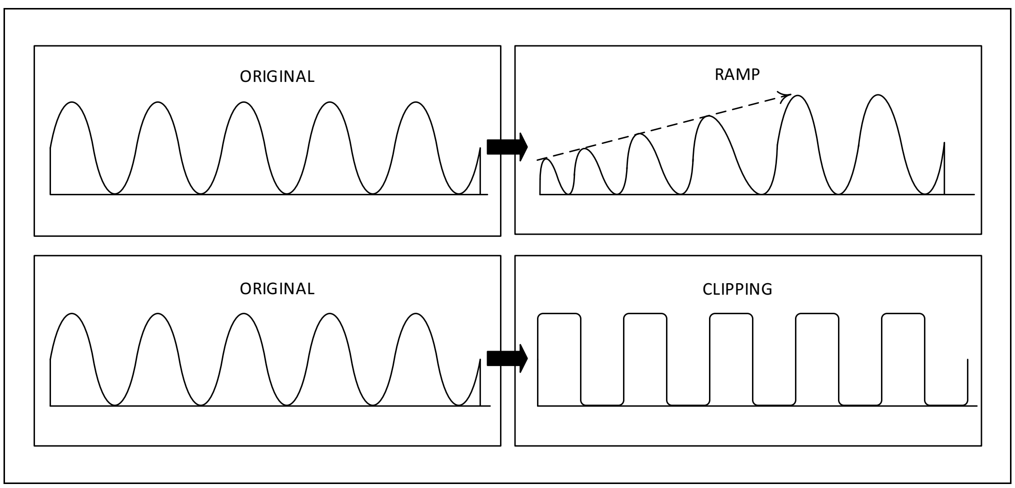


FIGURE 2-16: *Clipping and Ramp Effects.*

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.

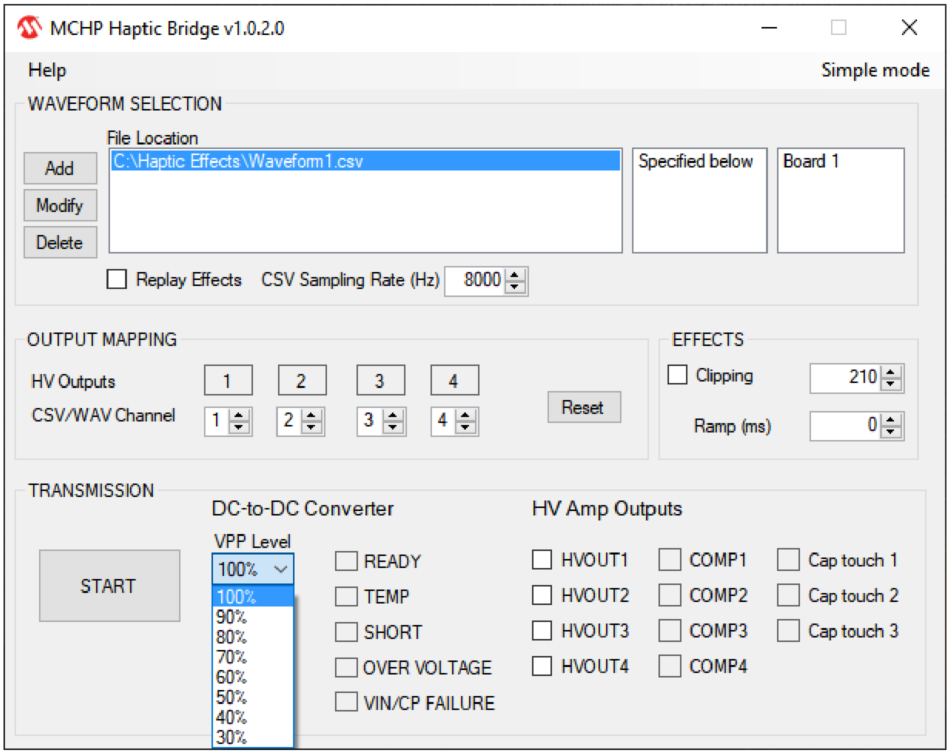


FIGURE 2-17: *DC-to-DC Converter VPP Selection.*

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.

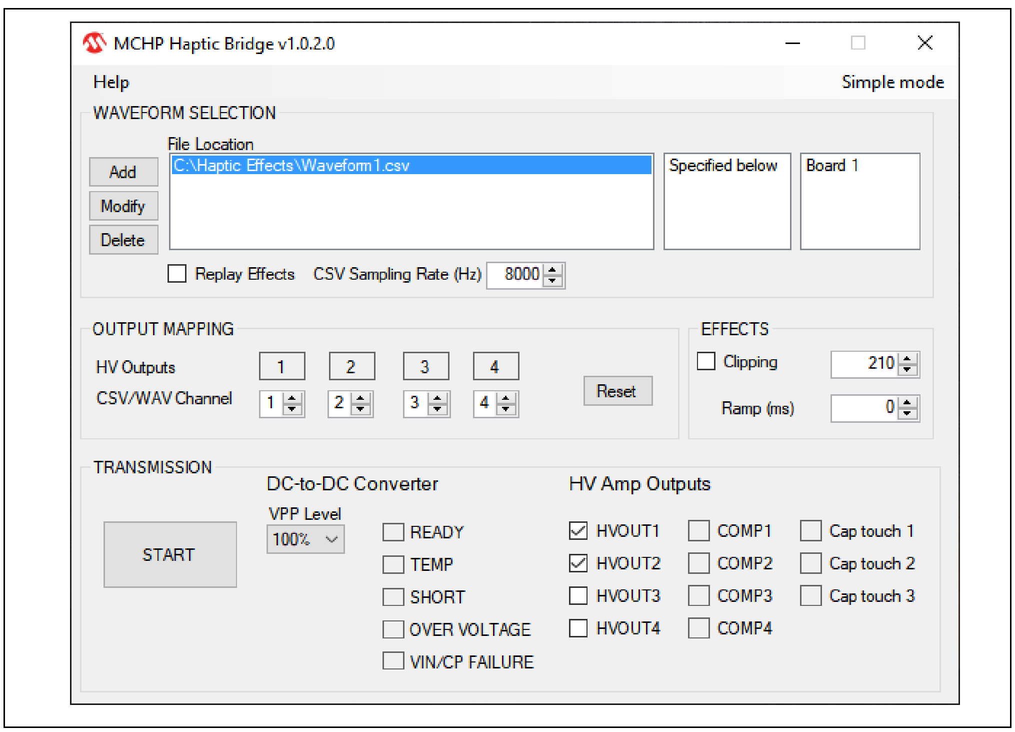


FIGURE 2-18: *HV Amp Outputs Selection.*

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

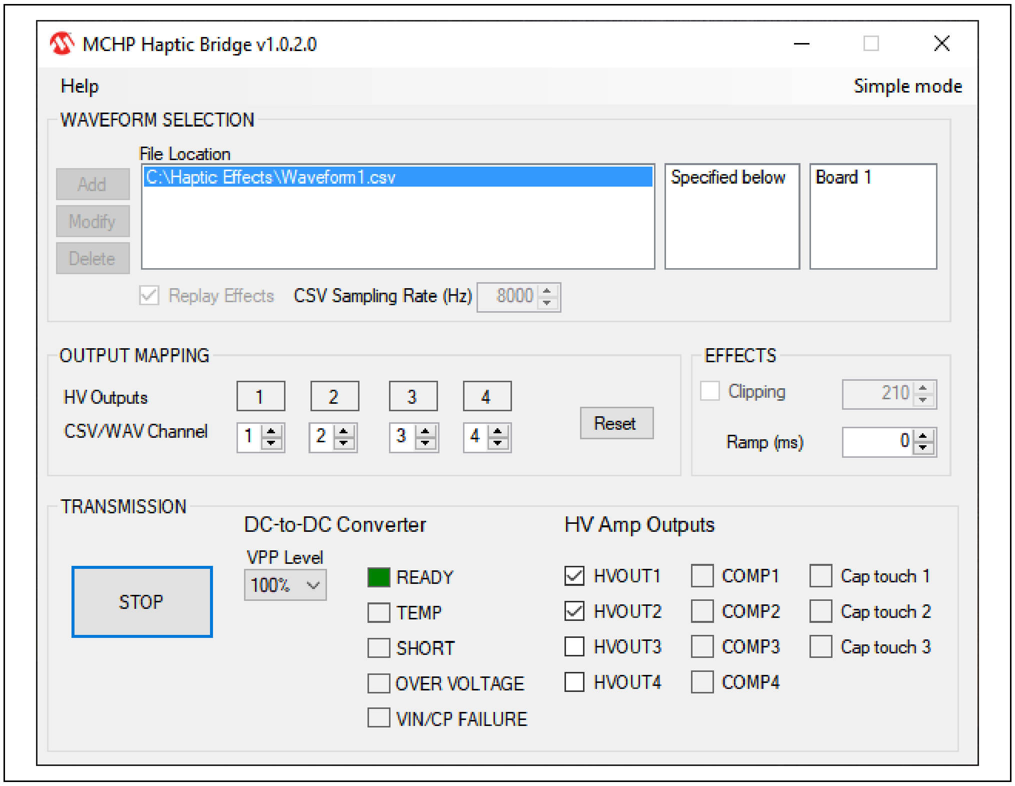


FIGURE 2-19: *Successful Transmission.*

4. 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:

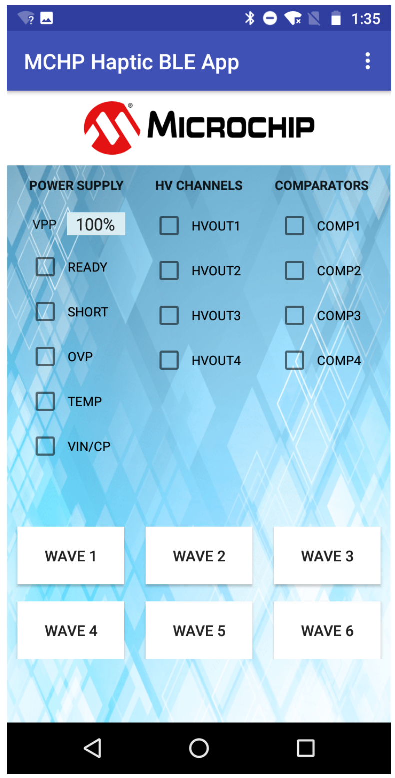


FIGURE 2-20: *MCHP Haptic BLE App.*

4. Select the desired VPP level.

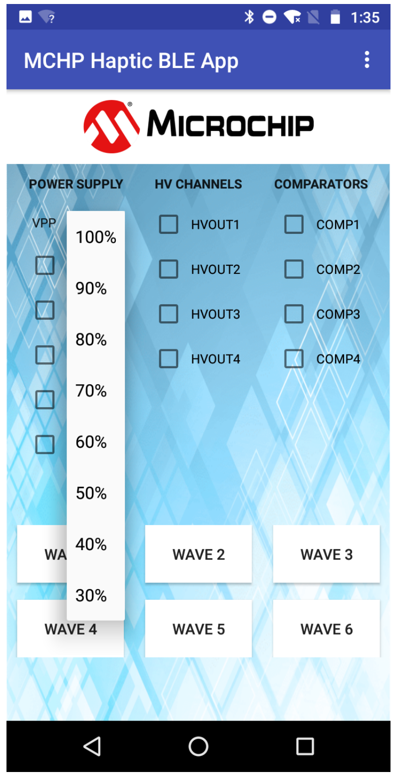


FIGURE 2-21: *Selecting the VPP Level.*

5. Select the HV CHANNELS for data transmission.

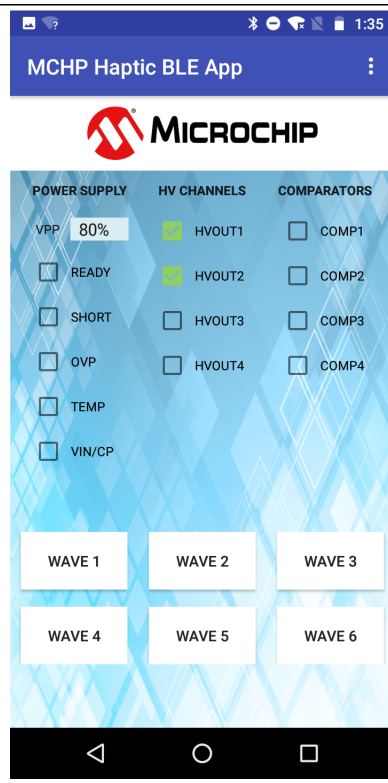


FIGURE 2-22: *HV CHANNELS Selection.*

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

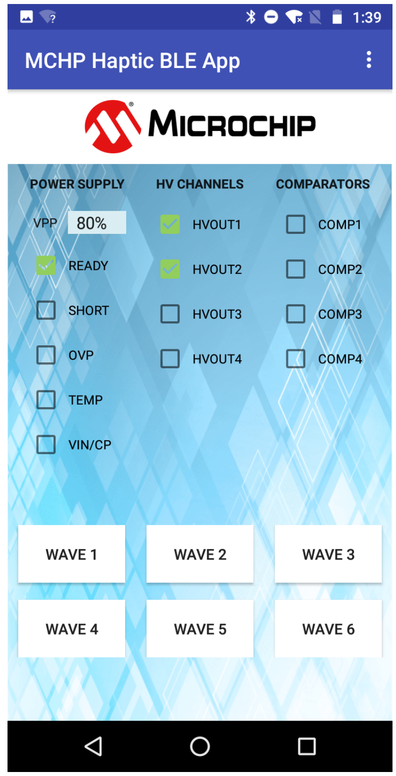


FIGURE 2-23: *Waveform Transmission.*

> 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 20mA (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

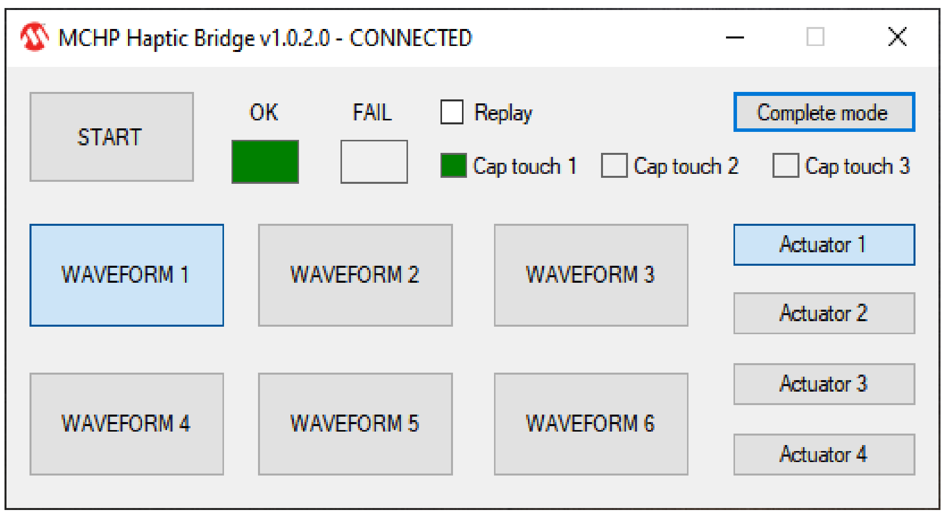


FIGURE 2-24: *Capacitive Touch Operation.*

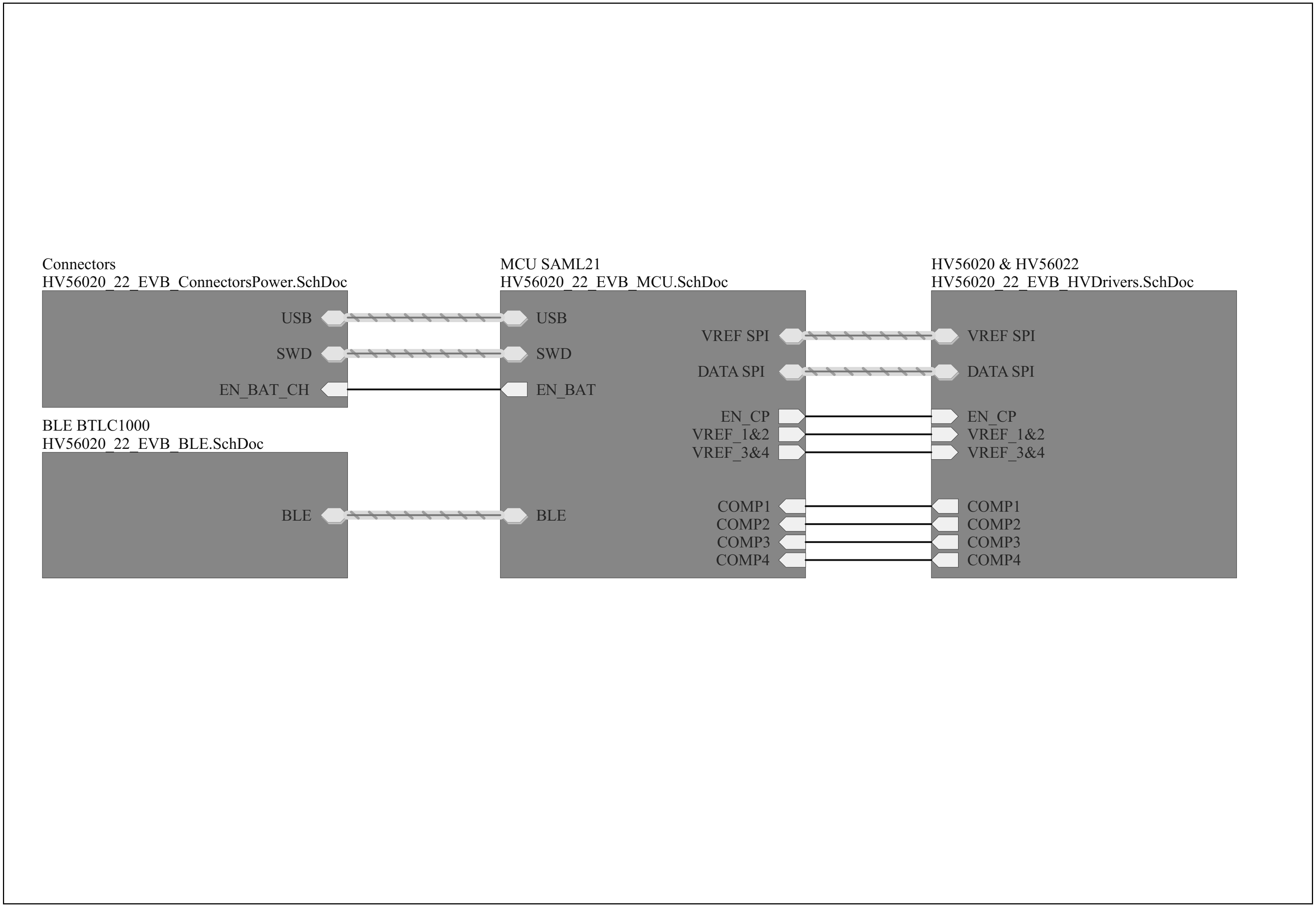
Appendix A. Schematic and Layouts

A.1 INTRODUCTION

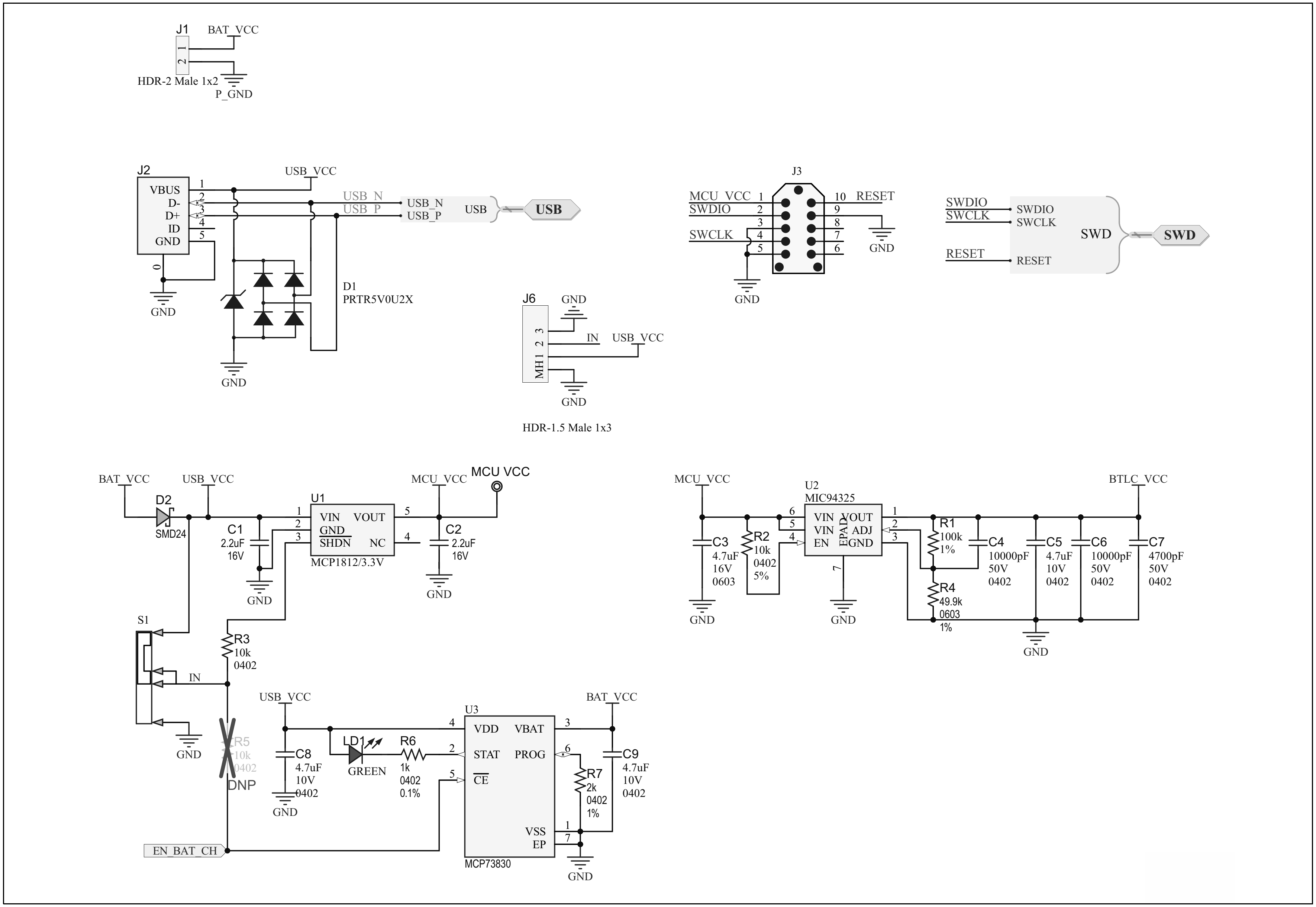
This appendix contains the following schematics and layouts for the HV56020/22 Evaluation Board:

- Board – Schematic BLE
- Board – Top Layer and Silk
- Board – Top Layer and Silk
- Board – Top Layer and Silk
- Board – Top Layer and Silk
- Board – Top Layer and Silk
- Board – Mid-Layer 1
- Board – Ground Plane
- Board – Power Plane
- Board – Mid-Layer 2
- Board – Bottom Layer and Silk

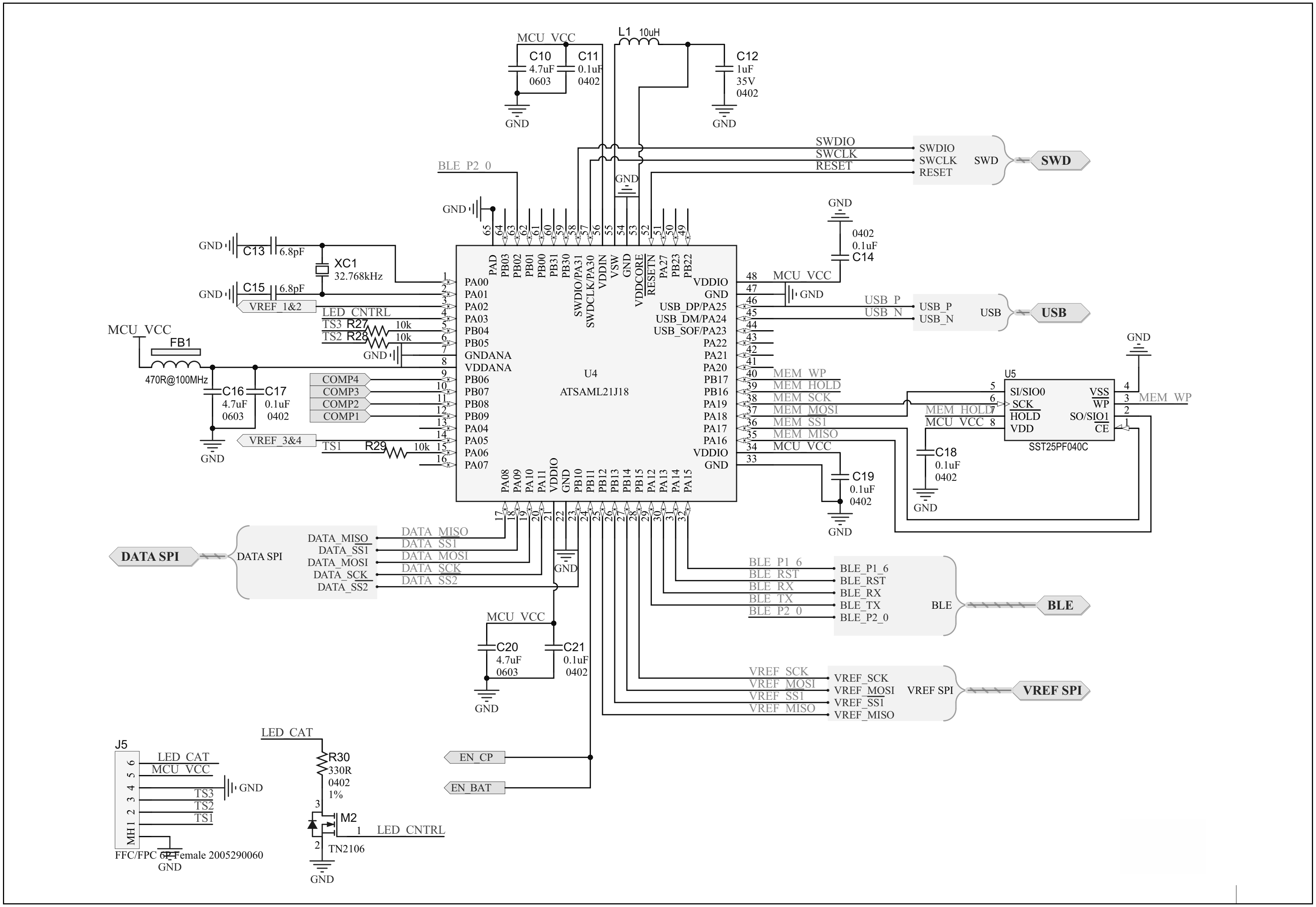
A.2 BOARD SCHEMATIC TOP LEVEL



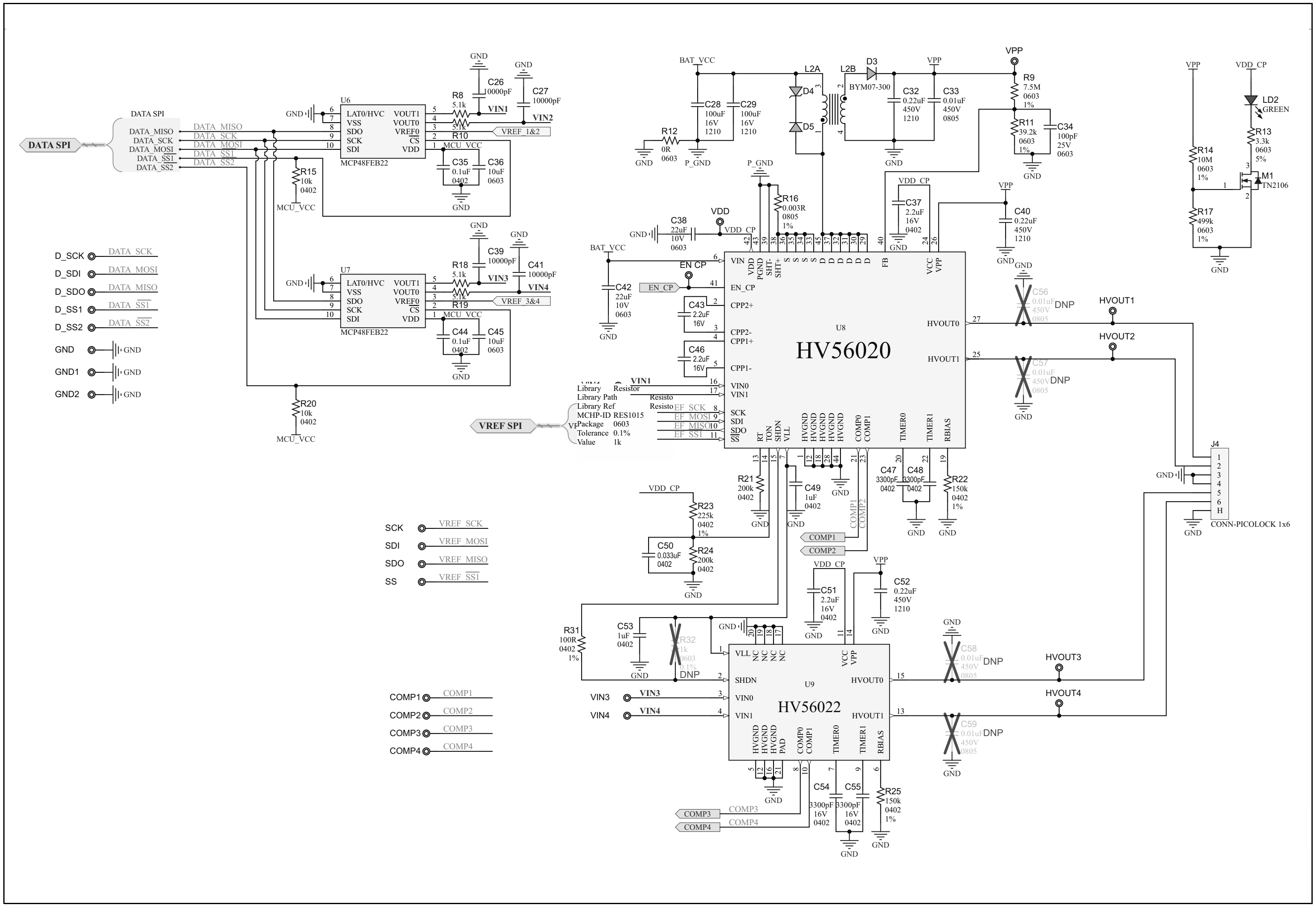
A.3 BOARD - SCHEMATIC CONNECTORS



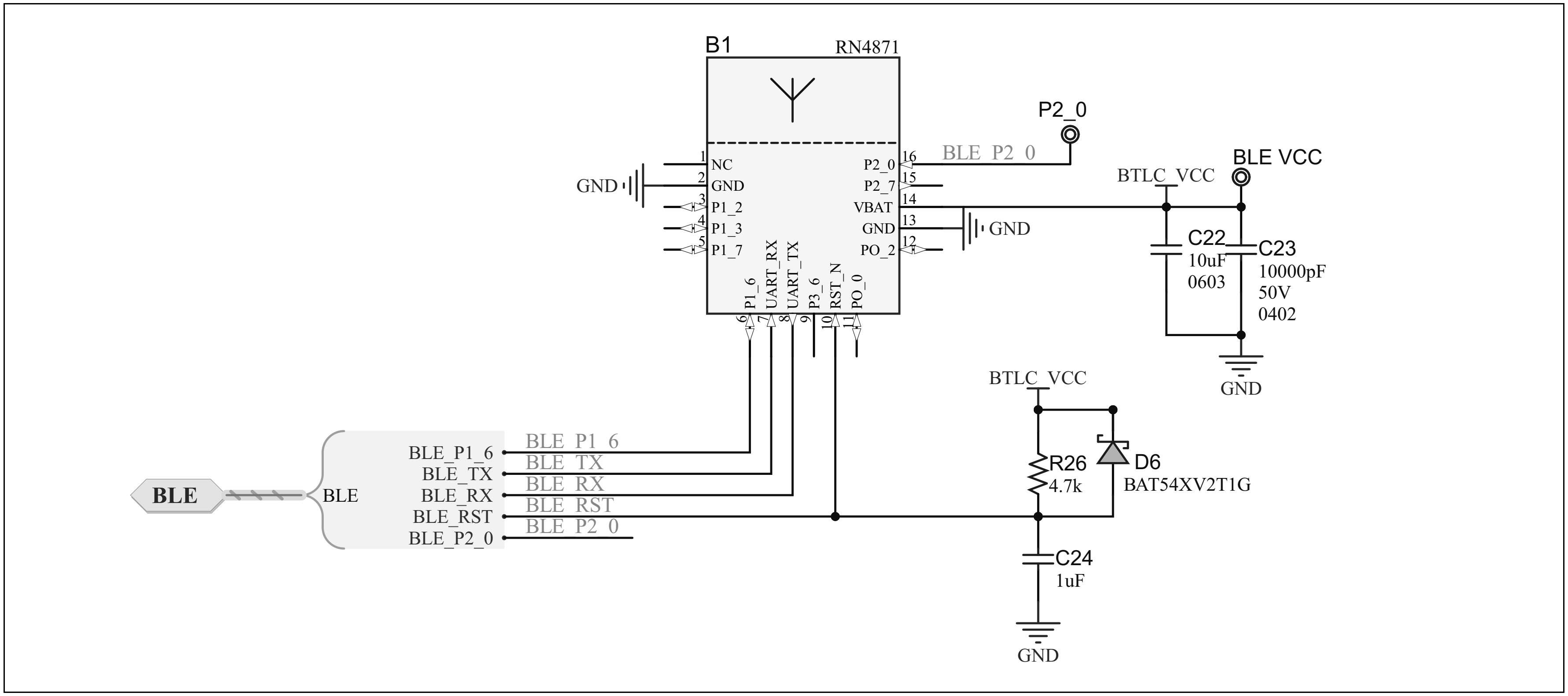
A.4 BOARD - SCHEMATIC MCU



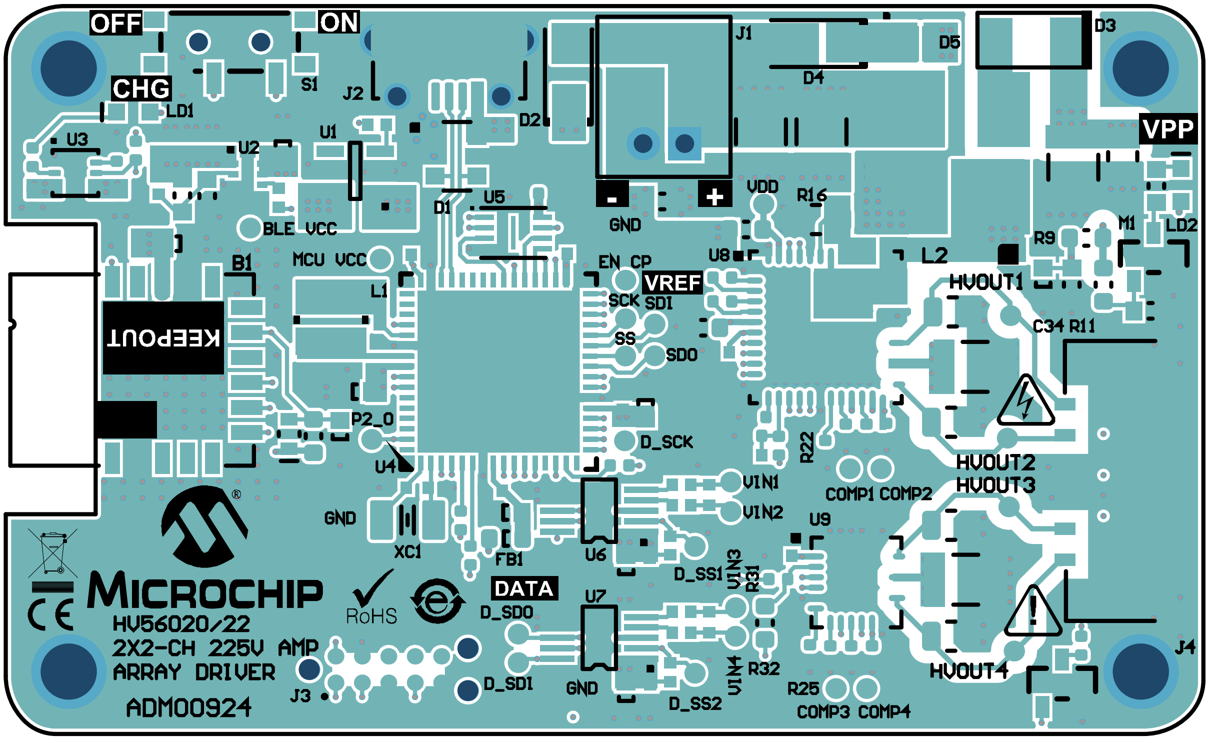
A.5 BOARD - SCHEMATIC HV DRIVERS



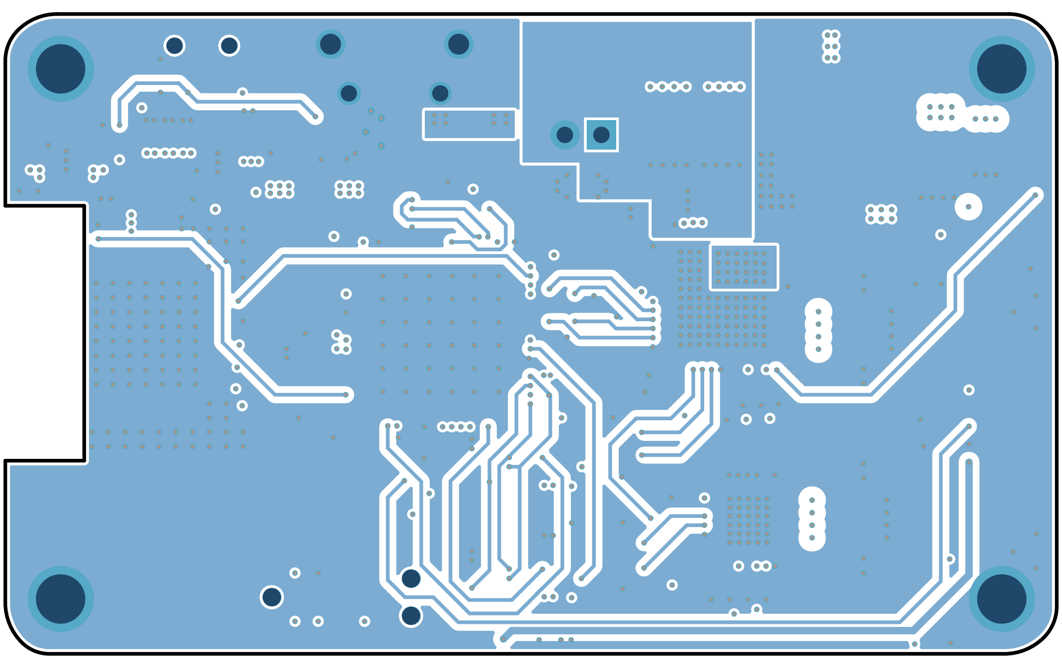
A.6 BOARD – SCHEMATIC BLE



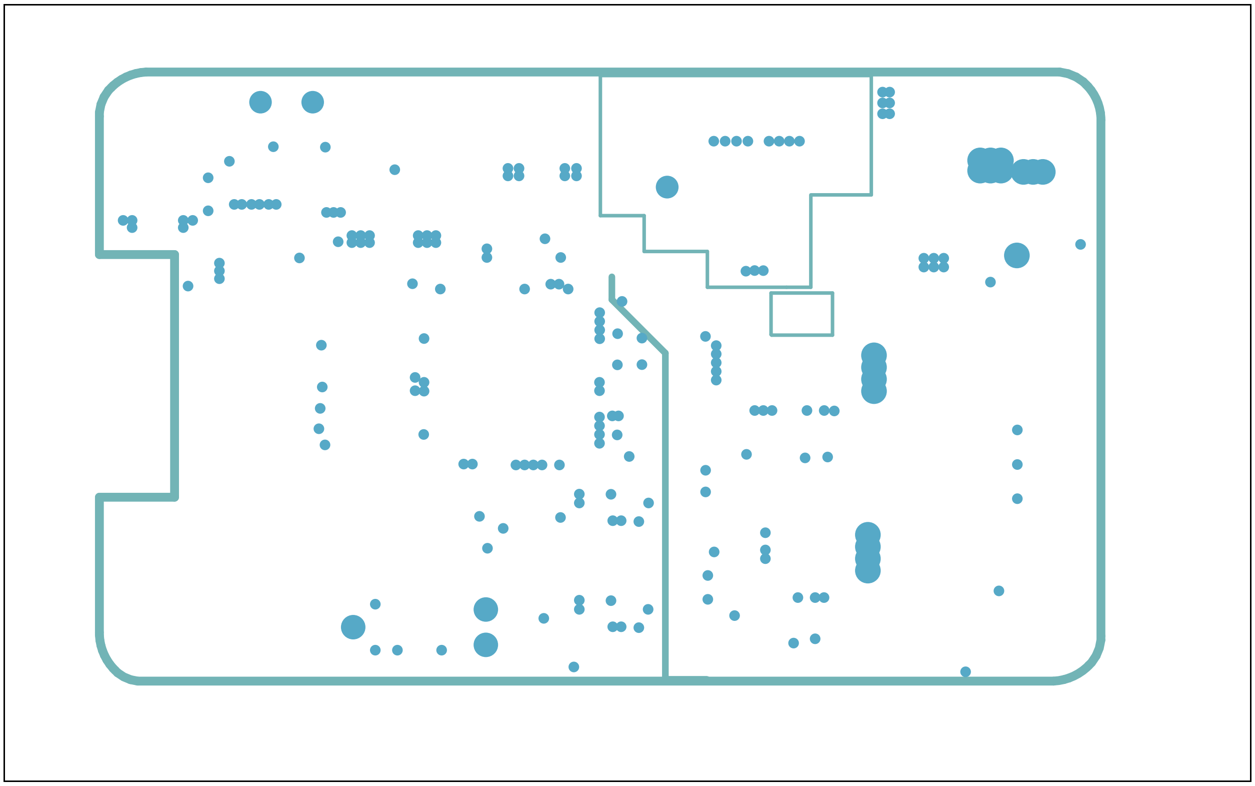
A.7 BOARD – TOP LAYER AND SILK



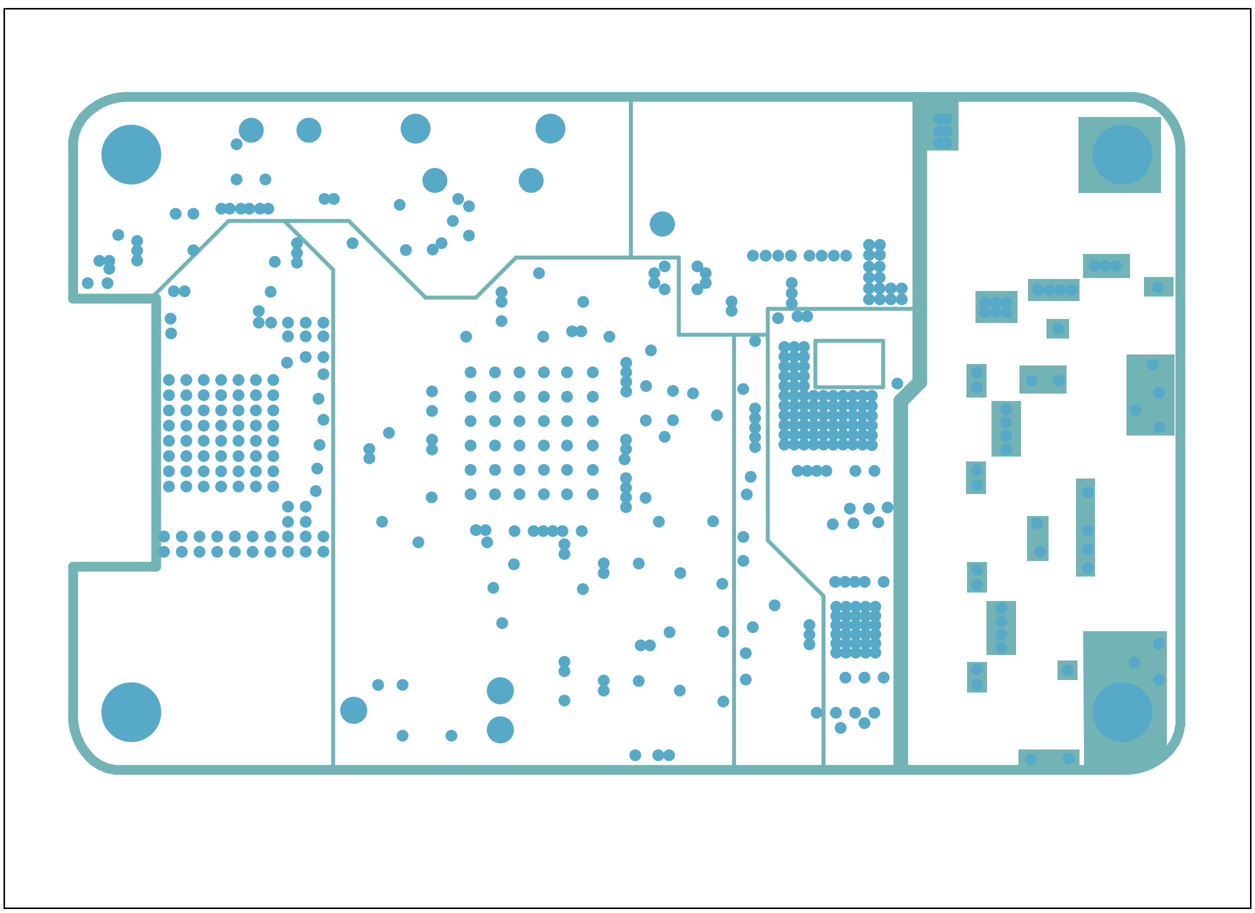
A.8 BOARD – MID-LAYER 1



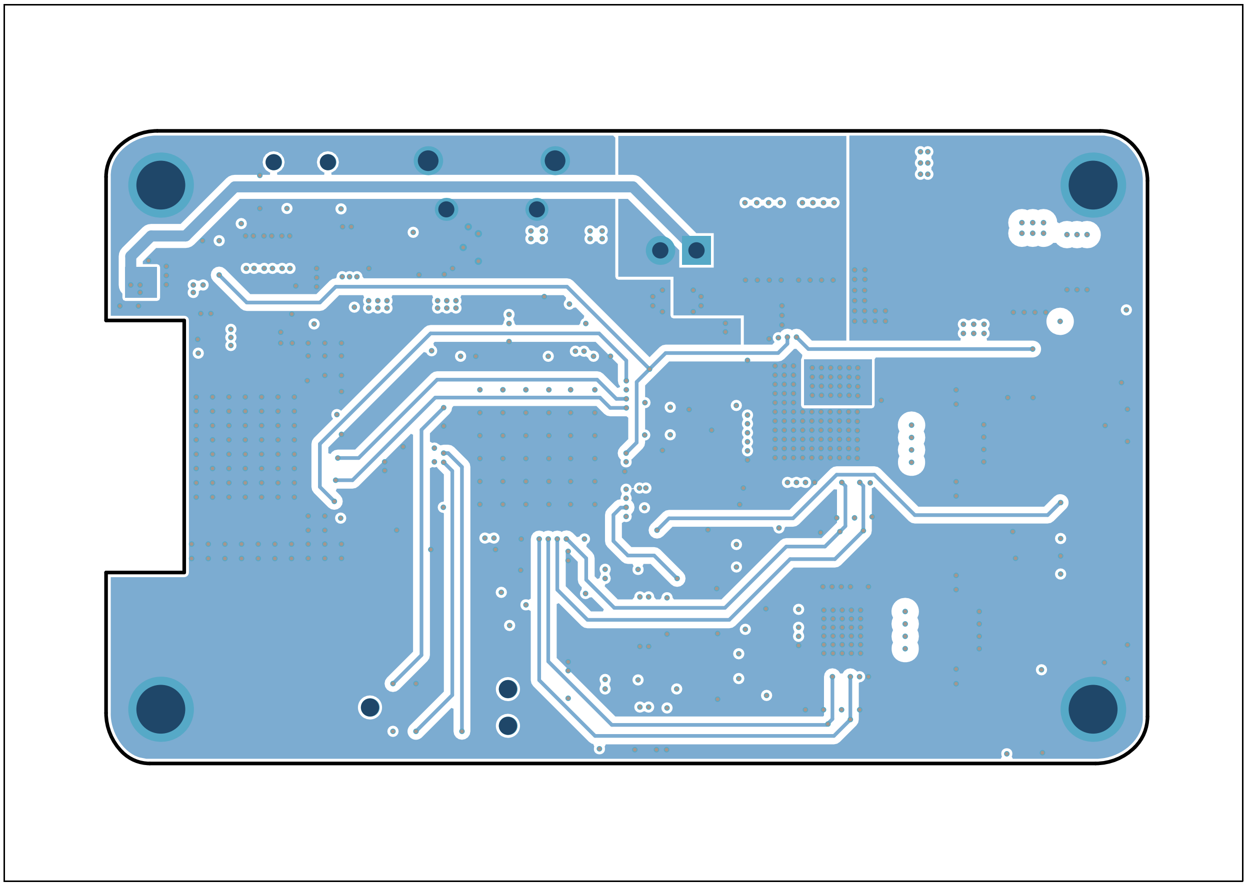
A.9 BOARD – GROUND PLANE



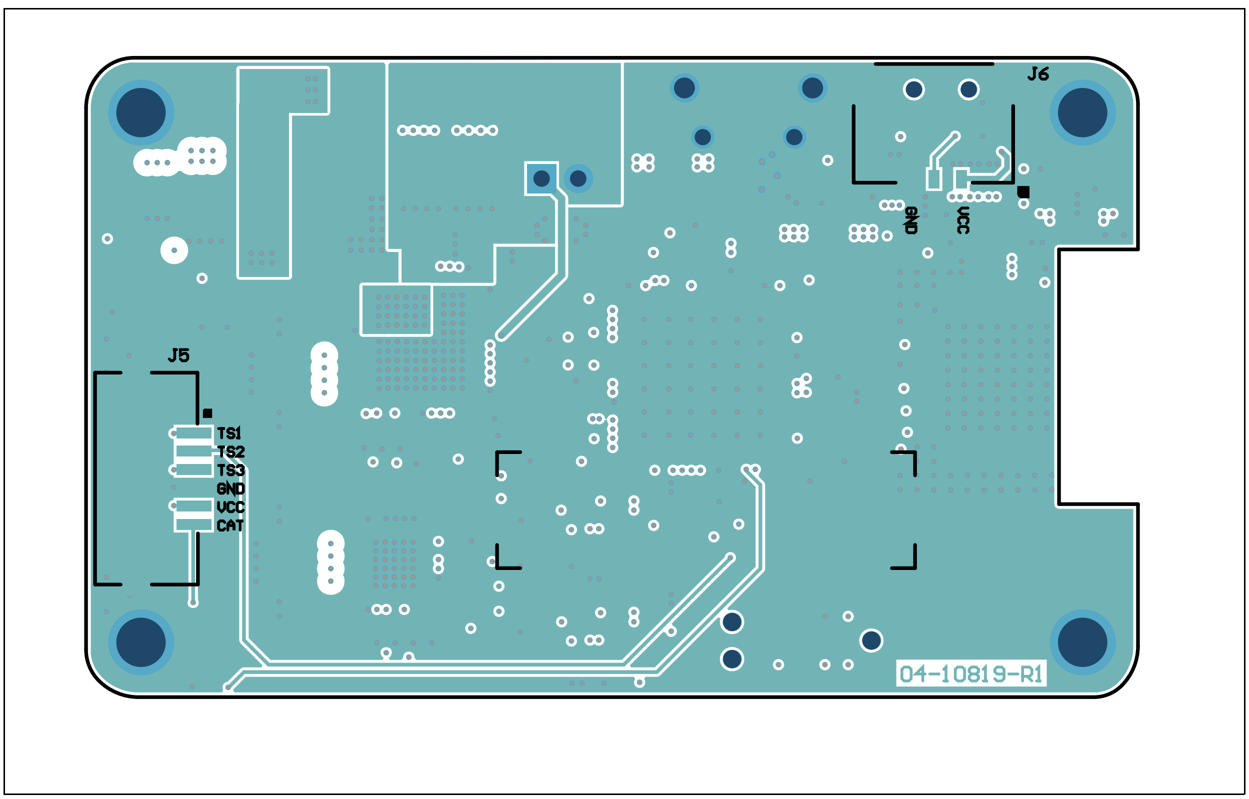
A.10 BOARD – POWER PLANE



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
1	B1	Microchip RF BLUETOOTH RN4871-I/RM130	Microchip Technology Inc.	**RN4871-I/RM130**
6	C1, C2, C37, C43, C46, C51	Ceramic Capacitor, 2.2 µF, 16V, 10%, X5R, Surface Mounted (SMD), 0402	TDK Corporation	C1005X5R1C225K050BC
1	C3	Ceramic Capacitor, 4.7 µF, 16V, 10%, X5R, SMD, 0603	TDK Corporation	C1608X5R1C475K080AC
4	C4, C6, C23, C25	Ceramic Capacitor, 10000 pF, 50V, 10%, X7R, SMD, 0402	Yageo Corporation	CC0402KRX7R9BB103
3	C5, C8, C9	Ceramic Capacitor, 4.7 µF, 10V, 10%, X5R, SMD, 0402	TDK Corporation	C1005X5R1A475K050BC
1	C7	Ceramic Capacitor, 4700 pF, 50V, 10%, X7R, SMD, 0402	Murata Electronics North America, Inc.	GRM155R71H472KA01J
3	C10, C16, C20	Ceramic Capacitor, 4.7 µF, 35V, 10%, X5R, SMD, 0603	Murata Electronics North America, Inc.	GRM188R6YA475KE15D
8	C11, C14, C17, C18, C19, C21, C35, C44	Ceramic Capacitor, 0.1 µF, 25V, 10%, X7R, SMD, 0402	TDK Corporation	C1005X7R1E104K050BB
3	C12, C49, C53	Ceramic Capacitor, 1 µF, 35V, 10%, X5R, SMD, 0402	Murata Electronics North America, Inc.	GRM155R6YA105KE11D
2	C13, C15	Ceramic Capacitor, 6.8 pF, 50V, 0.1 pF, NP0, SMD, 0402	Murata Electronics North America, Inc.	GRM1555C1H6R8BA01D
1	C22	Ceramic Capacitor, 10 µF, 25V, 20%, X5R, SMD, 0603	TDK Corporation	C1608X5R1E106M080AC
1	C24	Ceramic Capacitor, 1 µF, 25V, 20%, X5R, SMD, 0603	Panasonic - ECG	ECJ-1V41E105M
4	C26, C27, C39, C41	Ceramic Capacitor, 10000 pF, 16V, 10%, X7R, SMD, 0402	KEMET	C0402C103K4RACTU
2	C28, C29	Ceramic Capacitor, 100 µF, 16V, 20%, X5R, SMD, 1210	Yageo Corporation	CC1210MKX5R7BB107
3	C32, C40, C52	Ceramic Capacitor, 0.22 µF, 450V, 10%, X7T, SMD, 1210	TDK Corporation	C3225X7T2W224K200AA
1	C33	Ceramic Capacitor, 0.01 µF, 450V, 10%, X7T, SMD, 0805, AEC-Q200	TDK Corporation	CGA4F4X7T2W103M085AE
1	C34	Ceramic Capacitor, 100 pF, 25V, 10%, NP0, SMD, 0603	AVX Corporation	06033A101KAT2A
2	C36, C45	Ceramic Capacitor, 10 µF, 25V, 20%, X5R, SMD, 0603	Murata Electronics North America, Inc.	GRM188R61E106MA73D

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
2	C38, C42	Ceramic Capacitor, 22 µF, 10V, 20%, X5R, SMD, 0603	Samsung Electro-Mechanics, Inc.	CL10A226MPCNUBE
4	C47, C48, C54, C55	Ceramic Capacitor, 3300 pF, 16V, 10%, X7R, SMD, 0402	Murata Electronics North America, Inc.	GRM15XR71C332KA86D
1	C50	Ceramic Capacitor, 0.033 µF, 16V, 10%, X7R, SMD, 0402	TDK Corporation	CGA2B2X7R1C333K050BA
0	C56, C57, C58, C59	Ceramic Capacitor, 0.01 µF, 450V, 10%, X7T, SMD, 0805, AEC-Q200	TDK Corporation	CGA4F4X7T2W103M085AE
1	D1	Diode TVS, 5.5V, SMD, SOT-143	Nexperia	PRTR5V0U2X,215
1	J3	Connector Tag 10P TC2050 SMT No legs	Tag-Connect LLC	TC2050-IDC-NL
1	D2	Diode, SCHOTTKY, SMD24, 500 mV, 2A, 40V, SOD-123FL	Micro Commercial Components Corp.	SMD24PL-TP
1	D3	Diode Rectifier, 0.5A, 300V, DO213-AA, AEC-Q101	Vishay Intertechnology, Inc.	BYM07-300-E3/98
1	D4	Zener Diode, 39V, 1W, SMD, SOD-123FL	Panasonic® - ECG	DZ2W39000L
1	D5	Diode Rectifier, 0.5V, 4A, 10V, SMD, U-DFN2020-2, AEC-Q101	Diodes Incorporated®	SBRT4U10LP-7
1	D6	Diode SCHOTTKY BAT54XV2T1G 30V 200mA 40V SOD-523	ON Semiconductor®	BAT54XV2T1G
1	FB1	Ferrite, 470R at 100 MHz, 1A, SMD, 0603	Murata Electronics North America, Inc.	BLM18PG471SN1D
1	J1	Connector Header, 2 Male, 1x2, Shrouded, 2 mm, MH, THT, R/A	JST Sales America, Inc.	S2B-PH-K-S(LF)(SN)
1	J2	Connector USB, 2.0 Micro-B, Female, Through Hole (TH)/SMD, Right Angle (R/A)	FCI	10118194-0001LF
1	J4	Connector Header, 1.5 Female, Gold, 1x6, R/A, SMD	Molex®	5040500691
1	J5	Connector Header, 1mm 6P Female 2005290060 SMD R/A	Molex®	2005290060
1	J6	Connector Header, 1.5 Male 1x3 Gold SMD R/A	Molex®	5040500391
1	LABEL1	Label Assembly, W/REV Level (Small Modules) per MTS-0002		
1	L1	Fixed Inductor, 10 µH, 1.2A, 240 mΩ, SMD	Murata Electronics North America, Inc.	LQH3NPN100MJRL
1	L2	Inductor, 1 µH:10 µH, 1:10, 8A SMD	Coilcraft	ZA9735-AE
2	LD1, LD2	LED Green Diode, 1.7V, 20 mA, 3.92 mcd, Diffused, SMD, 0603	OSRAM Opto Semiconductors GmbH	LG L29K-G2J1-24-Z
1	M1, M2	Analog MOSFET N-CH TN2106 60V 280mA 360mW 2.5R SOT23-3	Microchip Technology Inc.	**TN2106K1-G**
1	PCB1	HV56020/22 Evaluation Board – Printed Circuit Board	Microchip Technology Inc.	**04-10819-R1**

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
1	R1	Resistor, Thick Film (TKF), 100 kΩ, 1%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3EKF1003V
4	R2, R3, R15, R20	Resistor, TKF, 10 kΩ, 5%, 1/16W, SMD, 0402	Vishay/Dale	CRCW040210K0JNED
1	R4	Resistor, TKF, 49.9 kΩ, 1%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3EKF4992V
0	R5	Resistor, TKF, 10 kΩ, 5%, 1/16W, SMD, 0402, DO NOT POPULATE	Vishay/Dale	CRCW040210K0JNED
1	R6	Resistor, Thin Film (TF), 1 kΩ, 0.1%, 1/16W, SMD, 0402	Yageo Corporation	RT0402BRD071KL
1	R7	Resistor, TKF, 2 kΩ, 1%, 1/10W, SMD, 0402	Panasonic - ECG	ERJ-2RKF2001X
4	R8, R10, R18, R19	Resistor, TKF, 5.1 kΩ, 1%, 1/10W, SMD, 0402	Panasonic - ECG	ERJ-2RKF5101X
1	R9	Resistor, TKF, 7.5 MΩ, 1%, 1/10W, SMD, 0603	ROHM Semiconductor	KTR03EZPF7504
1	R11	Resistor, TKF, 39.2 kΩ, 1%, 1/10W, SMD, 0603	Stackpole Electronics, Inc.	RMCF0603FT39K2
1	R12	Resistor, TKF, 0Ω, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3GSY0R00V
1	R13	Resistor, TKF, 1 kΩ, 5%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3GEYJ102V
1	R14	Resistor, TKF, 10 MΩ, 1%, 1/10W, SMD, 0603 HV, AEC-Q200	ROHM Semiconductor	KTR03EZPF1005
1	R16	Resistor, Shunt, 0.003 mΩ, 1%, 1/2W, 0805, AEC-Q200	ROHM Semiconductor	PMR10EZPFV3L00
1	R17	Resistor, TKF, 499 kΩ, 1%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3EKF4993V
2	R21, R24	Resistor, TKF, 200 kΩ, 1%, 1/10W, SMD, 0402	Panasonic - ECG	ERJ-2RKF2003X
2	R22, R25	Resistor, TKF, 150 kΩ, 1%, 1/10W, SMD, 0402	Panasonic - ECG	ERJ-2RKF1503X
1	R23	Resistor, TKF, 225 kΩ, 1%, 1/16W, SMD, 0402	Stackpole Electronics, Inc.	RMCF0402FT255K
1	R26	Resistor, TKF, 4.7 kΩ, 1%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3GEYJ472V
3	R27, R28, R29	Resistor, TKF, 10 kΩ, 1%, 1/10W, SMD, 0402	Panasonic - ECG	ERJ-2GEJ103X
1	R30	Resistor, TKF 330R 1% 1/10W SMD, 0402	KOA Speer Electronics, Inc.	RK73H1ETTP3300F
1	XC1	Crystal 32.768kHz 7pF SMD CM7V-T1A	Micro Crystal	CM7V-T1A 32.768 kHz 7.0 pf +/- 20 ppm
1	S1	Switch Slide, SPDT, 4V, 0.3A	TE Connectivity Alcoswitch Switches	MLL1200S
1	U1	Analog LDO, 3.3V, 300 mA, SOT23-5	Microchip Technology Inc.	**MCP1812AT-033/OT**
1	U2	Analog Adjustable LDO, TDFN-6	Microchip Technology Inc.	**MIC94325YMT-TR**
1	U3	Analog Battery Charger, TDFN-6	Microchip Technology Inc.	**MCP73830T-2AAI/MYY-ND**

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
1	U4	MCU 32-bit, 48 MHz, 256 kB, 32 kB, QFN-64	Microchip Technology Inc.	**ATSAML21J18B-MNT**
1	U5	Memory Serial Flash, 4 Mb, 40 MHz, 8-UDFN, 2x3	Microchip Technology Inc.	**SST25PF040CT-40I/NP**
2	U6, U7	Analog DAC, 2-Channel, 12-bit MSOP-10	Microchip Technology Inc.	**MCP48FEB22-E/UN**
1	U8	Analog HV Driver, 2-Channel QFN-43	Microchip Technology Inc.	**HV56020-V/KXX**
1	U9	Analog HV Driver, 2-Channel QFN-20	Microchip Technology Inc.	**HV56022-V/KNX**
2	XC1, XC2	Crystal, 32.768 kHz, 7 pF, SMD, CM7V-T1A	Abracon® Corporation (LLC)	ABS07-32.768KHZ-7-T

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.

NOTES:

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.

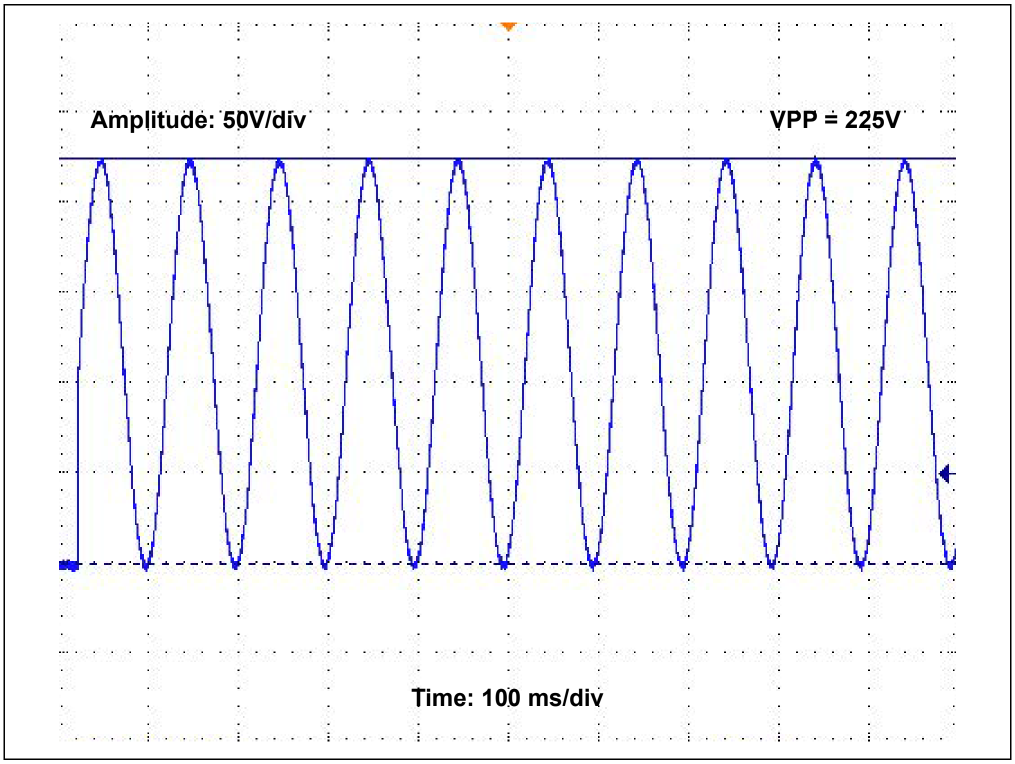


FIGURE C-1: DataFile HVOUT1.

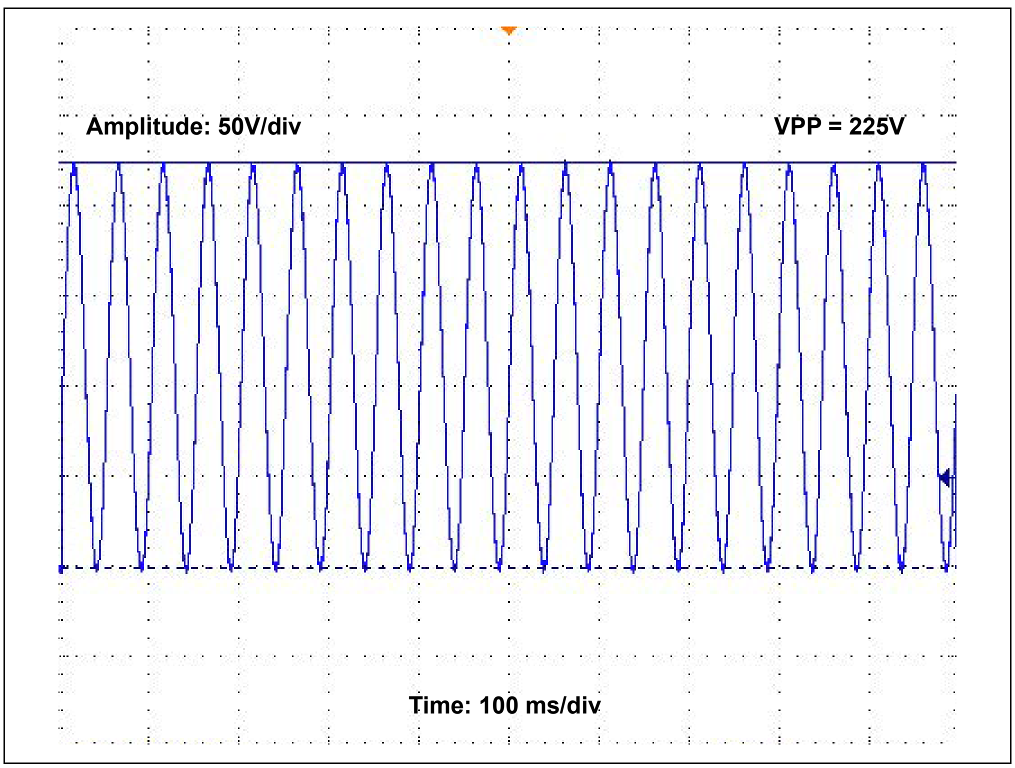


FIGURE C-2: DataFile HVOUT2.

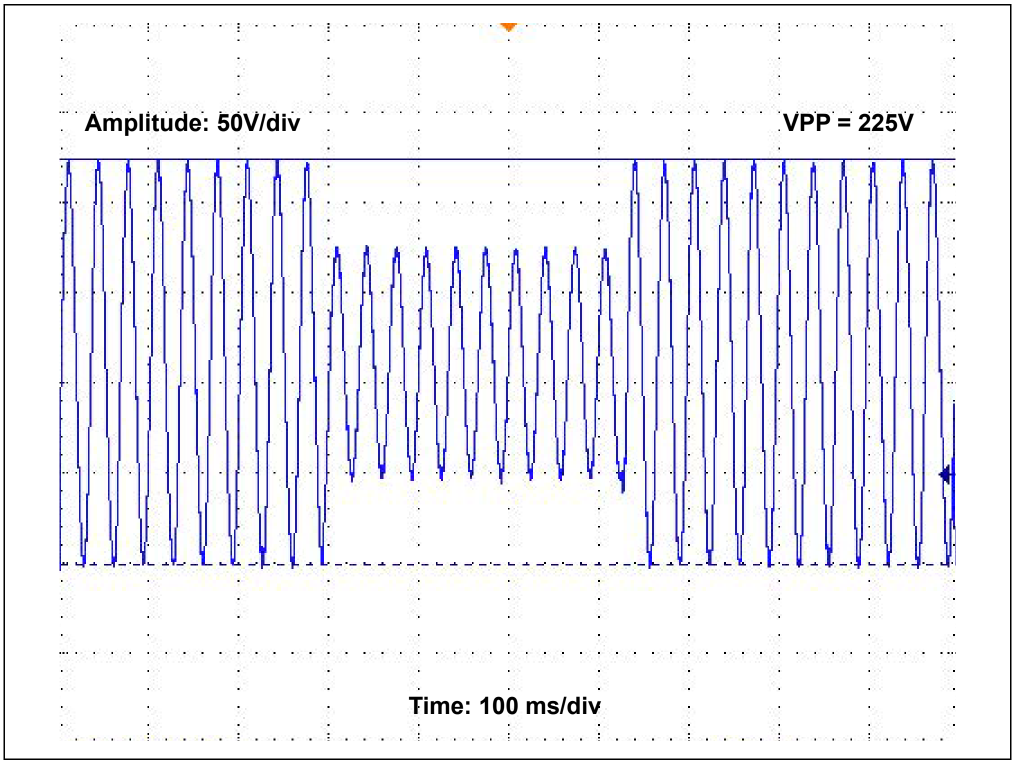


FIGURE C-3: *DataFile HVOUT3.*

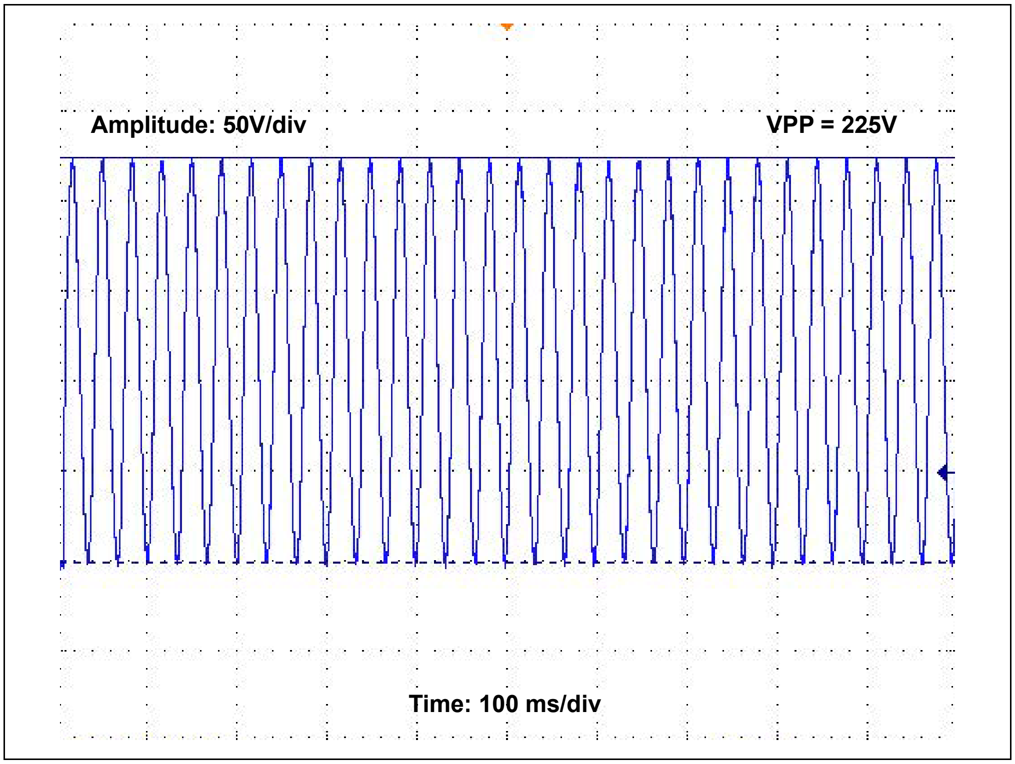


FIGURE C-4: *DataFile HVOUT4.*

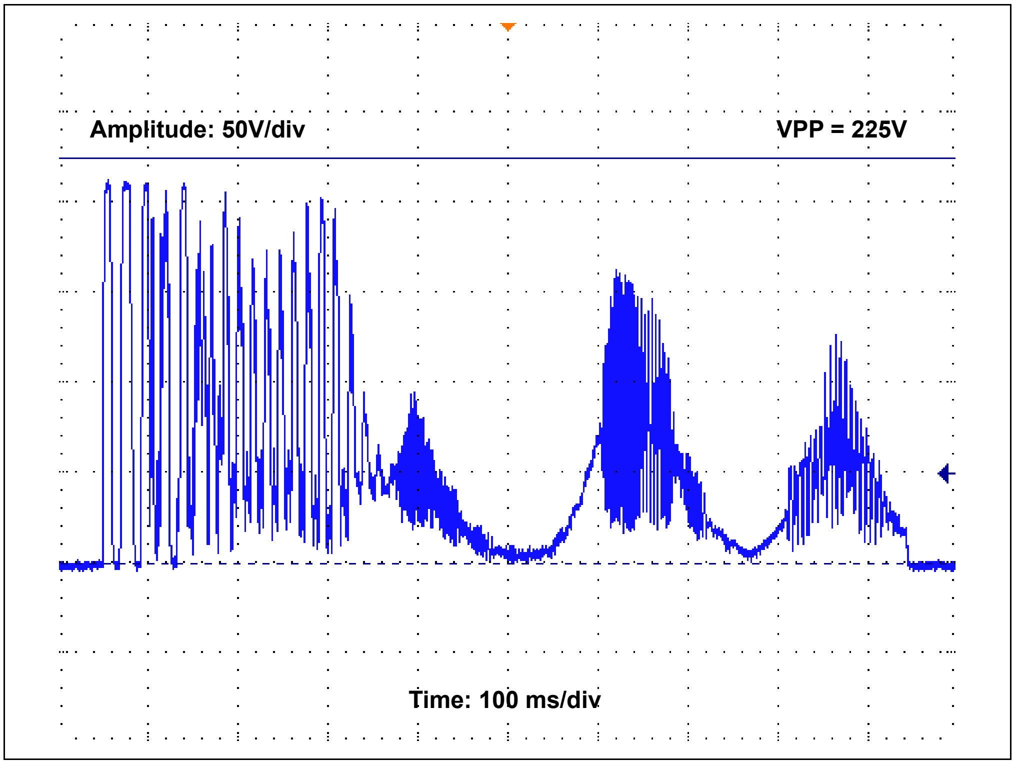


FIGURE C-5: Waveform 1, HVOUT1.

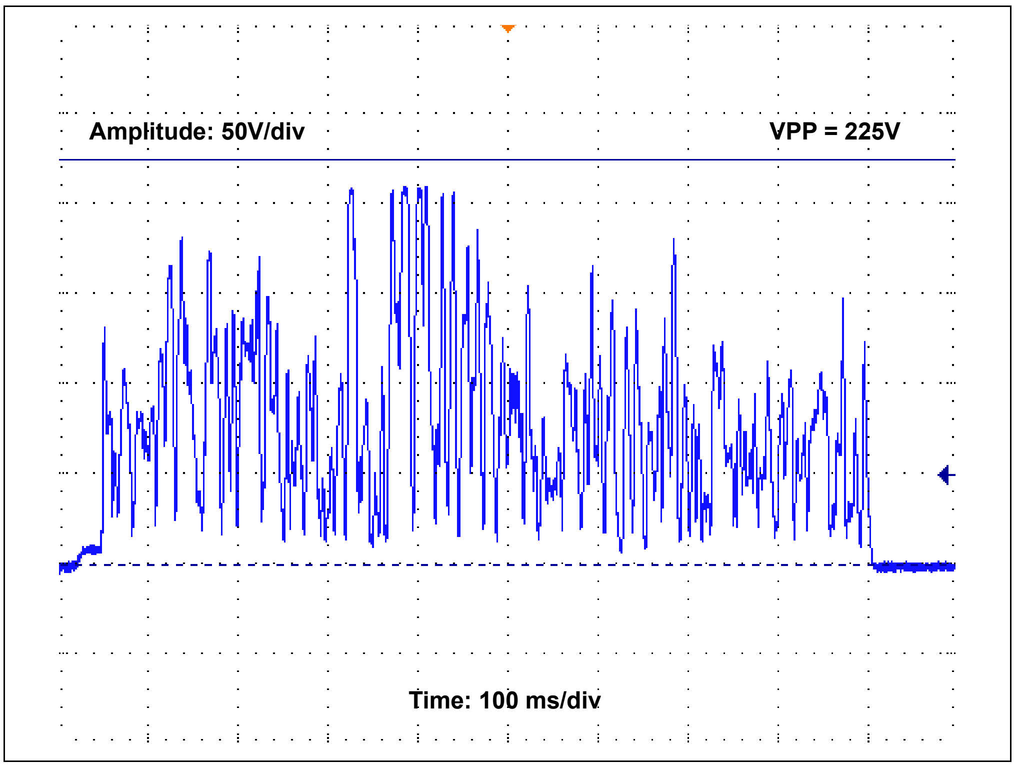


FIGURE C-6: Waveform 2, HVOUT1.

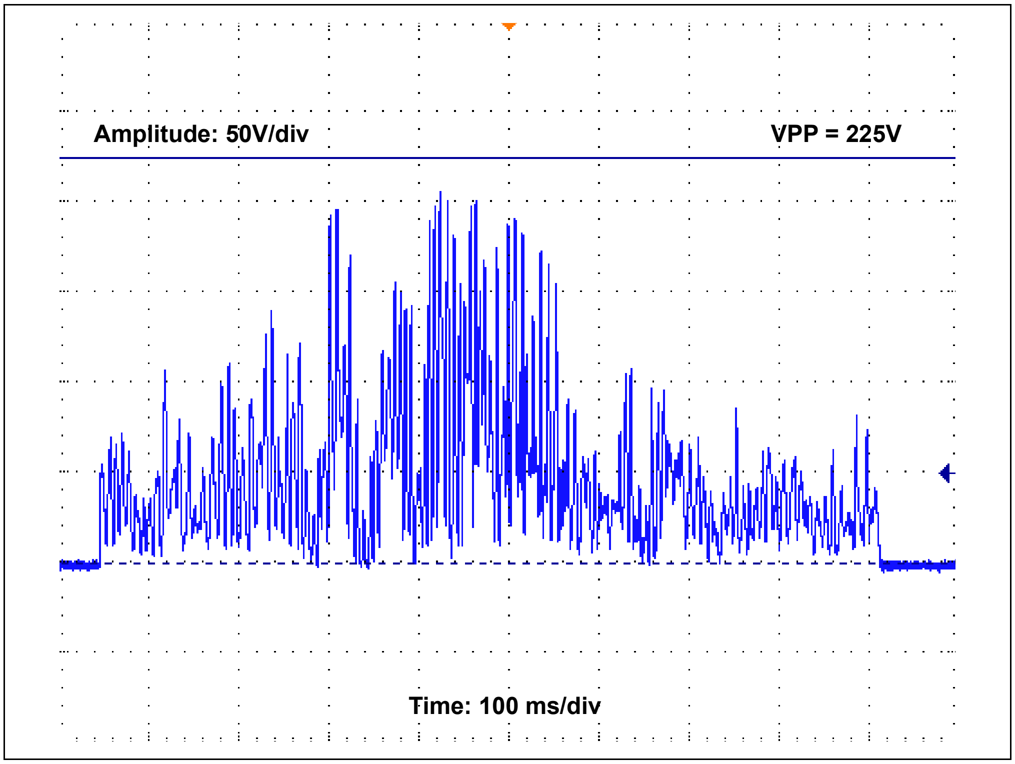


FIGURE C-7: Waveform 3, HVOUT1.

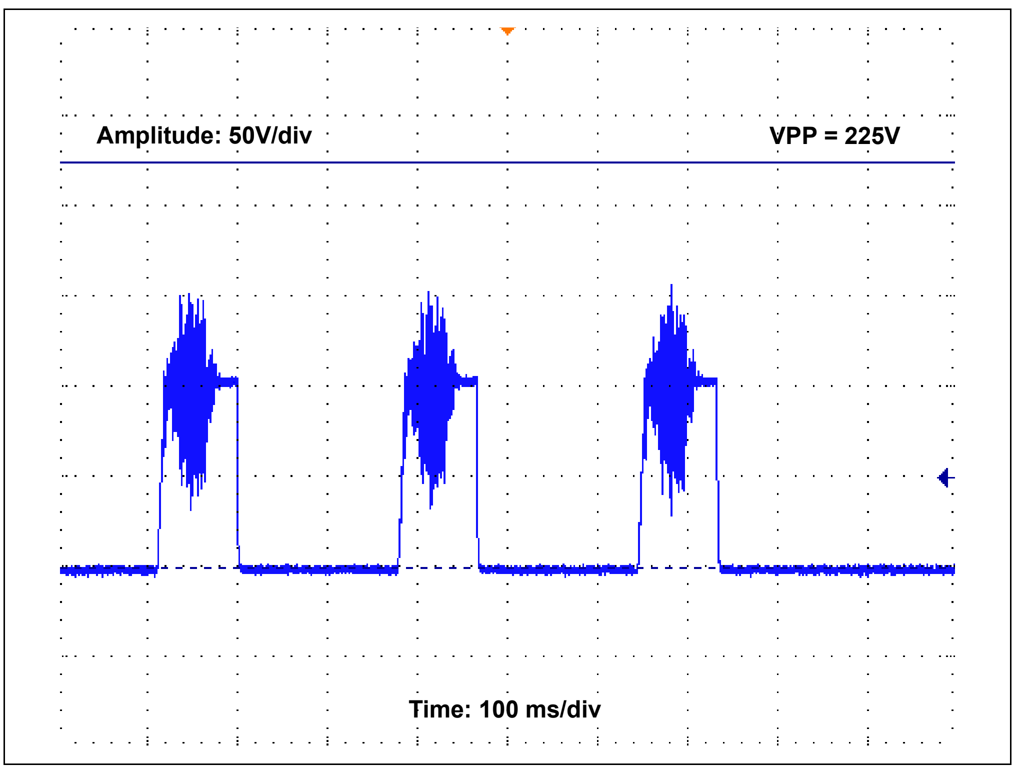


FIGURE C-8: Waveform 4, HVOUT1.

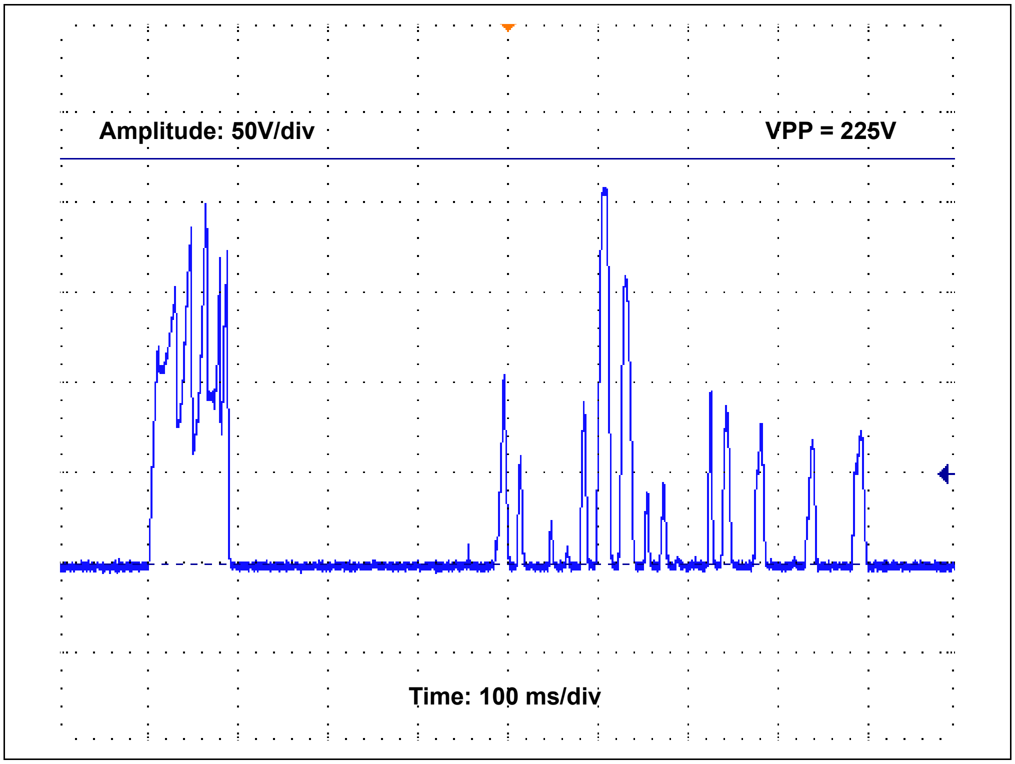


FIGURE C-9: Waveform 5, HVOUT1.

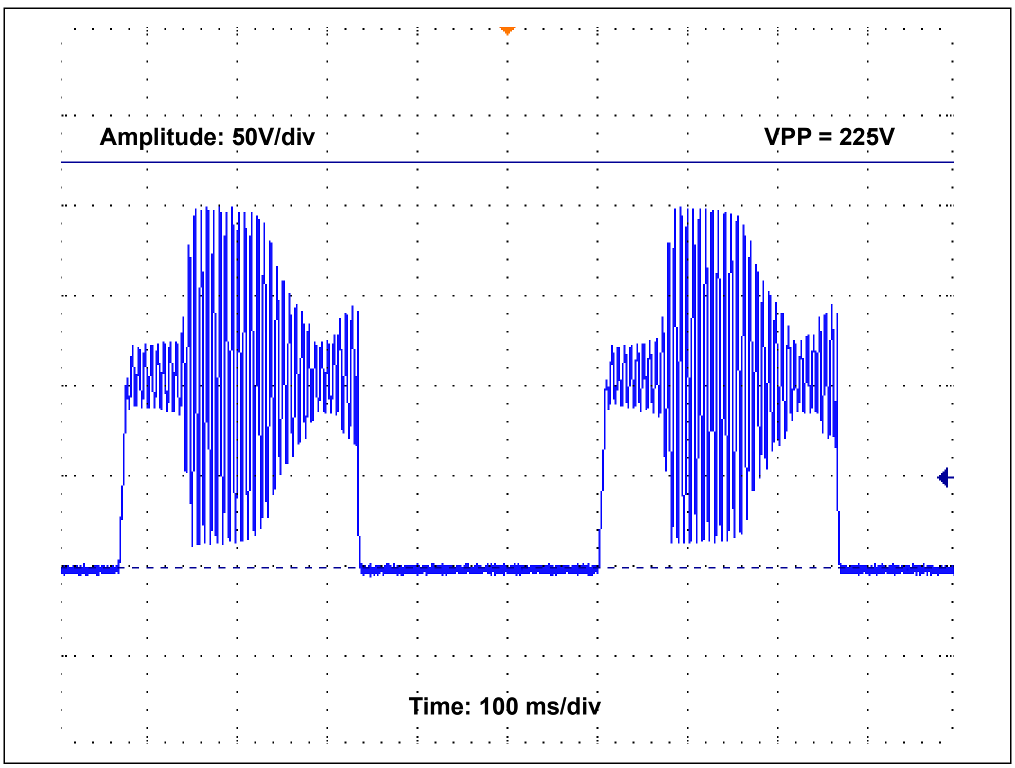


FIGURE C-10: Waveform 6, HVOUT1.

NOTES:

Worldwide Sales and Service

AMERICAS

Corporate Office
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7200
Fax: 480-792-7277
Technical Support:
http://www.microchip.com/support
Web Address:
www.microchip.com

Atlanta
Duluth, GA
Tel: 678-957-9614
Fax: 678-957-1455

Austin, TX
Tel: 512-257-3370

Boston
Westborough, MA
Tel: 774-760-0087
Fax: 774-760-0088

Chicago
Itasca, IL
Tel: 630-285-0071
Fax: 630-285-0075

Dallas
Addison, TX
Tel: 972-818-7423
Fax: 972-818-2924

Detroit
Novi, MI
Tel: 248-848-4000

Houston, TX
Tel: 281-894-5983

Indianapolis
Noblesville, IN
Tel: 317-773-8323
Fax: 317-773-5453
Tel: 317-536-2380

Los Angeles
Mission Viejo, CA
Tel: 949-462-9523
Fax: 949-462-9608
Tel: 951-273-7800

Raleigh, NC
Tel: 919-844-7510

New York, NY
Tel: 631-435-6000

San Jose, CA
Tel: 408-735-9110
Tel: 408-436-4270

Canada - Toronto
Tel: 905-695-1980
Fax: 905-695-2078

ASIA/PACIFIC

Australia - Sydney
Tel: 61-2-9868-6733

China - Beijing
Tel: 86-10-8569-7000

China - Chengdu
Tel: 86-28-8665-5511

China - Chongqing
Tel: 86-23-8980-9588

China - Dongguan
Tel: 86-769-8702-9880

China - Guangzhou
Tel: 86-20-8755-8029

China - Hangzhou
Tel: 86-571-8792-8115

China - Hong Kong SAR
Tel: 852-2943-5100

China - Nanjing
Tel: 86-25-8473-2460

China - Qingdao
Tel: 86-532-8502-7355

China - Shanghai
Tel: 86-21-3326-8000

China - Shenyang
Tel: 86-24-2334-2829

China - Shenzhen
Tel: 86-755-8864-2200

China - Suzhou
Tel: 86-186-6233-1526

China - Wuhan
Tel: 86-27-5980-5300

China - Xian
Tel: 86-29-8833-7252

China - Xiamen
Tel: 86-592-2388138

China - Zhuhai
Tel: 86-756-3210040

ASIA/PACIFIC

India - Bangalore
Tel: 91-80-3090-4444

India - New Delhi
Tel: 91-11-4160-8631

India - Pune
Tel: 91-20-4121-0141

Japan - Osaka
Tel: 81-6-6152-7160

Japan - Tokyo
Tel: 81-3-6880- 3770

Korea - Daegu
Tel: 82-53-744-4301

Korea - Seoul
Tel: 82-2-554-7200

Malaysia - Kuala Lumpur
Tel: 60-3-7651-7906

Malaysia - Penang
Tel: 60-4-227-8870

Philippines - Manila
Tel: 63-2-634-9065

Singapore
Tel: 65-6334-8870

Taiwan - Hsin Chu
Tel: 886-3-577-8366

Taiwan - Kaohsiung
Tel: 886-7-213-7830

Taiwan - Taipei
Tel: 886-2-2508-8600

Thailand - Bangkok
Tel: 66-2-694-1351

Vietnam - Ho Chi Minh
Tel: 84-28-5448-2100

EUROPE

Austria - Wels
Tel: 43-7242-2244-39
Fax: 43-7242-2244-393

Denmark - Copenhagen
Tel: 45-4485-5910
Fax: 45-4485-2829

Finland - Espoo
Tel: 358-9-4520-820

France - Paris
Tel: 33-1-69-53-63-20
Fax: 33-1-69-30-90-79

Germany - Garching
Tel: 49-8931-9700

Germany - Haan
Tel: 49-2129-3766400

Germany - Heilbronn
Tel: 49-7131-72400

Germany - Karlsruhe
Tel: 49-721-625370

Germany - Munich
Tel: 49-89-627-144-0
Fax: 49-89-627-144-44

Germany - Rosenheim
Tel: 49-8031-354-560

Israel - Ra'anana
Tel: 972-9-744-7705

Italy - Milan
Tel: 39-0331-742611
Fax: 39-0331-466781

Italy - Padova
Tel: 39-049-7625286

Netherlands - Drunen
Tel: 31-416-690399
Fax: 31-416-690340

Norway - Trondheim
Tel: 47-7288-4388

Poland - Warsaw
Tel: 48-22-3325737

Romania - Bucharest
Tel: 40-21-407-87-50

Spain - Madrid
Tel: 34-91-708-08-90
Fax: 34-91-708-08-91

Sweden - Gothenberg
Tel: 46-31-704-60-40

Sweden - Stockholm
Tel: 46-8-5090-4654

UK - Wokingham
Tel: 44-118-921-5800
Fax: 44-118-921-5820

02/28/20