HV56266
1-CH Hi-V Amp Haptics Evaluation Kit User's Guide

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Preface

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Documents are identified with a "DS" number. This number is located on the bottom of each page, in front of the page number. The numbering convention for the DS number is "DSXXXXXA", where "XXXXX" 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 www.microchip.com on line help. Select the Help menu, and then Topics to open a list of available on line help files.

INTRODUCTION

This chapter contains general information that will be useful to know before using the HV56266 1-CH Hi-V Amp Haptics Evaluation Kit. 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 HV56266 1-CH Hi-V Amp Haptics Evaluation Kit as a development tool to evaluate the HV56266 Single +300V High Voltage Operational Amplifier. The user's guide layout is as follows:

- **Chapter 1. "Product Overview"** – Important information about the HV56266 1-CH Hi-V Amp Haptics Evaluation Kit.
- **Chapter 2. "Installation and Operation"** – This chapter includes a detailed description of each function of the HV56266 1-CH Hi-V Amp Haptics Evaluation Kit and instructions for how to begin using the HV56266 1-CH Hi-V Amp Haptics Evaluation Kit.
- **Appendix A. "Schematic & PCB Layout"** – Shows the schematic and PCB layout diagrams for the HV56266 1-CH Hi-V Amp Haptics Evaluation Kit.
- **Appendix B. "Bill of Materials"** – Lists the parts used to build the HV56266 1-CH Hi-V Amp Haptics Evaluation Kit.
- **Appendix C. "Waveforms"** – Describes various waveforms for the HV56266 1-CH Hi-V Amp Haptics Evaluation Kit.

CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

DOCUMENTATION CONVENTIONS

Description	Represents	Examples
Arial font:		
Italic characters	Referenced books	*MPLAB® IDE User's Guide*
	Emphasized text	...is the *only* 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	*File>Save*
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	*`file`*`.o`, where *`file`* can be any valid filename
Square brackets [ ]	Optional arguments	`mcc18 [options]` *`file`* `[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 HV56266 1-CH Hi-V Amp Haptics Evaluation Kit. Another useful document is listed below. The following Microchip document is available and recommended as a supplemental reference resource.

- **HV56266 Data Sheet –** ***"Single +300V High Voltage Operational Amplifier" (DS20006751).***

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, Microchip consultant program member listing
- **Business of Microchip** – Product selector and ordering guides, latest Microchip press releases, listing of seminars and events, listings of Microchip sales offices, distributors and factory representatives

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- 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 in the back of this document.

Technical support is available through the website at: http://support.microchip.com.

DOCUMENT REVISION HISTORY

Revision A (December 2022)

- Initial release of this document.

NOTES:

Chapter 1. Product Overview

1.1 INTRODUCTION

HV56266 1-CH Hi-V Amp Haptics Evaluation Kit (EV86G67A) is a demonstration platform for haptics applications using the HV56266 High Voltage Operational Amplifier. This kit includes both a driver board and a controller board. The controller board is developed using a Microchip ATSAML21J18B-MNT SAM MCU and a Graphical User Interface (GUI) is provided to send command and waveform patterns to the MCU via a USB port.

The HV56266 is a Single +300V High Voltage Operational Amplifier which operates on +300V and +5V supplies. It is capable of converting a low voltage input signal to a high voltage output up to 295V. The closed-loop gain of the amplifier is set by two external resistors in a noninverting amplifier configuration. It is designed to drive a maximum of 15 pF capacitive load.

The HV56266 1-CH Hi-V Amp Haptics Evaluation Kit consists of a driver board and a controller board. The driver board is populated with an HV56266 High Voltage Operational Amplifier, a class B buffer, 12V to 130V boost converter and a 5V linear regulator. A class B buffer is added to raise the output current capability to drive a heavy 3.4 µF haptics actuator load. A typical haptics applications requires the system to drive a load in the range of 100V.

A Microchip ATSAML21J18B-MNT SAM MCU and a 4 Mbit flash memory are populated on the controller board, which provides the logic control and generates the intended low voltage analog voltage waveform to the driver board. The two boards are connected together via a 10-pin 2.54 mm pitch header connector.

A GUI software runs in a Windows®-based PC and communicates with the controller board via a USB cable. The firmware can be loaded to the MCU via MPLAB® PICkit™ 4 (8-pin 2.54 mm pitch header connector) or ICE kit (10-pin 1.27 mm pitch connector).

Note: **RISK WARNING of ELECTRICAL SHOCK**. This board uses **MULTIPLE HAZARDOUS HIGH VOLTAGES**. Disconnect all high voltage supplies before working on it. **Electrical Safety Precondition** must be taken when the user is working or running this board.

This chapter provides an overview of the HV56266 1-CH Hi-V Amp Haptics Evaluation Kit, and covers the following topics:

- Features
- Devices Summary
- Technical Specifications
- Functional Description
- What the HV56266 1-CH Hi-V Amp Haptics Evaluation Kit Includes

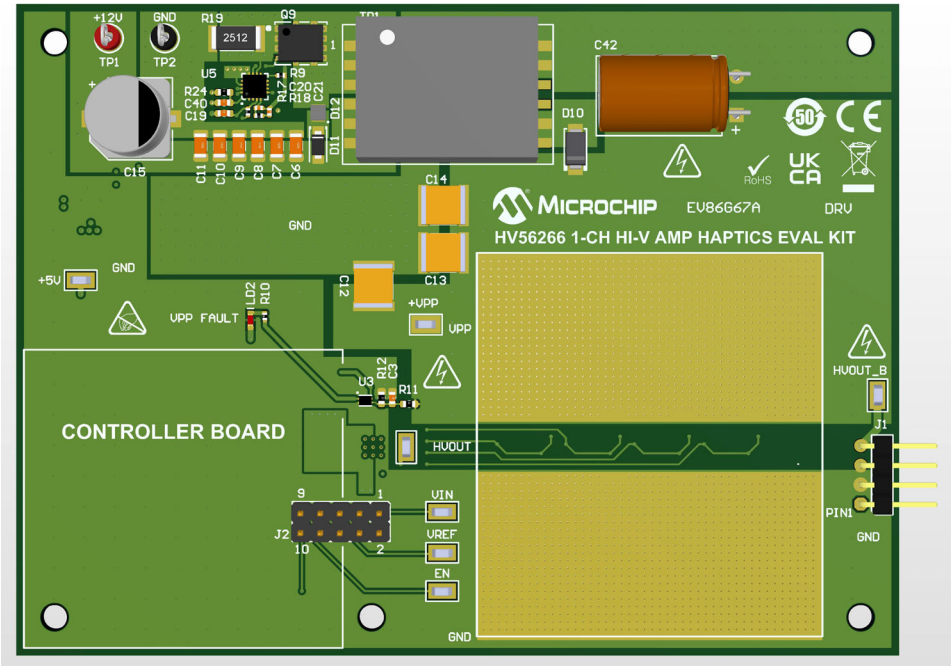


FIGURE 1-1: *EV86G67A Evaluation Board Diagram (Driver Board).*

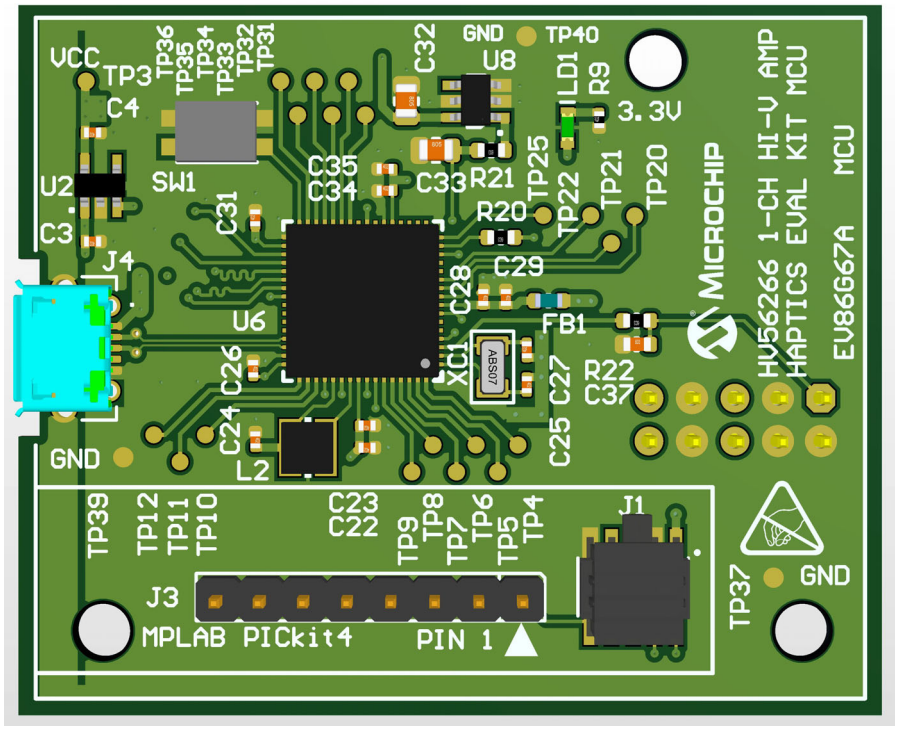


FIGURE 1-2: *EV86G67A Evaluation Board Diagram (Controller Board).*

1.2 FEATURES

- HV56266 Single +300V High Voltage Operational Amplifier
- +12V to +130V High Voltage Boost Converter
- +12V to +5V Linear Regulator
- Up to 3.4 µF Capacitive Load
- ATSAML21J18B-MNT Microcontroller
- 4 Mbit Flash Memory
- 8-pin 2.54 mm Pitch Header Pin for MPLAB PICkit4 Programmer
- 10-pin 1.27 mm Pitch Connector for ICE Programmer (available footprint)
- Single +12V Power Supply

1.3 DEVICES SUMMARY

The HV56266 1-CH Hi-V Amp Haptics Evaluation Kit demonstrates the following Microchip products on board:

- HV56266T-E/RXB, Single +300V High Voltage Operational Amplifier
- TN2130MF-G, N-CH High Voltage MOSFET
- TP5335MF-G, P-CH High Voltage MOSFET
- ATSAML21J18B-MNT, Microcontroller
- SST25PF040CT-401/NP, Memory Serial FLASH 4 Mbit 40 MHz
- MCP1501T-33E/CHY, 3.3V Voltage Reference
- MCP1812AT-033, 3.3V Linear Regulator
- MCP1633-E/MG, PWM Controller 2.2 MHz
- MIC842NYMT-T5, Analog Comparator 1-CH
- MCP1799T-5002H/TT, Analog LDO Regulator
- MIC5504-3.3YM5-TR, Single 300 mA LDO

1.4 TECHNICAL SPECIFICATIONS

Parameter		Value
Supply Voltage Rails	+12V input supply	12V ± 5%
Connector to the microcontroller controller board		8-pin 2.54 mm pitch header connector
High Voltage Output		4-pin 2.54 mm pitch horizontal header connector
Controller Board LED Indicator	+3.3V supply	Green LEDs
Driver Board LED Indicator	+5.0V supply	Red LED
PCB Board Dimension	Driver board	115 x 85 mm (4.5 x 3.4 Inch)
	Controller board	51 x 42 mm (2.0 x 1.7 Inch)

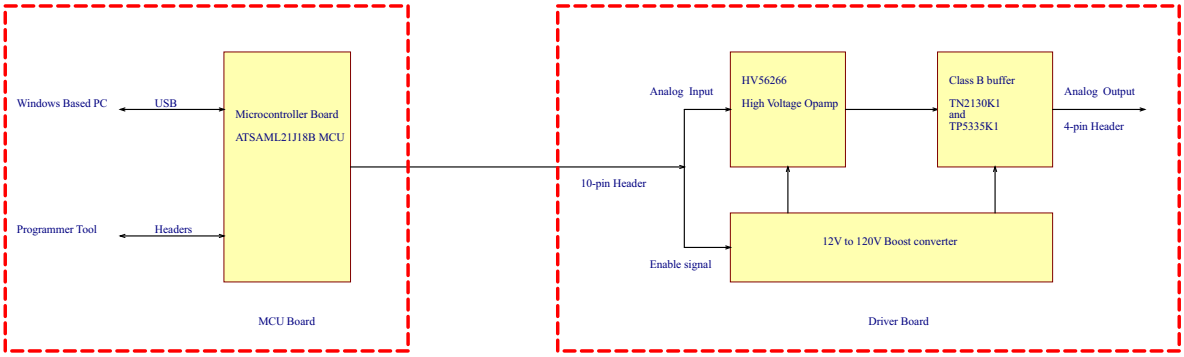


FIGURE 1-3: *HV56266 1-CH Hi-V Amp Haptics Evaluation Kit Simplified Block Diagram.*

1.5 FUNCTIONAL DESCRIPTION

HV56266 1-CH Hi-V Amp Haptics Evaluation Kit (EV86G67A) is capable of driving a single high capacitance surface haptics actuator. This haptics evaluation kit consists of a controller board and a driver board. The HV56266 High Voltage Operational Amplifier is installed and operates in the driver board to actuate an external load.

1.5.1 Controller Board

The main purpose of the controller board is to generate a proper analog small signal for the high voltage amplifier. The GUI provides several waveform options: sinusoidal or user-defined waveforms. The user-defined waveforms are stored in a CSV format file and the stored numbers are the DAC codeword values in decimal format.

The microcontroller accepts the data from the GUI and produces the output using its internal 12-bit digital-to-analog converter (DAC). In addition, the microcontroller may use its second DAC output to create an external reference voltage to adjust the supply voltage of the high voltage power supply. The microcontroller GPIO output also provides a proper control signal to enable the high voltage power supply.

If the user prefers a different controller, an external controller board can connect to the driver evaluation board via its 10-pin 2.54 mm pitch header connector. The pin assignment is shown in the schematics.

1.5.2 High Voltage Driver Board

The high voltage driver board consists of an HV56266 single-channel high-voltage operational amplifier, four class-B buffers connected in parallel, one linear regulator and one high voltage DC/DC boost converter. Both the linear regulator and the boost converter are used to power the HV56266 device and the buffer. The boost converter converts the 12V supply voltage to 130V. The boost converter 130V output voltage can be adjusted using an external reference voltage from the controller board. The linear regulator creates a 5V voltage supply from the 12V source to power the HV56266 device.

The class-B buffer is capable of driving a load of a few µF in hundreds of Hz. The exposed copper on the PCB is acting as a heat sink to dissipate the heat from the power MOSFETs. Some exposed copper pads are connected to the high voltage potential; therefore, the user must avoid contacting the exposed copper from electrical shock.

1.5.3 DC/DC Boost Converter

A Microchip MCP1633 PWM controller is used for the high voltage boost converter in a flyback configuration. It accepts either an external or an internal reference voltage for its operation. This boost converter generates a maximum of 130V supply to power the high voltage operational amplifier. An enable (EN) function is controlled by the controller board to power on/off this converter.

1.5.4 LED Indicators

A red LED lights up when the high voltage (130V) supply output is below 80V threshold. A Microchip MIC842N is used for this function. When the driver board is at idle, the DC/DC converter is set to disable mode to save power. Therefore, this LED is on during idle. When the high voltage output is in active mode, the DC/DC is enabled and the LED normally turns off during operation. This LED indicator tells the user when the high voltage supply does not output the minimum required voltage at that state.

1.5.5 Software

It is recommended to operate the driver evaluation board in conjunction with the controller board. There is a GUI software and a firmware available at the Microchip website. First, the user is required to program the controller board with the firmware. The GUI software can be run from a Windows PC to control the driver IC via the USB port.

1.6 WHAT THE HV56266 1-CH HI-V AMP HAPTICS EVALUATION KIT INCLUDES

The HV56266 1-CH Hi-V Amp Haptics Evaluation Kit includes:

- EV86G67A Driver Board
- EV86G67A Controller Board
- HV56266 1-CH Hi-V Amp Haptics Evaluation Kit User's Guide (download from Microchip website)

Chapter 2. Installation and Operation

2.1 GETTING STARTED

The HV56266 1-CH Hi-V Amp Haptics Evaluation Kit is fully assembled and tested for haptics application. The driver board only requires a single +12V supply voltage rails and the controller board can be powered by the USB 5V connection.

2.1.1 Additional Tools Required for Operation

1. An oscilloscope with minimum 500 MHz BW and a high-impedance probe with minimum of 300V breakdown voltage.
2. A Windows-based PC is needed to run the GUI software and install the firmware. Both software files can be obtained from the Microchip website. In addition, the Microchip MPLAB software and C-complier can also be used for application specific programs per user's choice.

Note: To update the latest software driver and demonstration program, please go to www.microchip.com website.

2.2 HARDWARE SETUP PROCEDURE

To operate the HV56266 1-CH Hi-V Amp Haptics Evaluation Kit (with the EV86G67A controller board), the following steps must be completed to setup the hardware:

1. Install the controller board onto the driver board via J2 driver board connector.
2. Connect the USB cable between a personal computer (PC) and the controller board.
3. Connect an external +12V power supplies to the +12V and ground terminals.
4. Make sure all required wires and cables are secure. Turns on the +12V power supply after the USB cable is connected.

Note: The recommended power-up sequence, please see the Table 2-2 below.

WARNING

Please observe the polarity of each power supply rails and set the voltage and current limit carefully. Note that the +/-80V is maximum limit for VPP0/VNN0. The VPP1/VNN1 voltages have to be equal or within the VPP0/VNN0 rail's voltages.

2.2.1 HV56266 1-CH Hi-V Amp Haptics Evaluation Kit Power Supply Voltage and Current Configuration

The HV56266 1-CH Hi-V Amp Haptics Evaluation Kit board TP1 and TP2 terminals have to be connected to the power supply sources shown in the table below.

Table 2-1: POWER SUPPLY VOLTAGES & CURRENT-LIMIT SETTINGS

Terminal	Rail Name	Voltage	Peak-Current Limit
TP1 to TP2	+12V	+12V	+5A

Note 1: The GND and HVGND terminals are connected together in the PCB.

2.3 INTERFACE CONNECTIONS

TABLE 2-2: J1 OUTPUT INTERFACE SIGNALS

PIN	Name	I/O Type	Signal Discretion
J1-1	TOUCH	Analog voltage input	N/A
J1-4	HVOUT_B	Analog voltage output	High Voltage Op Amp Buffered Output
J1-2,3	GND	Ground	System ground

TABLE 2-3: J2 CONTROL INTERFACE SIGNALS

PIN	Name	I/O Type	Signal Discretion
J2-1	VIN	Analog voltage input	High voltage op amp input voltage
J2-5	VREF_AMP	Analog voltage input	DC/DC converter reference voltage from MCU
J2-6	VREF	Analog voltage input	N/A
J2-9	EN_AMP	3.3V CMOS logic input	DC/DC converter enable signal
J2-10	TOUCH	Analog voltage input	N/A
J2-2,3,4,7,8	GND	Ground	System ground

2.4 GRAPHICAL USER INTERFACE MANUAL

The Microchip ATSAML21J18B-MNT SAM MCU based controller board generates the control signal and analog signal for the EV86G67A driver board. This GUI is designed for this microcontroller. The user can create their own GUI and firmware with this SAM MCU using the MPLAB PICkit4 or ICE programmers. That is beyond the scope of this user's guide. Please contact Microchip Technology for further assistance.

2.4.1 SETUP PROCEDURE

Please follow and complete the hardware setup described in **Section 2.2 "Hardware Setup Procedure"**. After the hardware setup is completed, the user can run the GUI software.

2.4.2 FIRMWARE INSTALLATION

Please visit the Microchip website and download the firmware for the HV56266 1-CH Hi-V Amp Haptics Evaluation Kit.

In order to load the firmware into this controller, the user needs to download and install the latest version of Microchip MPLAB IPE tool.

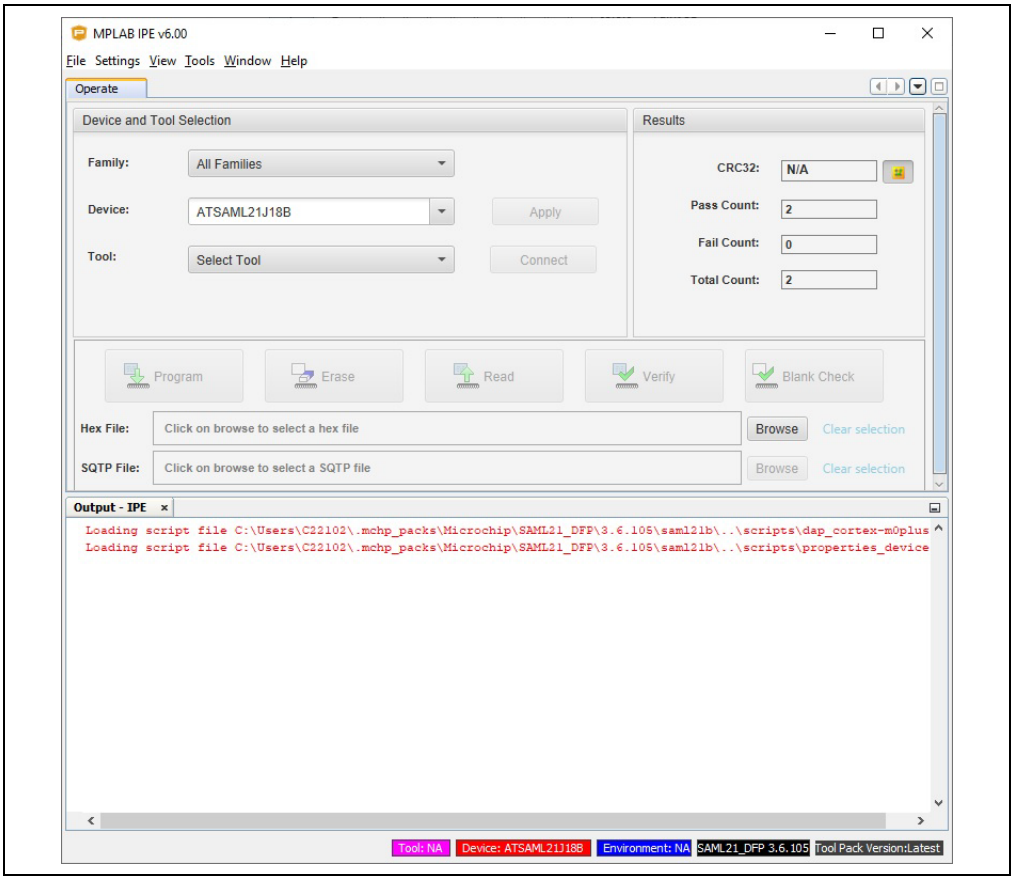


FIGURE 2-1: *MPLAB IPE Window.*

1. Run the MPLAB IPE tool.
2. Connect the programmer tool (either MPLAB PICkit4 or ICE tool) to the controller board. PICkit4 tool uses J3 8-pin header connection and ICE tool uses J1 10-pin connection of the controller board.
3. Select ATSAML21J18B in the device section. Click the Connect button (Connect button may gray out when using ICE tool).
4. Choose the proper programming tool in the Tool section.
5. Click the Browse button in the Hex File section. Select the firmware hex file. Then click the Program button.
6. After it is completed, click the Disconnect button and close IPE program.

The firmware is now ready. The programmer tool is no longer needed. Unplug the programmer tool from the controller board.

2.4.3 GRAPHICAL USER INTERFACE INSTALLATION AND COMMUNICATION LINK SETUP

The user can download the HV56266 Evaluation Kit GUI program from the Microchip website. After the firmware has been installed, users may run the GUI program directly from their PC. Unzip the downloaded file and run setup to install the GUI in PC. Then, run the GUI software.

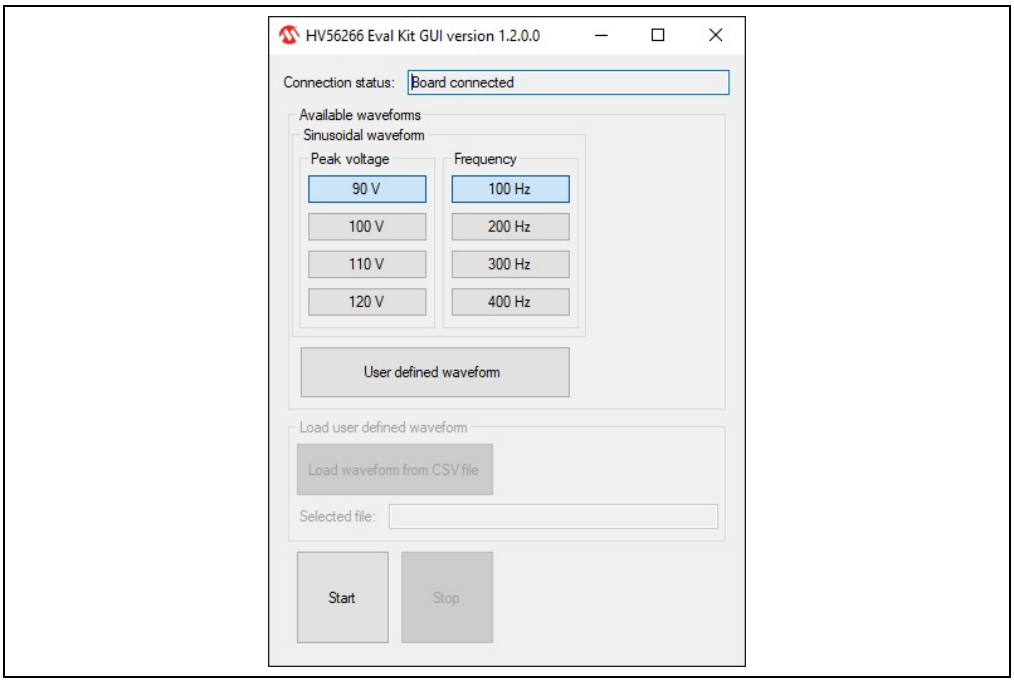


FIGURE 2-2: *GUI Window.*

Prior to running the GUI software, the user should check that the USB connection is in place. This USB port is used to communicate between the GUI software and controller board.

1. Run the HV56266 1-CH Hi-V Amp Haptics Evaluation Kit GUI software from the PC. If the GUI detects the controller board, it will show "Board connected" in the status box.
2. Choose one of the four waveforms for the high voltage output.
3. Press START to enable the output.
4. Examine the output voltage at connector J1 of the driver board.
5. Press STOP to terminate the output.

Note: In step 2, if the user defined waveform is chosen, press the LOAD button and select a CSV file to load the waveform. Then, proceed to step 3.

2.5 TEST PROCEDURES

Please follow **Section 2.1 "Getting Started"** and **Section 2.4 "Graphical User Interface Manual"** to set up both the hardware and the software (firmware and GUI).

2.5.1 Waveform Configuration

2.5.1.1 SINUSOIDAL WAVEFORM

The following settings are available for the user to set the output waveform. The user can select the peak voltage and the frequency. After these are selected, press the START button to start the high voltage output. The system will output 10 sinusoidal cycles and then off for 40 cycles. Then, it will repeat the 10 cycles on and 40 cycles off. The user can press the STOP button to stop the output.

Peak Voltage	Frequency
90V	100 Hz
100V	200 Hz
110V	300 Hz
120V	400 Hz

2.5.1.2 USER DEFINED WAVEFORM

The user can also enter its own waveform pattern using the User defined waveform. The GUI can load a set of numbers from a CSV format file. The CSV file contains a column of data which is the codeword for the 12-bit DAC. The 12-bit DAC accept the number from 0 to 4095. The GUI normally accepts data up to twenty thousand points. Normally, 8000 points are a typical data set size. The GUI reads the data one by one and counts the number of data in the CSV file. The number of data determines the sampling frequency. For example, if there are 8000 data points, it will set the DAC to have 8000 samples per second.

In order to use the user defined waveform, press the Load waveform from CSV file button. Select the CSV file and press open. Then, press Start button to start the high voltage.

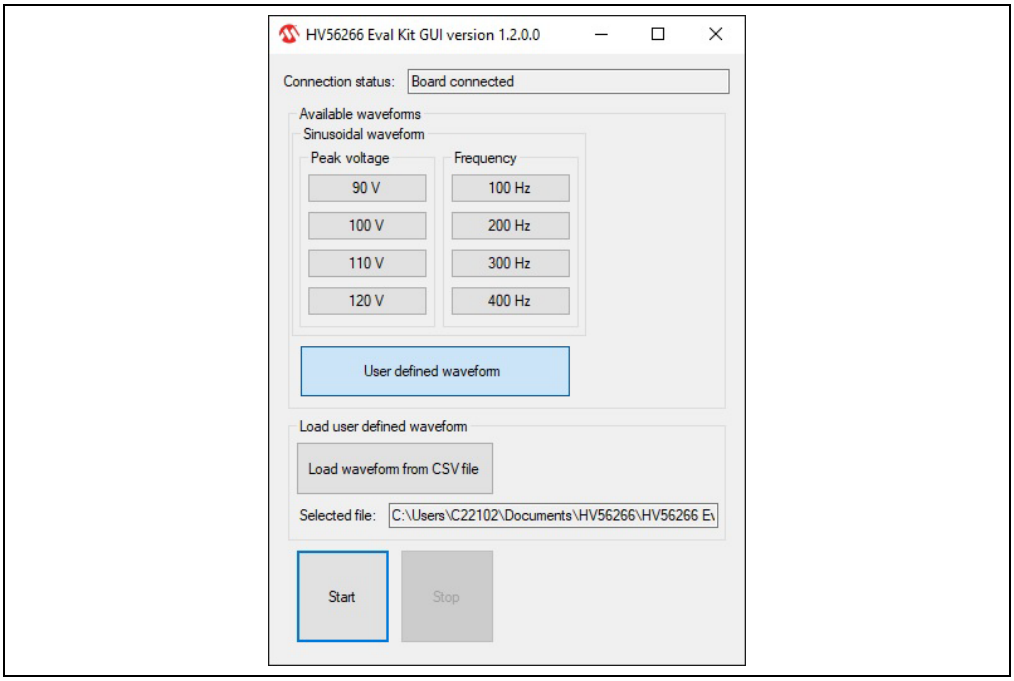


FIGURE 2-3: *User Defined Waveform Entry.*

2.5.1.3 BUILT-IN WAVEFORMS WITHOUT GUI/PC

The firmware in the controller board has a few simple built-in waveforms and the user can access it without using the GUI/PC. There is a push button on the controller board that can be used to cycle through all three built-in waveforms. After the controller board has been turned on, the user can press the push button once to activate the first built-in waveform pattern. It will cycle through all three waveforms by pressing the button once. The output will go back to idle after it finishes cycling through all built-in waveforms.

Built-in waveforms:

1. Sine 170 Hz, 80V, 10 cycles on and 40 cycles off
2. Sine 200 Hz, 100V, 10 cycles on and 40 cycles off
3. Sine 250 Hz, 120V, 10 cycles on and 40 cycles off.

2.6 SUGGESTED TESTS TO BE EXAMINED BY USERS

The HV56266 1-CH Hi-V Amp Haptics Evaluation Kit has to follow the power-on procedure before any of the following tests are executed. The easiest way is to load the firmware to the controller board and then use the built-in waveforms to test the driver board described in **Section 2.5.1.3 "Built-in Waveforms without GUI/PC"**.

> **Note:** The typical voltage and waveforms are provided in **Appendix C. "Waveforms"**.

Chapter 3. PCB Design and Layout Notes

3.1 PCB LAYOUT TECHNIQUES FOR HV56266 HIGH VOLTAGE BUFFERED DRIVER

The HV56266 1-CH Hi-V Amp Haptics Evaluation Kit is an integrated solution with high voltage driver and high voltage boost converter. The PCB design and layout are critical to ensure a successful implementation and circuit operation.

3.1.1 Thermal Dissipation

The HV56266 High Voltage Operational Amplifier is a high voltage low current device which is used to drive a small capacitive load. In order to drive a large capacitive load in the range of a couple µF, four pairs of N-channel and P-channel high voltage MOSFET transistors are added as a current buffer for the amplifier. A large amount of heat is generated in these high voltage MOSFET transistors if a continuous AC waveform is used to drive a large capacitive load.

Four 44 mm by 22 mm exposed copper pads help to dissipate the heat from these transistors. Two sit on the top layer and two on bottom. These transistors are in the DFN package which has a large metal pad to bring the heat out of the package easily. The exposed copper should not be covered by solder mask.

In addition, the top and bottom layers of the printed circuit board have 2.5 oz of copper content which acts as a heat sink.

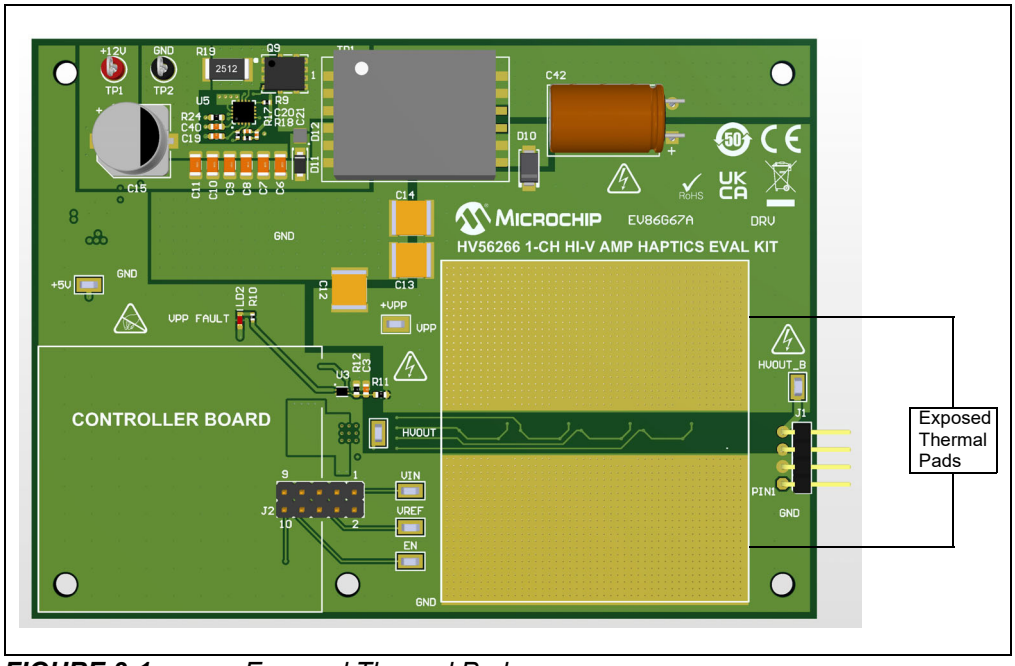


FIGURE 3-1: *Exposed Thermal Pads.*

NOTES:

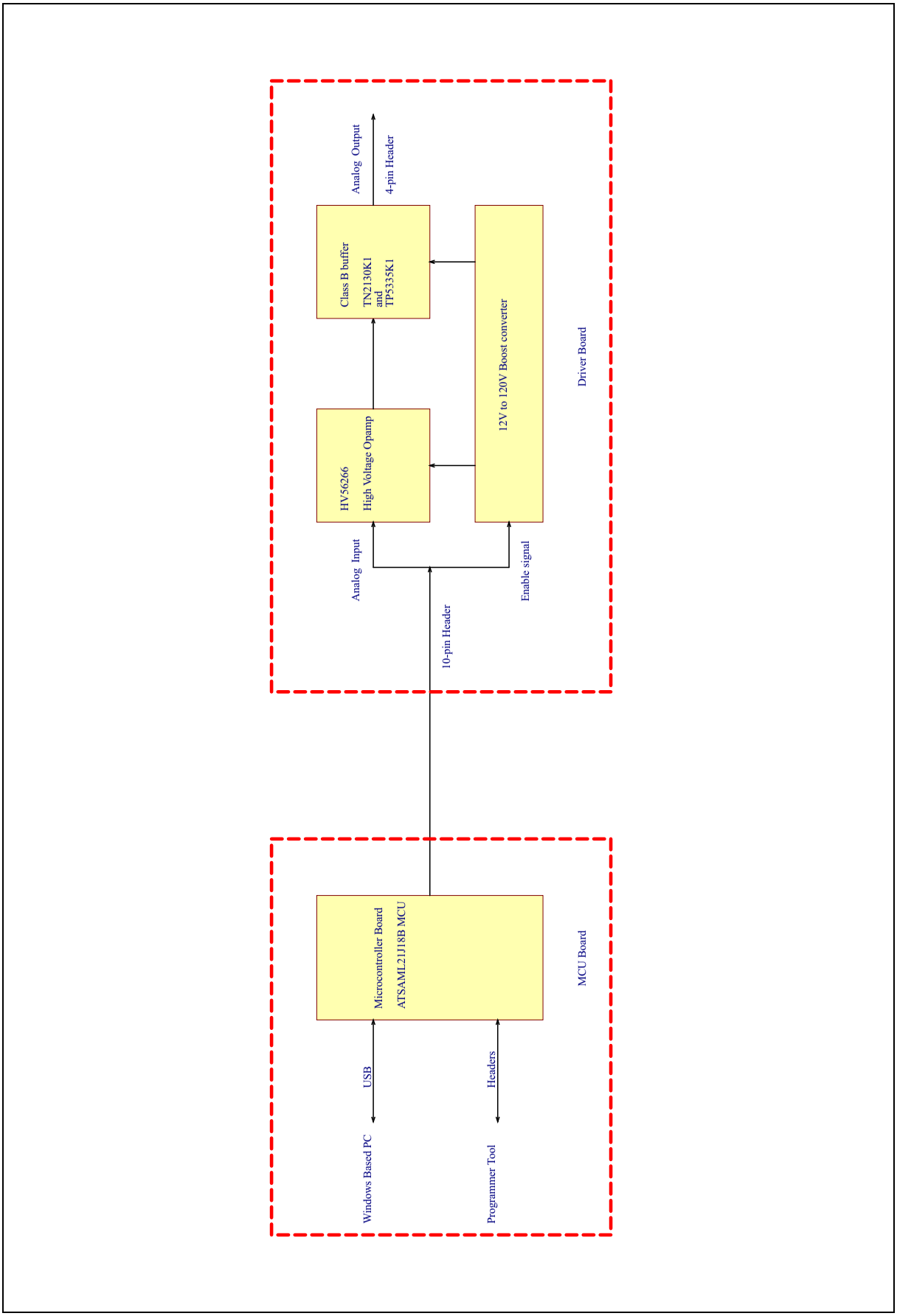
Appendix A. Schematic & PCB Layout

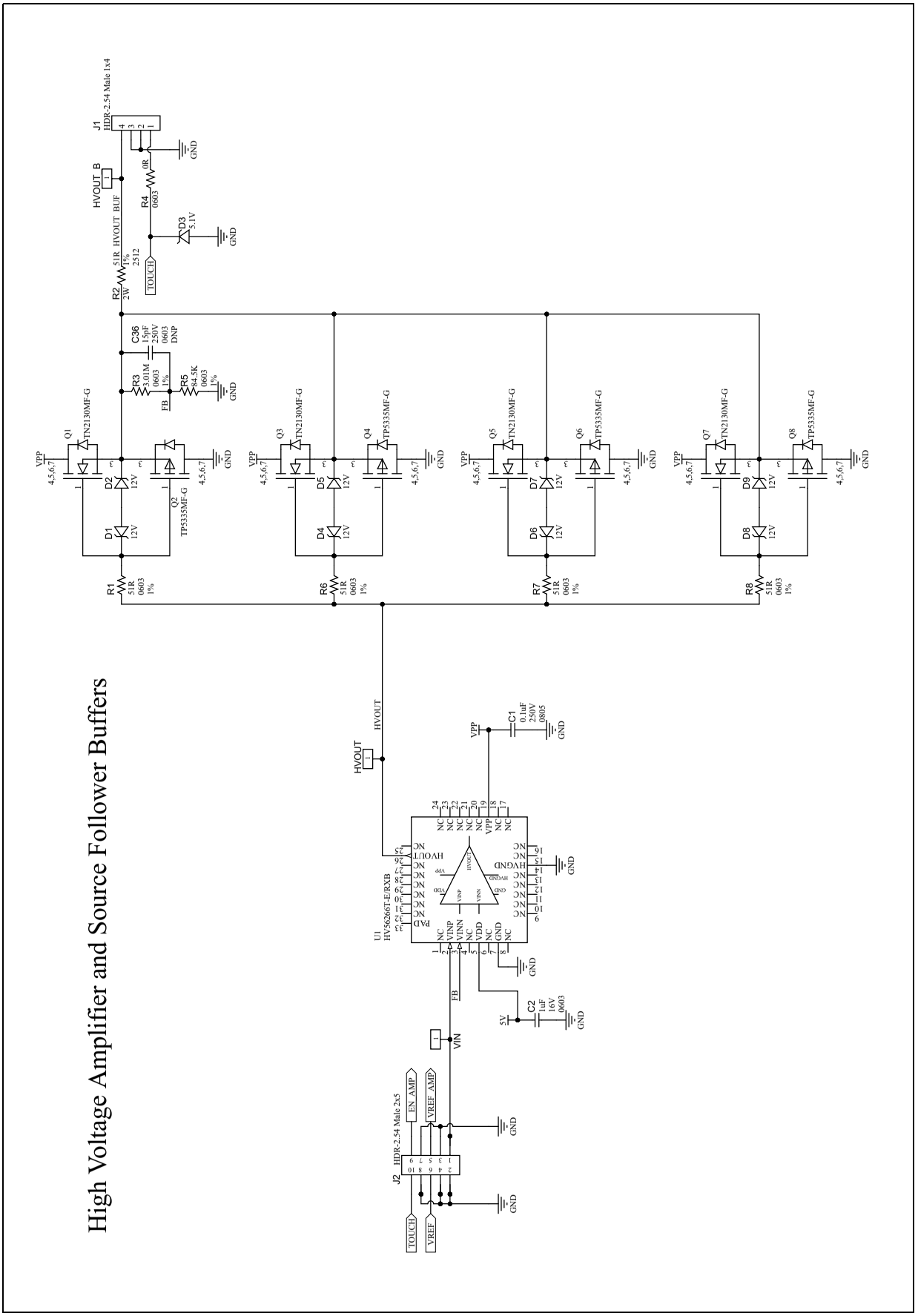
A.1 INTRODUCTION

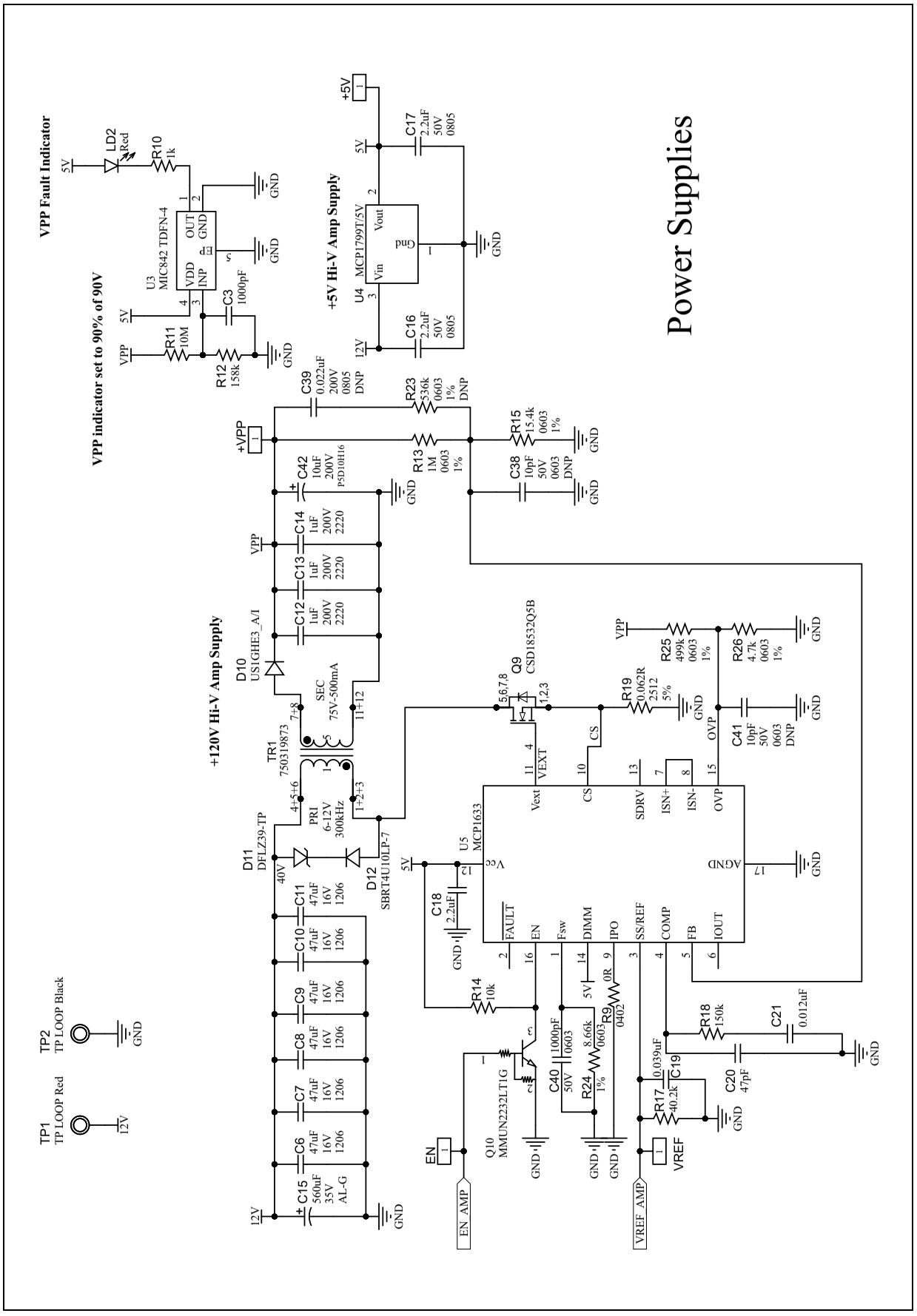
This appendix contains the following schematics and layouts for the HV56266 1-CH Hi-V Amp Haptics Evaluation Kit:

- Driver Board – Schematics
- Driver Board – Top Silk
- Driver Board – Top Copper and Silk
- Driver Board – Inner Copper Layer 1
- Driver Board – Inner Copper Layer 2
- Driver Board – Inner Copper Layer 3
- Driver Board – Bottom Copper
- Driver Board – Bottom Copper and Silk
- Driver Board – Bottom Silk
- Controller Board – Schematics
- Controller Board – Top Silk
- Controller Board – Top Copper and Silk
- Controller Board – Inner Copper Layer 1
- Controller Board – Inner Copper Layer 2
- Controller Board – Inner Copper Layer 3
- Controller Board – Bottom Copper
- Controller Board – Bottom Copper and Silk
- Controller Board – Bottom Silk

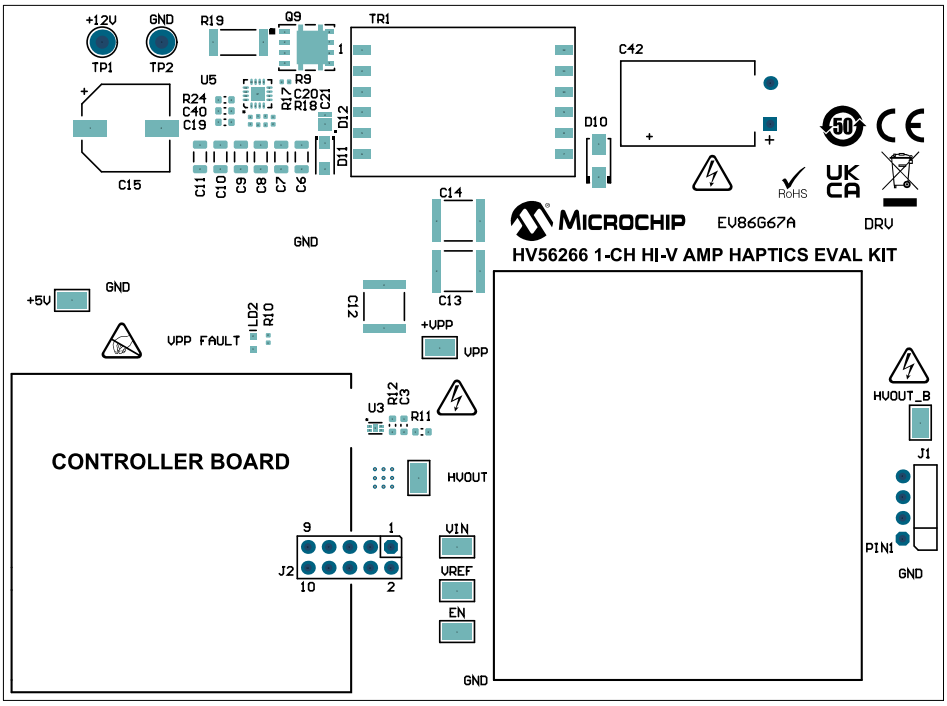
A.2 DRIVER BOARD – SCHEMATICS



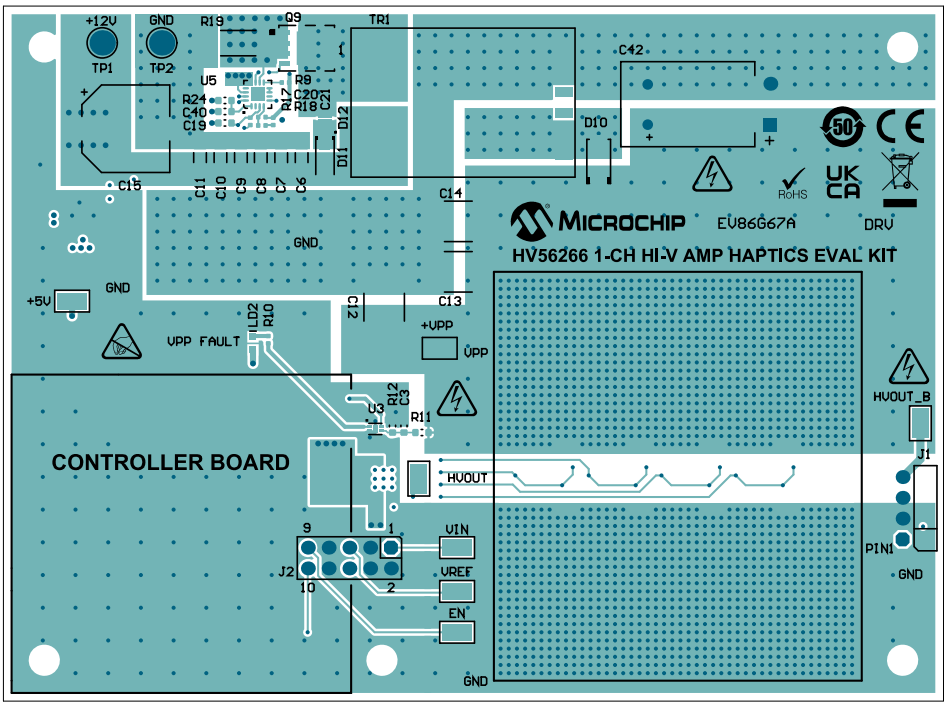

High Voltage Amplifier and Source Follower Buffers
J1
HDR-2.54 Male 1x4
HVOUT_B
HVOUT_BUF
R4
0603
0R
D3
5.1V
GND
R2
2W
51R
1%
2512
TOUCH
C36
15pF
250V
0603
DNP
R3
10.1M
0603
1%
R5
84.5K
0603
1%
FB
VPP
4,5,6,7
Q1
TN2130MF-G
Q2
TP5335MF-G
Q3
TN2130MF-G
Q4
TP5335MF-G
Q5
TN2130MF-G
Q6
TP5335MF-G
Q7
TN2130MF-G
Q8
TP5335MF-G
D1
D2
D4
D5
D6
D7
D8
D9
12V
R1
R6
R7
R8
51R
0603
1%
HVOUT
C1
0.1uF
250V
0805
U1
HV562661-E/RXB
PAD
NC
VINP
VINN
VDD
GND
HVOUT
HVGND
VPP
C2
1uF
16V
0603
5V
VIN
J2
HDR-2.54 Male 2x5
EN_AMP
VREF_AMP
TOUCH
VREF



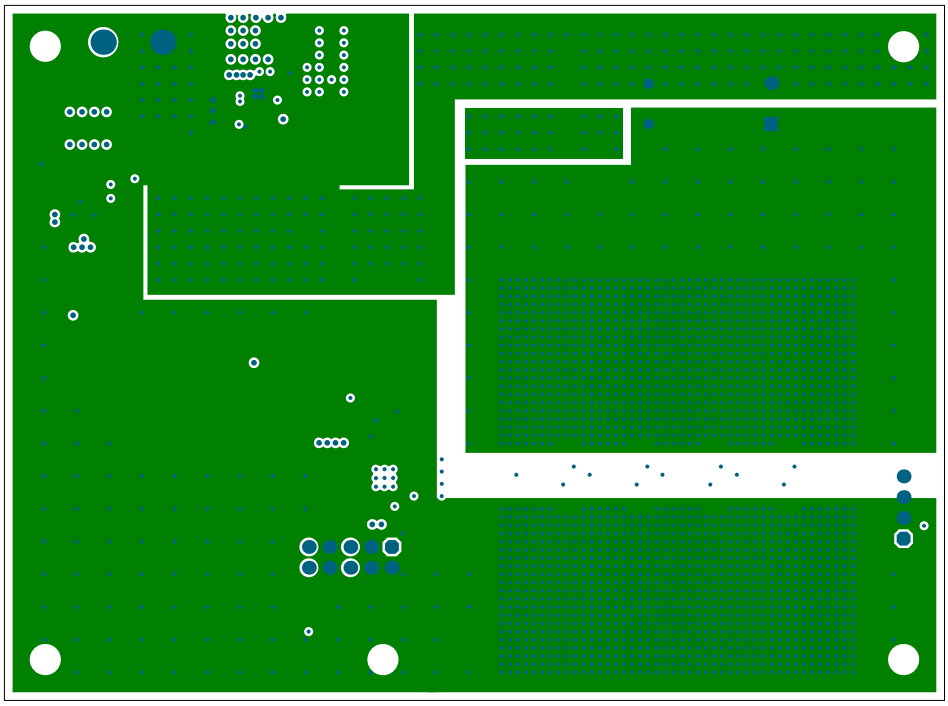
A.3 DRIVER BOARD – TOP SILK



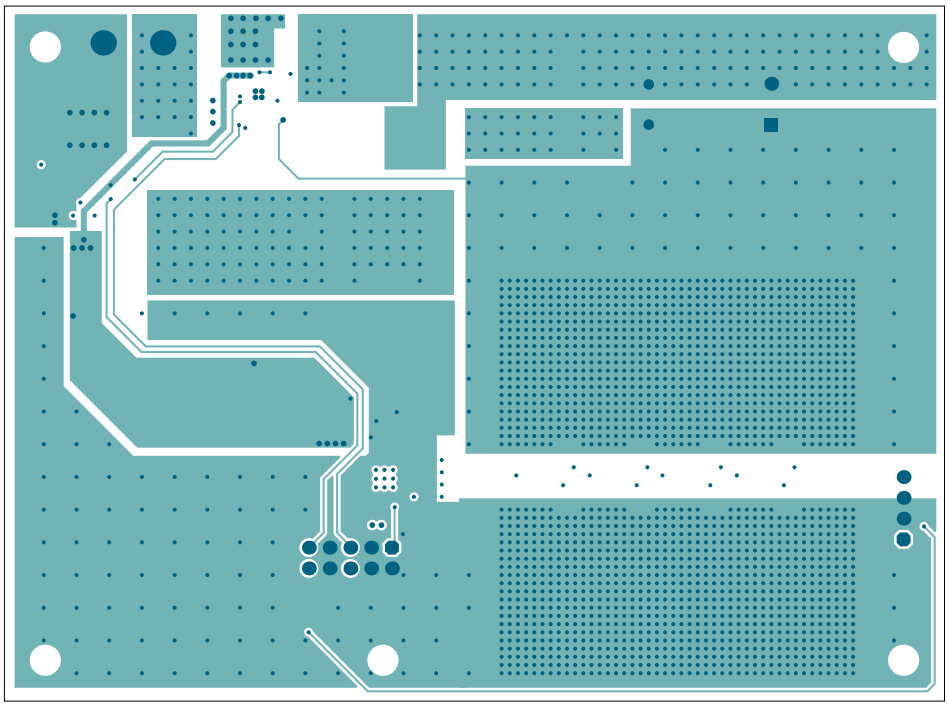
A.4 DRIVER BOARD – TOP COPPER AND SILK



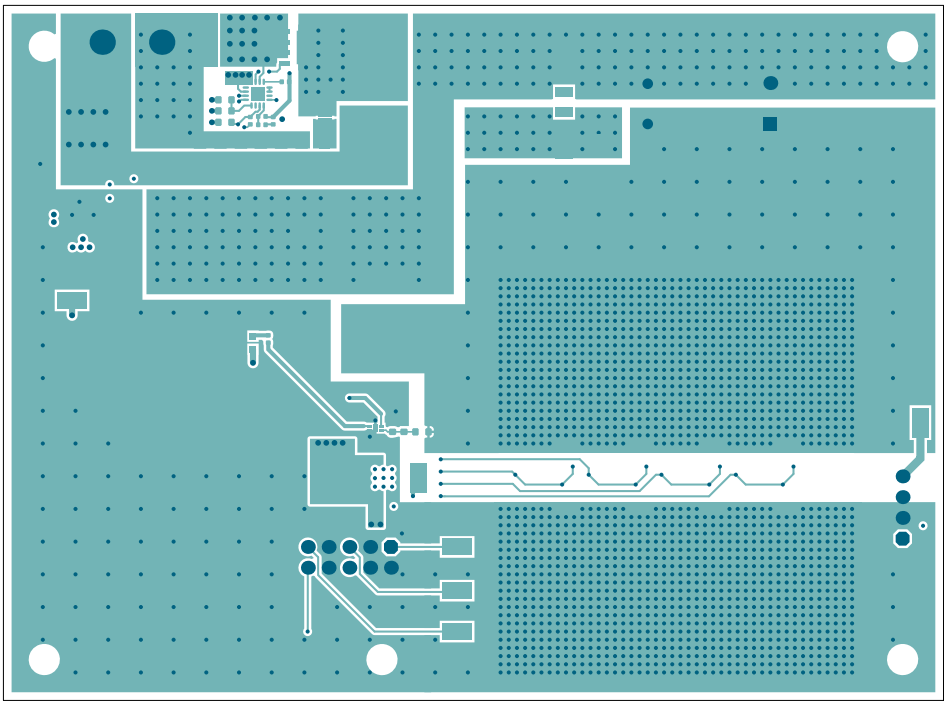
A.5 DRIVER BOARD – INNER COPPER LAYER 1



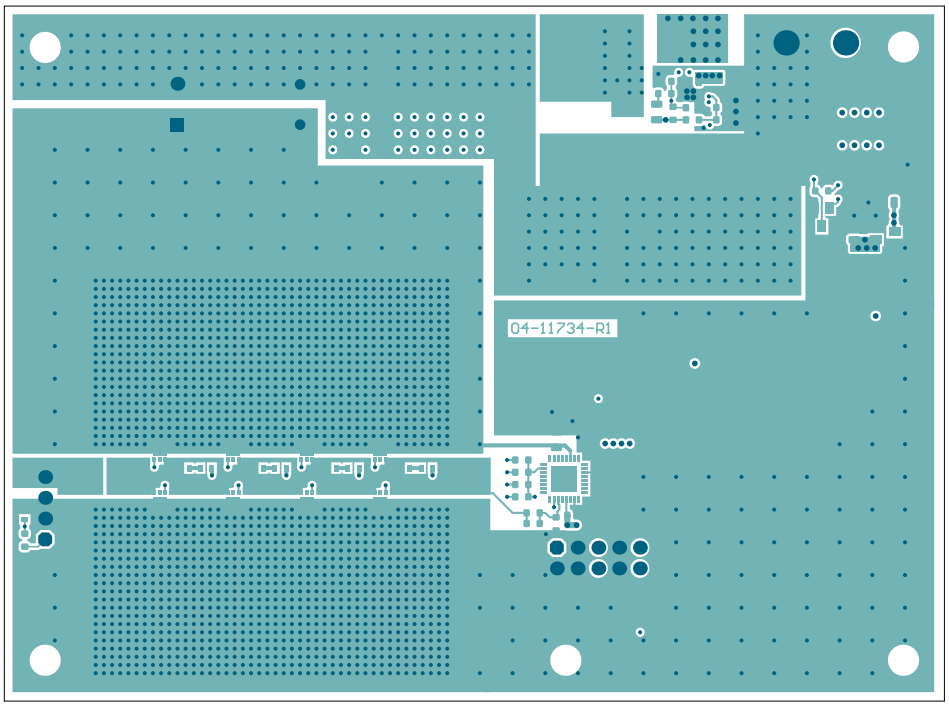
A.6 DRIVER BOARD – INNER COPPER LAYER 2



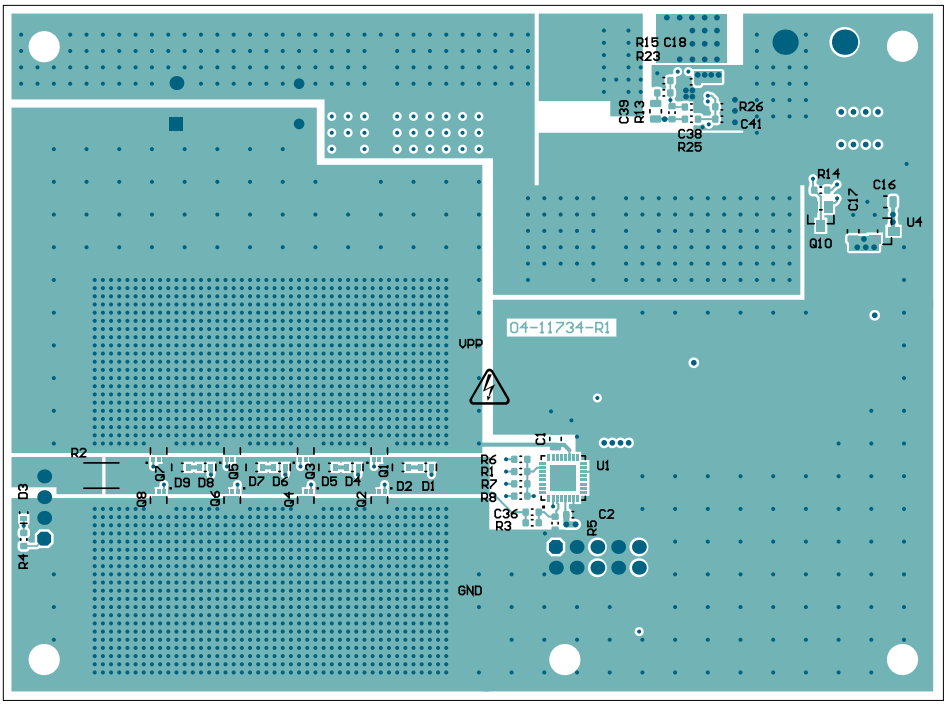
A.7 DRIVER BOARD – INNER COPPER LAYER 3



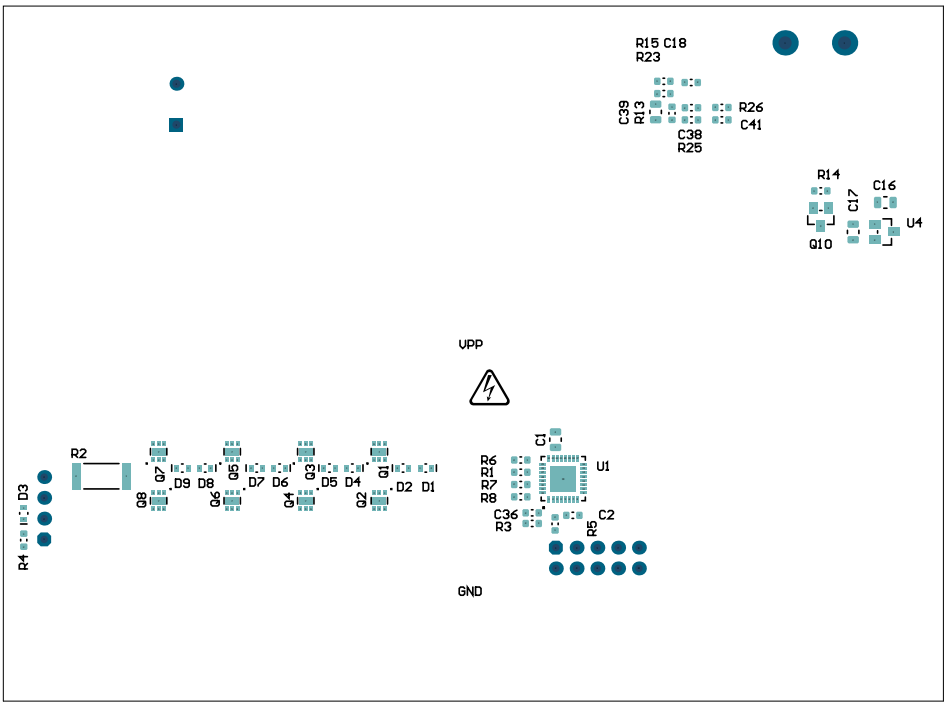
A.8 DRIVER BOARD – BOTTOM COPPER



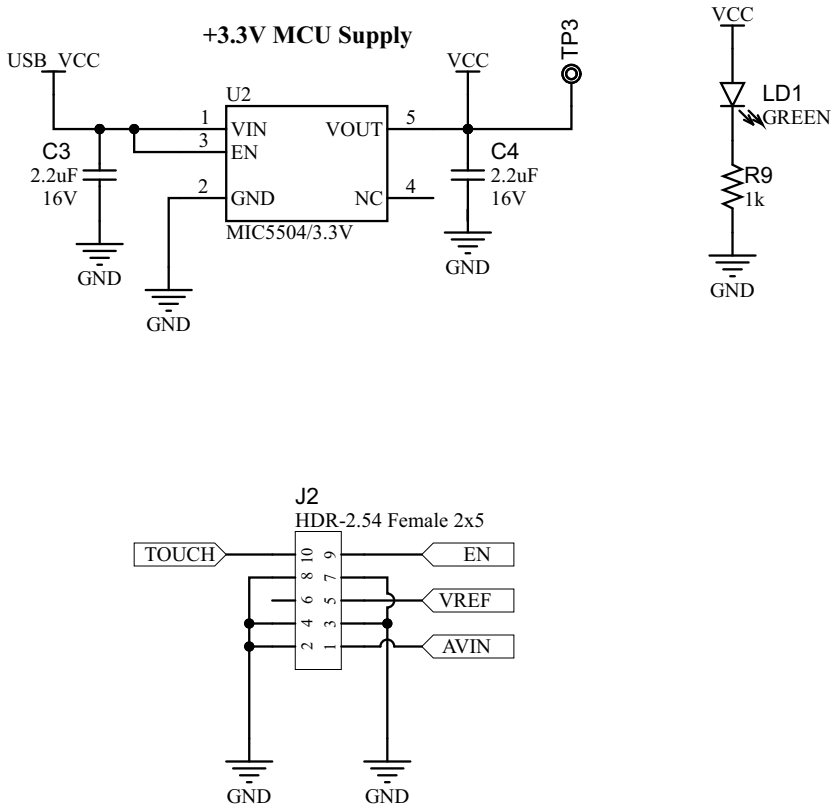
A.9 DRIVER BOARD – BOTTOM COPPER AND SILK



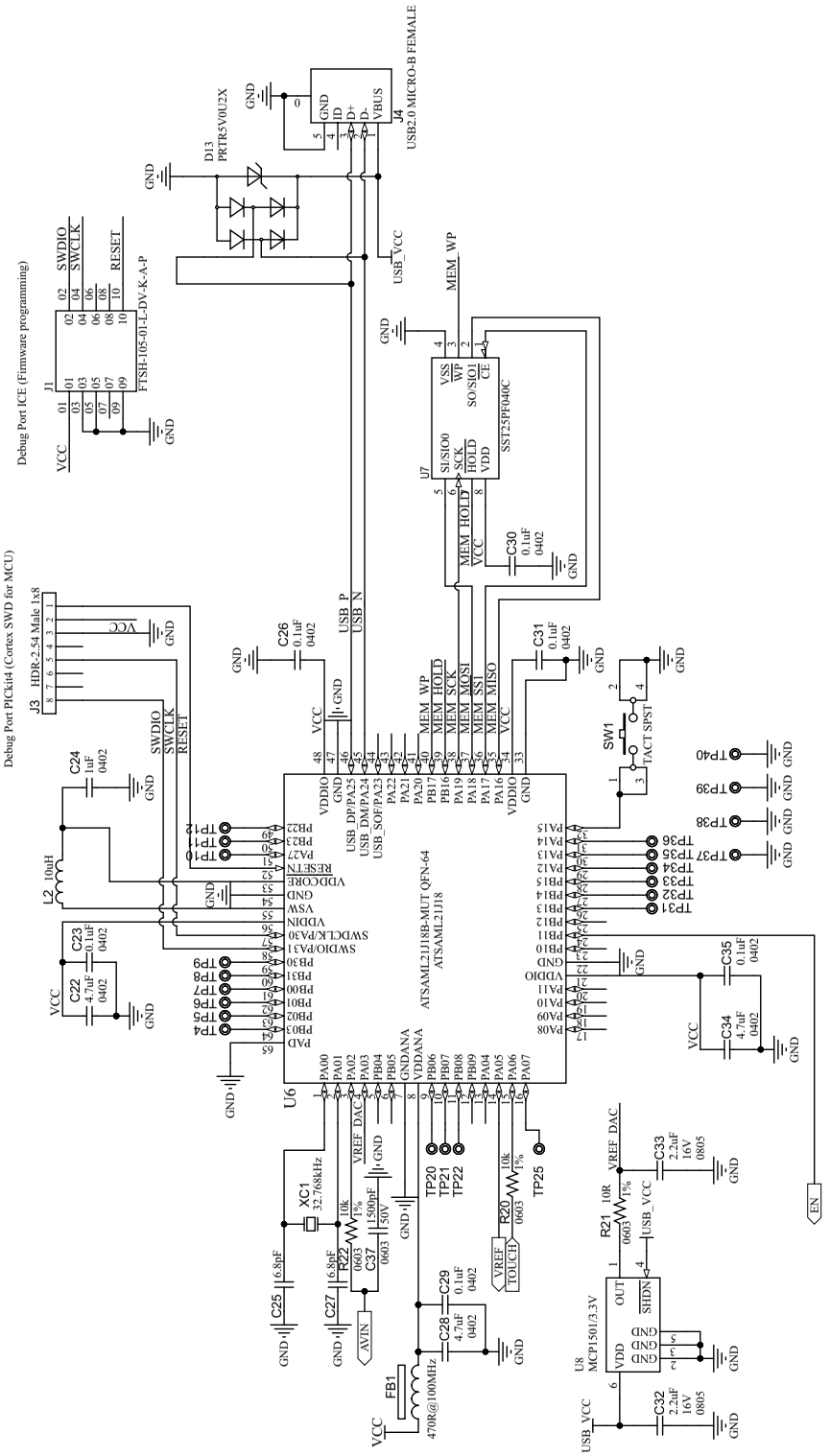
A.10 DRIVER BOARD – BOTTOM SILK



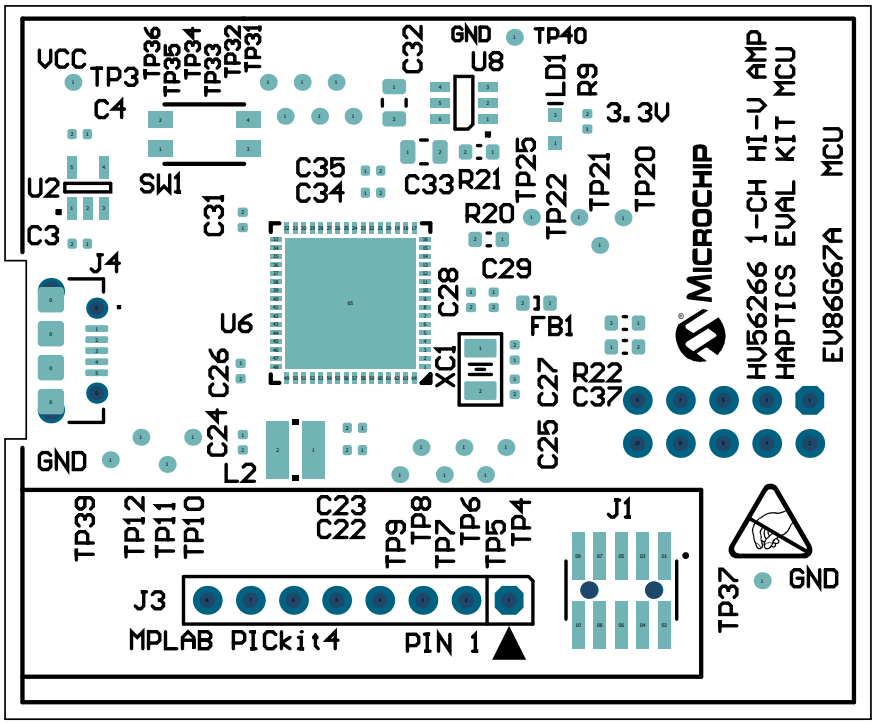
A.11 CONTROLLER BOARD – SCHEMATICS



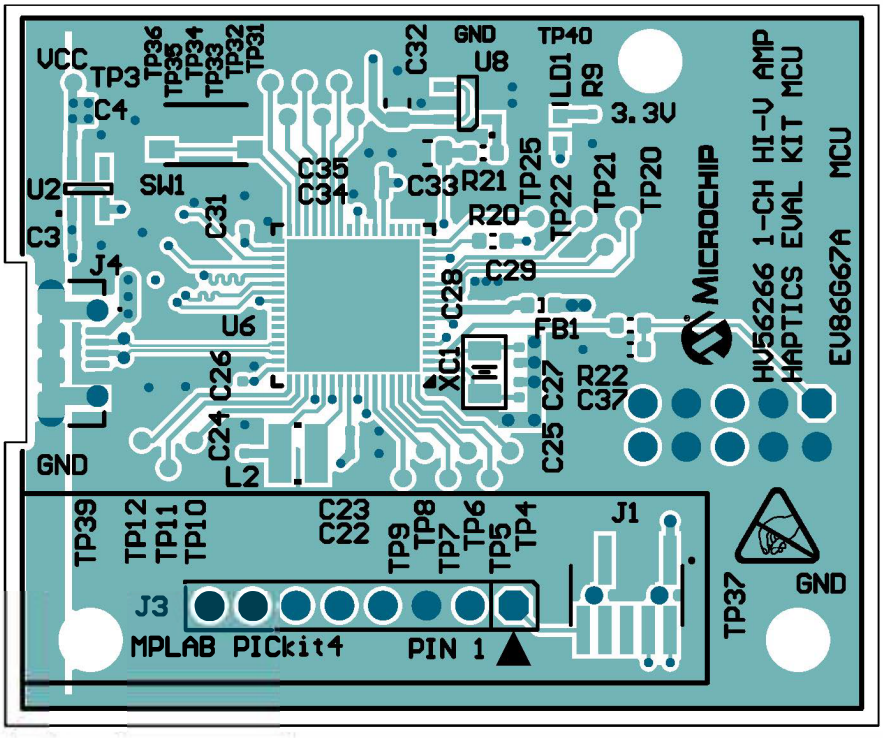
Microcontroller, USB, Memory and Voltage Reference



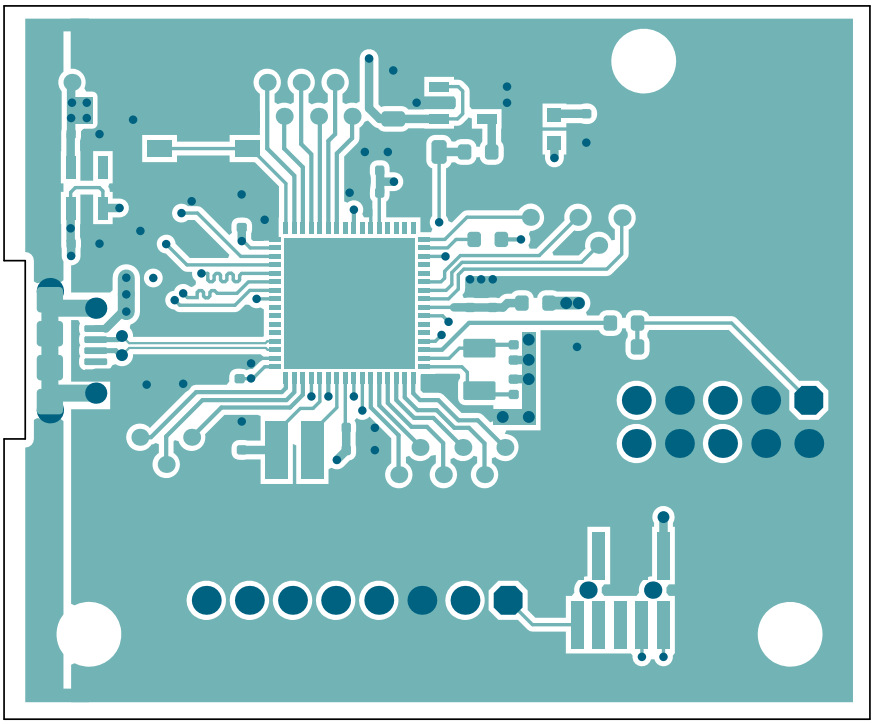
A.12 CONTROLLER BOARD – TOP SILK



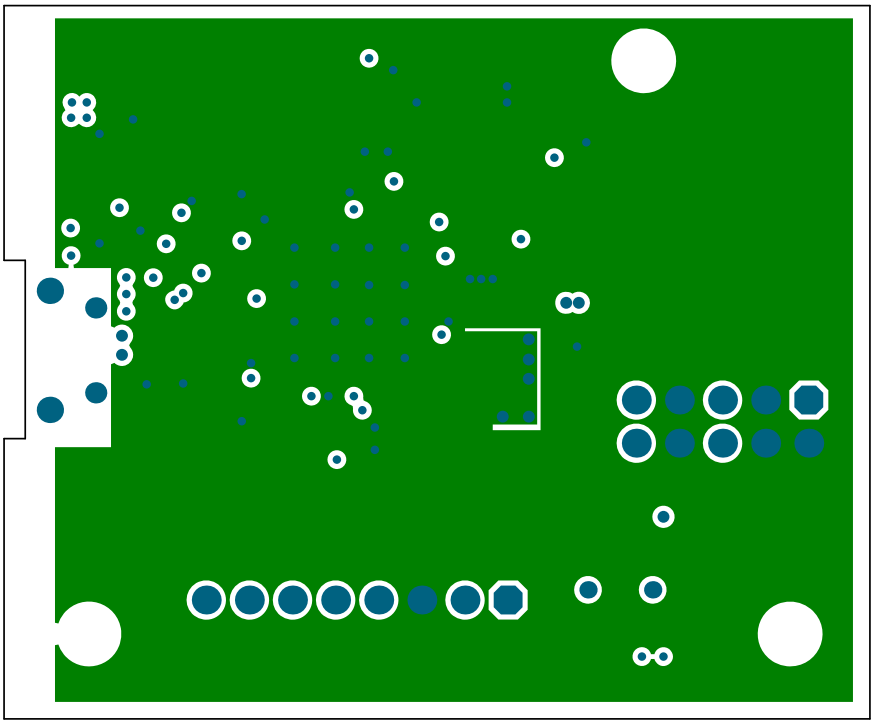
A.13 CONTROLLER BOARD – TOP COPPER AND SILK



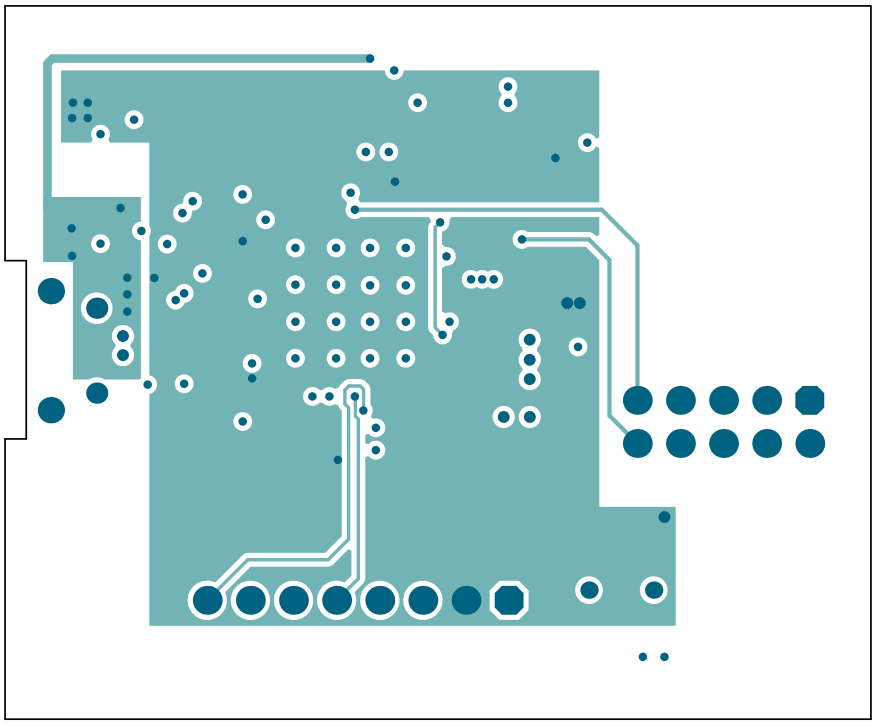
A.14 CONTROLLER BOARD – INNER COPPER LAYER 1



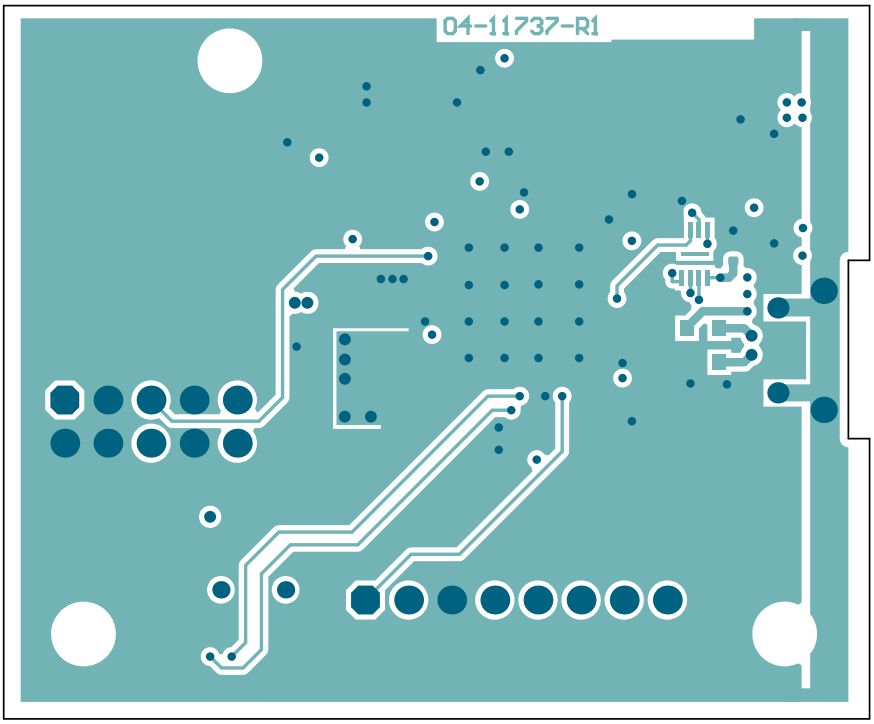
A.15 CONTROLLER BOARD – INNER COPPER LAYER 2



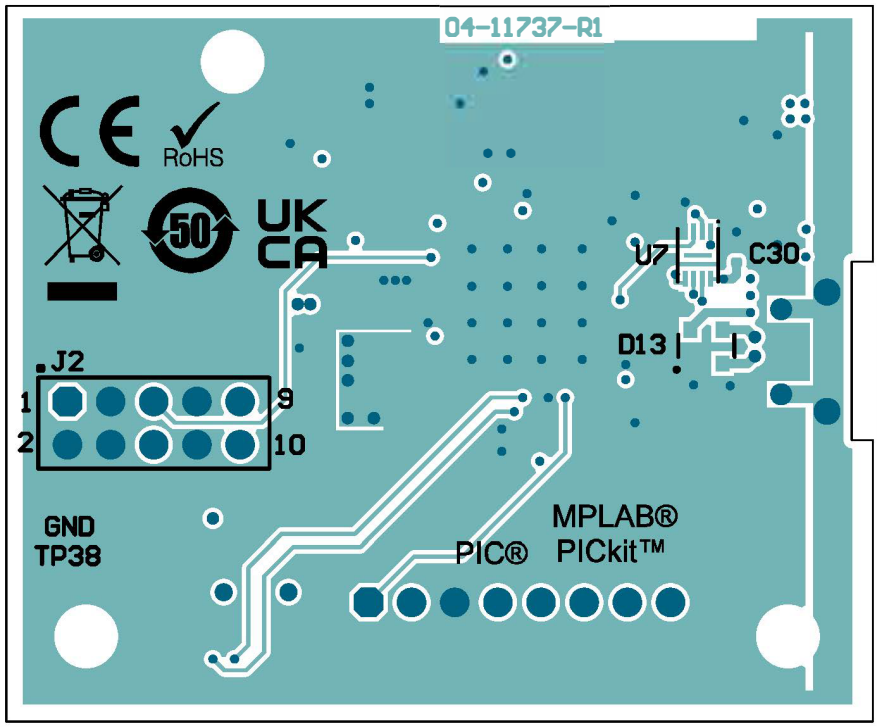
A.16 CONTROLLER BOARD – INNER COPPER LAYER 3



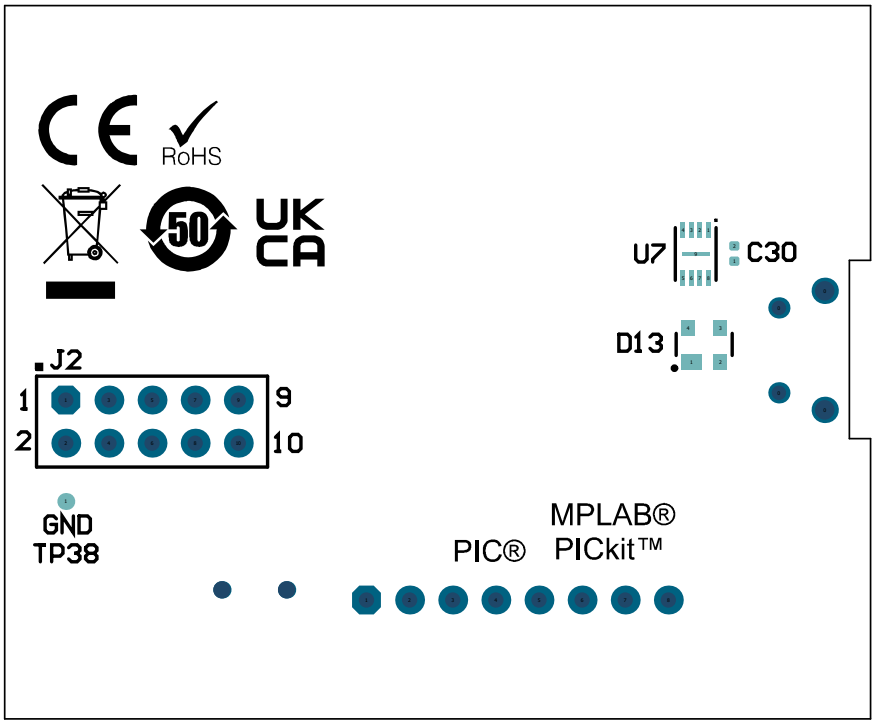
A.17 CONTROLLER BOARD – BOTTOM COPPER



A.18 CONTROLLER BOARD – BOTTOM COPPER AND SILK



A.19 CONTROLLER BOARD – BOTTOM SILK



Appendix B. Bill of Materials

TABLE B-1: BILL OF MATERIALS (BOM) – DRIVER BOARD

Qty	Reference	Description	Manufacturer	Part Number
7	+5V, +VPP, EN, HVOUT, HVOUT_B, VIN, VREF	Connector, TP, Loop, Tin, SMD	Harwin PLC.	S1751-46R
1	C1	Capacitor, ceramic, 0.1 µF, 250V, X7T, 0805	TDK Corporation	C2012X7T2E104K125AA
1	C2	Capacitor, ceramic, 1 µF, 16V, 10%, X5R, SMD, 0603	Kyocera AVX Components	0603YD105KAT2A/4K
1	C3	Capacitor, ceramic, 1000 pF, 10%, 50V, X7R, SMD, 0603, AEC-Q200	TDK Corporation	CGA3E2X7R1H102K080AA
6	C6, C7, C8, C9, C10, C11	Capacitor, ceramic, 47 µF, 16V, 20%, X5R, SMD, 1206	Kyocera AVX Components	1206YD476MAT2A
3	C12, C13, C14	Capacitor, ceramic, 1 µF, 200V, 10%, X7R, SMD, 2220	Murata Manufacturing Co., Ltd.	GRM55DR72D105KW01L
1	C15	Capacitor, aluminum, 560 µF, 35V, 20%, SMD, G, AEC-Q200	Panasonic® - ECG	EEE-FN1V561UP
2	C16, C17	Capacitor, ceramic, 2.2 µF, 50V, 10%, X5R, SMD, 0805	TDK Corporation	C2012X5R1H225K125AB
1	C18	Capacitor, ceramic, 2.2 µF, 16V, 80%, Y5V, SMD, 0603	Yageo Corporation	CC0603ZRY5V7BB225
1	C19	Capacitor, ceramic, 0.039 µF, 50V, 10%, X7R, SMD, 0603	Kyocera AVX Components	06035C393KAT2A\4K
1	C20	Capacitor, ceramic, 47 pF, 50V, 5%, NP0, SMD, 0402	Murata Manufacturing Co., Ltd.	GCM1555C1H470JA16D
1	C21	Capacitor, ceramic, 0.012 µF, 16V, 10%, X7R, SMD, 0402	Murata Manufacturing Co., Ltd.	GRM155R71C123KA01D
1	C40	Capacitor, ceramic, 1000 pF, 50V, 10%, X7R, SMD, 0603	Cal-Chip Electronics Inc.	GMC10X7R102K50NTL_F
1	C42	Capacitor, aluminum, 10 µF, 200V, 20%, RAD, P5D10H16, TH	United Chemi-Con	EKXG201ELL100MJ16S
8	D1, D2, D4, D5, D6, D7, D8, D9	Diode, Zener, BZT52C12TQ-7-F, 12V, 370 mW, SOD-523, AEC-Q101	Diodes Incorporated®	BZT52C12TQ-7-F
1	D3	Diode, Zener, MM5Z4689T1G, 5.1V, 500 mW, SMD, SOD-523, AEC-Q101	ON Semiconductor®	MM5Z4689T1G
1	D10	Diode, rectifier, US1, 1V, 1A, 400V, SMD, DO-214AC, SMA	Vishay Semiconductor Diodes Division	US1GHE3_A/I

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 MATERIALS (BOM) – DRIVER BOARD (CONTINUED)

Qty	Reference	Description	Manufacturer	Part Number
1	D11	Diode, Zener, DFLZ39-TP, 39V, 1W, SMD, SOD-123FL	Micro Commercial Components (MCC)	DFLZ39-TP
1	D12	Diode, rectifier, SBRT4U10LP-7, 0.5V, 4A, 10V, SMD, U-DFN2020-2, AEC-Q101	Diodes Incorporated	SBRT4U10LP-7
1	J1	Connector, HDR-2.54, male, 1x4, Gold, 5.84MH, TH, R/A	Samtec, Inc.	TSW-104-08-S-S-RA
1	J2	Connector, HDR-2.54, male, 2x5, tin, 5.84MH, TH, vertical	Sullins Connector Solutions	PEC05DAAN
1	LD2	Diode, LED, red, 1.75V, 20 mA, clear, SMD, 0603	ROHM Semiconductor	SML-310LTT86
1	PCB	Printed Circuit Board	—	04-11497-RE
1	Q9	Transistor, FET, N-CH, 60V, 100A, 156W, Power TDFN-8	Texas Instruments	CSD18532Q5B
1	Q10	Transistor, BJT, NPN, Prebias, 50V, 100 mA, 246 mW, SOT-23-3	ON Semiconductor	MMUN2232LT1G
4	R1, R6, R7, R8	Resistor, TKF, 51R, 1%, 1/10W, SMD, 0603	Yageo Corporation	RC0603FR-0751RL
1	R2	Resistor, TKF, 51R, 1%, 2W, SMD, 2512, AEC-Q200	TE Connectivity AMP	352151RFT
1	R3	Resistor, TKF, 3.01M, 1%, 1/10W, SMD, 0603	Yageo Corporation	RC0603FR-073M01L
1	R4	Resistor, TKF, 0R, 1/10W, SMD, 0603, AEC-Q200	Panasonic - ECG	ERJ-3GEY0R00V
1	R5	Resistor, TKF, 84.5k, 1%, 1/10W, SMD, 0603	Yageo Corporation	RC0603FR-0784K5L
1	R9	Resistor, TKF, 0R, 1/16W, SMD, 0402	Yageo Corporation	RC0402JR-070RL
1	R10	Resistor, TKF, 1k, 1%, 1/10W, SMD, 0402	Panasonic - ECG	ERJ-2RKF1001X
1	R11	Resistor, TKF, 10M, 5%, 1/10W, SMD, 0603, AEC-Q200	Panasonic - ECG	ERJ-3GEYJ106V
1	R12	Resistor, TKF, 158k, 1%, 1/10W, SMD, 0603	Yageo Corporation	RC0603FR-07158KL
1	R13	Resistor, TKF, 1M, 1%, 1/10W, SMD, 0603	Yageo Corporation	RC0603FR-071ML
1	R14	Resistor, TF, 10k, 1%, 1/8W, SMD, 0603	Stackpole Electronics, Inc.	RNCP0603FTD10K0
1	R15	Resistor, TKF, 15.4k, 1%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3EKF1542V
1	R17	Resistor, TKF, 40.2k, 1%, 1/10W, SMD, 0402, AEC-Q200	Panasonic - ECG	ERJ-2RKF4022X
1	R18	Resistor, TKF, 150k, 1%, 1/10W SMD, 0402	Panasonic - ECG	ERJ-2RKF1503X
1	R19	Resistor, TKF, 0.062R, 5%, 2W, SMD, 2512	TE Connectivity	RLP73N3AR062JTE

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 MATERIALS (BOM) – DRIVER BOARD (CONTINUED)

Qty	Reference	Description	Manufacturer	Part Number
1	R24	Resistor, TKF, 8.66k, 1%, 1/10W, SMD, 0603	Yageo Corporation	RC0603FR-078K66L
1	R25	Resistor, TKF, 499k, 1%, 1/10W, SMD, 0603	Panasonic - ECG	ERJ-3EKF4993V
1	R26	Resistor, TKF, 4.7k, 1%, 1/10W, SMD, 0603	Yageo Corporation	RC0603FR-074K7L
1	TP1	Connector, TP, Loop, red, TH	Keystone® Electronics Corp.	5010
1	TP2	Connector, TP, Loop, black, 3.18x5.59, TH	Keystone Electronics Corp.	5006
1	TR1	Transformer, SMPS, 1:5, 75V, 500 mA, 1.2 µH, SMD, AEC-Q200	Wurth Elektronik	750319873

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-2: BILL OF MATERIALS (BOM) – DRIVER BOARD – MICROCHIP PARTS

Qty	Reference	Description	Manufacturer	Part Number
4	Q1, Q3, Q5, Q7	Transistor, FET, N-CH, 300V, 85 mA, DFN-6L	Microchip Technology Inc.	TN2130MF-G
4	Q2, Q4, Q6, Q8	Transistor, FET, P-CH, 350V, 85 mA, DFN-6L	Microchip Technology Inc.	TP5335MF-G
1	U1	Analog, Op Amp, 1-Ch, +300V, High Voltage, QFN-32	Microchip Technology Inc.	HV56266T-E/RXB
1	U3	Analog, comparator, 1-Ch, 4-TDFN	Microchip Technology Inc.	MIC842NYMT-T5
1	U4	Analog, LDO, 5V, SOT-23-3	Microchip Technology Inc.	MCP1799T-5002H/TT
1	U5	Analog, PWM, controller, 2.2 MHz, QFN-16	Microchip Technology Inc.	MCP1633-E/MG

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) – DRIVER BOARD – DO NOT POPULATE PARTS

Qty	Reference	Description	Manufacturer	Part Number
1	C36	Capacitor, ceramic, 15 pF, 250V, 1%, C0G, SMD, 0603	KEMET	CBR06C150FAGAC
2	C38, C41	Capacitor, ceramic, 10 pF, 5%, 50V, C0G, SMD, 0603	Wurth Elektronik	885012006051
1	C39	Capacitor, ceramic, 0.022 µF, 200V, 10%, X7R, SMD, 0805	Yageo Corporation	CC0805KKX7RABB223
1	R23	Resistor, TKF, 536k, 1%, 1/10W, SMD, 0603	Vishay Intertechnology, Inc.	CRCW0603536KFKEA

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) – CONTROLLER BOARD

Qty.	Reference	Description	Manufacturer	Part Number
2	C3, C4	Capacitor, ceramic, 2.2 µF, 16V, 10%, X5R, SMD, 0402	Murata Manufacturing Co., Ltd.	GRM155R61C225KE44D
3	C22, C28, C34	Capacitor, ceramic, 4.7 µF, 10V, 20%, X5R, SMD, 0402	Murata Manufacturing Co., Ltd.	GRM155R61A475MEAAD
6	C23, C26, C29, C30, C31, C35	Capacitor, ceramic, 0.1 µF, 25V, 10%, X7R, SMD, 0402	TDK Corporation	C1005X7R1E104K050BB
1	C24	Capacitor, ceramic, 1 µF, 35V, 10%, X5R, SMD, 0402	Murata Manufacturing Co., Ltd.	GRM155R6YA105KE11D
2	C25, C27	Capacitor, ceramic, 6.8 pF, 50V, 0.1 pF, NP0, SMD, 0402	Murata Manufacturing Co., Ltd.	GRM1555C1H6R8BA01D
2	C32, C33	Capacitor, ceramic, 2.2 µF, 16V, 20%, Y5V, SMD, 0805	KEMET	C0805C225Z4VACTU
1	C37	Capacitor, ceramic, 1500 pF 50V 5% C0G SMD 0603	Murata Manufacturing Co., Ltd.	GRM1885C1H152JA01D
1	D13	Diode, TVS, PRTR5V0U2X, 5.5V, SMD, SOT-143	Nexperia	PRTR5V0U2X,215
1	FB1	Ferrite, 470R, @100 MHz, 1A, SMD, 0603	Murata Manufacturing Co., Ltd.	BLM18PG471SN1D
1	J2	Connector, HDR-2.54, female, 2x5, Gold, TH, VERT	Samtec, Inc.	SSW-105-01-F-D
1	J3	Connector, HDR-2.54, male, 1x8, 5.84MH, TH, vertical	Samtec, Inc.	TSW-108-23-F-S
1	J4	Connector, USB2.0, MICRO-B, female, TH/SMD, R/A	Amphenol ICC (FCI)	10118194-0001LF
1	L2	Inductor, fixed, 10 µH, 1.2A, 240 M Ohm, SMD	Murata Manufacturing Co., Ltd.	LQH3NPN100MJRL
1	LD1	Diode, LED, green, 1.7V, 20 mA, 3.92 mcd, diffuse, SMD, 0603	OSRAM Opto Semiconductors GmbH.	LPL296-J2L2-25-0-20-R18-Z
1	PCB	Printed Circuit Board	—	04-11737-RD
1	R9	Resistor, TKF, 1k, 1%, 1/10W, SMD, 0402	Panasonic - ECG	ERJ-2RKF1001X
1	R20	Resistor, TKF, 10k, 1%, 1/10W, SMD, 0603	TE Connectivity	CRG0603F10K
1	R21	Resistor, TKF, 10R, 1%, 1/10W, SMD, 0603, AEC-Q200	Vishay Intertechnology, Inc.	CRCW060310R0FKEA
1	R22	Resistor, TF, 10k, 1%, 1/16W, SMD, 0603	TE Connectivity	CPF0603F10KC1
1	SW1	Switch, TACT, SPST, 15V, 20 mA	Panasonic - ECG	EVQ-P2002M
1	XC1	Crystal, 32.768 kHz, 7 pF, SMD, +/- 20 ppm	Micro Crystal AG	CM7V-T1A

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-5: BILL OF MATERIALS (BOM) – CONTROLLER BOARD – MICROCHIP PARTS

Qty	Reference	Description	Manufacturer	Part Number
2	U2	Analog, LDO, 3.3V, 300 mA, SOT23-5	Microchip Technology Inc.	MIC5504-3.3YM5-TR

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-5: BILL OF MATERIALS (BOM) – CONTROLLER BOARD – MICROCHIP PARTS

Qty	Reference	Description	Manufacturer	Part Number
1	U6	Microcontroller, 32-BIT, 48 MHz, 256 kB, 32kB, QFN-64	Microchip Technology Inc.	ATSAML21J18B-MNT
1	U7	Memory, Serial, Flash, 4 Mb, 40 MHz, 8-UDFN (2x3)	Microchip Technology Inc.	SST25PF040CT-40I/NP
1	U8	Analog, Voltage Reference, 3.3V, SOT-23-6	Microchip Technology Inc.	MCP1501T-33E/CHY

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-6: BILL OF MATERIALS (BOM) – CONTROLLER BOARD – DO NOT POPULATE PARTS

Qty	Reference	Description	Manufacturer	Part Number
1	J1	Connector, HDR-1.27, male, 2x5, SMD, vertical	Samtec, Inc.	FTSH-105-01-L-DV-K-A-P-TR

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-7: LIST OF MAGNETICS VENDORS

Manufacturers	Manufacturer Part Numbers	Package
Wurth Elektronik	750342957	Throughole
Wurth Elektronik	750319873	SMD
Sunlord	ATWPEE161618C400P	Throughole
Sunlord	ATWPEF161914B201T	SMD

Magnetics manufacturers contact Information:

Würth Elektronik eiSos GmbH & Co. KG
Max-Eyth-Str. 1
74638 Waldenburg, Germany
Phone: +49 7942 945 - 0
Fax: +49 7942 945 - 5000
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Phone: +86-755-2983 2333\2516\2526\2536
Fax: +86-755-26030600
www.sunlordinc.com

NOTES:

Appendix C. Waveforms

C.1 HV56266 1-CH HI-V AMP HAPTICS EVALUATION KIT TEST WAVEFORM EXAMPLES

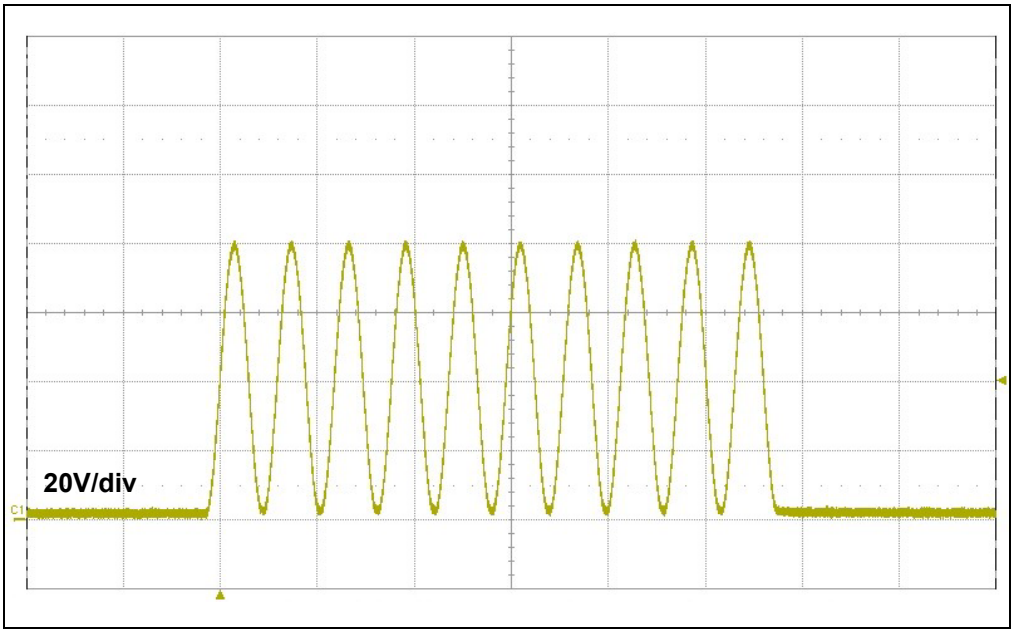

FIGURE C-1: *First Built-In Waveform.*

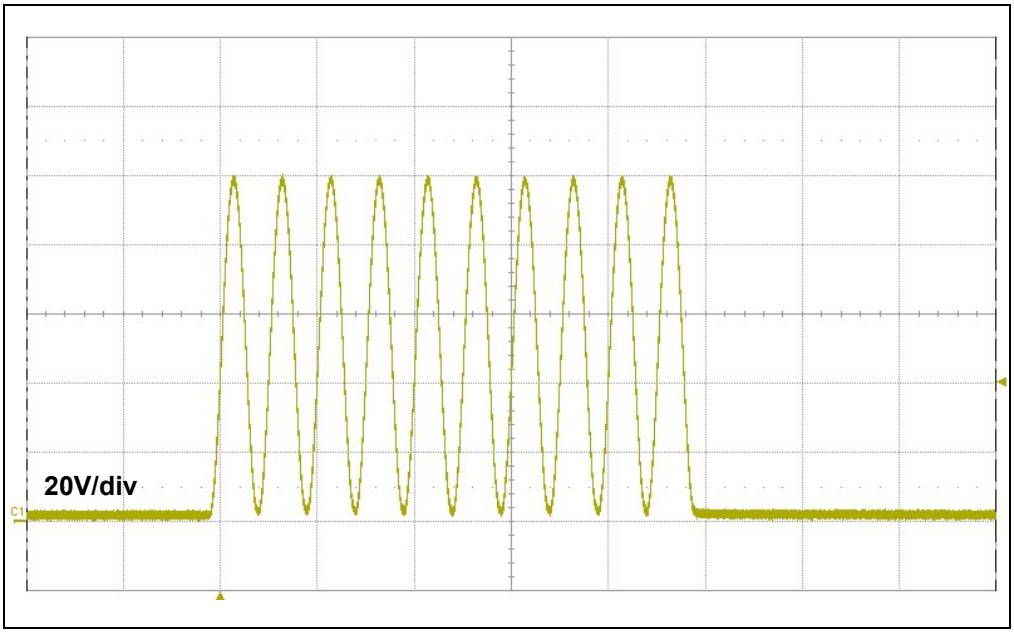

FIGURE C-2: *Second Built-In Waveform.*

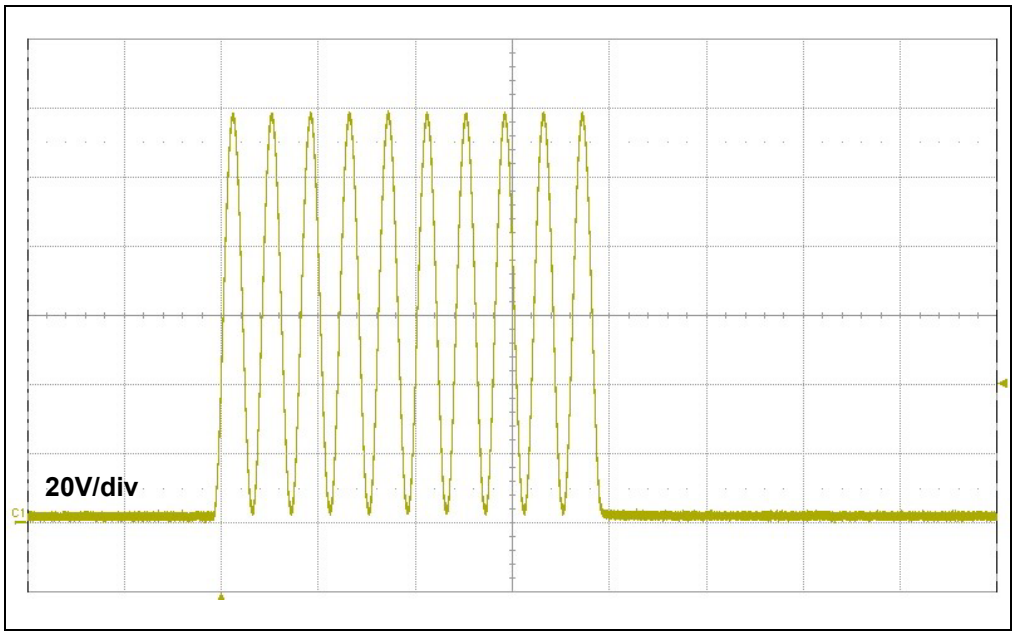

FIGURE C-3: *Third Built-In Waveform.*

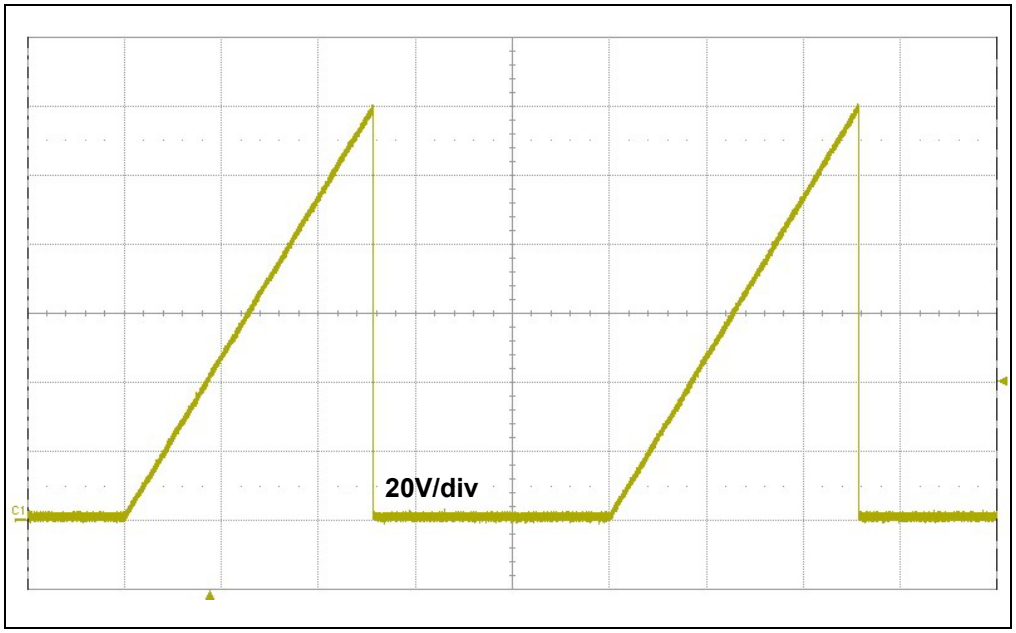

FIGURE C-4: *Example of User Defined Waveform.*

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