Ultrasound Power Board Reference Design User's Guide

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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, so some actual dialogs 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, 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 Ultrasound Power Board Reference Design. 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 Ultrasound Power Board Reference Design 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 Ultrasound Power Board Reference Design.
- **Chapter 2. "Installation and Operation"**– This chapter includes instructions for how to begin using the Ultrasound Power Board Reference Design.
- **Appendix A. "Schematics and Layouts"**– Shows the schematic and layout diagrams for the Ultrasound Power Board Reference Design.
- **Appendix B. "Bill of Materials (BOM)"**– Lists the parts used to build the Ultrasound Power Board Reference Design.
- **Appendix C. "Waveforms and Performance Curves"** – Describes the waveforms and performance curves for the Ultrasound Power Board Reference Design.

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 Ultrasound Power Board Reference Design. The following Microchip documents are available and recommended as a supplemental reference resource:

- **PIC16(L)F1713/6 Data Sheet – *"Cost Effective 8-Bit Intelligent Analog Flash Microcontrollers"* (DS40001708)**
- **MCP1631/HV/MCP1631V/VHV Data Sheet – *"High-Speed, Pulse Width Modulator"* (DS20002063)**
- **MCP65R41/6 Data Sheet – *"3 µA Comparator with Integrated Reference Voltage"* (DS20002269)**
- **MCP16301/H Data Sheet – *"High-Voltage Input Integrated Switch Step-Down Regulator"* (DS20005004)**
- **MCP1700 Data Sheet – *"Low Quiescent Current LDO" (DS20001826)***
- **MCP6H01 Data Sheet – *"1.2 MHz, 16V Op Amp"* (DS22243)**
- **MIC5270 Data Sheet – *"µCap Negative Low-Dropout Regulator",* (DS20006698)**
- **MIC5203 Data Sheet – *"µCap 80 mA Low-Dropout Regulator"* (DS20006609)**
- **MIC5205 Data Sheet – *"150 mA Low-Noise LDO Regulator"* (DS20005785)**
- **MCP6541/1R/1U/2/3/4 Data Sheet – *"Push-Pull Output Sub-Microamp Comparators"* (DS20001696)**

THE MICROCHIP WEBSITE

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- **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

CUSTOMER SUPPORT

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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://www.microchip.com/support.

DOCUMENT REVISION HISTORY

Revision A (December 2023)

- Initial Release of this Document.

Chapter 1. Product Overview

1.1 INTRODUCTION

This chapter provides an overview of the Ultrasound Power Board Reference Design and covers the following topics:

- Core Components Short Overview
- Ultrasound Power Board Reference Design Overview
- Ultrasound Power Board Reference Design Kit Contents

1.2 CORE COMPONENTS SHORT OVERVIEW

1.2.1 PIC16F1716 Device Overview

PIC16F(L)170X/171X microcontrollers combine Intelligent Analog integration with low cost and extreme low power (XLP) to suit a variety of general purpose applications. These 14 to 44-pin devices deliver on-chip Op Amps, Core Independent Peripherals (CLC, NCO and COG), Peripheral Pin Select and Zero-Cross Detect, providing increased design flexibility.

1.2.2 MCP1631 Device Overview

MCP1631/MCP1631V is a high-speed analog pulse width modulator (PWM) used to develop intelligent power systems. When combined with a microcontroller, MCP1631/MCP1631V will control the power system duty cycle providing output voltage or current regulation. The microcontroller can be used to adjust output voltage or current, switching frequency and maximum duty cycle, while providing additional features that make the power system more intelligent, robust and adaptable.

For applications that operate from a high voltage input, the MCP1631HV and MCP1631VHV devices can be used to operate directly from a +3.5V to +16V input. For these applications, an additional low drop out +5V or +3.3V regulated output is available and can provide current up to 250 mA to power a microcontroller and auxiliary circuits.

1.2.3 MCP65R41 Device Overview

The MCP65R41/6 family of push-pull and open-drain output comparators is offered with integrated reference voltages of 1.21V and 2.4V. This family provides ±1% (typical) tolerance while consuming 2.5 µA (typical) current. These comparators operate with a single-supply voltage as low as 1.8V to 5.5V, which makes them ideal for low cost and/or battery powered applications. These comparators are optimized for low-power, single-supply applications with greater than rail-to-rail input operation. The output limits supply current surges and dynamic power consumption while switching. The internal input hysteresis eliminates output switching due to internal noise voltage, reducing current draw. The MCP65R41 output interfaces to the CMOS/TTL logic. The open-drain output device MCP65R46 can be used as a level-shifter from 1.6V to 10V using a pull-up resistor. It can also be used as a wired-OR logic.

1.2.4 MCP16301 Device Overview

The MCP16301/H devices are highly integrated, high-efficiency, fixed-frequency, step-down DC-DC converters, available in a popular 6-pin SOT-23 package, that operate from input voltage sources up to 36V. Integrated features include a high-side switch, fixed-frequency peak current mode control, internal compensation, peak current limit and overtemperature protection. Only a few external components are necessary to develop a complete step-down DC-DC converter power supply. High converter efficiency is achieved by integrating the current-limited, low-resistance, high-speed N-Channel MOSFET and associated drive circuitry. High switching frequency minimizes the size of external filtering components, resulting in a small solution size.

The MCP16301/H devices can supply 600 mA of continuous current while regulating the output voltage from 2.0V to 15V. An integrated, high-performance peak current mode architecture keeps the output voltage tightly regulated, even during input voltage steps and output current transient conditions that are common in power systems.

1.2.5 MCP6404 Device Overview

The MCP6404 operational amplifier (op amp) has low quiescent current (45 µA, typical) and rail-to-rail input and output operation. This device is unity gain stable and has a gain bandwidth product of 1 MHz (typical). The MCP6404 is designed with Microchip's advanced CMOS process. It is offered in SOIC and TSSOP packages for the -40°C to +125°C temperature range and in SOIC for the -40°C to +150°C temperature range, with a power supply range of 1.8V to 6.0V. These features make the MCP6404 well suited for single-supply, battery-powered, automotive and industrial applications.

1.2.6 MCP1700 Device Overview

The MCP1700 is a family of CMOS low dropout (LDO) voltage regulators that can deliver up to 250 mA of current, while consuming only 1.6 µA of quiescent current (typical). The input operating range is specified from 2.3V to 6.0V, making it an ideal choice for two and three primary cell battery-powered applications, as well as single cell Li-Ion-powered applications. The MCP1700 is capable of delivering 250 mA with only 178 mV of input to output voltage differential (V_{OUT} = 2.8V). The output voltage tolerance of the MCP1700 is typically ±0.4% at +25°C and ±3% maximum over the operating junction temperature range of -40°C to +125°C. Output voltages available for the MCP1700 range from 1.2V to 5.0V. The LDO output is stable when using only 1 µF output capacitance. Ceramic, tantalum, or aluminum electrolytic capacitors can all be used for input and output. Overcurrent limit and overtemperature shutdown provide a robust solution for any application.

1.2.7 MIC5253 Device Overview

The MIC5253 is an efficient CMOS voltage regulator optimized for ultra-low-noise applications. It offers 1.5% initial accuracy, extremely low dropout voltage (165 mV at 100 mA), and low ground current (typically 95 µA at full load). The MIC5253 provides a very low noise output, ideal for RF applications, where a clean voltage source is required. A noise bypass pin is also available for further reduction of output noise.

Designed specifically for handheld and battery-powered devices, the MIC5253 provides a TTL logic-compatible enable pin. When disabled, power consumption drops nearly to zero. The MIC5253 also works with low-ESR ceramic capacitors, reducing the amount of board space necessary for power applications, which is critical in handheld wireless devices. Available in the Teeny™ SC-70-5 package, the MIC5253 offers a wide range of output voltages. Key features include current limit, thermal shutdown, faster transient response, and an active clamp to speed up device turnoff.

1.2.8 MIC5270 Device Overview

The MIC5270 is a µCap 100 mA negative regulator in an SOT-23-5 package. With better than 2% initial accuracy, this regulator provides a very accurate supply voltage for applications that require a negative rail. The MIC5270 sinks 100 mA of output current at very low dropout voltage (600 mV maximum at 100 mA of output current).

The µCap regulator design is optimized to work with low-value, low-cost ceramic capacitors. The output typically requires only a 1 µF capacitance for stability.

1.2.9 MIC5203 Device Overview

The MIC5203 is a µCap 80 mA linear voltage regulator with very low dropout voltage (typically 20 mV at light loads and 300 mV at 80 mA) and very low ground current (225 µA at 20 mA output), offering better than 3% initial accuracy with a logic-compatible enable input.

The µCap regulator design is optimized to work with low-value, low-cost ceramic capacitors. The outputs typically require only 0.47 µF of output capacitance for stability.

Designed especially for hand-held, battery-powered devices, the MIC5203 can be controlled by a CMOS or TTL compatible logic signal. When disabled, power consumption drops nearly to zero. If on-off control is not required, the enable pin may be tied to the input for 3-terminal operation. The ground current of the MIC5203 increases only slightly in dropout, further prolonging battery life. Key MIC5203 features include current limiting, overtemperature shutdown, and protection against reversed battery.

1.2.10 MIC5205 Device Overview

The MIC5205 is an efficient linear voltage regulator with ultra low-noise output, very low dropout voltage (typically 17 mV at light loads and 165 mV at 150 mA), and very low ground current (600 µA at 100 mA output). The MIC5205 offers better than 1% initial accuracy.

Designed especially for hand-held, battery-powered devices, the MIC5205 includes a CMOS or TTL compatible enable/shutdown control input. When shut down, power consumption drops nearly to zero. Regulator ground current increases only slightly in dropout, further prolonging battery life.

Key features include a reference bypass pin to improve its already excellent low-noise performance, reversed-battery protection, current limiting, and overtemperature shutdown.

1.2.11 MCP6544 Device Overview

The MCP6541/1R/1U/2/3/4 family of comparators is offered in single (MCP6541, MCP6541R, MCP6541U), single with Chip Select (CS) (MCP6543), dual (MCP6542) and quad (MCP6544) configurations. The outputs are push-pull (CMOS/TTL compatible) and are capable of driving heavy DC or capacitive loads.

These comparators are optimized for low-power, single-supply operation with greater than rail-to-rail input operation. The push-pull output of the MCP6541/1R/1U/2/3/4 family supports rail-to-rail output swing and interfaces with TTL/CMOS logic. The internal input hysteresis eliminates output switching due to internal input noise voltage, reducing current draw. The output limits supply current surges and dynamic power consumption while switching. This product family operates with a single-supply voltage as low as 1.6V and draws less than 1 µA per comparator of quiescent current.

1.2.12 MCP6H01 Device Overview

The MCP6H01/2/4 family of operational amplifiers has a wide supply voltage range of 3.5V to 16V and rail-to-rail output operation. This family is unity gain stable and has a gain bandwidth product of 1.2 MHz (typical). These devices operate with a single-supply voltage as high as 16V, while drawing only 135 µA per amplifier (typical) of quiescent current.

1.3 ULTRASOUND POWER BOARD REFERENCE DESIGN OVERVIEW

The Ultrasound Power Board Reference Design is intended to supply the necessary voltage rails for the Microchip ultrasound pulser demo boards.

The ultrasound pulser demo boards need a broad range of voltages in order to operate the transducers from the low levels associated with the digital control (1.8V, 2.5V, 3.3V, 5V) up to the +100V/-100V transducer drive.

The Ultrasound Power Board Reference Design automatically handles the power up and power down sequencing required by the pulser demo boards. Power good and current fault detection are also implemented for the board power supplies. Automatic shutdown is initiated in case of hazardous events.

The features listed above are meant to make the solution versatile and plug-and-play.

Since the receiver side of the ultrasound echoes on the supplied boards have very low amplitude, the Ultrasound Power Board is designed to have low ripple power supplies and optional external synchronization for the high voltage rails.

The Ultrasound Power Board can be used together with, but not limited to, the following Microchip ultrasound pulser boards:

- ADM00659 (HV7321 based ±80V, 2.5A, 4-channel integrated ultrasound pulser demo board)
- HV7350DB1 (HV7350 8-channel ±60V, ±1.0A, ultrasound pulser demo board)
- ADM00658 (HV7351 8-channel ±70V, ±3.0A, ultrasound pulser demo board)
- HV748DB1 (HV748 ±75V, 1.25A, ultrasound pulser demo board)

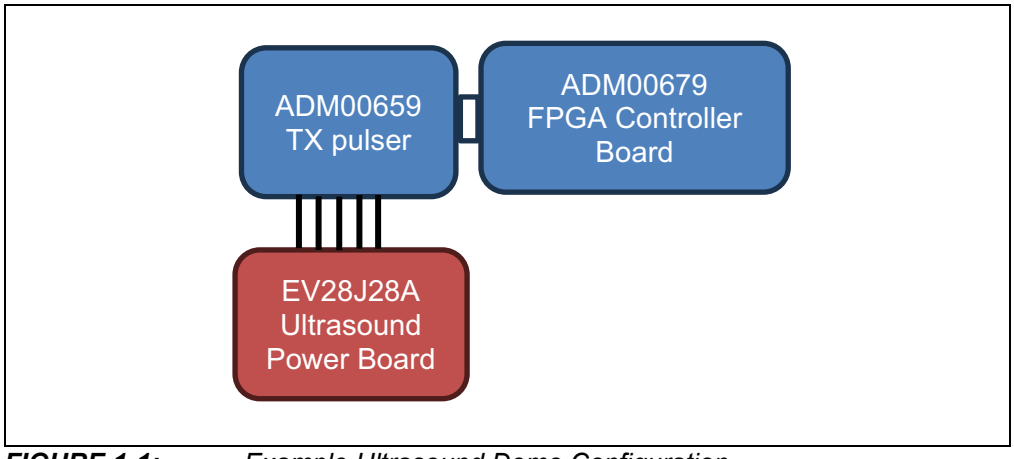


FIGURE 1-1: *Example Ultrasound Demo Configuration.*

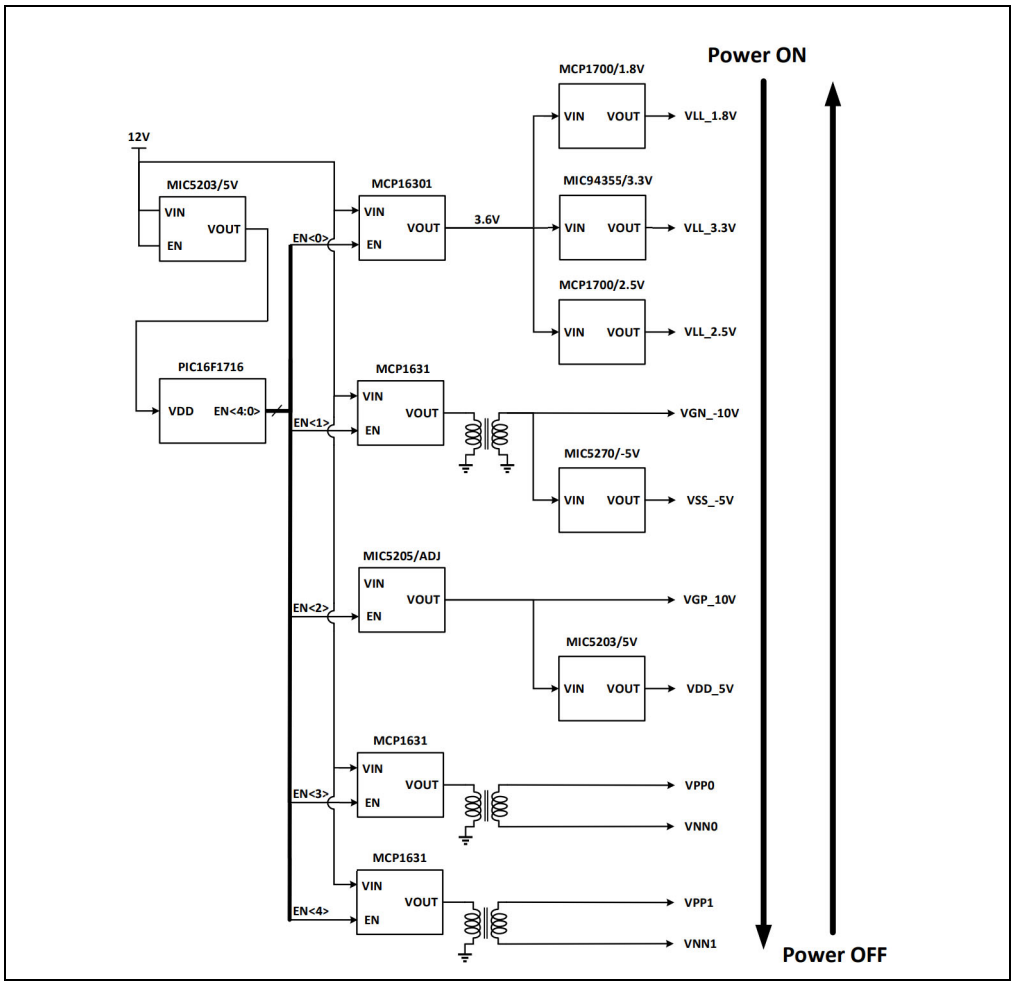


FIGURE 1-2: *Ultrasound Power Board Reference Design - Block Diagram.*

1.4 ULTRASOUND POWER BOARD REFERENCE DESIGN KIT CONTENTS

The Ultrasound Power Board Reference Design kit includes:

- Ultrasound Power Board Reference Design (EV28J28A)
- Important Information Sheet

NOTES:

Chapter 2. Installation and Operation

2.1 GETTING STARTED

The Ultrasound Power Board Reference Design is designed to supply all the needed voltage rails of Microchip ultrasound pulsers. Each output voltage needs to be connected to the corresponding connector on the pulser board.

2.1.1 Tools Required for Operation

- One Microchip Ultrasound Pulser Board
- External Power Supply with 12V Output

2.1.2 SW Tools

- None mandatory

2.1.3 Recommended Tools for Operation

- A Multimeter
- An Oscilloscope with Voltage Probes rated for 300V or above

2.2 ULTRASOUND POWER BOARD REFERENCE DESIGN SETUP PROCEDURE

WARNING

In order to prepare the Ultrasound Power Board Reference Design, fully read the User's Guide (this document) before proceeding to board setup and usage.

Assuming this board is used as a support hardware tool for a Microchip Ultrasound Pulser board, connect all voltage rails required by the chosen Ultrasound Pulser board to the corresponding connection point on the Ultrasound Power Board Reference Design.

If applicable, connect the ADM00679 platform board to the Ultrasound Pulser board.

Connect a 12V external power supply to the 12V/GND turrets on the Ultrasound Power Board, setting the current limit to at least 1A. Alternatively, use a brick 12V power supply compatible with the J2 Power Jack on the board.

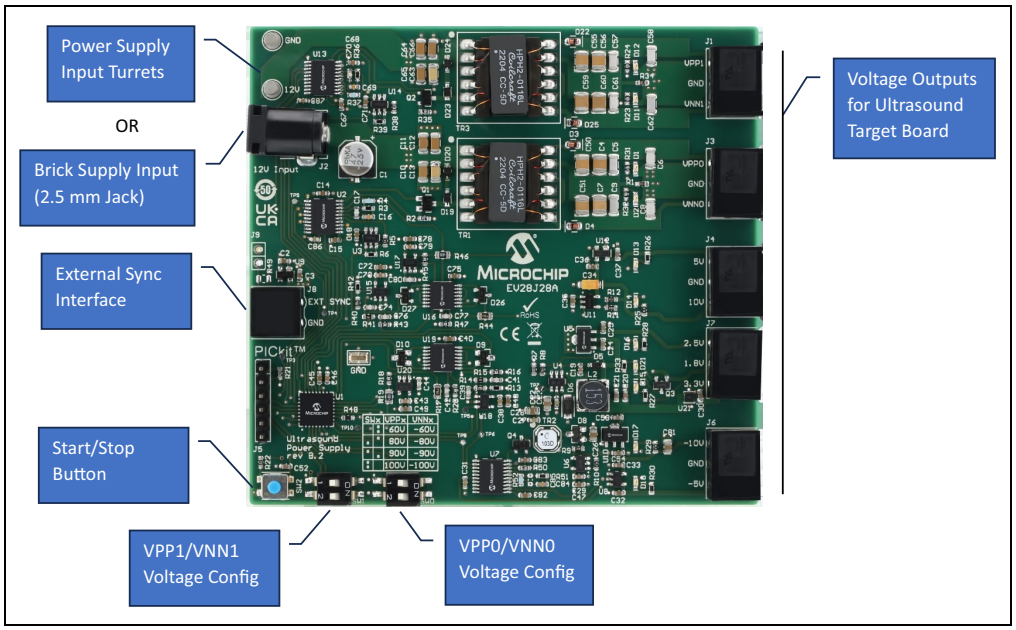


FIGURE 2-1: *Ultrasound Power Board Reference Design - External Connections.*

2.3 OPERATING THE ULTRASOUND POWER BOARD REFERENCE DESIGN

Once the 12V input is supplied by an external source, the Ultrasound Power Board starts in sleep mode. The on-board microcontroller is active, but all the Power Supplies on J1, J3, J4, J6, J7 (1.8V, 2.5V, 3.3V, ±5V, ±10V, VPP0/VNN0, VPP1/VNN1) are OFF. The LEDs associated with a Power Good state of the Power Supplies are also OFF.

While in sleep state, the user can select the desired VPP0/VNN0 voltage from SW0 and VPP1/VNN1 from SW1. The possible combinations are depicted in Figure 2-2, where "VPPx/VNNx" can be either VPP0/VNN0 or VPP1/VNN1.

VNNx is always the same voltage as VPPx(±1.5%), but negative. Each VPP0/VNN0 and VPP1/VNN1 can be configured independently to one of the output voltages: 60V, 80V, 90V or 100V.

By pressing the SW2 pushbutton on the Ultrasound Power Board, all the Power Supplies on J1, J3, J4, J6, J7 (1.8V, 2.5V, 3.3V, ±5V, ±10V, VPP0/VNN0, VPP1/VNN1) are turned ON, following the power-up order shown in Figure 1-2. The corresponding LEDs are also turned ON, signaling Power Good OK.

The voltage levels of VPP0/VNN0 and VPP1/VNN1 are set according to the selection on SW0 and SW1, priorly made in sleep mod . To set different values, the board needs to transition back to sleep mode, set new SW0 and SW1, then turn on the outputs again by SW2.

In order to re-enter sleep mode and turn OFF all the Power Supplies on J1, J3, J4, J6, J7 (1.8V, 2.5V, 3.3V, ±5V, ±10V, VPP0/VNN0, VPP1/VNN1), the button SW2 needs to be pressed. The power-down sequence is initiated according to Figure 1-2.

If a failure occurs during the operation of one or more Power supplies, the power-down sequencing is automatically initiated in order to protect both the power supplies and the associated Ultrasound Pulser board.

The monitored failures are:

- Overtemperature (all power supplies)
- Output over current (VPPx/VNNx)
- Output overvoltage (VPPx/VNNx)
- Output undervoltage (VPPx/VNNx)

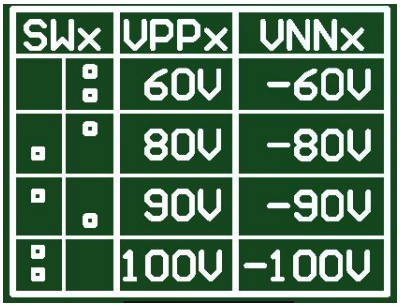


FIGURE 2-2: *VPPx/VNNx Voltage Configurations.*

The board also features an input for optional external synchronization. This means that the PWM pulses for VPP0/VNN0 and VPP1/VNN1 flyback switching can be provided by an external source. This is especially useful for applications where the receiver needs to monitor ultrasound echoes that are below 200 mV amplitude, regardless of the VPP/VNN ripple. The default PWM frequency, generated by the microcontroller, is 200 kHz. While in sleep state, the microcontroller monitors the "EXT_SYNC" interface. If an external PWM is detected, the microcontroller routes this as PWM for the switching controllers. A new cycle through sleep state is needed to return to the microcontoller generated internal PWM. Connectors J8 and J9 are fitted to interface the external synchronization (EXT_SYNC) input. Resistor R49 is not populated by default, but a 50Ω can be fitted in case the EXT_SYNC is provided from a 50Ω PWM generator. The PWM amplitude should not exceed 5V.

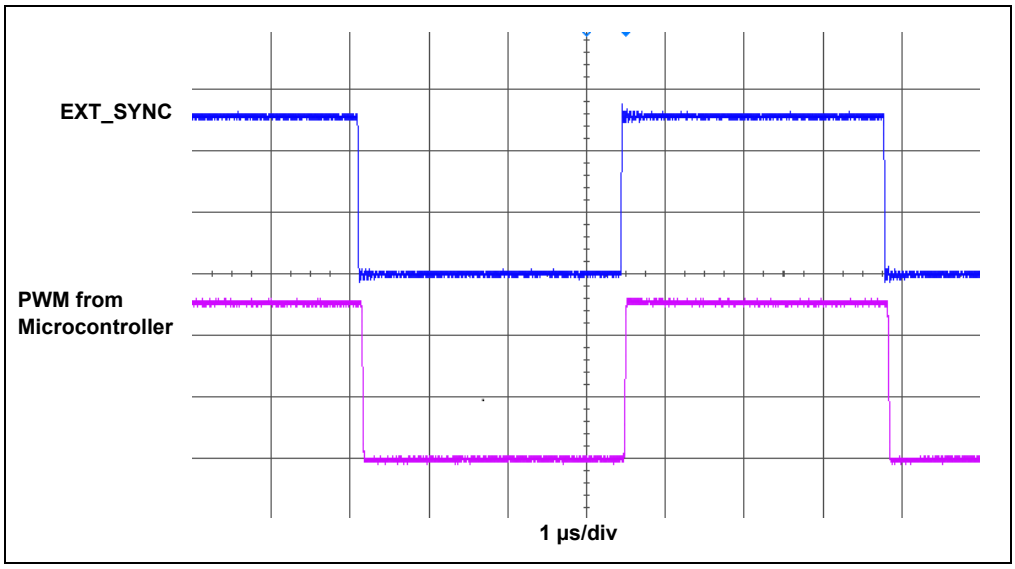


FIGURE 2-3: *External PWM Synchronization.*

2.4 DEVELOPER CONCERNS

Since the power supply operation is controlled and monitored individually by the on-board 8-bit microcontroller, the user is able to customize the firmware for specific operation.

The board features a pinheader interface for PICKIT4 on J5, in order to flash new firmware. Because some of the GPIOs are shared with the programming pins, the switches SW0 and SW1 must be set to OFF position beforehand.

Note: In order to comply with the required power-up/down sequences and voltage levels, please consult the recommended data sheets i.

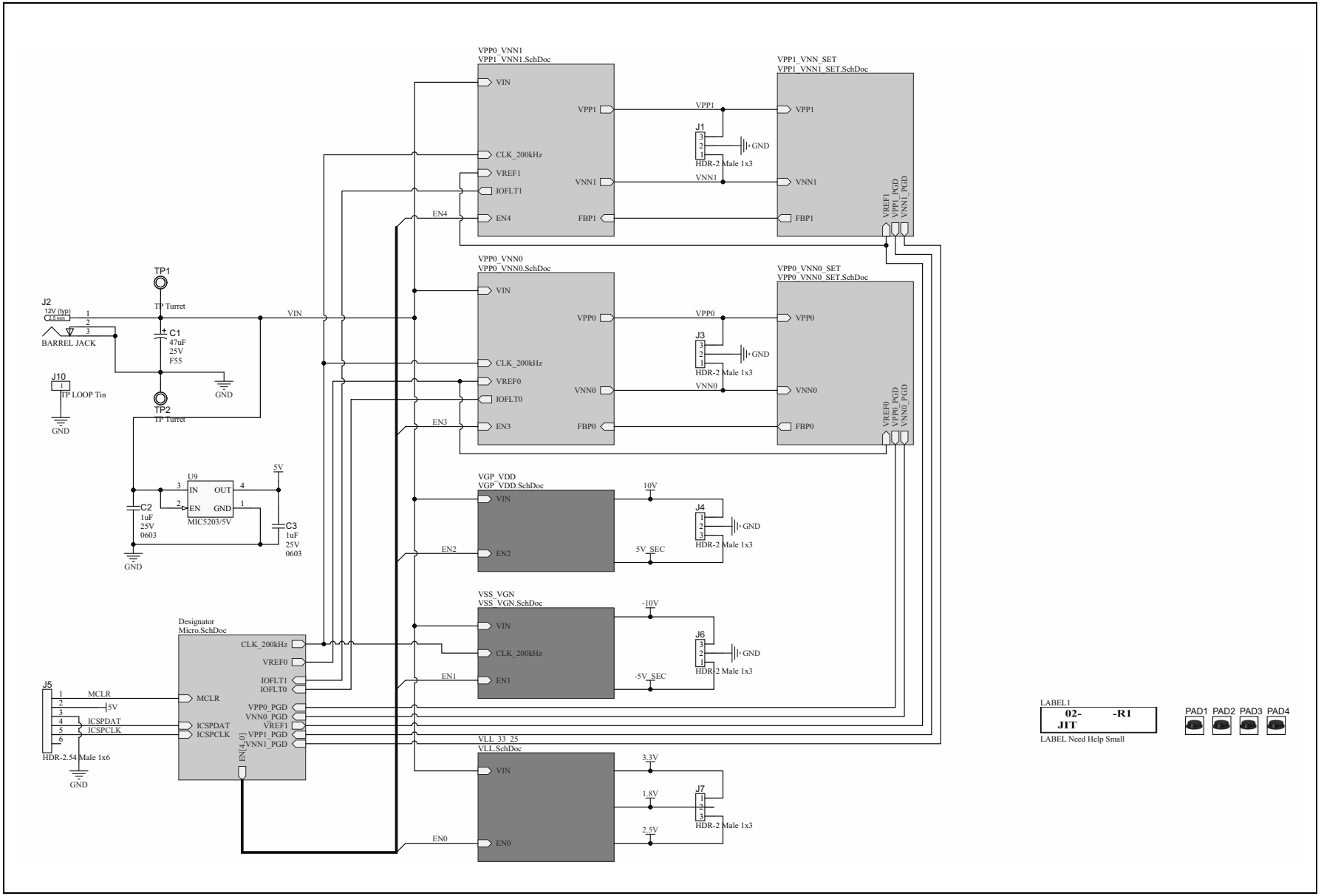
Appendix A. Schematics and Layouts

A.1 INTRODUCTION

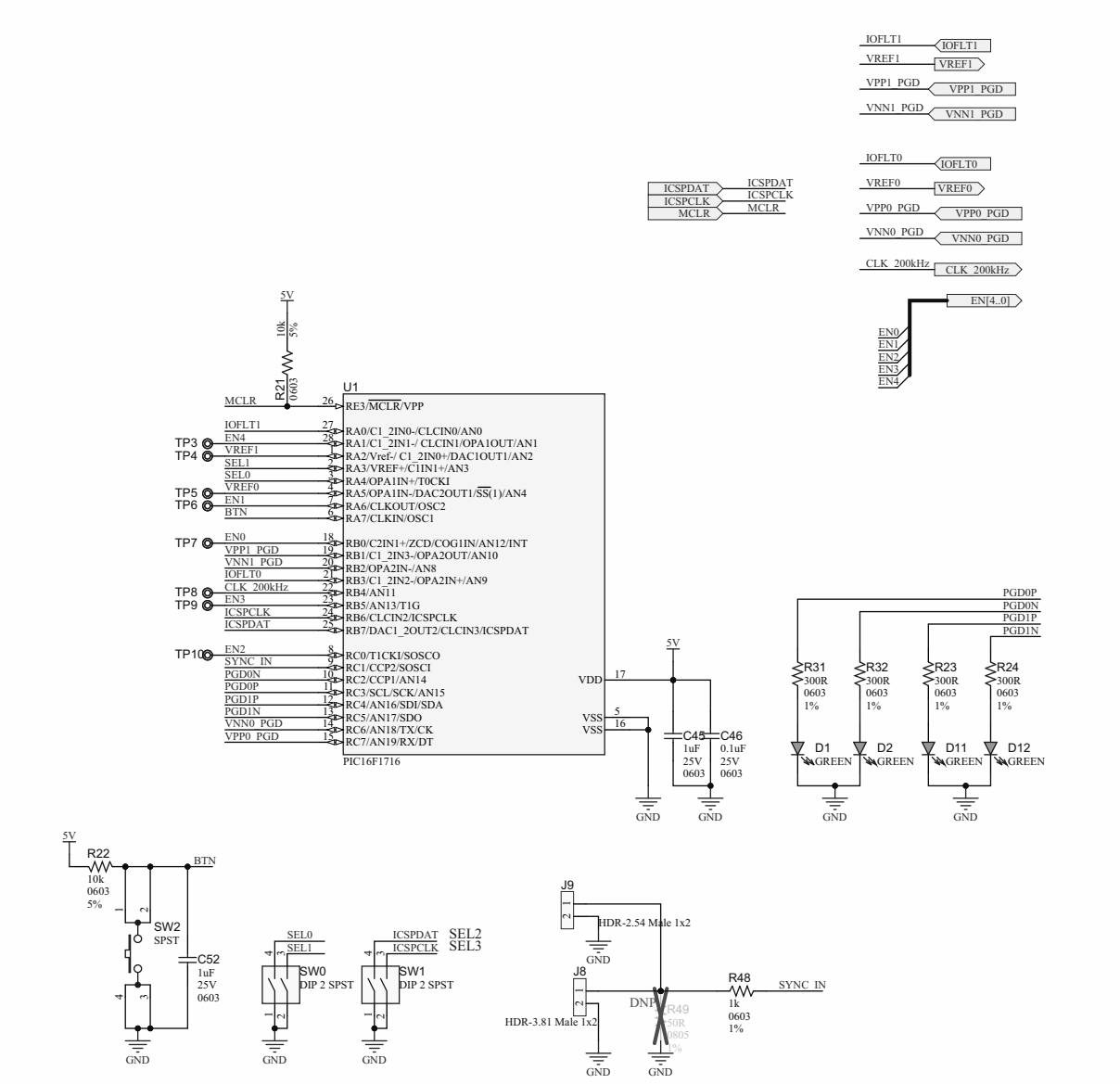
This appendix contains the following schematics and layouts for the Ultrasound Power Board Reference Design (EV28J28A).

- Schematic — Top Sheet
- Schematic — Microcontroller
- Schematic — 5V and 10V
- Schematic — 1.8V, 2.5V, 3.3V
- Schematic — VPP0/VNN0
- Schematic — VPP0/VNN0 Power Good
- Schematic — VPP1/VNN1
- Schematic — VPP1/VNN1 Power Good
- Schematic — -10V and -5V
- Top Silk
- Top Copper and Silk
- Top Copper
- Mid Layer 1
- Mid Layer 2
- Bottom Copper
- Bottom Copper and Silk
- Bottom Silk

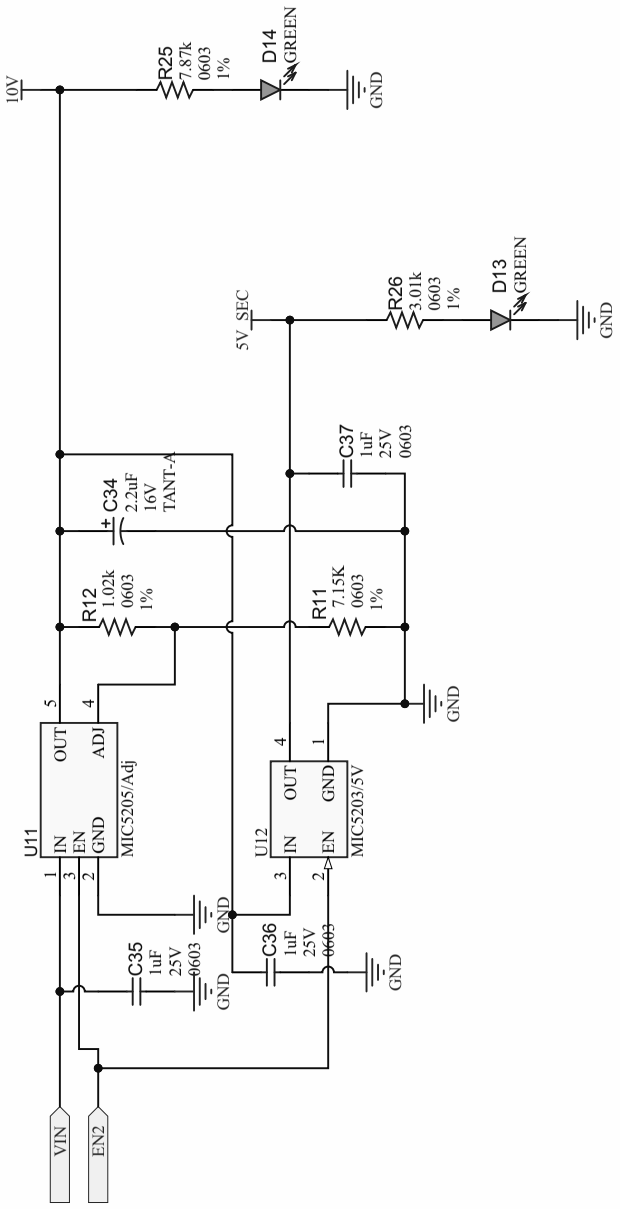
A.2 SCHEMATIC — TOP SHEET



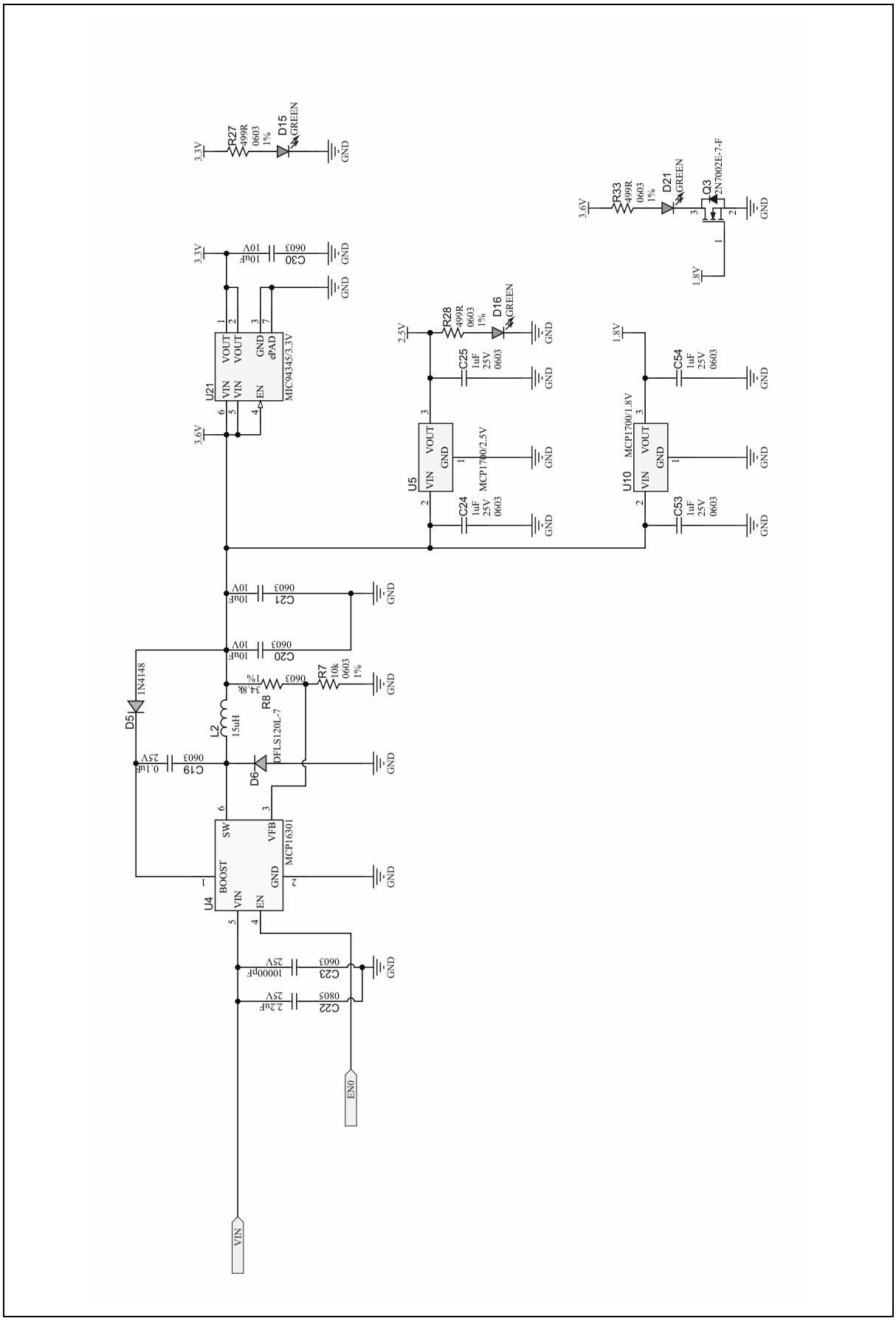
A.3 SCHEMATIC — MICROCONTROLLER



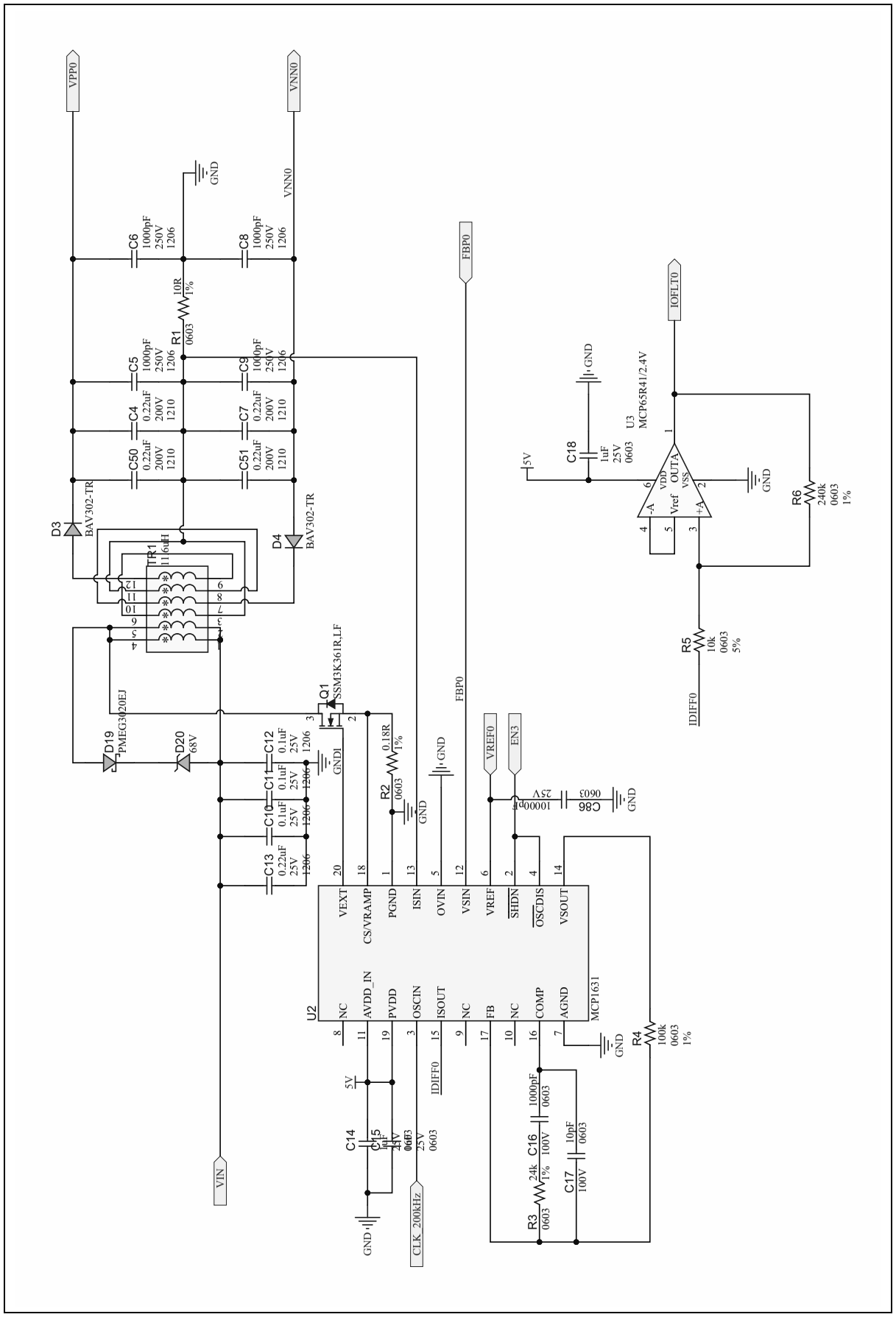
A.4 SCHEMATIC — 5V AND 10V



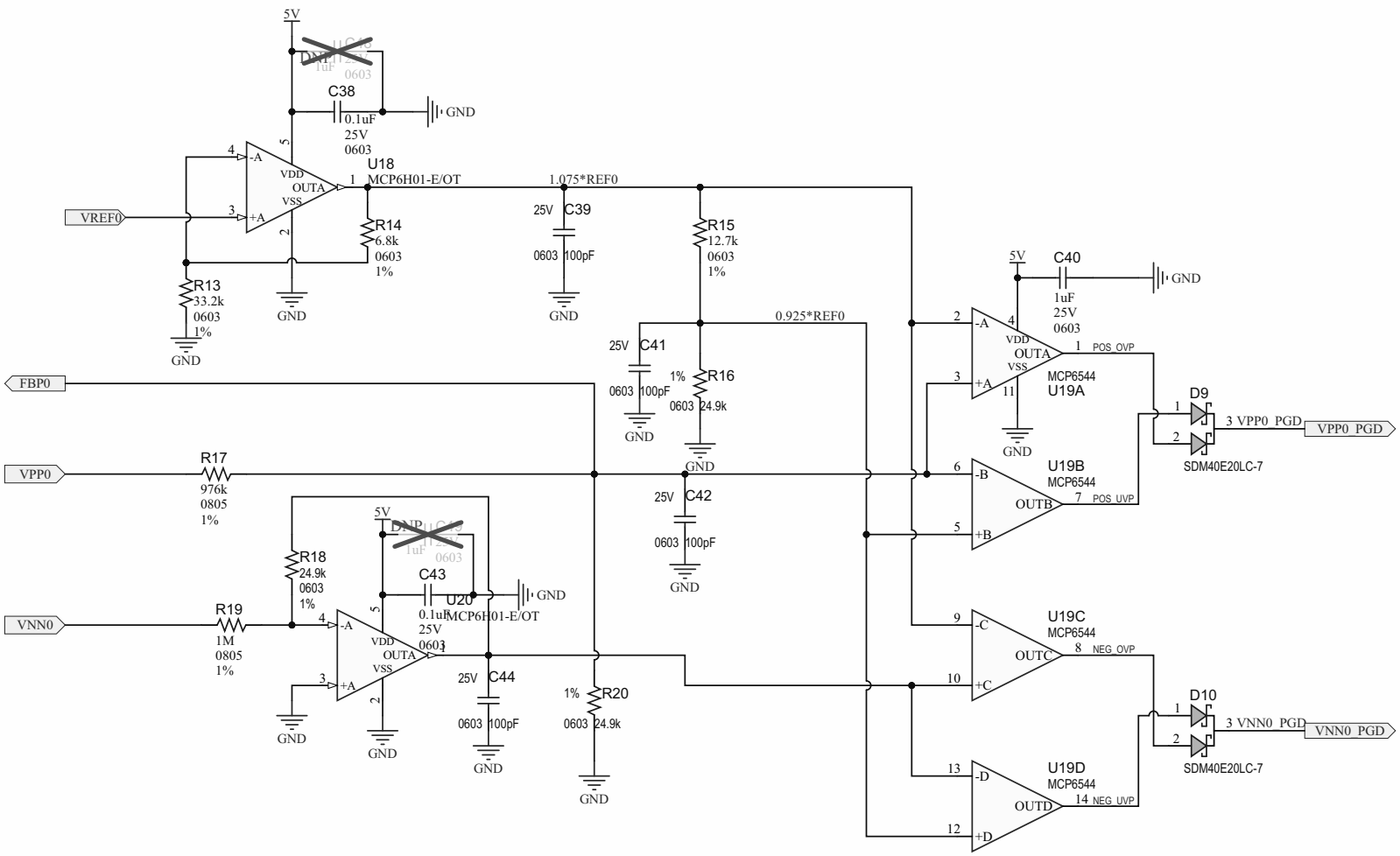
A.5 SCHEMATIC — 1.8V, 2.5V, 3.3V



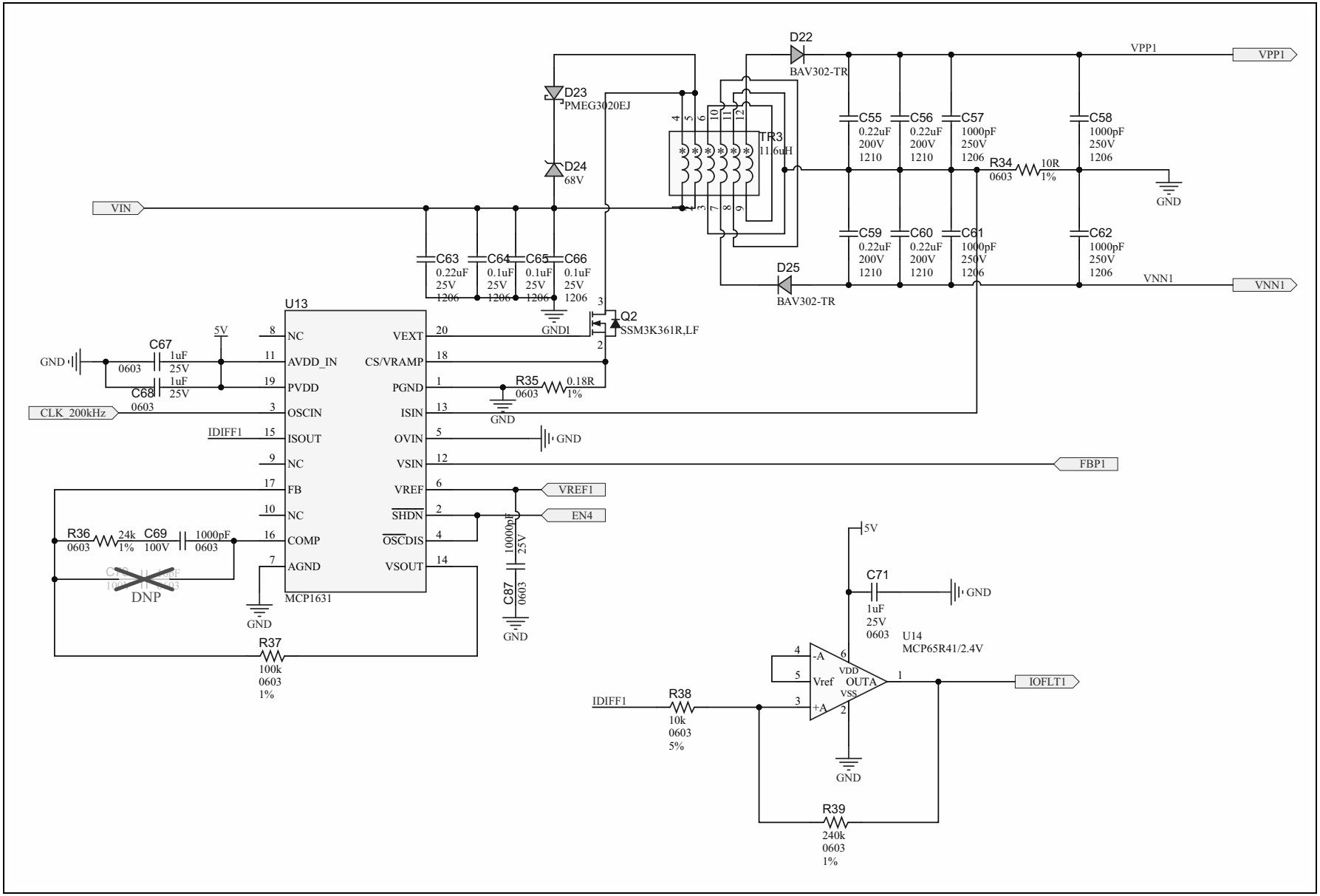
A.6 SCHEMATIC — VPP0/VNN0



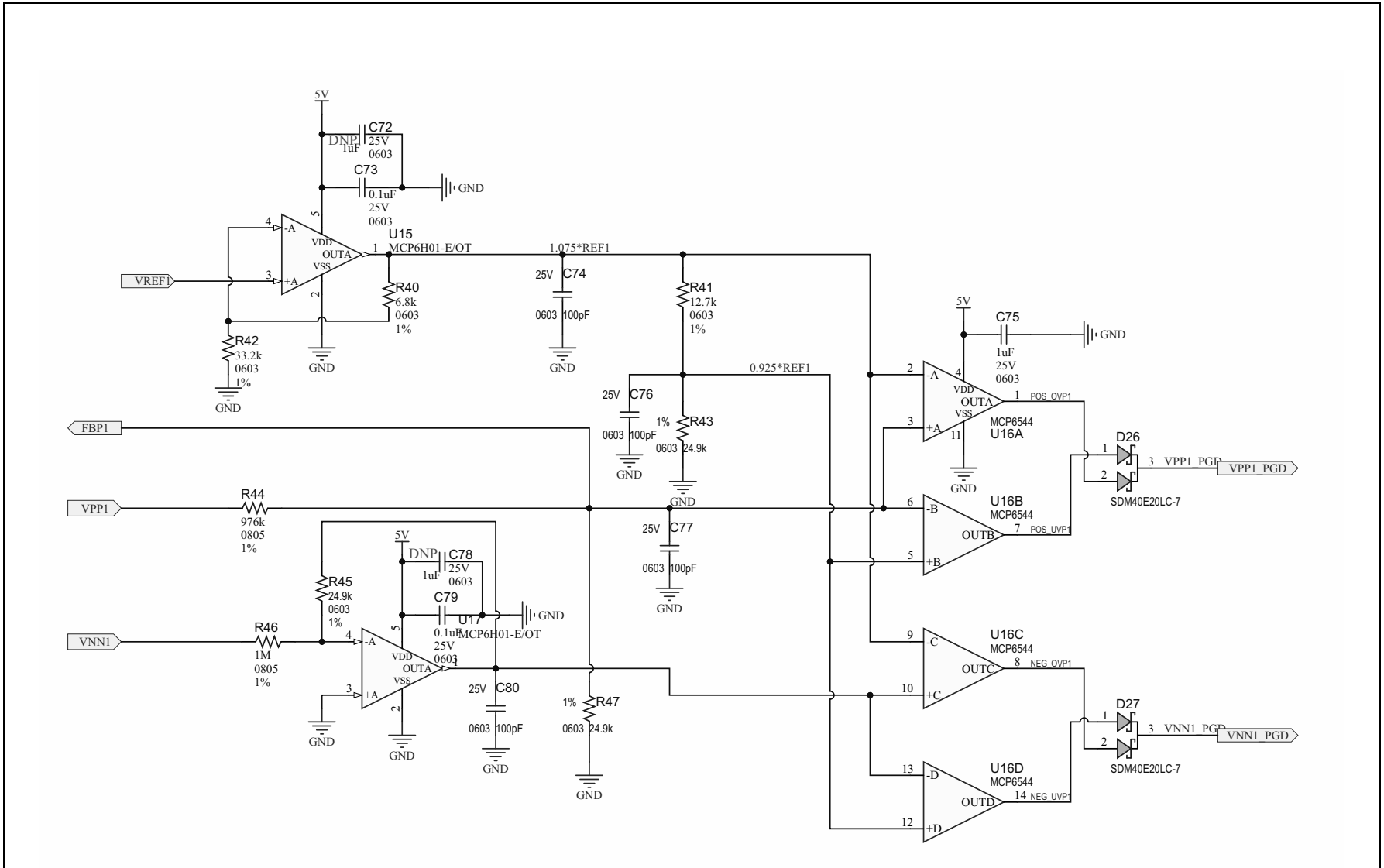
A.7 SCHEMATIC — VPP0/VNN0 POWER GOOD



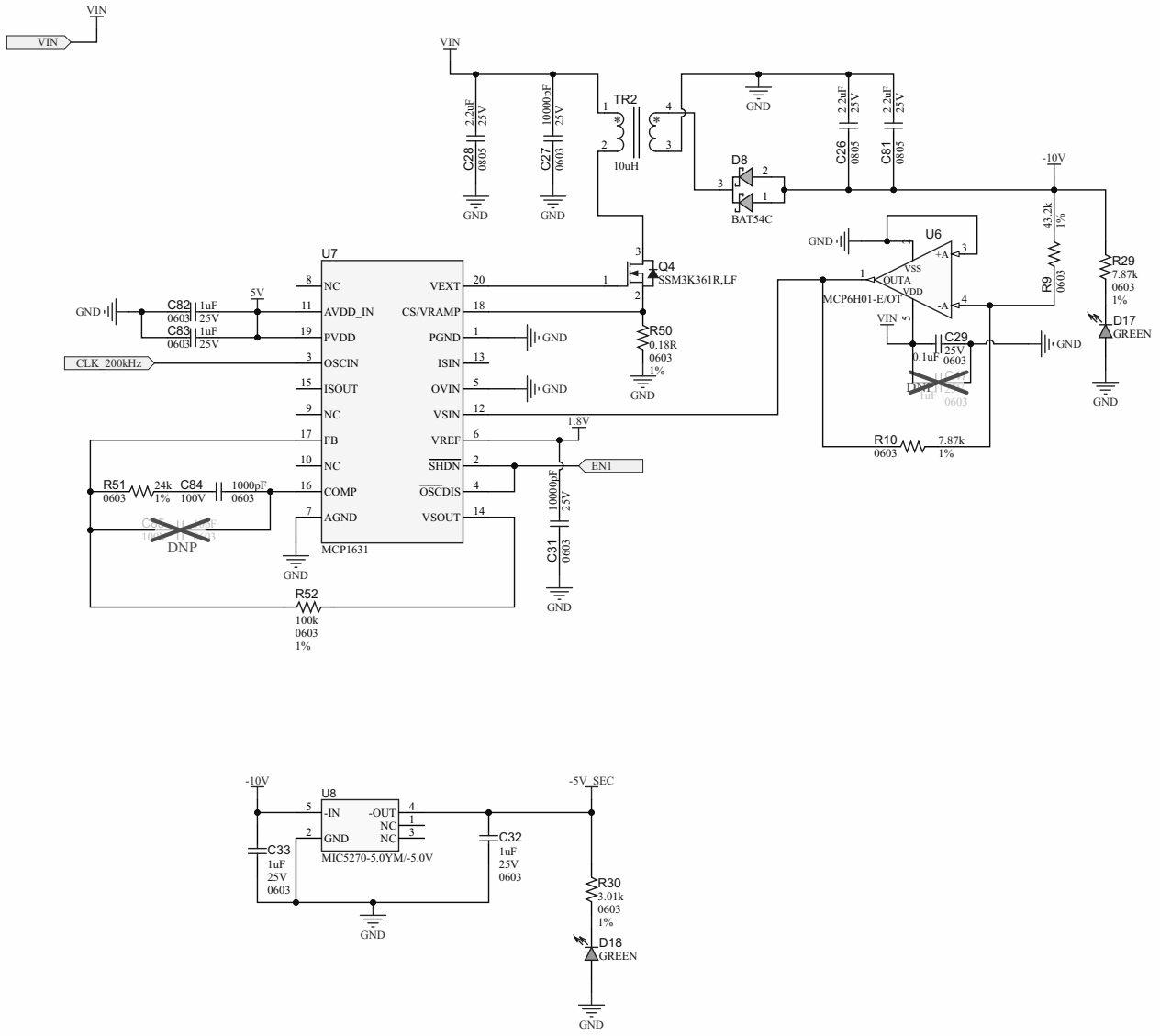
A.8 SCHEMATIC — VPP1/VNN1



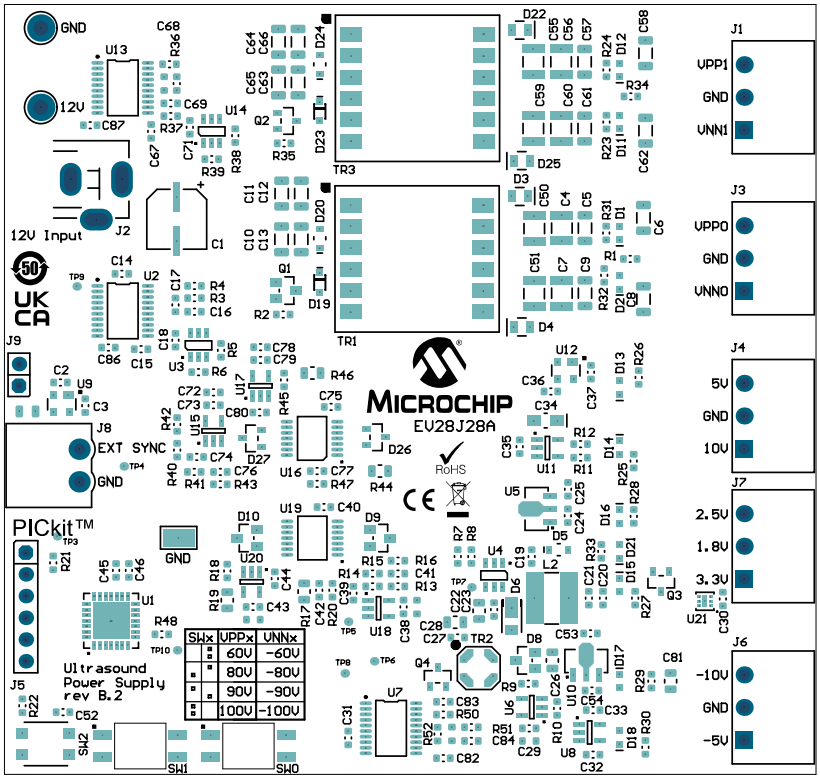
A.9 SCHEMATIC — VPP1/VNN1 POWER GOOD



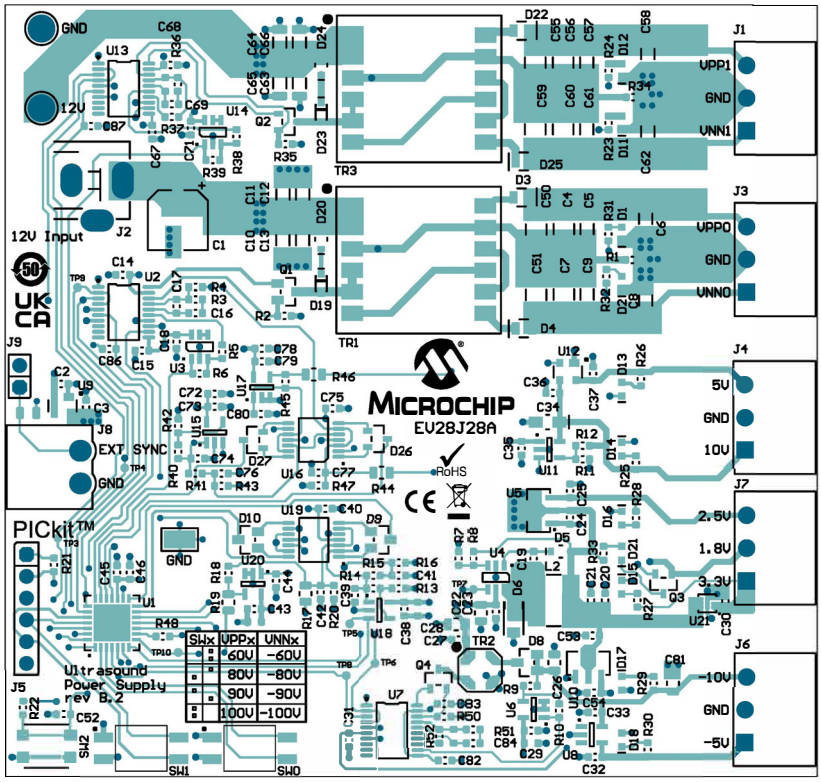
A.10 SCHEMATIC — -10V AND -5V



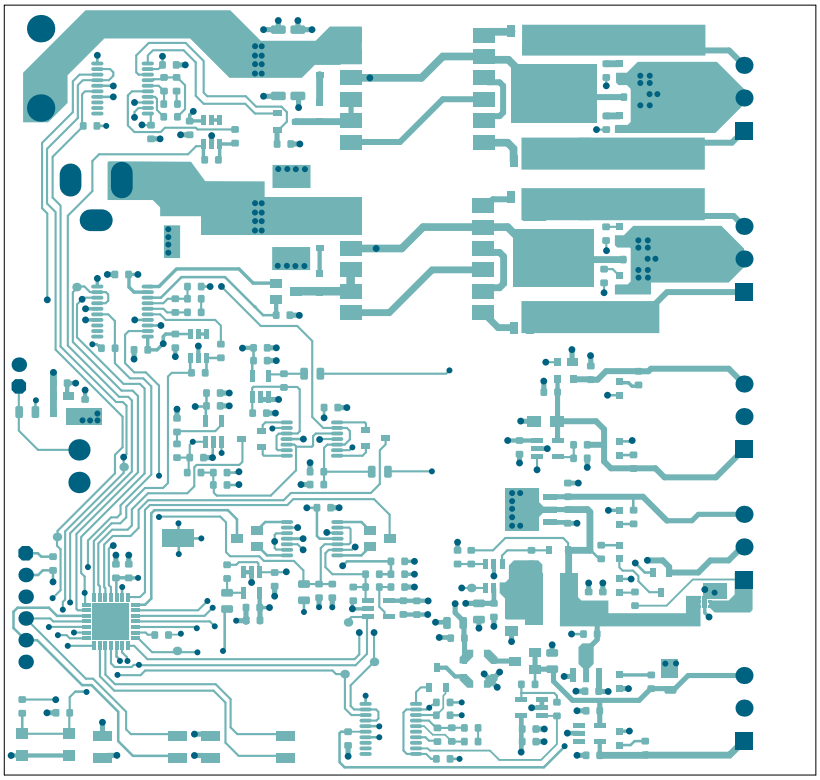
A.11 TOP SILK



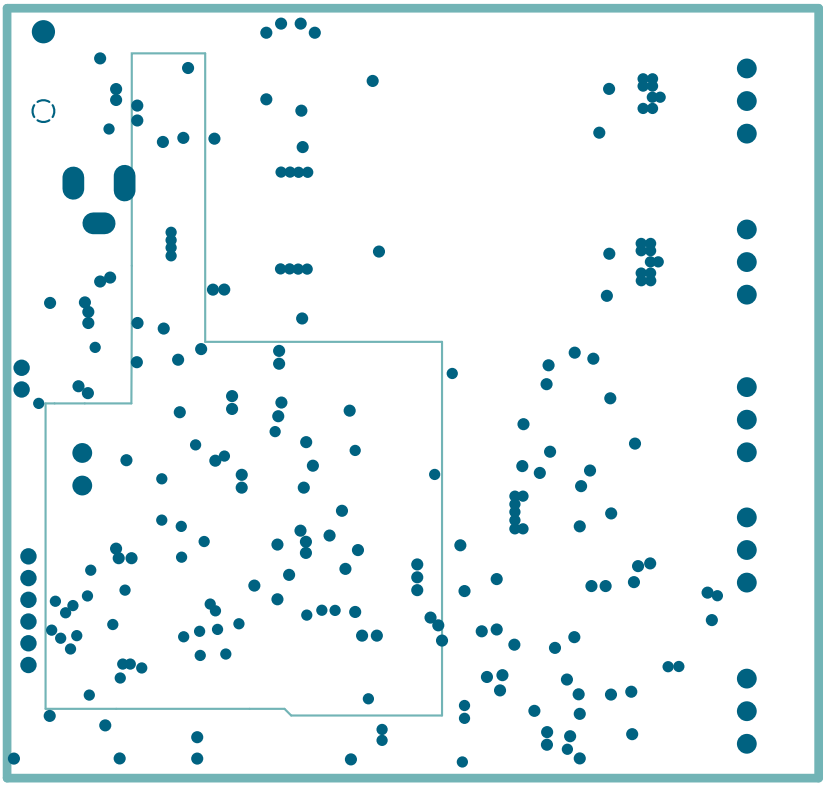
A.12 TOP COPPER AND SILK



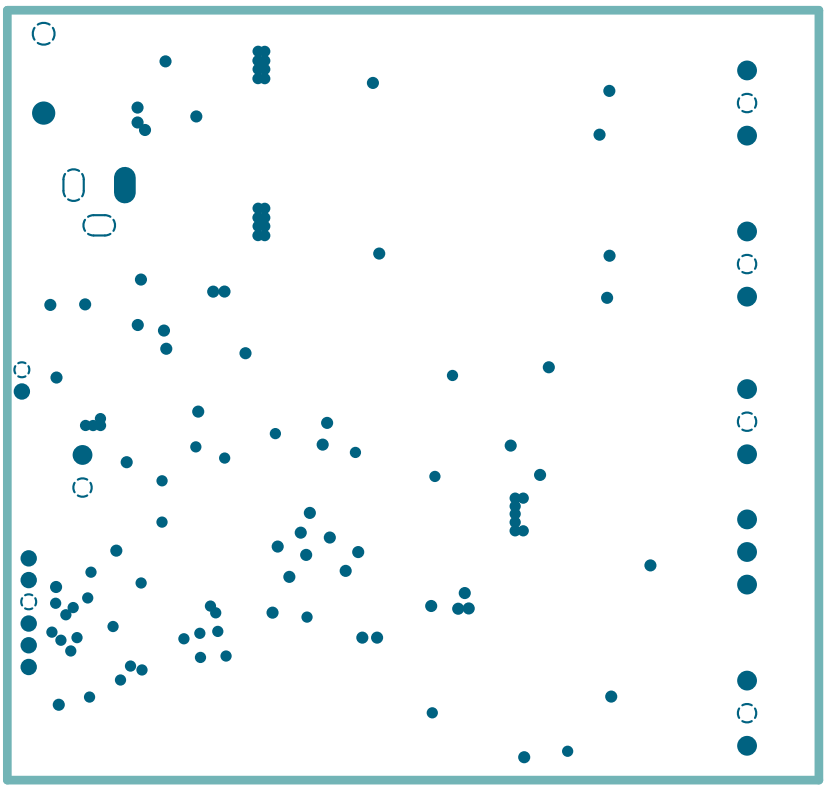
A.13 TOP COPPER



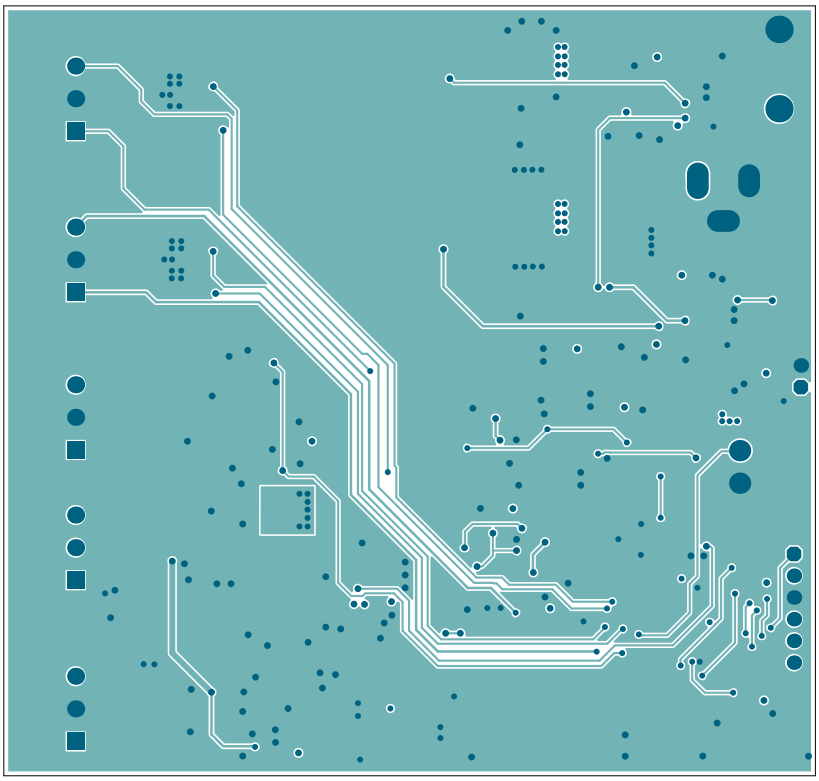
A.14 MID LAYER 1



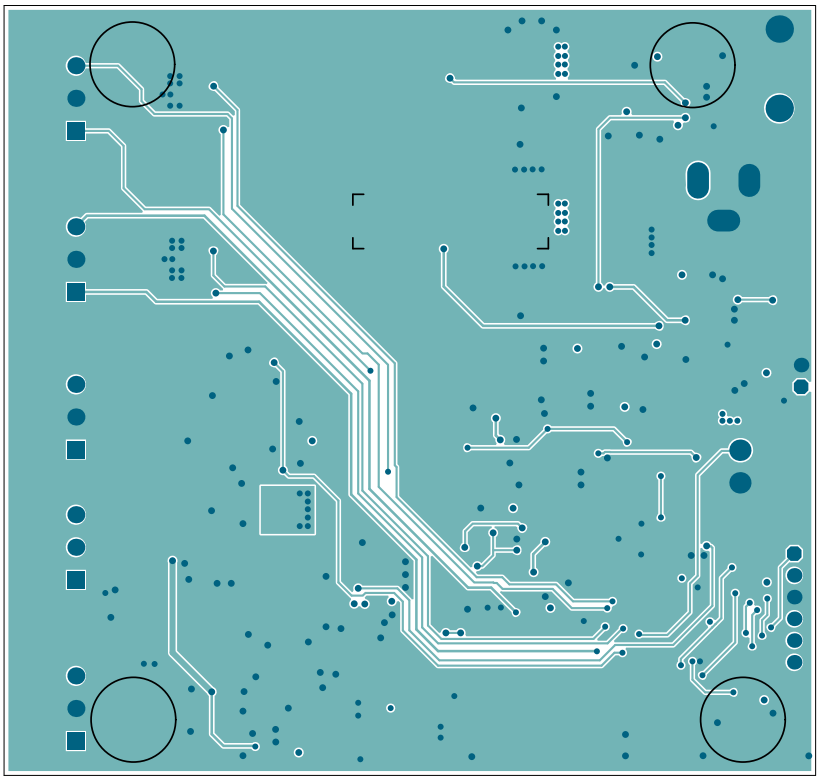
A.15 MID LAYER 2



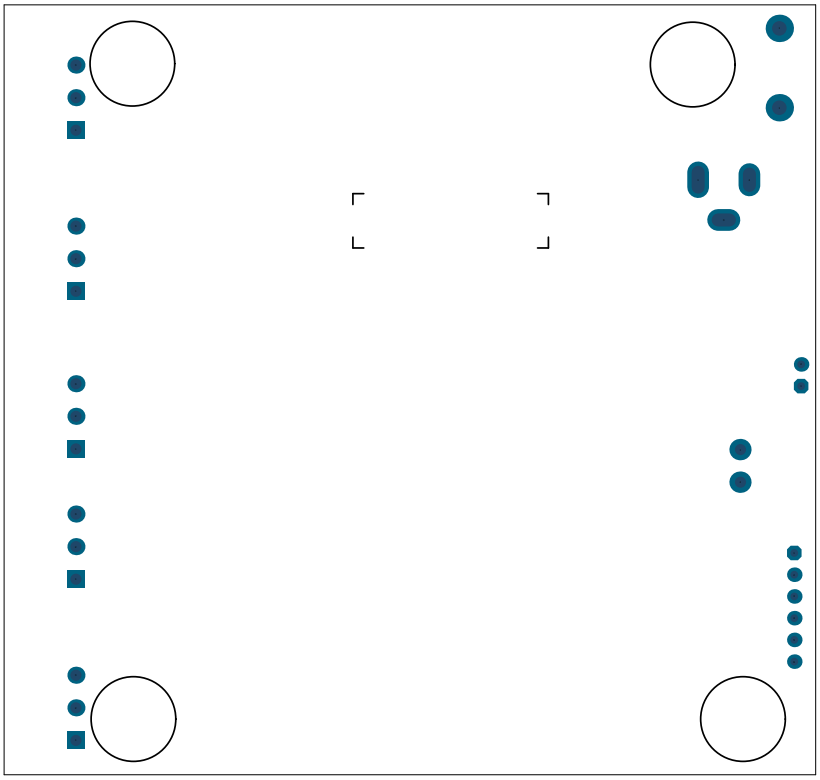
A.16 BOTTOM COPPER



A.17 BOTTOM COPPER AND SILK



A.18 BOTTOM SILK



Appendix B. Bill of Materials (BOM)

TABLE B-1: BILL OF MATERIALS

Qty.	Reference	Description	Manufacturer	Part Number
1	C1	Capacitor, Aluminum, 47 µF, 25V, 20%, SMD, F55	United Chemi-Con	EMVA250ADA470MF55G
23	C2, C3, C14, C15, C18, C24, C25, C32, C33, C35, C36, C37, C40, C45, C52, C53, C54, C67, C68, C71, C75, C82, C83	Capacitor, Ceramic, 1 µF, 25V, 10%, X7R, SMD, 0603	Wurth Elektronik	885012206076
8	C4, C7, C50, C51, C55, C56, C59, C60	Capacitor, Ceramic, 0.22 µF, 200V, 10%, X7R, SMD, 1210	KEMET	C1210C224K2RAC7800
8	C5, C6, C8, C9, C57, C58, C61, C62	Capacitor, Ceramic, 1000 pF, 250V, 5%, NPO, SMD, 1206	KEMET	C1206C102KAGECAUTO
6	C10, C11, C12, C64, C65, C66	Capacitor, Ceramic, 0.1 µF, 25V, 10%, X7R, SMD, 1206	KEMET	C1206F104K3RACTU
2	C13, C63	Capacitor, Ceramic, 0.22 µF, 25V, 10%, X7R, SMD, 1206	AVX Corporation	12063C224KAT2A
3	C16, C69, C84	Capacitor, Ceramic, 1000 pF, 100V, 5%, NP0, SMD, 0603	Murata Electronics®	GRM1885C2A102JA01J
1	C17	Capacitor, Ceramic, 10 pF, 100V, 5%, NP0, SMD, 0603	Murata Electronics	GRM1885C2A100JA01D
7	C19, C29, C38, C43, C46, C73, C79	Capacitor, Ceramic, 0.1 µF, 25V, 20%, X7R, SMD, 0603	KEMET	C0603C104M3RACTU
3	C20, C21, C30	Capacitor, Ceramic, 10 µF, 10V, 20%, X5R, SMD, 0603	Samsung	CL10A106MP8NNNC
4	C22, C26, C28, C81	Capacitor, Ceramic, 2.2 µF, 25V, 10%, X7R, SMD, 0805	Wurth Electronics	885012207079
5	C23, C27, C31, C86, C87	Capacitor, Ceramic, 10000 pF, 25V, 10%, X7R, SMD, 0603	Samsung Electro-Mechanics	CL10B103KA8NNNC
1	C34	Capacitor, Tantalum, 2.2 µF, 16V, 20%, 4.9Ohm, SMD, A	Panasonic® - ECG	ECS-T1CY225R
8	C39, C41, C42, C44, C74, C76, C77, C80	Capacitor, Ceramic, 100 pF, 25V, 10%, NP0, SMD, 0603	AVX Corporation	06033A101KAT2A

Note: 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

Qty.	Reference	Description	Manufacturer	Part Number
11	D1, D2, D11, D12, D13, D14, D15, D16, D17, D18, D21	Diode, LED, Green, 2.2V, 25 mA, 15mcd, Clear, SMD, 0603	Kingbright Electronic Co., Ltd.	APT1608SGC
4	D3, D4, D22, D25	Diode, Rectifier, Small Signal Switching, 1V, 250 mA, 150V, MicroMELF	Vishay Semiconductor Diodes Division	BAV302-TR
1	D5	Diode, Rectifier, 855 mV, 300 mA, 75V, SOD-323	Diodes Incorporated®	1N4148WS-7-F
1	D6	Diode, Schottky, 320 mV, 1A, 20V, POWERDI-123	Diodes Incorporated	DFLS120L-7
1	D8	Diode, Schottky, Array, 800 mV, 200 mA, 30V, SOT-23-3	Fairchild Semiconductor®	BAT54C
4	D9, D10, D26, D27	Diode, Schottky, Array, 20V, SOT23-3	Digi-Key® Electronics	SDM40E20LC-7DICT-ND
2	D19, D23	Diode, Rectifier, 620 mV, 2A, 30V, SOD-323F	Nexperia USA Inc.	PMEG3020EJ,115
2	D20, D24	Diode, Zener, 68V, 300 mW, SOD-323	NXP Semiconductors	BZX384-C68,115
5	J1, J3, J4, J6, J7	Connector, Header-3.81, Male, 1x3, Shrouded, TH, R/A	Molex, LLC	0395121003
1	J2	Connector, Jack, Power Barrel, Black, Male, TH, RA	CUI Devices	PJ-002BH
1	J5	Connector, Header-2.54, Male, 1x6, Tin, 5.84 MH, TH, Vertical	Sullins Connector Solutions	PEC06SAAN
1	J8	Connector, Header-3.81, Male, 1x2, Tin, Shroud, 3.50 MH, TH, R/A	Molex, LLC	0395121002
1	J9	Connector, Header-2.54, Male, 1x2, Tin, 6.75 MH, TH, Vertical	Molex, LLC	0901200122
1	J10	Connector, TP, Loop, Tin, SMD	Harwin Inc	S1751-46R
1	L2	Inductor, 15 µH, 1.16A, 20%, SMD, MSS6132	Coilcraft	MSS6132-153ML
3	Q1, Q2, Q4	Transistor, FET, N-CH, 100V, 3.5A, 1.2W, SOT-23-3	Toshiba	SSM3K361R,LF
1	Q3	Transistor, FET, N-CH, 60V, 250 mA, 370 mW SOT-23-3	Diodes Incorporated®	2N7002E-7-F
2	R1, R34	Resistor, Thin Film, 10R, 1%, 1/16W, SMD, 0603	TE Connectivity, Ltd.	CPF0603F10RC1
3	R2, R35, R50	Resistor, Thick Film, 0.18R, 1%, 1/10W, 0603	Panasonic® - ECG	ERJ-3RSFR18V
3	R3, R36, R51	Resistor, Thick Film, 24k, 1%, 1/10W, SMD, 0603	Panasonic® - ECG	ERJ-3EKF2402V
3	R4, R37, R52	Resistor, Thin Film, 100k, 1%, 1/8W, SMD, 0603	Vishay	MCT06030C1003FP500
4	R5, R21, R22, R38	Resistor, Thick Film, 10k, 5%, 1/10W, SMD, 0603	Panasonic® - ECG	ERJ-3GEYJ103V
2	R6, R39	Resistor, Thick Film, 240k, 1%, 1/10W, SMD, 0603	Panasonic® - ECG	ERJ-3EKF2403V
1	R7	Resistor, Thick Film, 10k, 1%, 1/10W, SMD, 0603	ROHM Semiconductor	MCR03EZPFX1002

Note: 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

Qty.	Reference	Description	Manufacturer	Part Number
1	R8	Resistor, Thick Film, 34.8k, 1%, 1/10W, SMD, 0603	Panasonic Electronic Components	ERJ-3EKF3482V
1	R9	Resistor, Thick Film, 43.2k, 1%, 1/10W, SMD, 0603	Panasonic	ERJ-3EKF4322V
3	R10, R25, R29	Resistor, Thick Film, 7.87k, 1%, 1/10W, SMD, 0603	Yageo Corporation	9T06031A7871FBHFT
1	R11	Resistor, Thick Film, 7.15k, 1%, 1/10W, SMD, 0603	Panasonic Electronic Components	ERJ-3EKF7151V
1	R12	Resistor, Thick Film, 1.02k, 1%, 1/10W, SMD, 0603, Automotive AEC-Q200	Panasonic	ERJ-3EKF1021V
2	R13, R42	Resistor, Thin Film, 33.2k, 1%, 1/10W, SMD, 0603	Panasonic	ERJ-3EKF3322V
2	R14, R40	Resistor, Thick Film, 6.8k, 1%, 1/10W, SMD, 0603	Yageo Corporation	RC0603FR-076K8L
2	R15, R41	Resistor, SMD, 12.7k, 1%, 1/10W, 0603, AEC-Q200	Panasonic Electronic Components	ERJ-3EKF1272V
6	R16, R18, R20, R43, R45, R47	Resistor, Thick Film, 24.9k, 1%, 1/10W, SMD, 0603	Yageo Corporation	RC0603FR-0724K9L
2	R17, R44	Resistor, Thick Film, 976k, 1%, 1/8W, SMD, 0805	Panasonic	ERJ-6ENF9763V
2	R19, R46	Resistor, Thick Film, 1M, 1%, 1/8W, SMD, 0805	Panasonic	ERJ-6ENF1004V
4	R23, R24, R31, R32	Resistor, Thick Film, 300R, 1%, 1/10W, SMD, 0603	Yageo Corporation	RC0603FR-07300RL
2	R26, R30	Resistor, Thick Film, 3.01k, 1%, 1/10W, SMD, 0603	Panasonic	ERJ-3EKF3011V
3	R27, R28, R33	Resistor, Thick Film, 499R, 1%, 1/10W, SMD, 0603	Panasonic	ERJ-3EKF4990V
1	R48	Resistor, Thick Film, 1k, 1%, 1/10W, SMD, 0603	Vishay	CRCW06031K00FKEA
2	SW0, SW1	Switch, DIP, 2 SPST, 24V, 25 mA, SMD	Wurth Electronics	418121270802
1	SW2	Switch, TACT, SPST, 16V, 100 mA, SMD	Bourns Inc.	7914G-1-032E
2	TP1, TP2	Connector, TP, PIN, Tin, TH	Harwin Plc.	H2121-01
2	TR1, TR3	Transistor, SMPS, Hexa-Path, 6 Coils, 1:1, SMD	Coilcraft	HPH2-0116
1	TR2	Inductor, 10 µH, 1.1A, 20%, SMD, L4.4W4.4H1.2	Coilcraft	LPD4012-103MRC

Note: 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) – MICROCHIP PARTS

Qty	Reference	Description	Manufacturer	Part Number
1	U1	MCU, 8-bit, 32 MHz, 8K, 1K, 28-QFN	Microchip Technology Inc.	PIC16F1716-I/ML
3	U2, U7, U13	Analog, PWM, Controller, 2 MHz, TSSOP-20	Microchip Technology Inc.	MCP1631T-E/ST
2	U3, U14	Analog, Comparator, 1-CH, SOT-23-6	Microchip Technology Inc.	MCP65R41T-2402E/CHY
1	U4	Analog, Switcher, Buck 2V to 15V, SOT-23-6	Microchip Technology Inc.	MCP16301T-E/CH
1	U5	Analog, LDO, 2.5V, SOT-89-3	Microchip Technology Inc.	MCP1700T-2502E/MB
5	U6, U15, U17, U18, U20	Analog, OPAMP, 1-Ch, 1.2 MHz, SOT-23-5	Microchip Technology Inc.	MCP6H01T-E/OT
1	U8	Analog, LDO, Negative, 5.0V, 100 mA, SOT23-5	Microchip Technology Inc.	MIC5270-5.0YM5-TR
2	U9, U12	Analog, LDO, 5V, SOT-143	Microchip Technology Inc.	MIC5203-5.0YM4-TR
1	U10	Analog, LDO, 1.8V, SOT-89-3	Microchip Technology Inc.	MCP1700T-1802E/MB
1	U11	Analog, LDO, ADJ, 150 mA, SOT-23-5	Microchip Technology Inc.	MIC5205YM5-TR
2	U16, U19	Analog, Comparator, 4-CH, TSSOP-14	Microchip Technology Inc.	MCP6544T-E/ST
1	U21	Analog, LDO, 3.3V, TDFN-6	Microchip Technology Inc.	MIC94345-SYMT-T5
1	PCB1	Printed Circuit Board	Microchip Technology Inc.	11267-R2

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, ASSY W/REV Level (Small Modules) Per MTS-0002	—	
4	PAD1, PAD2, PAD3, PAD4	Mechanical Hardware Rubber Pad, Cylindrical, 0.374" x 0.189" Clear	Essentra Components	RBS-35

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
0	C47, C48, C49, C72, C78	Capacitor, Ceramic, 1 µF, 25V, 10%, X7R, SMD, 0603	Wurth Electronics	885012206076
0	C70, C85	Capacitor, Ceramic, 10 pF, 100V, 5%, NP0, SMD, 0603	Murata	GRM1885C2A100JA01D
0	R49	Resistor, TKF, 50R, 1%, 1/8W, SMD, 0805	Vishay/Dale	CRCW080550R0FKTA

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 and Performance Curves

C.1 TYPICAL WAVEFORMS AND PERFORMANCE CURVES

This chapter shows typical performance parameters and curves for the Ultrasound Power Board Reference Design.

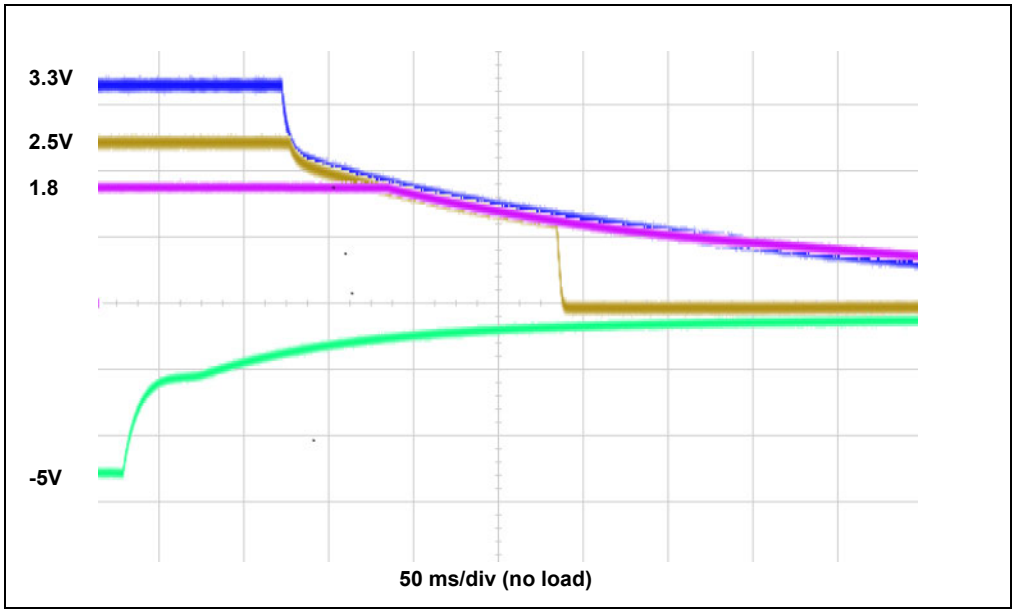


FIGURE C-1: *Power Down: 1.8V, 2.5V, 3.3V, -5V.*

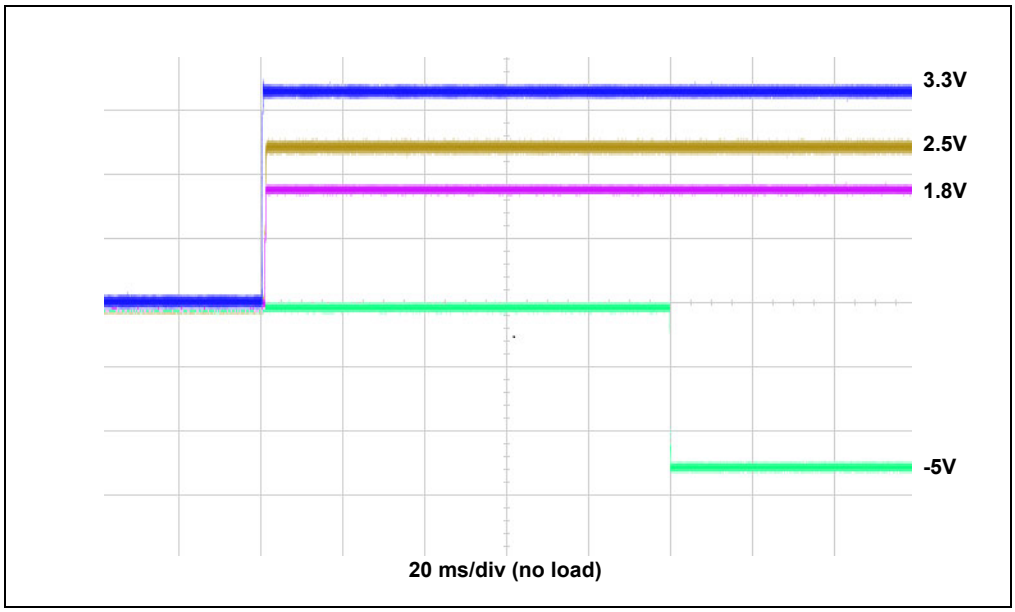


FIGURE C-2: *Power Up: 1.8V, 2.5V, 3.3V, -5V.*

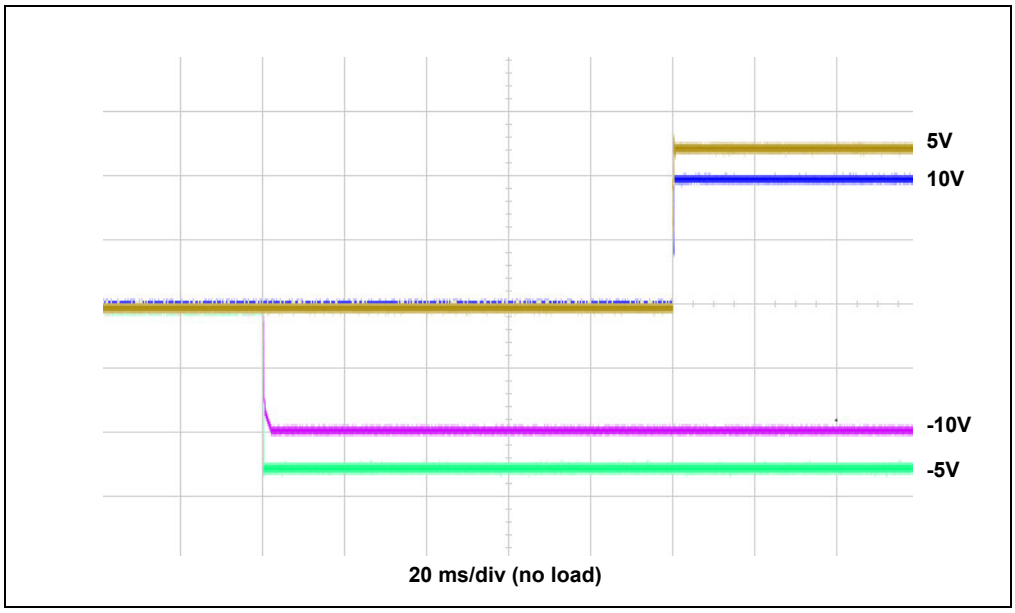


FIGURE C-3: *Power Up: 10V, -10V, 5V, -5V.*

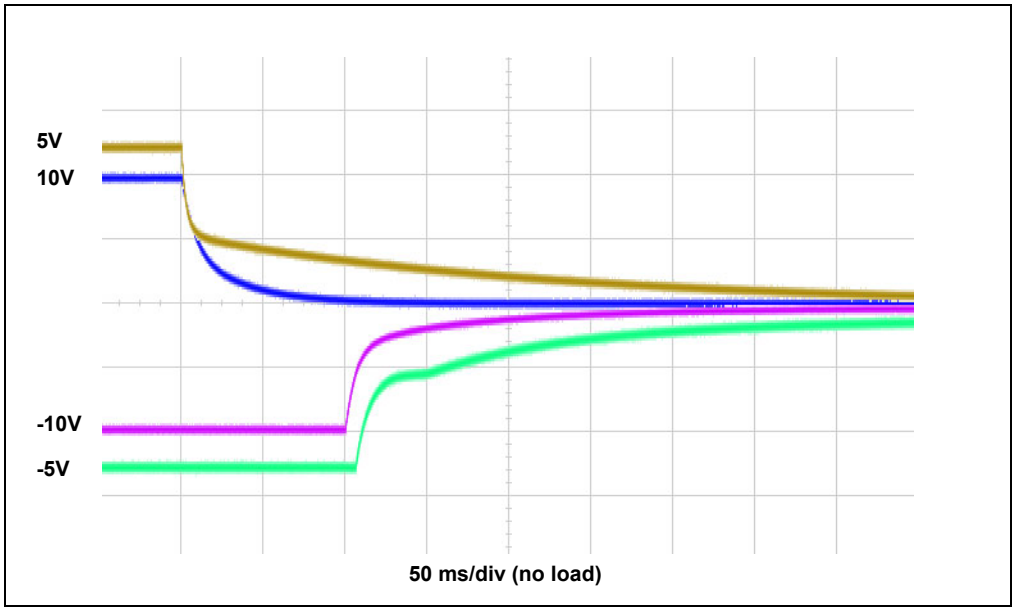


FIGURE C-4: *Power Down: 10V, -10V, 5V, -5V.*

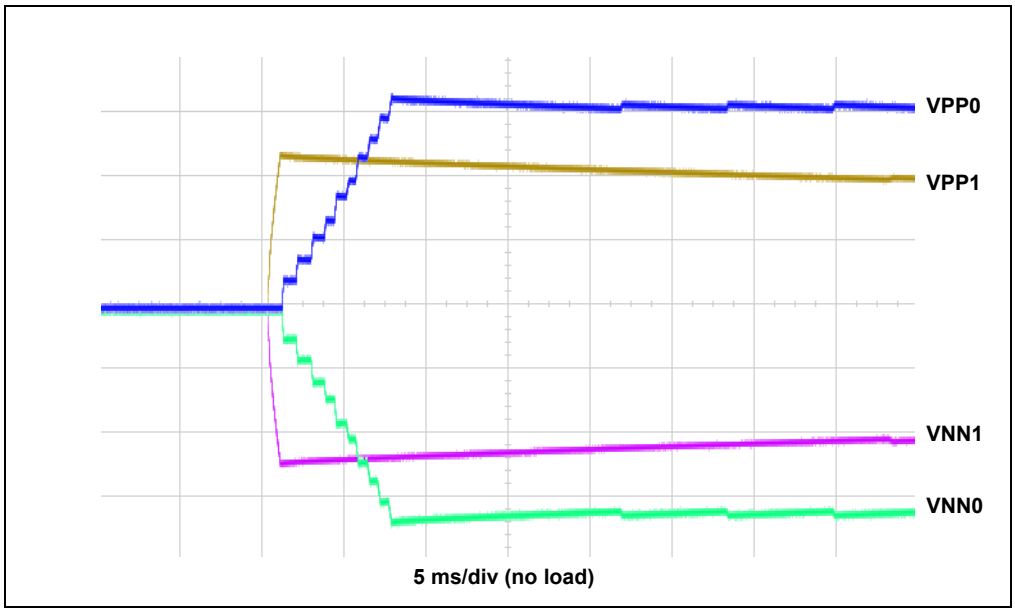


FIGURE C-5: *Power Up: VPP0, VNN0, VPP1, VNN1.*

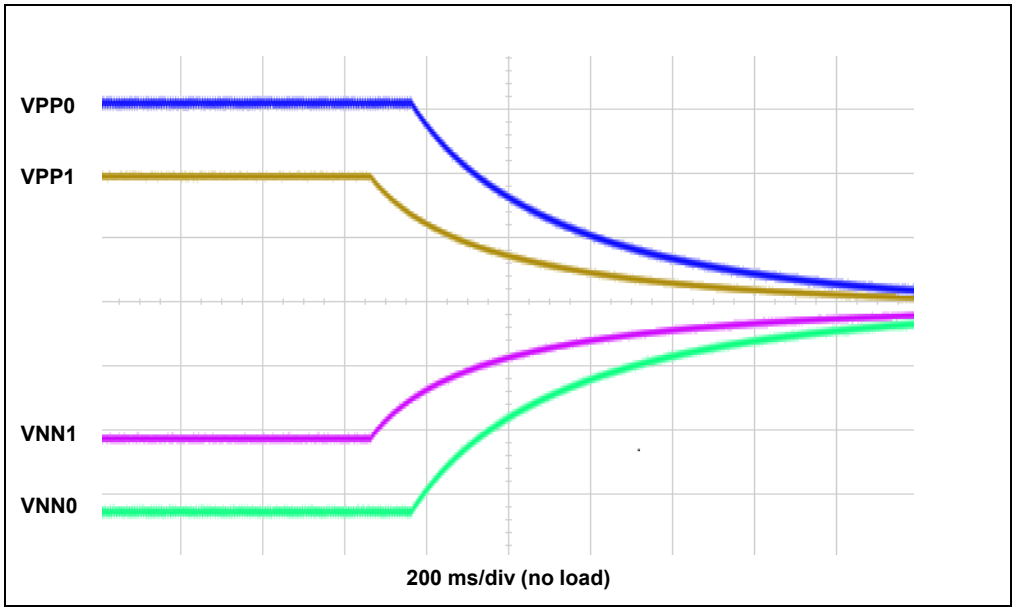


FIGURE C-6: *Power Down: VPP0, VNN0, VPP1, VNN1.*

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