MIC45212 Current Sharing Reference Design

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Object of Declaration: MIC45212

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Derek Carlson
VP Development Tools

11-NOV-16
Date

NOTES:

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 "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 MIC45212. Items discussed in this chapter include:

- Document Layout
- Conventions Used in this Guide
-
- Recommended Reading
- The Microchip Web Site
- Customer Support
- Document Revision History

DOCUMENT LAYOUT

This document describes how to use the MIC45212 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 MIC45212.
- **Chapter 2. "Installation and Operation"** – Includes instructions on installing and starting the Microchip Chip Manager application.
- **Appendix A. "Schematic and Layouts"** – Shows the schematic and layout diagrams for the MIC45212.
- **Appendix B. "Bill of Materials (BOM)"** – Lists the parts used to build the MIC45212.

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	<u>*File>Save*</u>
Bold characters	A dialog button	Click **OK**
	A tab	Click the **Power** tab
N'Rnnnn	A number in verilog format, where N is the total number of digits, R is the radix and n is a digit.	4'b0010, 2'hF1
Text in angle brackets < >	A key on the keyboard	Press <Enter>, <F1>
Courier New font:		
Plain Courier New	Sample source code	`#define START`
	Filenames	`autoexec.bat`
	File paths	`c:\mcc18\h`
	Keywords	`_asm, _endasm, static`
	Command-line options	`-Opa+, -Opa-`
	Bit values	`0, 1`
	Constants	`0xFF, 'A'`
Italic Courier New	A variable argument	*`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 MIC45212. Other useful documents are listed below. The following Microchip document is available and recommended as a supplemental reference resource:

MIC45212-1/-2 Data Sheet – *"MIC45212-1/-2 26V/14A DC-to-DC Power Module Data Sheet"* (DS20005607A)

MIC45212-1/-2 Application Note – *"MIC45212-1/MIC45212-2 64-Lead H4QFN 12mm x 12mm Package Soldering Guidelines"* (ANLPS205)

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- **General Technical Support** – Frequently Asked Questions (FAQs), technical support requests, online discussion groups, Microchip consultant program member listing
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- Technical Support

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Technical support is available through the web site at: http://www.microchip.com/support.

DOCUMENT REVISION HISTORY

Revision A (February 2017)

- Initial Release of this Document.

MIC45212 CURRENT SHARING REFERENCE DESIGN

Table of Contents

Chapter 1. Product Overview

1.1 INTRODUCTION

This chapter provides an overview of the MIC45212 Current Sharing Reference Design and covers the following topics:

- MIC45212 Short Overview
- What Is the MIC45212 Current Sharing Reference Design?
- What Does the MIC45212 Current Sharing Reference Design Kit Include?

1.2 MIC45212 SHORT OVERVIEW

The MIC45212 is a synchronous step-down regulator module featuring a unique adaptive on-time control architecture. The module incorporates a DC-to-DC controller, power MOSFETs, bootstrap diode, bootstrap capacitor and an inductor in a single package, simplifying the design and layout process for the end user.

The fully-optimized design can deliver up to 14A current under a wide input voltage range of 4.5V to 26V without requiring additional cooling.

The MIC45212 comes in two architecture variants: HyperLight Load (for low power consumption at light loads) and Hyper Speed Control (for ultra-fast transient response).

The MIC45212 Current Sharing Reference Design uses only the Hyper Speed Control variant for improved load transient response.

The device is available in 64-pin 12 mm x 12 mm x 4 mm QFN package that provide good heat transfer to the PCB copper planes.

1.3 MIC45212 Key Features

- Up to 14A output current
- No compensation required
- >93% efficiency
- Output voltage: 0.8V to 5.5V with 1% accuracy
- Adjustable switching frequency from 200 kHz to 600 kHz
- HyperLight Load (MIC45212-1) improves light load efficiency
- Hyper Speed Control (MIC45212-2) architecture enables fast transient response
- -40°C to +125°C junction temperature range
- Thermal-Shutdown protection
- Short-circuit protection with hiccup mode
- Adjustable current limit
- Available in 64-pin 12 mm x 12 mm x 4 mm QFN package

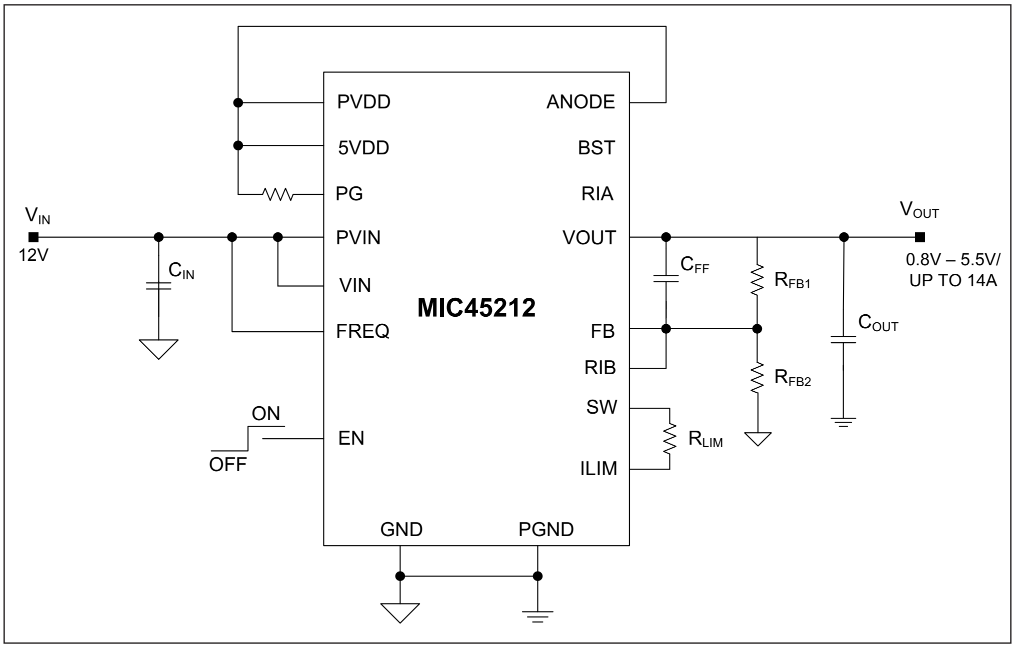


FIGURE 1-1: *Typical MIC45212 Application.*

1.4 WHAT IS THE MIC45212 CURRENT SHARING REFERENCE DESIGN?

The MIC45212 Current Sharing Reference Design is used to demonstrate the Microchip Technology's MIC45212 device in a load sharing configuration in order to double the current capabilities and improve load transient response. The design uses two MIC45212 modules in the typical schematic with the addition of an operational amplifier, a bipolar transistor and some passive components. The output current is measured using both the Master and Slave internal inductor DCR, and the difference generates a correction signal in the form of a current injected into the Slave feedback node. By setting the default value of the Slave's output voltage to a lower value than the Master, the correction signal current can be assumed to always be unipolar. Therefore, the circuit implementation is simplified.

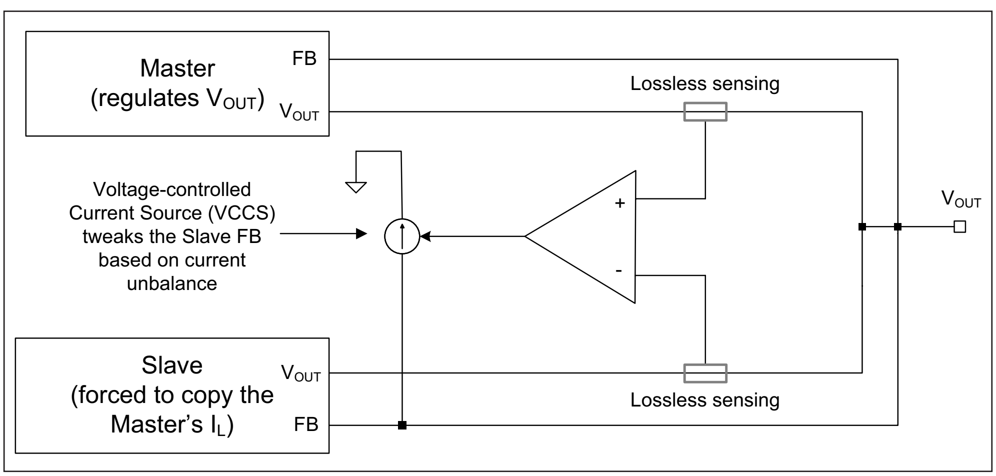


FIGURE 1-2: *MIC45212 Current Sharing Reference Design Block Diagram*

This current measuring and adjusting scheme does not affect the overall efficiency as the current sharing control system exploits loss-less inductor DCR current sensing, while using low-power components.

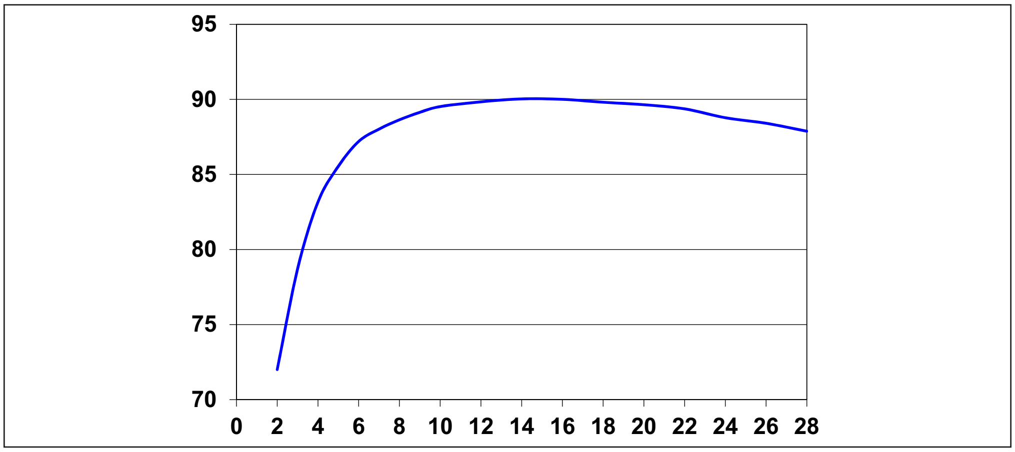


FIGURE 1-3: *MIC45212 Current Sharing Reference Design Efficiency (V_{IN} = 12V, V_{OUT}= 3.3V)*

1.5 WHAT DOES THE MIC45212 CURRENT SHARING REFERENCE DESIGN KIT INCLUDES?

The MIC45212 Current Sharing Reference Design kit includes the following items:

- MIC45212 Current Sharing Reference Design (ADM00777)
- Important Information Sheet

NOTES:

Chapter 2. Installation and Operation

2.1 INTRODUCTION

The MIC45212 has been developed for applications that require a high amount of current, in excess on 14A with good line and load regulation. The MIC45212 uses an adaptive on-time control scheme to obtain a constant switching frequency in steady state and to simplify the control compensation. The constant on-time architecture also helps decrease the load transient response time compared to a fixed-frequency controller.

The MIC45212 Current Sharing Reference Design board contains two MIC45212s operating in parallel without the need for switching frequency synchronization. This mode of parallel operation for COT buck devices is covered by U.S. Patent 9,214,866. In heavy load transient conditions, both modules can concurrently help in the correction of the output voltage without the intervention of the current sharing loop, since the voltage feedback is provided to both converters. This helps decrease the reaction time even further and creates a very good response with low overshoot and undershoots.

The MIC45212 Current Sharing Reference Design doubles the output current's capabilities and improves load transient response by using two MIC45212 modules and a minimum number of external components while still providing good heat distribution. In light load situations, the Slave module can be disabled to decrease total power consumption without any variation in the output voltage.

2.2 BOARD FEATURES

The MIC45212 Current Sharing Reference Design has the following features:

- Input voltage range from 5.5V to 26V
- Output voltage (maximum recommended): 3.3V
- Maximum output current: 28A
- Current sharing error: <5% for Iout>15A
- Input filter for decreased input current ripple

2.3 GETTING STARTED

The MIC45212 Current Sharing Reference Design board is fully-assembled and tested to evaluate and demonstrate the MIC45212 modules operating in a current-sharing configuration.

2.3.1 Powering the MIC45212 Current Sharing Reference Design

Soldered terminals are available for input voltage connections. The maximum input voltage should not exceed 26V. Due to the high power necessary for the MIC45212 Current Sharing Reference Design, a powerful power supply must be used. For example, when delivering an output current of 28A at 3.3V, powered from 12V, the board uses around 8A of current, so the power supply must be able to supply more than 8A.

As an alternative, the MIC45212 Current Sharing Reference Design can be powered from two power supplies. To achieve this, the input filter inductors must be de-soldered and the power supplies connected directly to the inputs of the modules, marked VINM and VINS. In this configuration, the power supplies can be of slightly different voltages, but they still need to be able to deliver a combined power bigger then the total output power.

The minimum Input Voltage is determined by the control circuitry. The MIC45212 Current Sharing Reference Design features a 5V LDO (MCP1804T) to deliver a stabilized voltage to the control operational amplifier and both modules' pull-up resistors. The MCP1804T is powered from the biggest voltage potential of the two modules' inputs through low voltage-drop diodes.

Please note that because of the high input current, the cable voltage drop must be considered when setting the power supply voltage.

The MIC45212 Current Sharing Reference Design was developed to be used as a demonstration application of the ability of the MIC45212 to drive high current loads with high precision and very good load transient response.

After connecting the power supply, both modules will be powered and enabled and the board will deliver the nominal output voltage.

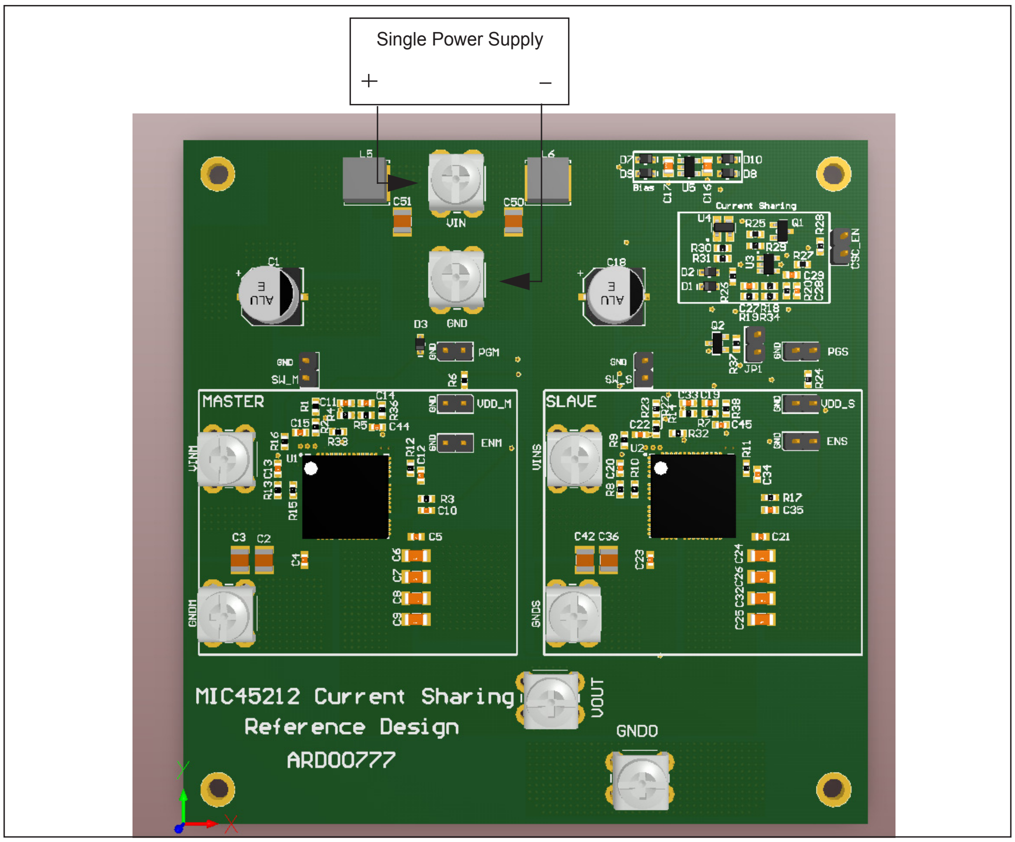


FIGURE 2-1: *MIC45212 Current Sharing Reference Design Board Setup*

2.4 BOARD TESTING

Before powering the MIC45212 Current Sharing Reference Design board, verify that the Current Sharing Enable jumper (CSC_EN) or R28 are present.

1. Connect the input supply as shown in Figure 2-1. Please observe the polarity to

avoid board damage.

2. Connect the load (electronic load, resistive load, etc.) to the VOUT and GNDO terminals.
3. For accurate voltage measurements, a voltmeter must be connected to the board terminals for both input and output voltages.
4. Test points are available for switching node voltage and Power-Good measurements as well as Enable pins. For accurate measurement, please use the local GND as reference (all test points have local ground pairs).

Note that the input and output wires must be properly chosen to sustain the test current: at least 20AWG (0.5 mm^2) for input and 10AWG (5.26 mm^2) for output.

2.4.1 Load transient response

An important advantage of the MIC45212 Current Sharing Reference Design is the greatly-improved load transient response.

With both converters working in parallel according to the proposed scheme, the Load Transient response is almost two times better than a single-phase Constant On-Time (COT) module with the same output capacitance (80 mV vs. 150 mV, or, in a worst-case scenario,100 mA to 12A load transient).

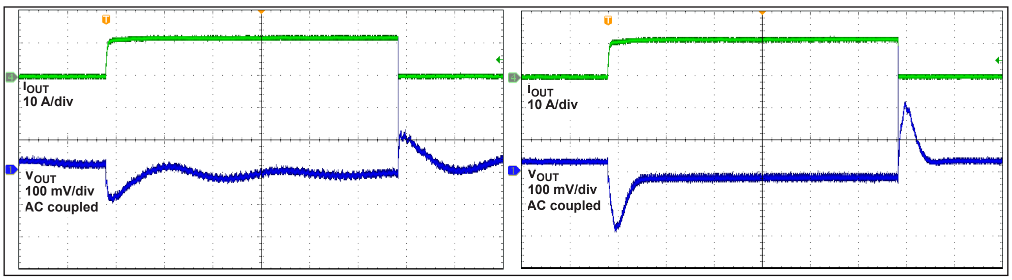


FIGURE 2-2: MIC45212 Current Sharing Reference Design Load Transient response comparison (both converters vs one converter with the same amount of output capacitance)

The non-synchronized dual-phase COT scheme allows the Slave to momentarily revert back to voltage regulation mode at the edge of the load transient (because the Slave still has its own feedback divider). This allows both Master and Slave to switch ON (or OFF) independently and simultaneously to support the load change.

2.4.2 Current Sharing balance

In high-power applications, heat is an issue, as it can cause uneven heating of components and decrease reliability. Good air flow and board cooling will help decrease temperatures, but for a reliable system, a balanced power supply is needed.

The MIC45212 Current Sharing Reference Design uses a current control scheme that balances the load between converters. This allows converters to heat evenly and prevents temperature unbalances that can cause the most heated converter to go into thermal shutdown under heavy load.

The MIC45212 Current Sharing Reference Design can typically maintains a difference between Master and Slave input current of less then 150 mA (for 4.5A Master and Slave input current), allowing the Slave to follow the Master’s current closely (see **Section 2.4.3 “How does the MIC45212 Current Sharing Reference Design work?”**).

Because of this, the input current error between Master and Slave input currents will decrease with the increase in load current (the DCR mismatch will have higher influence at heavy loads and the op-amp's input offset voltage will have moreyh7nj influence at light loads).

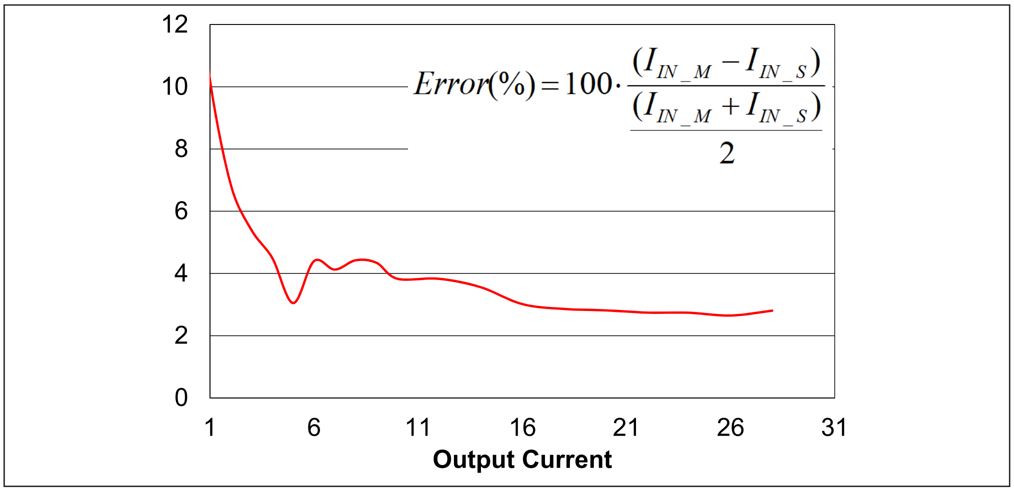


FIGURE 2-3: MIC45212 Current Sharing Reference Design Current Balance

The current sharing scheme optimally operates at increased loads while at light load the unbalance between modules increases. However, at light loads, the Slave can be disabled for decreased power consumption.

During load transient conditions, the current sharing will stabilize in less than 400 µs.

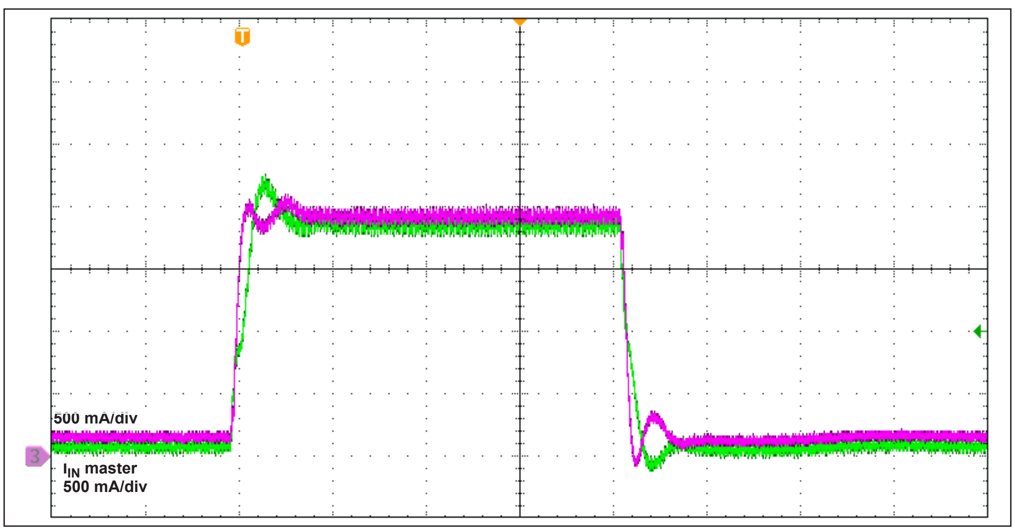


FIGURE 2-4: MIC45212 Current Sharing Balance During Load Transients (100 mA to 12A)

This response can be improved for fast switching applications by modifying the operational amplifier compensation.

2.4.3 How does the MIC45212 Current Sharing Reference Design work?

2.4.3.1 THEORY OF OPERATION

When power is applied to the MIC45212 Current Sharing Reference Design board, both Master and Slave modules power-up and start switching. The modules have different feedback resistor networks: The Master must be set to the desired output voltage and Slave must be at a lower set voltage. The board has a nominal output of 3.3V, so the Master module is set for 3.3V while the Slave nominal voltage is set for around 2.8V (based on the calculations done is **Section 2.4.3.4 "Choosing the feedback resistors"**).

The Current Sharing loop works by monitoring the inductor current of each module and adjusts the Slave's output voltage until both Master and Slave inductor current are matched. The current sharing accuracy is limited mainly by the matching of the DCR of the internal inductors of the modules, by layout symmetry and by the current sharing loop amplifier offset voltage.

The switching frequencies of the modules are not synchronized, as the MIC45212 can not be synchronized to external clock. In order to achieve this operation, output ripple to FB pin must be adequately suppressed and enough self-injected ripple must be used.

2.4.3.2 CONTROL CIRCUIT FUNCTIONALITY

The control loop is composed mainly of a low-offset, high-precision operational amplifier (e.g., the MCP6071 or the MCP6V71T), a voltage-controlled current source (small-signal NPN transistor) and a frequency compensation network. The current sensing scheme uses the inductor DCR to measure the inductor current so there is no need for external shunt resistors. This loss-less current sensing method improves efficiency, but the current sharing accuracy is limited by the matching of the inductors' DCRs.

The resulting voltage drops, which include the output voltage as a common-mode contribution, are compared by the op-amp and when any unbalance is detected. The NPN bipolar transistor is controlled to either sink more or less current, thus rising or lowering the slave output voltage. An emitter resistor is used to control the transconductance gain, and to ensure less sensitivity of bias point from ground shifts while keeping the transistor far away from saturation. A voltage drop of 200 mV to 300 mV should be used.

The operating point of the NPN transistor must be chosen so that the bias current is kept well over 10 μA to improve dynamic response.

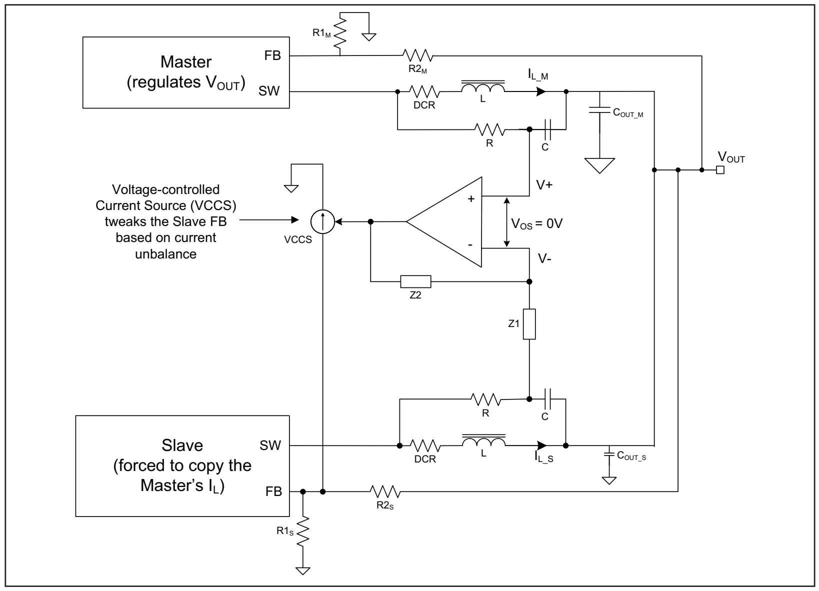


FIGURE 2-5: MIC45212 Current Sharing Reference Design Theory of Operation

The Current Sharing balance is as good as the op-amp input voltage offset, inductor DCR and board symmetry. If Master and Slave layout is not symmetrical, the difference in the current readout paths will appear as a DCR mismatch.

2.4.3.3 CHOOSING THE OPERATIONAL AMPLIFIER

The current balance of the MIC45212 Current Sharing Reference Design is determined by three factors: the inductor DCR, the chosen operational amplifier's (op-amp) input offset voltage, and the layout symmetry vs. the op-amp ground reference point. The integrated inductor DCR can vary up to 10% between devices and temperature. If the layout is done properly, its effect is minimal and can be ignored. Considering the latter, the input offset voltage of the op-amp becomes critical for precise current balancing. Very good performance can be obtained with MCP6V71T because of its very low offset voltage of 8 µV.

The current sharing error (as shown in Figure 2-3) can be approximated using the following formula:

EQUATION 2-1:

$$e = 2 \times \frac{V_{OS} + \Delta R \times I_M}{2 \times I_M \times R_M - I_M \times \Delta R + V_{OS}} \times 100$$

The inductor inside the MIC45212 has a DCR of typical 3 mΩ (R_M) and a maximum of 3.3 mΩ. I_M is the Master's input current. V_{OS} is the input offset voltage of the op-amp, and ΔR is the DCR difference between Master and Slave's inductors (typical DCR difference is under 0.1 mΩ).

The effect of the input offset of the chosen op-amp is shown next for comparison.

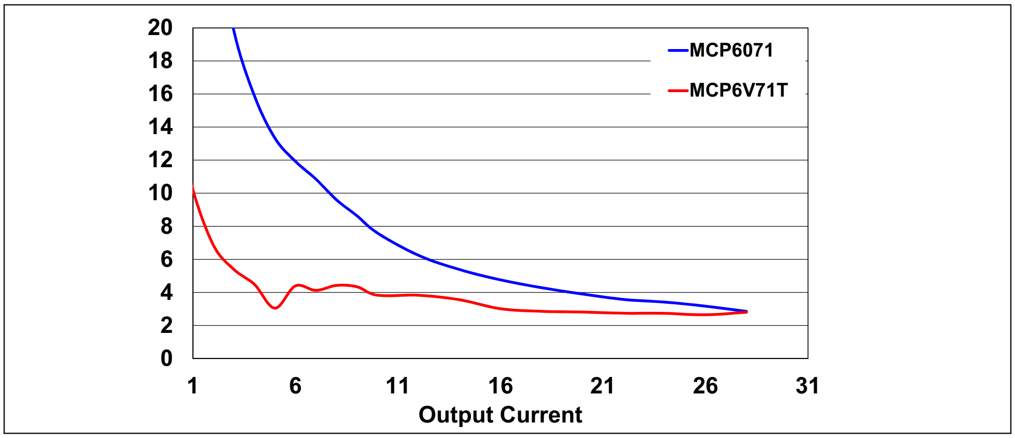


FIGURE 2-6: Current Sharing Error between MCP6071 (100 µV) and MCP6V71T (8 µV)

Using a more precise op-amp, the current sharing error is improved over all output current range, but the difference tends to minimize at full load. As the load increases and the offset voltage becomes negligible in comparison to the combination of DCR mismatch, the current sharing error asymptotically tends to the inductors DCR mismatch ΔR/R.

2.4.3.4 CHOOSING THE FEEDBACK RESISTORS

The first step is to chose the desired output voltage. The MIC45212 Current Sharing Reference Design is set for 3.3V output voltage and this will be used as an example.

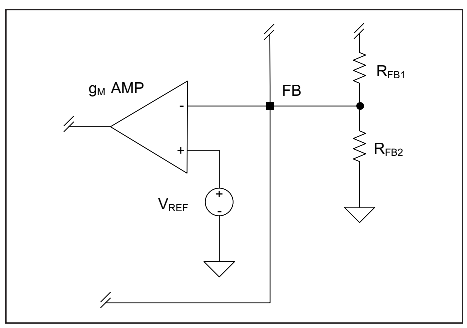


FIGURE 2-7: Voltage Divider Configuration

EQUATION 2-2:

$$V_{OUT} = V_{FB} \times \left(1 + \frac{R_{FB1}}{R_{FB2}}\right)$$

The MIC45212 feedback voltage is 0.8V.

A typical value for R_{FB1} is 10 kΩ. Using Equation 2-1, the R_{FB2} value is calculated as 3.125 kΩ but a standard value is chosen: 3.24 kΩ.

In order to calculate the feedback divider for the Slave, different steps must be used.

First, a typical value for the top resistor (R_{FB1s}) in chosen as 10 kΩ. Current from the top resistor must be calculated using Equation 2-2, and the resulting value is 250 µA.

EQUATION 2-3:

$$I_{FB1s} = \frac{(V_O - V_{REF})}{R_{FB1s}}$$

Then a DC operating point bias current (Q1 collector current) of the current sharing circuit must be chosen. Here, three considerations come into the picture:

1. the current of Q1 must be large enough to still ensure some reasonable amount of Gain-Bandwidth product f_T
2. the bias point of Q1 must be adequately desensitized against FB voltage and resistor tolerances
3. the current in the feedback divider must be large enough to dominate the slave dynamic response during load transient. In other words, the current of Q1 must be a relatively small fraction of the current flowing into R_{FB1s}.

In light of all the considerations mentioned above, a value of around 50 µA (one-fifth of the current flowing through R_{FB1s}) seems to satisfy all requirements.

EQUATION 2-4:

$$I_{CSB} = \frac{I_{FB1s}}{5}$$

Now, the bottom resistor current must be calculated using Equation 2-4. The resulting current is 200 µA.

EQUATION 2-5:

$$I_{FB2s} = I_{FB1s} - I_{CSB}$$

The bottom resistor of the feedback divider can now be calculated using Equation 2-5.

The resulting value is 4 kΩ. A standard value is chosen: 3.92 kΩ.

EQUATION 2-6:

$$R_{FB2s} = \frac{V_{REF}}{I_{FB2s}}$$

To verify that the bias current value from the current sharing circuit is still well over 10 µA (for adequate dynamic response), the new value must be calculated using Equation 2-6. The resulting current of 44.87 µA is acceptable so the resistor was a good choice.

EQUATION 2-7:

$$I_{CSB} = I_{FB2s} - \frac{V_{REF}}{R_{FB1s}}$$

Table 2-1 provides resistor values for some common output voltages.

TABLE 2-1: V_{OUT} PROGRAMMING RESISTORS LOOK-UP TABLE

V_{OUT}	R_{FB2m}	R_{FB2s}
1V	40.2 kΩ	49.9 kΩ
1.2V	20 kΩ	24.9 kΩ
1.5V	11.5 kΩ	14.3 kΩ
1.8V	8.06 kΩ	10 kΩ
2.5V	4.75 kΩ	5.9 kΩ
3.3V	3.24 kΩ	4.02 kΩ

Please note that the output voltage can’t be 0.8V due to the current sharing scheme (the Slave voltage must be always set lower than the Master’s).

2.4.3.5 CHOOSING THE DC BIAS POINT

In order to establish a predictable transconductance gain and to reduce the sensitivity to noise caused by shifts of the ground voltage, a resistor (marked R27 is the MIC45212 Current Sharing Reference Design board) is added to the emitter of the NPN transistor (marked Q1 is the MIC45212 Current Sharing Reference Design board). The drop across this resistor must be around 200 mV to 300 mV to keep the NPN transistor far away from saturation and ensure good response to changes in Output currents. If a 250 mV voltage drop is chosen, the resistor value can be calculated with Equation 2-7. The resulting value is 5.57 kΩ.

EQUATION 2-8:

$$R_{27} = \frac{V_{R27}}{I_{CSB}}$$

Again, a standard value of 5.6 kΩ is chosen and the voltage drop is recalculated with Equation 2-8. The resulting voltage drop of 250.8 mV is in the recommended interval so the resistor is a good choice.

EQUATION 2-9:

$$V_{R27} = R_{27} \times I_{csb}$$

2.4.3.6 NON-SYNCHRONIZED FREQUENCY SELECTION

In order to minimize extra ripple due to spurious cross-synchronization, the two paralleled MIC45212 modules should preferably operate with some systematic frequency difference, such that the switching patterns appear to not be correlated to each other. This is achieved by setting the Master’s frequency to the desired value and setting a slightly lower value for the Slave (the opposite is also possible).

The MIC45212 Current Sharing Reference Design board uses 600 kHz as the Master’s frequency and setting the frequency of the Slave to 450 kHz using Equation 2-9, where f_O is 600 kHz, R_{top} is 10 kΩ and R_{bottom} is 30 kΩ.

EQUATION 2-10:

$$f_{SW} = f_O \times \frac{R_{bottom}}{R_{top} + R_{bottom}}$$

2.4.3.7 INPUT FILTER SELECTION

Because of the non-synchronized operation of the MIC45212 Current Sharing Reference Design, a PI filter was selected for the input LC filter. This LC input filter would reduce the total input current ripple and decouple the input voltages of the MIC45212 converters.

The PI filter is composed of 2 x 10 µF capacitors connected in parallel and an LC filter using 1 µH inductors and the MIC45212 module’s input capacitors.

Filter damping is provided by the ESR of the additional electrolytic bulk capacitor.

The cutoff frequency (and the resonant frequency) of this filter can be calculated using Equation 2-10. The result is 9.5 kHz, well under the 150 kHz systematic frequency difference between the switching modules.

EQUATION 2-11:

$$f_0 = \frac{1}{2 \times \pi \times \sqrt{L \times C}}$$

The filter inductor must sustain the maximum input current needed by the converters and must have as little DCR as possible. There is no need for full shielded inductors as there are no fast switching currents.

The MIC45212 Current Sharing Reference Design board uses semi-shielded inductors for decreased board space and cost saving.

Figure 2-8 demonstrates a good balance between the input filter and frequency selection. Using the values calculated above, the resulting input current ripple is less then 20 mA at 28A output current powered from a single 12V power supply.

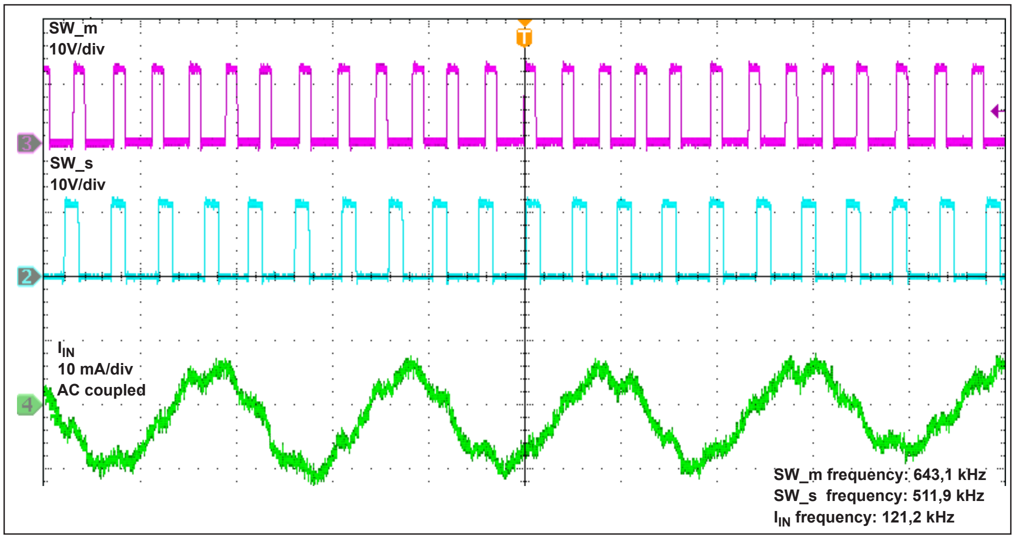


FIGURE 2-8: *MIC45212 Current Sharing Reference Design Input Current Ripple at 28A Load*

While powered from two power supplies, the two input filter capacitors can be eliminated and, if the input ripple doesn't matter, then the filter inductors can also be eliminated. Doing this will not affect the functionality of the MIC45212 Current Sharing Reference Design.

2.4.3.8 BOARD DESIGN AND LAYOUT CONSIDERATIONS

Limiting the complexity of the current-sharing control to a single op-amp requires great care in laying out the board. In fact, in addition to the DCR drop signals, the sensing paths for the op-amp inputs include the output voltage and the high-current traces from the respective module output up to the point-of-load where the feedback voltage is taken and the high-current return traces to the point where the op-amp is referenced.

For best current sharing balance, the board layout for both modules must be as similar as possible, with symmetric output power planes merging in one spot. The output ground must also be symmetrical from both modules and must be connected directly to the modules' ground pins (see PCB Layout). For best output ripple, the output capacitors for both modules must be connected directly to the output and ground planes of the modules.

The reference point of the MIC45212 feedback resistor divider networks and the current balance circuit both have important roles in this process.

The feedback point of the MIC45212 master module must be as close to the load as possible. Doing this will maintain an accurate voltage under load while compensating for the voltage drop through the power planes.

The current balance circuit must be carefully referenced to the electrical mid-point of the output ground (at equal distance to both modules) to prevent any unbalance cased by the noise in the ground planes or voltage unbalance due to ground voltage shifting (caused by the high currents).

Because of the high currents, wide power traces or copper planes must be used. A minimum of four-layer PCB board is recommended for good power distribution, good current balance, and heat distribution and easy layout. The power traces or power planes must be doubled on as many layers as possible for minimum power loss and maximized efficiency.

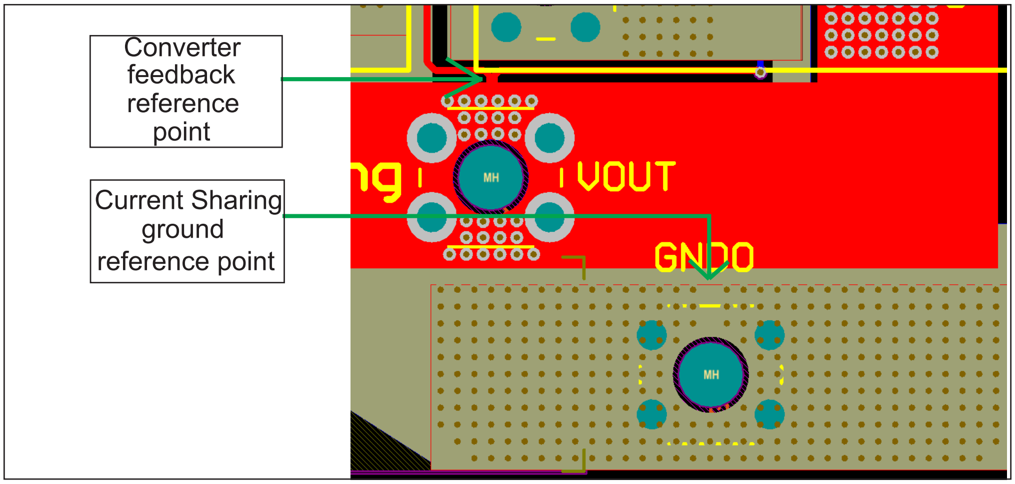


FIGURE 2-9: *Current Sharing Reference Points*

NOTES:

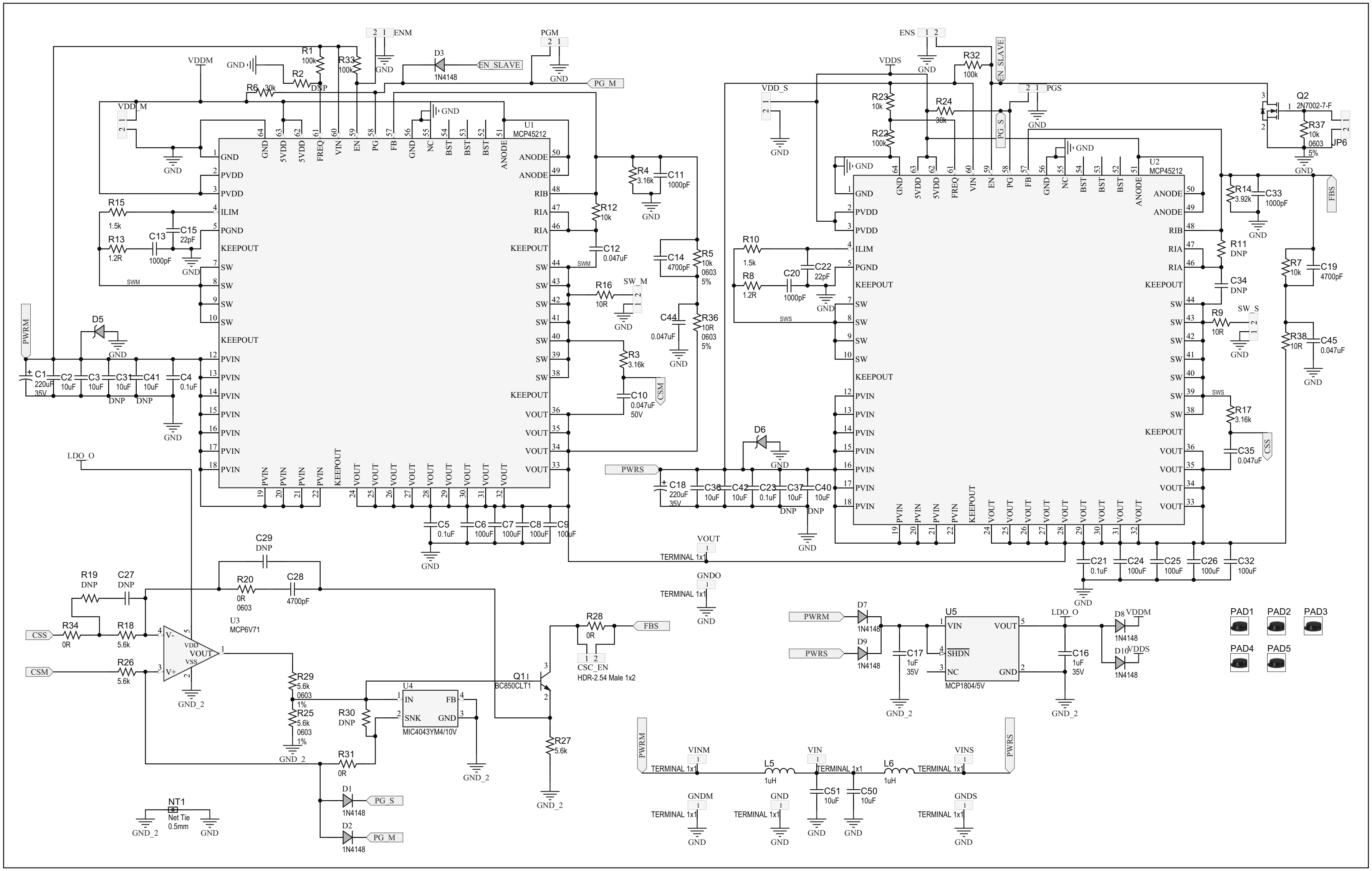
Appendix A. Schematic and Layouts

A.1 INTRODUCTION

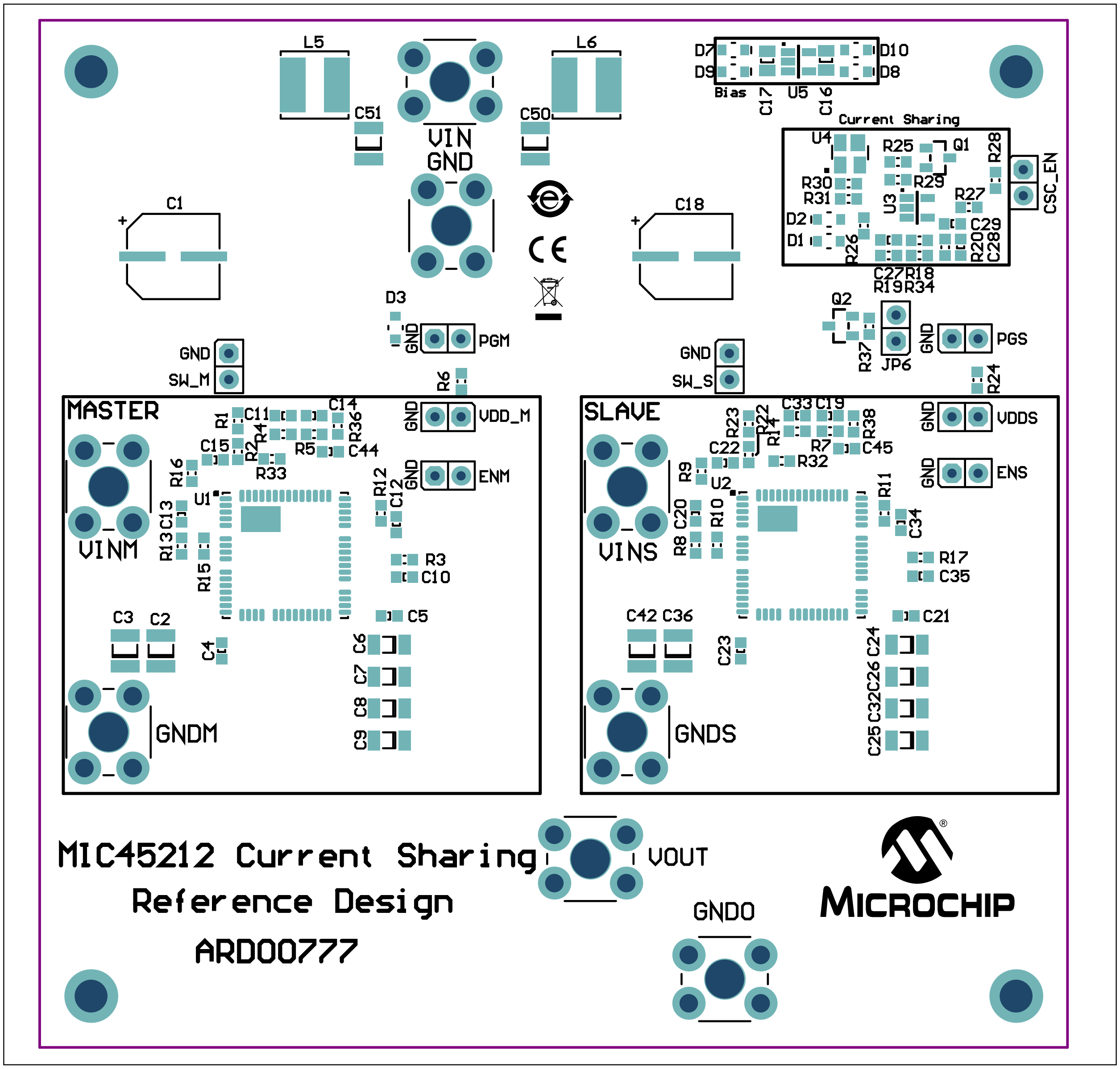
This appendix contains the following schematics and layouts for the MIC45212 Current Sharing:

- Board – Schematic
- Board – Top Silk
- Board – Top Copper and Silk
- Board – Top Copper
- Board - Mid Layer 1
- Board - Mid Layer 2
- Board – Bottom Copper
- Board – Bottom Copper and Silk
- Board – Bottom Silk

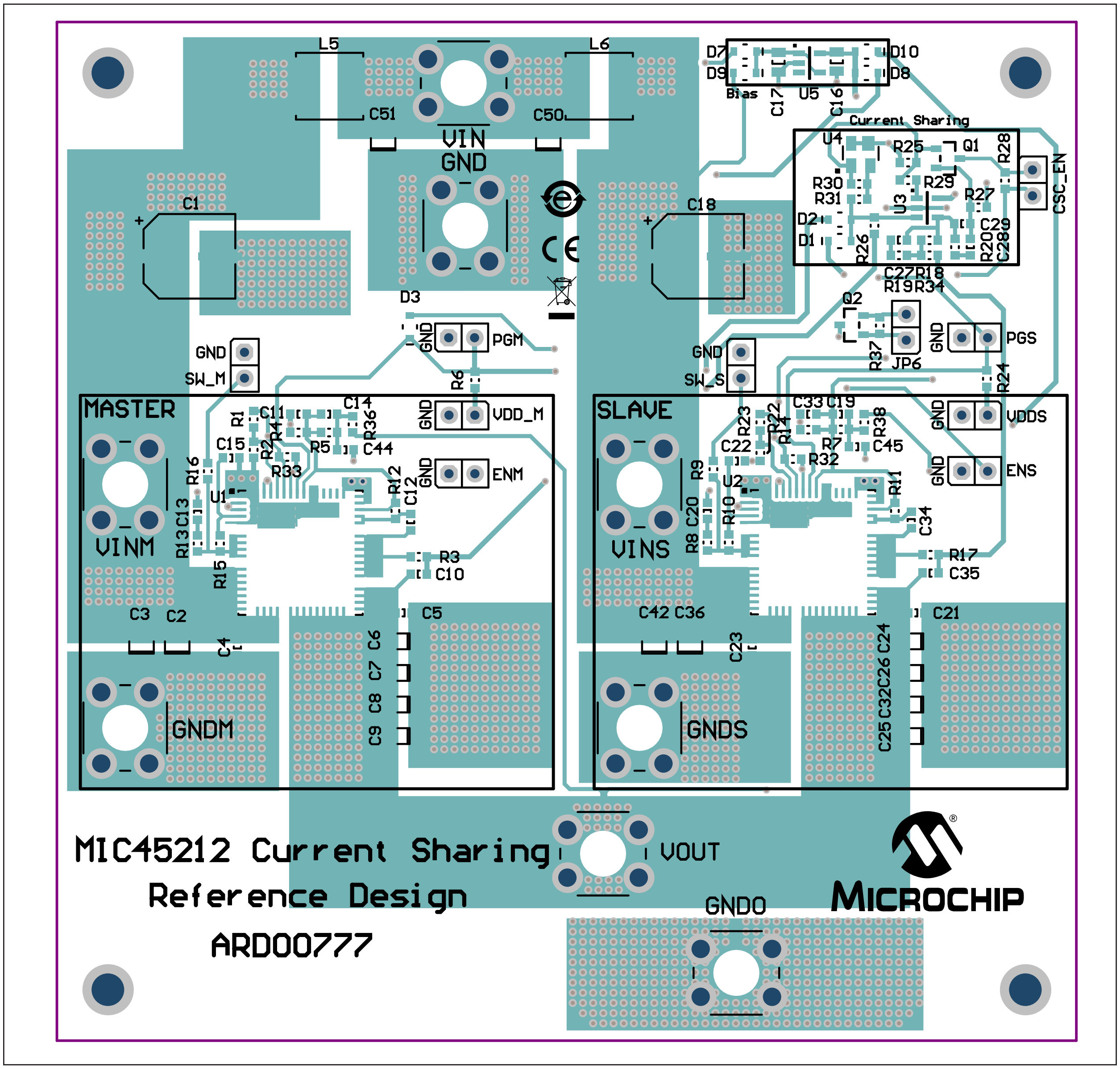
A.2 BOARD – SCHEMATIC



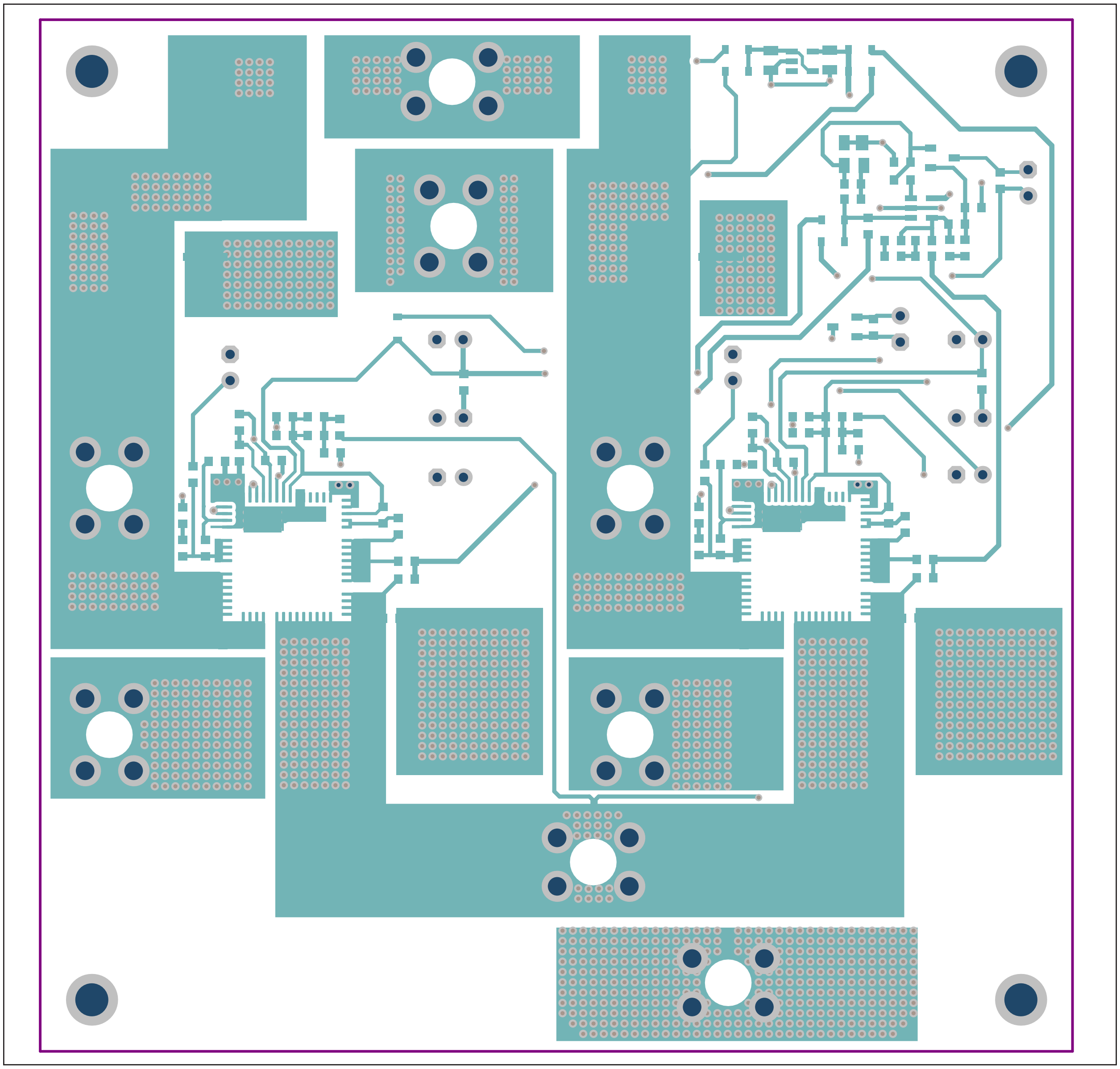
A.3 BOARD – TOP SILK



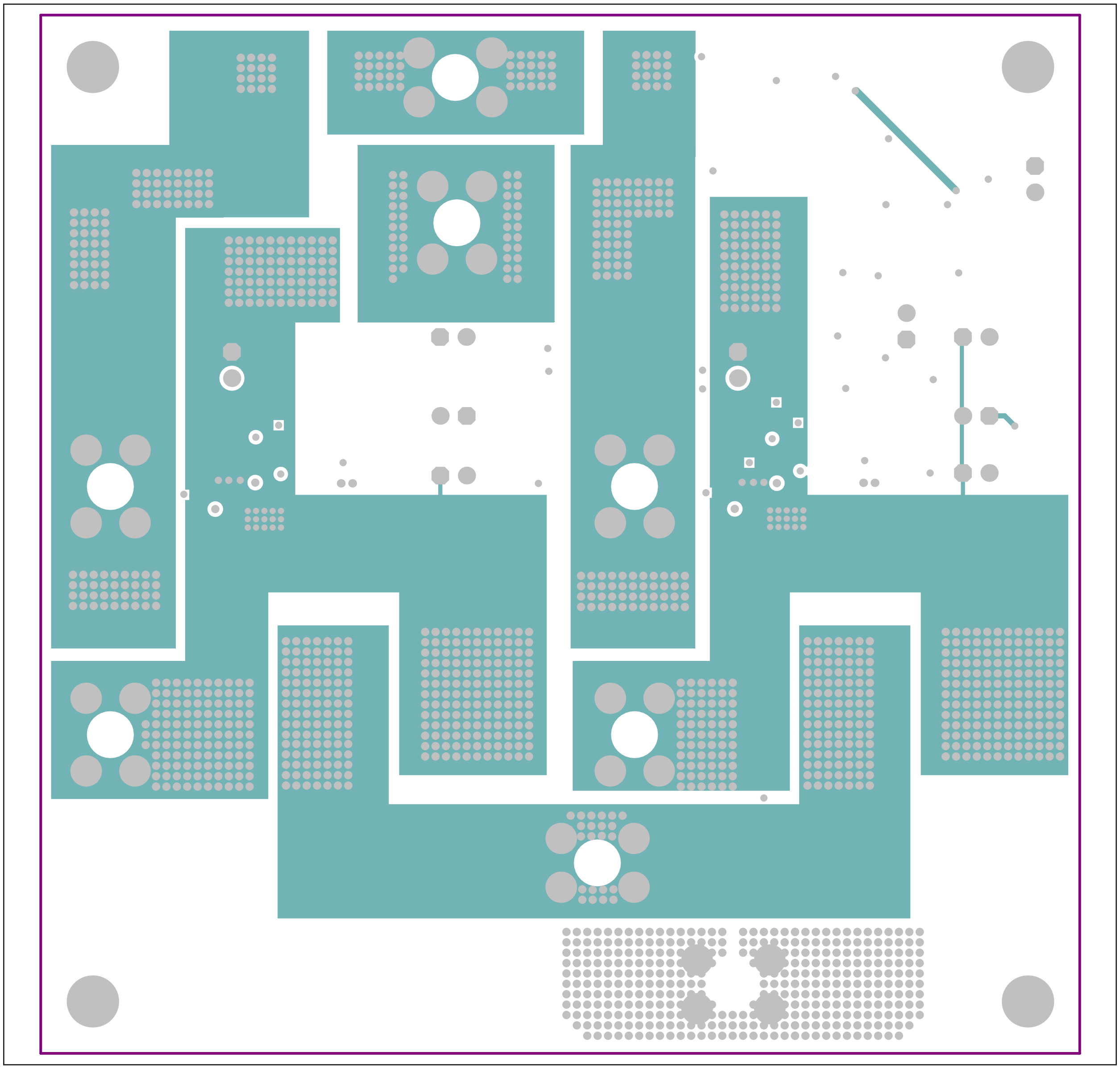
A.4 BOARD – TOP COPPER AND SILK



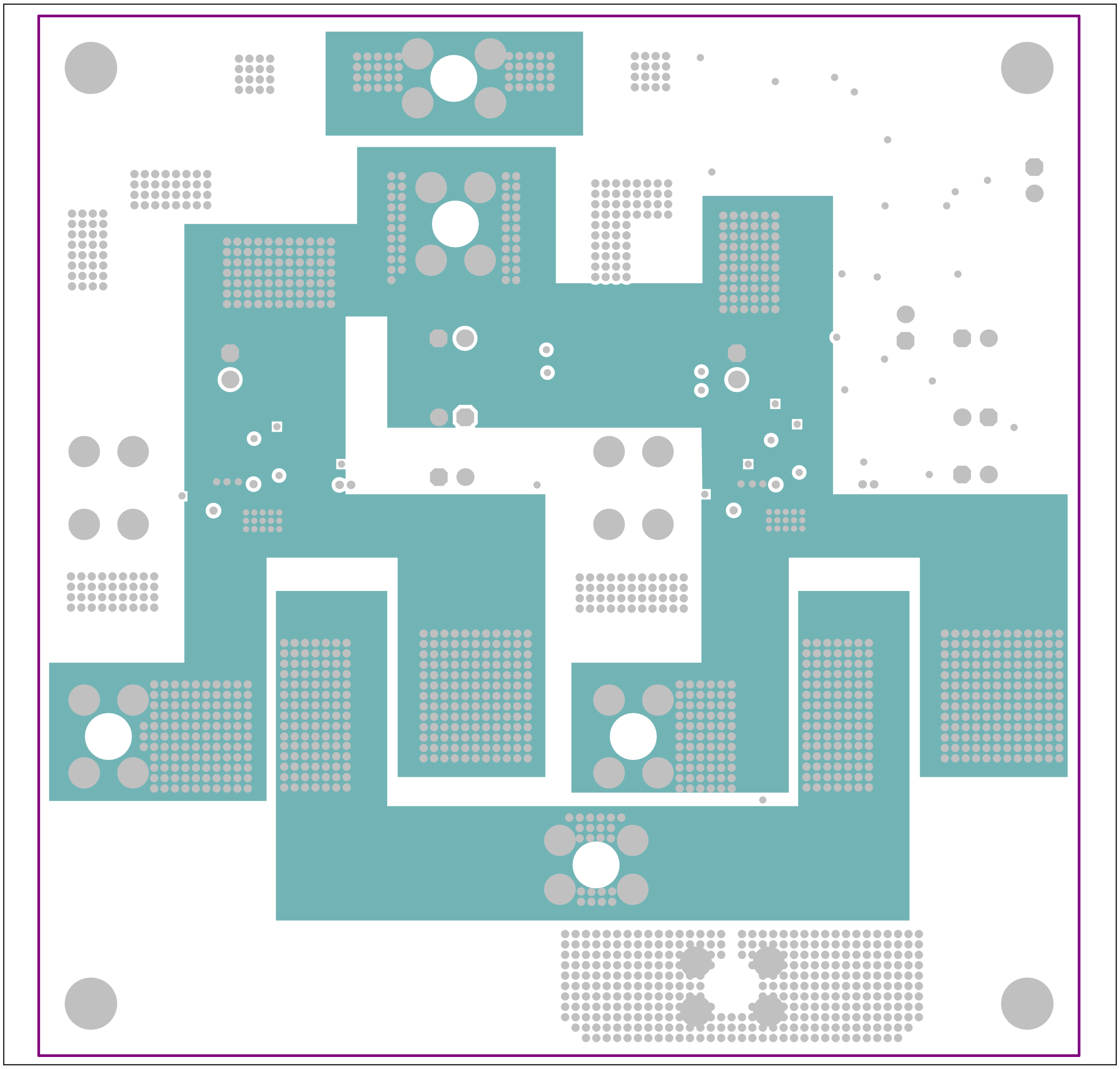
A.5 BOARD – TOP COPPER



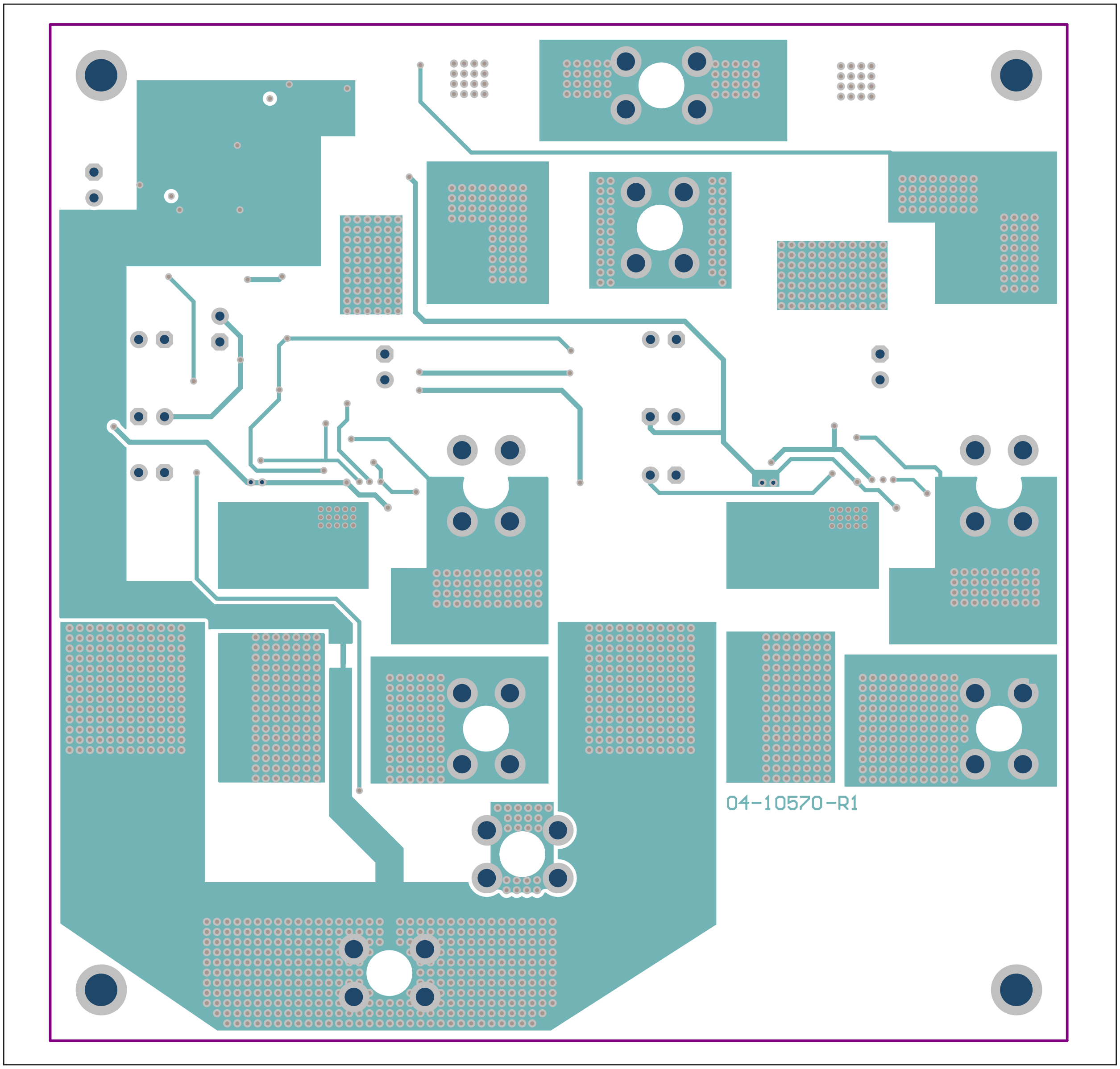
A.6 BOARD - MID LAYER 1



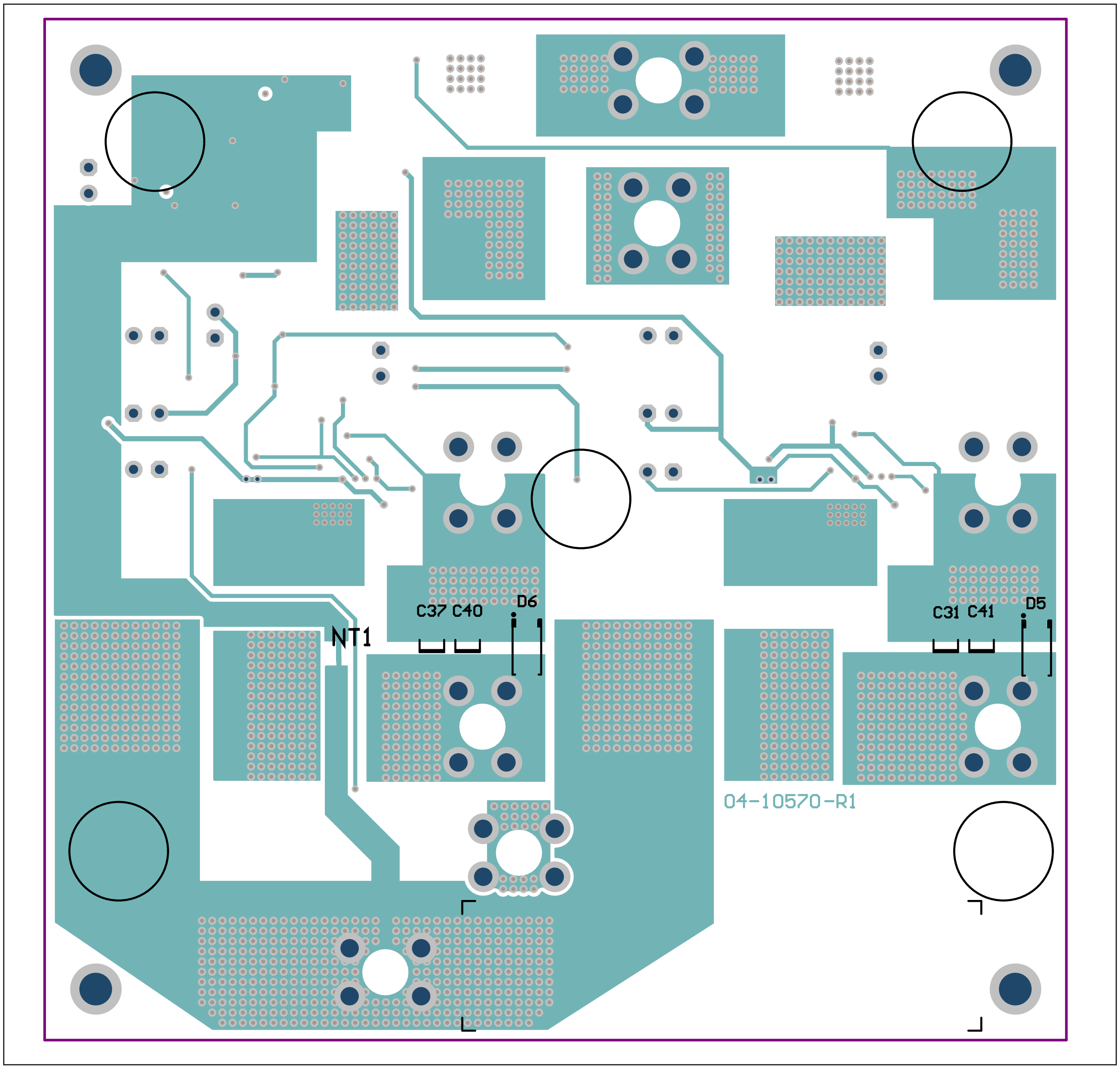
A.7 BOARD - MID LAYER 2



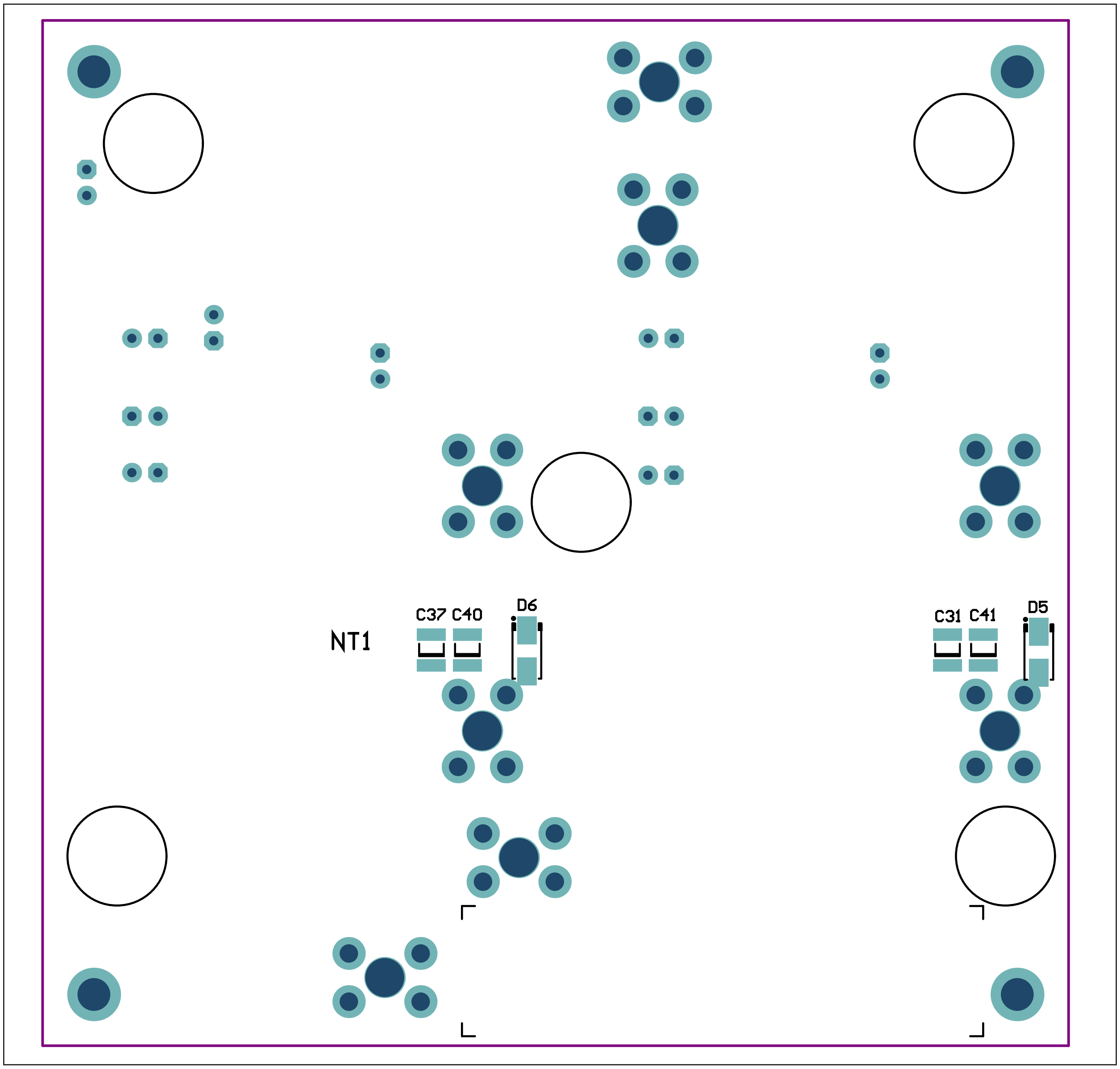
A.8 BOARD – BOTTOM COPPER



A.9 BOARD – BOTTOM COPPER AND SILK



A.10 BOARD – BOTTOM SILK



Appendix B. Bill of Materials (BOM)

TABLE B-1: BILL OF MATERIALS (BOM)(1)

Qty.	Reference	Description	Manufacturer	Part Number
2	C1, C18	CAP ALU 220 µF 35V 20% SMD E	Nichicon Corporation	UWT1V221MNL1GS
6	C2, C3, C36, C42, C50, C51	CAP CER 10 µF 50V 20% X7S SMD 1210	TDK Corporation	C3225X7S1H106M
4	C4, C5, C21, C23	CAP CER 0.1 µF 50V 20% X7R SMD 0603	TDK Corporation	C1608X7R1H104M
8	C6, C7, C8, C9, C24, C25, C26, C32	CAP CER 100 µF 10V 20% X5R SMD 1206	TDK Corporation	C3216X5R1A107M160AC
5	C10, C12, C35, C44, C45	CAP CER 0.047 µF 50V 10% X7R SMD 0603	TDK Corporation	C1608X7R1H473K080AA
4	C11, C13, C20, C33	CAP CER 1000 pF 50V 20% X7R SMD 0603	TDK Corporation	C1608X7R2A102K080AA
3	C14, C19, C28	CAP CER 4700 pF 50V 5% NP0 SMD 0603	TDK Corporation	C1608C0G1H472J080AA
2	C15, C22	CAP CER 22 pF 50V 5% C0G SMD 0603	KEMET	C0603C220J5GACTU
2	C16, C17	CAP CER 1 µF 35V 10% X7R SMD 0805	TDK Corporation	CGA4J3X7R1V105K125AB
5	D3, D7, D8, D9, D10	DIO RECT 1N4148 855 mV 300 mA 75V SOD-323	Diodes Incorporated®	1N4148WS-7-F
8	J1, J2, J3, J4, J5, J6, J7, J8	CON TERMINAL 15A Female 1x1 TH VERT	Keystone Electronics Corp.	8195
9	JP1, JP2, JP3, JP4, JP5, JP6, JP7, JP8, JP10	CON HDR-2.54 Male 1x2 Gold 5.84MH TH VERT	FCI	77311-118-02LF
1	JP9	CON HDR-2.54 Male 1x2 Tin 6.75MH TH VERT	Molex®	0901200122
2	L5, L6	INDUCTOR 1uH 6A 30% SMD L6W6H4.5	TDK Corporation	VLS6045EX-1R0N
5	PAD1, PAD2, PAD3, PAD4, PAD5	MECH HW RUBBER PAD CYLINDRICAL D9.53H5.97	3M	SJ61A2
1	PCB	Printed Circuit Board - MIC45212 Evaluation Board	Microchip Technology, Inc.	04-10570-R1
1	Q1	TRANS BJT NPN BC850CLT1 45V 100 mA 225 mW SOT-23-3	ON Semiconductor®	BC850CLT1
1	Q2	TRANS FET N-CH 2N7002-7-F 60V 170 mA 370 mW SOT-23-3	Diodes Incorporated®	2N7002-7-F
4	R1, R22, R32, R33	RES TF 100k 1% 1/8W SMD 0603	Vishay Intertechnology, Inc.	MCT06030C1003FP500

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)[1] (CONTINUED)

Qty.	Reference	Description	Manufacturer	Part Number
3	R3, R4, R17	RES TKF 3.16k 1% 1/10W SMD 0603	Panasonic® - ECG	ERJ-3EKF3161V
5	R5, R7, R12, R23, R37	RES TKF 10k 5% 1/10W SMD 0603	Panasonic® - ECG	ERJ-3GEYJ103V
2	R6, R24	RES TKF 30k 5% 1/10W SMD 0603	Panasonic® - ECG	ERJ-3GEYJ303V
2	R8, R13	RES TKF 1.2R 1% 1/10W SMD 0603	Panasonic® - ECG	CRCW06031R20FNEA
4	R9, R16, R36, R38	RES TKF 10R 5% 1/10W SMD 0603	Panasonic® - ECG	ERJ-3GEYJ100V
2	R10, R15	RES TKF 1.5k 1% 1/10W SMD 0603	Panasonic® - ECG	ERJ-3EKF1501V
1	R14	RES TKF 3.92k 1% 1/10W SMD 0603	Panasonic® - ECG	ERJ-3EKF3921V
5	R18, R25, R26, R27, R29	RES TKF 5.6k 1% 1/10W SMD 0603	Yageo Corporation	RC0603FR-075K6L
4	R20, R28, R31, R34	RES TKF 0R 1/10W SMD 0603	Panasonic® - ECG	ERJ-3GSY0R00V
2	U1, U2	MCHP ANALOG VOLTAGE REG 0.8V - 5.5V MIC45212-2YMP-T1 QFN-64	Microchip Technology, Inc.	MIC45212-2YMP-T1
1	U3	MCHP ANALOG OPAMP 2 MHz MCP6V71T-E/OT SOT-23-5	Microchip Technology, Inc.	MCP6V71T-E/OT
1	U4	MCHP ANALOG VREF 10V MIC4043YM4 SOT-143	Microchip Technology, Inc.	MIC4043YM4-TR
1	U5	MCHP ANALOG LDO 5V MCP1804T-5002I/OT SOT-23-5	Microchip Technology, Inc.	MCP1804T-5002I/OT

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

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