
Abstract

The goal of this design guide is to aid in rapidly prototyping a new design on an Intersil evaluation board using an existing reference design provided from an application engineer as a starting point. This procedure will give a solid first pass of a new design with additional fine tuning and output filter modification required once the end application board is laid out and tested. Use this guide for quickly checking the feasibility and performance of key parts (e.g., inductors, FETs, bulk caps, etc.) that may differ from those called out in reference designs against both Intel and Intersil specifications. This is by no means an exhaustive reference to designing with Intersil regulators; it is a stepping stone to getting a new design up and running before additional, more thorough, testing can be done.

Table of Contents

Assumptions	2
Required Equipment	2
Optional Equipment	2
Design Procedure	2

List of Figures

FIGURE 1. V_{DROOP} Adjustment	3
FIGURE 2. Load Response Adjustment.....	3
FIGURE 3. Compensation Adjustment	3

Assumptions

This guide assumes the following:

- An Intersil evaluation board is being used for testing
- The desired inductor, FETs and/or output capacitors have been chosen
- A reference design provided by Applications is being used as a starting point
- DCR sensing

Required Equipment

- Oscilloscope
- Digital multimeter
- Intel Gen 4 VRTT with appropriate interposer
- R-C substitution box
- V_{IN} and +5V power supplies
- Evaluation board documentation
- Part datasheet

Optional Equipment

- Differential oscilloscope probe for V_{OUT}
- Electronic load - more accurate for DC loads than VRTT
- Additional R-C substitution boxes - speed up the process by changing multiple components at once
- List of standard 1% resistor values

Design Procedure

1. Modify the evaluation board to configure it with the desired inductor(s), FETs and number of output bulk and ceramic capacitors.
 - Not all ceramic caps are created equal and capacitors from different vendors do not give the same performance. For quick design checks, leave the MLCCs used by Intersil on the board. For more thorough testing, populate the exact ones to be used in the end application.
2. Leave the compensation components used by the reference design in place. They should provide a good starting point for a reasonable range of output filters.
3. Calculate R_i using the formula below and solder connections from the R-C box to the appropriate resistor on the evaluation board. Dial the box to the 1% resistor value closest to the calculated result.

$$R_i = \frac{R_{ntcnet} \cdot DCR \cdot I_{CCmax}}{N \cdot \left(R_{ntcnet} + \frac{R_{sum}}{N} \right) \cdot I_{droopmax}} \quad (\text{EQ. 1})$$

- For single phase designs, set $N = 1$
 - If using the Intersil default design parameters:
 - $R_{sum} = 3.65k\Omega$
 - $R_{ntcnet} = 5.875k\Omega$ (see datasheet for formulas if changing NTC network)
 - $I_{droopmax} = 48\mu A$ (This sets the OCP point 25% higher than I_{CCmax} as OCP trips when $I_{droop} = 60\mu A$.)
 - For low I_{CCmax} applications $I_{droopmax}$ might need to be decreased to allow for additional current when slewing V_{OUT} .
4. Using the VRTT, or electronic load, apply an appropriate DC load to the part that will not damage any components such as the FETs. Adjust R_i in 1% resistor value increments while monitoring the voltage at the IMON pin until it is as close as possible to the correct value. Use the formula below to find the IMON voltage for a given load current.
 - Typically $R_{IMON} = 100k\Omega$ and any further adjustments to this value can be made after the rest of the design is completed.

$$V_{IMON} = 1.2V \left(\frac{I_{LOAD}}{I_{CCmax}} \right) \quad (\text{EQ. 2})$$

Solder the final resistor value in place for R_i and move the R-C box to the R_{droop} resistor on the feedback resistor to dial in the DC load line.

5. Calculate R_{droop} using the following formula and dial the R-C box to the closest 1% value.

$$R_{droop} = \frac{I_{CCmax}}{I_{droopmax}} \cdot DC_LL \quad (\text{EQ. 3})$$

- If using the Intersil default design parameters:
 - $I_{droopmax} = 48\mu A$
6. Using a VRTT, load the part with a transient from 1A to I_{CCmax} at a 300Hz rep rate, and monitor V_{OUT} on the scope. Set the time base on the scope so that one full cycle is visible. Position the cursors on the scope as shown in [Figure 1 on page 3](#) and adjust R_{droop} in 1% increments until V_{droop} is dialed into spec.
 - A duty cycle of 50% or lower is recommended for the load transient.

$$V_{droop} = DC_LL \cdot (I_{CCmax} - 1) \quad (\text{EQ. 4})$$

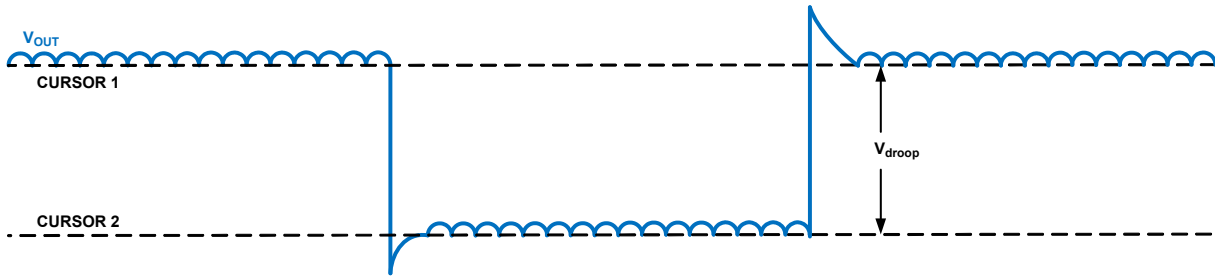


FIGURE 1. V_{DROOP} ADJUSTMENT

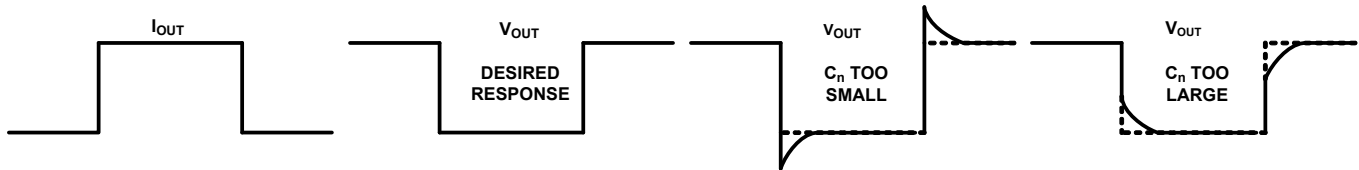


FIGURE 2. LOAD RESPONSE ADJUSTMENT

7. Solder the final resistor value in place for R_{droop} and move the R-C box to the C_n capacitor in the DCR network.
8. Calculate C_n and dial the R-C box to the closest standard capacitor value possible. If necessary, assume two capacitors in parallel when setting the substitution box.

$$C_n = \frac{L}{\left(\frac{R_{ntcnet} \cdot \frac{R_{sum}}{N}}{R_{netcnet} + \frac{R_{sum}}{N}} \right) \cdot DCR} \quad (EQ. 5)$$

- For single phase designs, set $N = 1$
 - If using the Intersil default design parameters:
 - $R_{sum} = 3.65k\Omega$
 - $R_{ntcnet} = 5.875k\Omega$ (see datasheet for formulas if changing NTC network)
9. Using a VRTT, load the part with a transient from 1A to I_{CCmax} , at a 300Hz rep rate, and monitor V_{OUT} on the scope. Set the time base on the scope so that one full cycle is visible. Adjust C_n in standard capacitor increments until V_{OUT} matches the desired response.
 - A duty cycle of 50% or lower is recommended for the load transient. (See [Figure 2](#))
 10. Solder down the final C_n capacitor value(s) and move the R-C box to the compensation components.
 11. Using a VRTT, load the part with a transient from 1A to I_{CCmax} , at a 300Hz rep rate, and monitor V_{OUT} on the scope. Trigger on the falling edge of V_{OUT} and adjust the compensation components as needed to fine tune the transient response. (See [Figure 3](#))
 - A duty cycle of 50% or lower is recommended for the load transient.

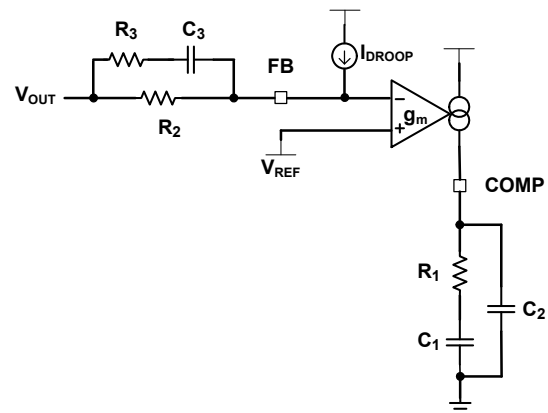


FIGURE 3. COMPENSATION ADJUSTMENT

- Compensation scheme assumes $C_1 \gg C_2$ and $R_2 \gg R_3$
 - Make sure overall response is square through C_n adjustment in Step 9.
 - R_3 and C_2 can be used to adjust the initial response to a load step ($\sim 2\mu s$ after insertion)
 - C_3 can be used to adjust the response approximately 5 to $10\mu s$ after load step
 - R_1 and C_1 can adjust the transient response $>10\mu s$ after load step.
12. Sweep the load transient repetition rate up to 1MHz with the persistence feature of the scope turned on while checking if over and undershoot on V_{OUT} meet the required Intel specs. Adjust compensation and C_{OUT} as needed to pass.

13. Check the following parameters to ensure they are within spec and iterate through the design process as needed until all requirements are met.

- CCM ripple at no load and full load
- DCM ripple at OA and light loads
- DC load line
- Transient response

The completed design can then be used as a starting point on the end application board and further modified as more thorough testing is completed. If assistance is required during the design process, contact an Intersil FAE or Applications Engineer.

Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation or any other use of the circuits, software, and information in the design of your product or system. Renesas Electronics disclaims any and all liability for any losses and damages incurred by you or third parties arising from the use of these circuits, software, or information.
2. Renesas Electronics hereby expressly disclaims any warranties against and liability for infringement or any other claims involving patents, copyrights, or other intellectual property rights of third parties, by or arising from the use of Renesas Electronics products or technical information described in this document, including but not limited to, the product data, drawings, charts, programs, algorithms, and application examples.
3. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
4. You shall not alter, modify, copy, or reverse engineer any Renesas Electronics product, whether in whole or in part. Renesas Electronics disclaims any and all liability for any losses or damages incurred by you or third parties arising from such alteration, modification, copying or reverse engineering.
5. Renesas Electronics products are classified according to the following two quality grades: "Standard" and "High Quality". The intended applications for each Renesas Electronics product depends on the product's quality grade, as indicated below.
"Standard": Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; industrial robots; etc.
"High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control (traffic lights); large-scale communication equipment; key financial terminal systems; safety control equipment; etc.
Unless expressly designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not intended or authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems; surgical implantations; etc.), or may cause serious property damage (space system; undersea repeaters; nuclear power control systems; aircraft control systems; key plant systems; military equipment; etc.). Renesas Electronics disclaims any and all liability for any damages or losses incurred by you or any third parties arising from the use of any Renesas Electronics product that is inconsistent with any Renesas Electronics data sheet, user's manual or other Renesas Electronics document.
6. When using Renesas Electronics products, refer to the latest product information (data sheets, user's manuals, application notes, "General Notes for Handling and Using Semiconductor Devices" in the reliability handbook, etc.), and ensure that usage conditions are within the ranges specified by Renesas Electronics with respect to maximum ratings, operating power supply voltage range, heat dissipation characteristics, installation, etc. Renesas Electronics disclaims any and all liability for any malfunctions, failure or accident arising out of the use of Renesas Electronics products outside of such specified ranges.
7. Although Renesas Electronics endeavors to improve the quality and reliability of Renesas Electronics products, semiconductor products have specific characteristics, such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Unless designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not subject to radiation resistance design. You are responsible for implementing safety measures to guard against the possibility of bodily injury, injury or damage caused by fire, and/or danger to the public in the event of a failure or malfunction of Renesas Electronics products, such as safety design for hardware and software, including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult and impractical, you are responsible for evaluating the safety of the final products or systems manufactured by you.
8. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. You are responsible for carefully and sufficiently investigating applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive, and using Renesas Electronics products in compliance with all these applicable laws and regulations. Renesas Electronics disclaims any and all liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
9. Renesas Electronics products and technologies shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You shall comply with any applicable export control laws and regulations promulgated and administered by the governments of any countries asserting jurisdiction over the parties or transactions.
10. It is the responsibility of the buyer or distributor of Renesas Electronics products, or any other party who distributes, disposes of, or otherwise sells or transfers the product to a third party, to notify such third party in advance of the contents and conditions set forth in this document.
11. This document shall not be reprinted, reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.
12. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products.
(Note 1) "Renesas Electronics" as used in this document means Renesas Electronics Corporation and also includes its directly or indirectly controlled subsidiaries.
(Note 2) "Renesas Electronics product(s)" means any product developed or manufactured by or for Renesas Electronics.

(Rev.4.0-1 November 2017)



SALES OFFICES

Renesas Electronics Corporation

<http://www.renesas.com>

Refer to "<http://www.renesas.com/>" for the latest and detailed information.

Renesas Electronics America Inc.
1001 Murphy Ranch Road, Milpitas, CA 95035, U.S.A.
Tel: +1-408-432-8888, Fax: +1-408-434-5351

Renesas Electronics Canada Limited
9251 Yonge Street, Suite 8309 Richmond Hill, Ontario Canada L4C 9T3
Tel: +1-905-237-2004

Renesas Electronics Europe Limited
Dukes Meadow, Millboard Road, Bourne End, Buckinghamshire, SL8 5FH, U.K
Tel: +44-1628-651-700, Fax: +44-1628-651-804

Renesas Electronics Europe GmbH
Arcadiastrasse 10, 40472 Düsseldorf, Germany
Tel: +49-211-6503-0, Fax: +49-211-6503-1327

Renesas Electronics (China) Co., Ltd.
Room 1709 Quantum Plaza, No.27 ZhichunLu, Haidian District, Beijing, 100191 P. R. China
Tel: +86-10-8235-1155, Fax: +86-10-8235-7679

Renesas Electronics (Shanghai) Co., Ltd.
Unit 301, Tower A, Central Towers, 555 Langao Road, Putuo District, Shanghai, 200333 P. R. China
Tel: +86-21-2226-0888, Fax: +86-21-2226-0999

Renesas Electronics Hong Kong Limited
Unit 1601-1611, 16/F., Tower 2, Grand Century Place, 193 Prince Edward Road West, Mongkok, Kowloon, Hong Kong
Tel: +852-2265-6688, Fax: +852-2886-9022

Renesas Electronics Taiwan Co., Ltd.
13F, No. 363, Fu Shing North Road, Taipei 10543, Taiwan
Tel: +886-2-8175-9600, Fax: +886-2-8175-9670

Renesas Electronics Singapore Pte. Ltd.
80 Bendemeer Road, Unit #06-02 Hyflux Innovation Centre, Singapore 339949
Tel: +65-6213-0200, Fax: +65-6213-0300

Renesas Electronics Malaysia Sdn.Bhd.
Unit 1207, Block B, Menara Amcorp, Amcorp Trade Centre, No. 18, Jln Persiaran Barat, 46050 Petaling Jaya, Selangor Darul Ehsan, Malaysia
Tel: +60-3-7955-9390, Fax: +60-3-7955-9510

Renesas Electronics India Pvt. Ltd.
No.777C, 100 Feet Road, HAL 2nd Stage, Indiranagar, Bangalore 560 038, India
Tel: +91-80-67208700, Fax: +91-80-67208777

Renesas Electronics Korea Co., Ltd.
17F, KAMCO Yangjae Tower, 262, Gangnam-daero, Gangnam-gu, Seoul, 06265 Korea
Tel: +82-2-558-3737, Fax: +82-2-558-5338