

Introduction

This Application Note describes the trimming technique for DC/DC converter modules using industry standards for output voltage trim. The DC/DC converter module design equations are presented from the datasheets, a circuit model for the DC/DC converter is shown, circuit equations for using a digital pot (DCP) are derived and resistor values are shown for the two most popular industry standards.

As of this writing, there are two standards for DC/DC converter module that attempt to create standard pinouts, standard package size, standard electrical specifications and standard controls such as ON/OFF and output voltage setting.

The first standard was the Point of Load Alliance (POLA) established by Texas Instruments, Artyzen, Emerson Astec, Ericsson and others. A typical POLA DC/DC converter module is the Texas Instruments PTH12050, which features an adjustable output voltage of 0.8V to 5.5V with a 6 amp output current from a +12V input voltage. There are many other variations of this DC/DC converter module for other input voltages and load currents from any vendor that is part of the POLA. Within their product families, all POLA modules are interchangeable and, therefore, second sourced by any POLA vendor. Appendix A on [page 5](#) shows the typical voltage setting technique and datasheet trim circuit.

The second standard that is more recent is the Distributed Power Open Standards Alliance (DOSA) founded by Tyco Electronics and SynQor; recent members include Celestica, Delta, Ericsson and Lambda. Their web site is www.dosapower.com for additional information. A typical DOSA DC/DC converter module is the Tyco Electronics Austin Lynx II # ATA010A0X3-SR which features an adjustable output voltage of 0.75V to 5.0V with a 10 amp output current from a +12V input voltage. There are many other variations of this DC/DC converter module for other input voltages and load currents from any vendor that is part of the DOSA. Within their product families, all DOSA modules are interchangeable and, therefore, second sourced by any DOSA vendor. Appendix B on [page 5](#) shows the typical voltage setting technique and datasheet trim circuit. Throughout this application note, the Texas Instruments PTH12050 POLA module and TycoAustin Lynx II # ATA010A0X3-SR DOSA module are shown in the design examples. However, any module which complies with the POLA or DOSA standard should be interchangeable.

It must be noted that POLA modules are not pin compatible with DOSA modules. Also, DC/DC converter modules, which are not part of POLA or DOSA may or may not be compatible with DC/DC converter modules from other vendors.

Module trim with software control of a DC/DC converter module output voltage is desirable for several reasons:

1. Margin testing is often required in the engineering qualification test to four-corner test the system against tolerance variations in the DC/DC converter output voltages.
2. Margin testing is often performed as part of production final system tests.
3. Margin testing can be done as part of a regular in-field preventative maintenance test to attempt to predict a system failure.
4. As the core voltage requirement of controllers, gate arrays, etc. change with each new generation of devices it is helpful to be able to perform software changes of output voltage instead of requiring an ECO to change a resistor value.

POLA Modules DCP Circuit and Table of Resistors Values

Figure 1 and Tables 1 and 2 show the circuit for interfacing POLA modules to a DCP. For high output voltage (1.2V to 5.5V) POLA modules (PTH12050W) the circuit and tables show the external resistor values (R_W , R_Y) for an ISL95810UIU8 256 tap, 50k DCP. The ISL95810UIU8 DCP allows an adjustment range of nominal $V_{OUT} \pm 10\%$ by changing the DCP code from full scale value (255_{10}) to zero value (000_{10}). The complete circuit analysis, circuit model and design equations are shown in Appendix C on page 6 and Appendix D on page 7.

For low output voltage (0.8 to 1.8V) POLA modules (PTH12050L) Table 2 shows the external resistor values (R_W , R_Y) for an ISL95810UIU8 256 tap, 50k DCP.

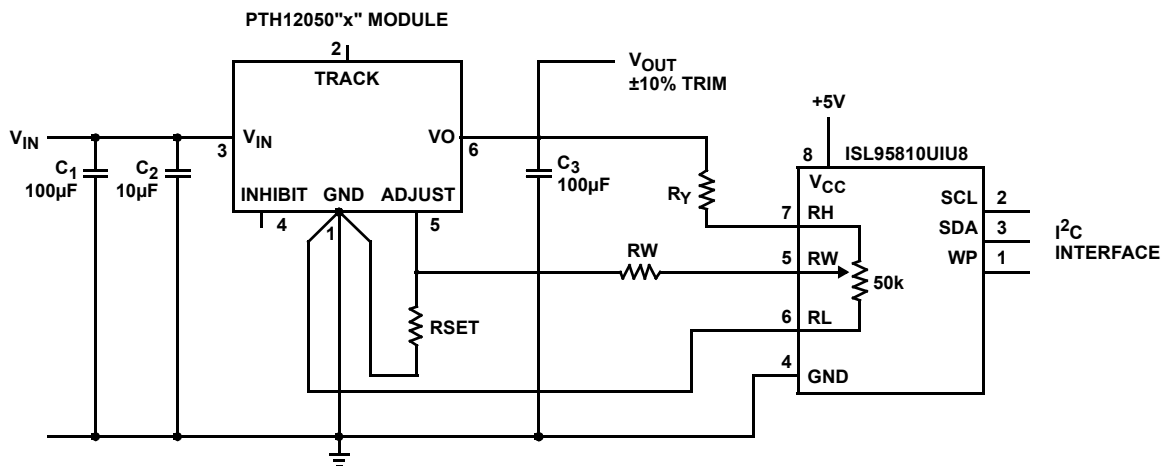
TABLE 1. HIGH OUTPUT VOLTAGE RESISTOR VALUES FOR POLA MODULE

NOMINAL V_{OUT} (VDC)	MINIMUM V_{OUT} (VDC)	MAXIMUM V_{OUT} (VDC)	R_{SET} (k Ω)	R_W (k Ω)	R_Y (Ω)
3.3	3.000	3.600	1.69	14.3	8.06k
2.5	2.250	2.750	3.83	26.1	2.49k
1.8	1.620	1.980	11	36.5	511
1.5	1.372	1.651	26.7	39.2	0

Minimum V_{OUT} at Full Scale Code
 Nominal V_{OUT} at 1/2 Full Scale Code
 Maximum V_{OUT} at Zero Code

TABLE 2. LOW OUTPUT VOLTAGE RESISTOR VALUES FOR POLA MODULE

NOMINAL V_{OUT} (VDC)	MINIMUM V_{OUT} (VDC)	MAXIMUM V_{OUT} (VDC)	R_{SET} (k Ω)	R_W (k Ω)	R_Y (Ω)
1.5	1.350	1.650	2.61	3.74	6.65k
1.2	1.080	1.320	11.5	21.5	422
1.0	0.900	1.100	44.2	32.4	0



"x" indicates W-suffix for 1.2V to 5.5V Module.
 "x" indicates L-suffix for 0.8V to 1.8V Module.

FIGURE 1. CIRCUIT FOR POLA MODULE

DOSA Modules DCP Circuit and Table of Resistors Values

For DOSA modules (Tyco Austin Lynx II, # ATA010A0X3-SR) [Figure 2](#) and [Table 3](#) show the external resistor values (R_W , R_Y) for an ISL95810UIU8 256 tap, 50k DCP. The ISL95810UIU8 DCP allows an adjustment range of nominal $V_{OUT} \pm 10\%$ by changing the DCP code from full scale value (255_{10}) to zero value (000_{10}). The complete circuit analysis, circuit model and design equations are shown in Appendix C on [page 6](#) and Appendix E on [page 8](#).

TABLE 3. RESISTOR VALUES FOR DOSA MODULE

NOMINAL V_{OUT} (VDC)	MINIMUM V_{OUT} (VDC)	MAXIMUM V_{OUT} (VDC)	R_{TRIM} (k Ω)	R_W (k Ω)	R_Y (Ω)
5.0	4.500	5.500	1.27	26.1	7.87k
3.3	3.000	3.600	2.87	47.5	4.32k
2.5	2.250	2.750	4.64	51.1	1.96k
1.8	1.620	1.980	8.66	59	309
1.5	1.372	1.651	12.7	68.1	0
1.2	1.080	1.320	23.7	66.5	0

Minimum V_{OUT} at Full Scale Code
 Nominal V_{OUT} at 1/2 Full Scale Code
 Maximum V_{OUT} at Zero Code

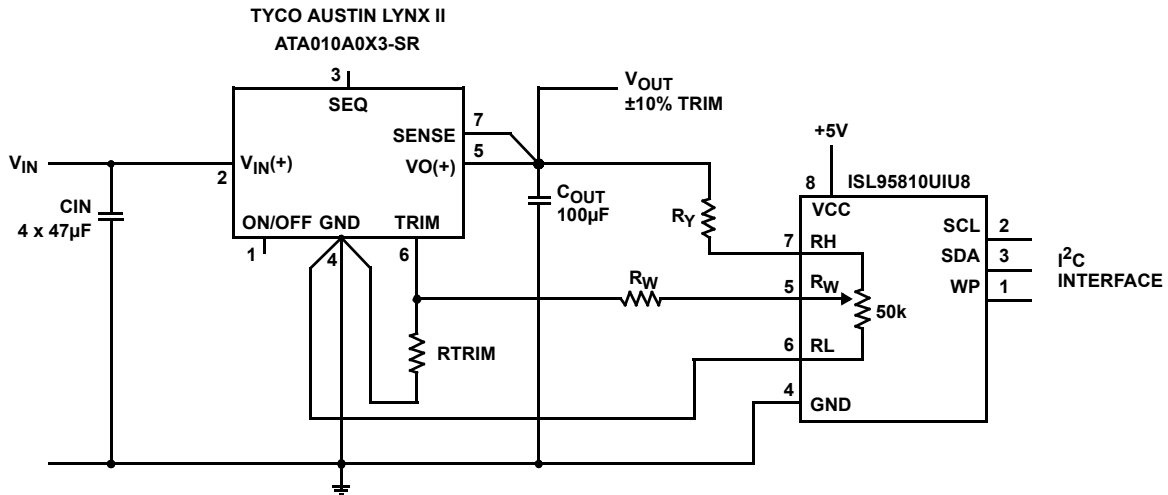


FIGURE 2. CIRCUIT FOR DOSA MODULE

Example of Vicor DC/DC Converter Modules

For Vicor Generation 2 modules (#V48C5C100B for example) [Figure 3](#) and [Table 4](#) show the external resistor values (R_W , R_Y) for an ISL95810UIU8 256 tap, 50k DCP. The ISL95810UIU8 DCP allows an adjustment range of nominal $V_{OUT} \pm 10\%$ by changing the DCP code from full scale value (255_{10}) to zero value (000_{10}). The complete circuit analysis, circuit model and design equations are shown in Appendix F on [page 8](#).

TABLE 4. RESISTOR VALUES FOR VICOR GENERATION 2 MODULE

NOMINAL V_{OUT} (VDC)	MINIMUM V_{OUT} (VDC)	MAXIMUM V_{OUT} (VDC)	Rpot End-End (k Ω)	R_W (k Ω)	R_Y (k Ω)
5.0	4.500	5.500	50	9.09	17.4

Discrete DC/DC Converter Circuits Using Intersil Monolithic 2A Step-Down Regulator IC

The same technique for using a DCP to trim the output voltage of a DC/DC converter module can also be applied to a discrete DC/DC converter circuit as shown in [Figure 4](#). The EL7532 circuit is set for a nominal output voltage of 1.8V. The ISL95810UIU8 DCP allows an adjustment range of 1.62V to 2.00V ($1.8V \pm 10\%$) by changing the DCP code from full scale value (255_{10}) to zero value (000_{10}). The circuit analysis for the output voltage vs code is similar to the analysis for the POLA or DOSA module as described in the Appendix C on [page 6](#) and is available upon request.

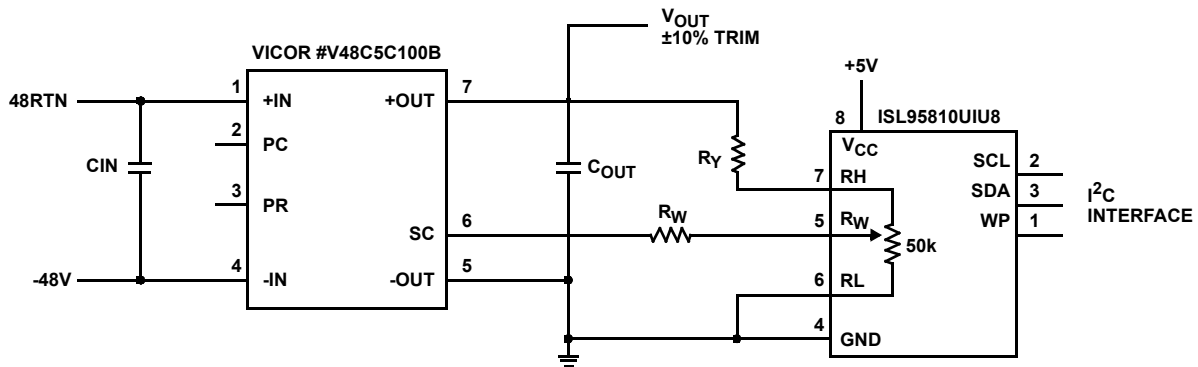


FIGURE 3. CIRCUIT FOR VICOR GENERATION 2 MODULE

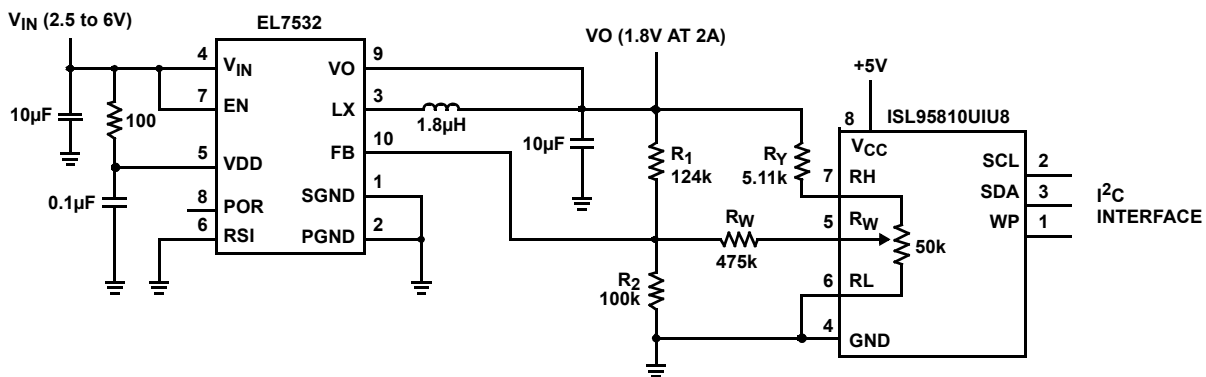


FIGURE 4. CIRCUIT FOR DISCRETE DC/DC MODULE

Appendix A: Standard POLA Output Voltage Settings and Trim

To set the output voltage of a POLA DC/DC converter module, an external resistor, R_{SET} , is added from the Adjust pin to the GND pin as shown in Figure 5. With the TI #PTH12050 DC/DC converter module there are two parts - one for high output voltage (1.2V to 5.5V) indicated by a W suffix and a second for low voltage (0.8V to 1.8V) indicated by an L suffix.

$$R_{SET} = 10k / (V_o - V_{MIN}) - R_s$$

Where V_o = Desired output voltage

$$V_{MIN} = 1.2V \text{ for W-suffix part} \\ = 0.8V \text{ for L-suffix parts}$$

$$R_s = 1.82k\Omega \text{ for W-suffix parts} \\ = 7.87k\Omega \text{ for L-suffix parts}$$

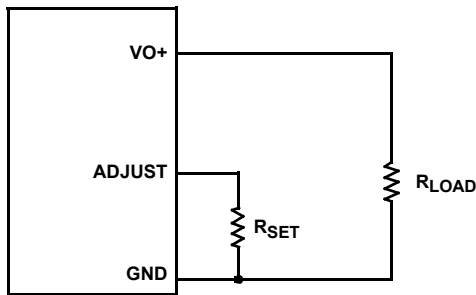


FIGURE 5. POLA OUTPUT VOLTAGE SET CIRCUIT

Output voltage margining is implemented by adding external resistors for margining up ($R_{MARGIN-UP}$) and margining down ($R_{MARGIN-DOWN}$); the resistors are connected into the Trim pin with external N-channel FETs Q1 and Q2. With this technique only three output voltages can be set; nominal (both Q1 and Q2 off), margin up output voltage (Q1 on) and margin down voltage (Q2 on). No intermediate voltage steps are available.

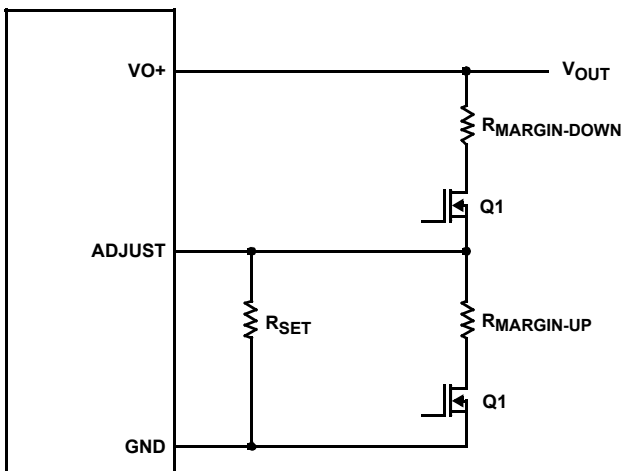


FIGURE 6. POLA MARGIN CIRCUIT

Other POLA modules (PTH12060W) include Margin Up and Margin Down pins for $\pm 5\%$ output voltage margining. However, they require external FETs for controlling the Margin Up and Margin Down pins.

Replacing the two resistors and FETs with a digital pot (DCP) allows a large number of output voltages to be set under software control. It will be shown in the next section that the range of the output voltage can be set with two fixed resistors connected to the DCP wiper and top terminal.

Appendix B: Standard DOSA Output Voltage Settings and Trim

To set the output voltage of a DOSA DC/DC converter module, an external resistor, R_{TRIM} is added from the TRIM pin to the GND pin as shown in Figure 7.

$$R_{TRIM} = 10500 / (V_o - 0.7525) - 1000$$

Where V_o = Desired output voltage

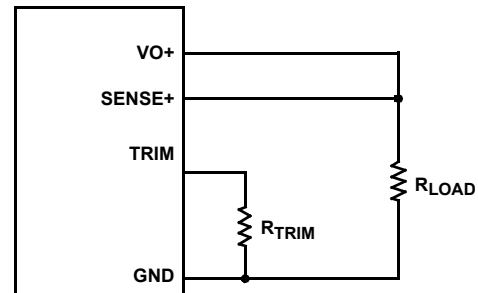


FIGURE 7. DOSA OUTPUT VOLTAGE SET CIRCUIT

Output voltage margining is implemented by adding external resistors for margining up ($R_{MARGIN-UP}$) and margining down ($R_{MARGIN-DOWN}$); the resistors are connected into the Trim pin with external N-channel FETs Q1 and Q2. With this technique only three output voltages can be set; nominal (both Q1 and Q2 off), margin-up output voltage (Q1 on) and margin-down voltage (Q2 on). No intermediate voltage steps are available.

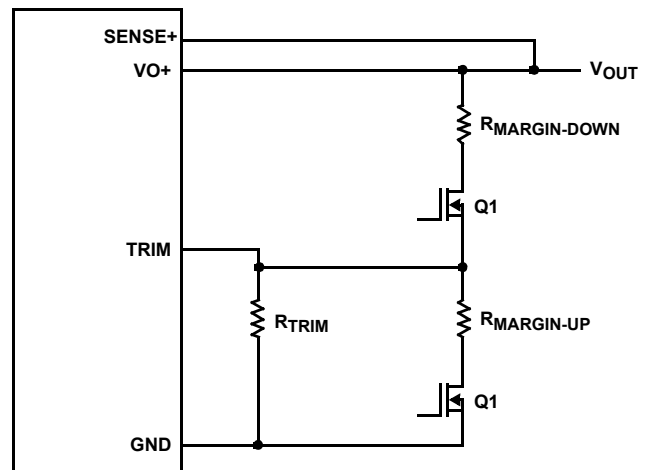


FIGURE 8. DOSA MARGIN CIRCUIT

Replacing the two resistors and FETs with a DCP allows a large number of output voltages to be set under software control. It will be shown in the next section that the range of the output voltage can be set with two fixed resistors connected to the DCP wiper and top terminal.

Appendix C: POLA and DOSA DC/DC Converter Circuit Model and Design Equations

To use a DCP for controlling the output voltage of a DC/DC converter module it is necessary to obtain a circuit model of the feedback circuit internal to the DC/DC converter module. Some DC/DC converter module vendors show the circuit model on their datasheets or application notes. If the circuit model is not available, it is necessary to derive the model from the output voltage vs adjust resistor equation.

The output voltage of a POLA or DOSA DC/DC converter module can be adjusted for trimming and margining purposes by using the circuit in [Figure 9](#). Resistor R_W sets the width of the adjustment range and resistor R_Y is used to center the adjustment range around its nominal output with the DCP set to midscale. Because the DCP presents a “load” to the feedback network, the resistance of both sides of the DCP must be considered.

For analysis, the equivalent circuit with node assignments is used ([Figure 10](#)).

Summing Currents at Each Node:

$$\begin{aligned} (V_o - V_r)/R_1 + (V_1 - V_r)/R_S + (0 - V_r)/R_2 &= 0 && \text{(Node } V_r) \\ (V_r - V_1)/R_S + (V_2 - V_1)/R_W + (0 - V_1) R_{ADJ} &= 0 && \text{(Node } V_1) \\ (V_o - V_2)/R_T + (V_1 - V_2)/R_W + (0 - V_2)/R_B &= 0 && \text{(Node } V_2) \end{aligned}$$

For a DCP

$$\begin{aligned} R_{BOT} &= R_{EE} * \text{Code}/N \\ R_{TOP} &= R_{EE} - R_{BOT} \\ \text{Where } R_{EE} &= \text{DCP end to end resistance} \\ \text{Code} &= \text{Digital input code (0 to N)} \\ N &= \text{Number of taps} \end{aligned}$$

Solving for V_o :

$$V_o = V_r * (X - R_1/(B * D * R_s^2)) / (1 + E * R_1/R_S)$$

$$\begin{aligned} \text{Where } X &= 1 + R_1/R_S + R_1/R_2 \\ B &= 1/R_S + 1/R_W + 1/R_{ADJ} \\ C &= 1/R_T + 1/R_W + 1/R_B \\ D &= 1 - 1/(B * C * R_W^2) \\ E &= 1/(B * C * D * R_W * R_T) \\ R_T &= R_{TOP} + R_Y \end{aligned}$$

Since this is a very messy non-linear equation, an [Excel worksheet](#) was prepared to calculate the DC/DC converter module output voltage with a given DCP digital code.

In addition to the Excel worksheet, to calculate the output voltage with a DCP code, R_W and R_Y resistor values, the three node equations were programmed into TK Solver (Universal Technical Systems). TK Solver has the ability to back solve a set of equations with any variable being set as an input or output variable. The TK Solver rules sheet is available upon request.

A SPICE simulation could also be used to calculate the output voltage with a DCP input code; however, SPICE does not provide the ability to calculate resistor values. SPICE could only be used to verify the circuit analysis and calculate the output voltage with a DCP input code

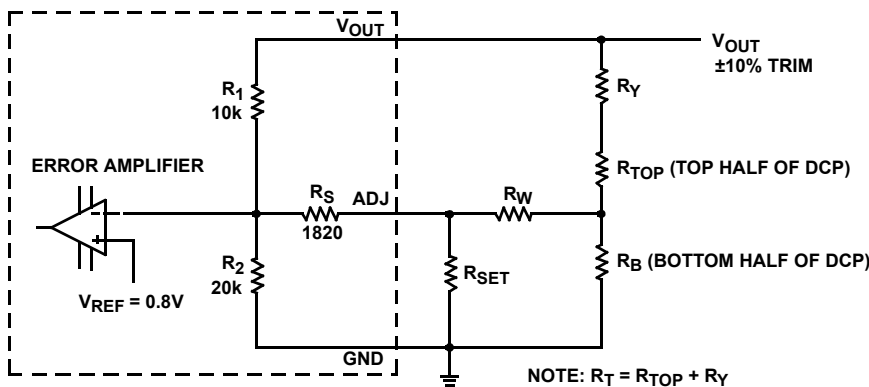


FIGURE 9. POLA MODULE CIRCUIT MODEL WITH DCP

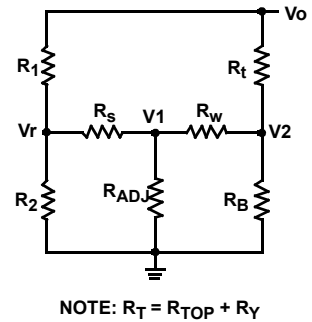


FIGURE 10. EQUIVALENT POLA MODULE CIRCUIT WITH NODE ASSIGNMENT

Appendix D: POLA DC/DC Converter Circuit Model

The POLA DC/DC converter module circuit model high output voltage parts is shown in [Figure 11](#).

For low output voltage (0.8V to 1.8V) POLA DC/DC converter module, resistor R_2 (20k) is removed and R_S value is changed to 7.87k; the circuit model is shown in [Figure 12](#).

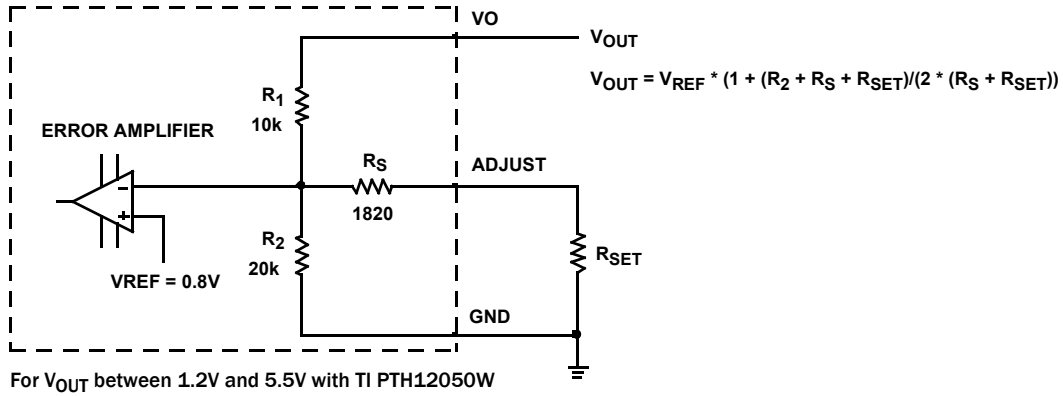


FIGURE 11. HIGH OUTPUT VOLTAGE POLA MODULE CIRCUIT MODEL WITH DCP

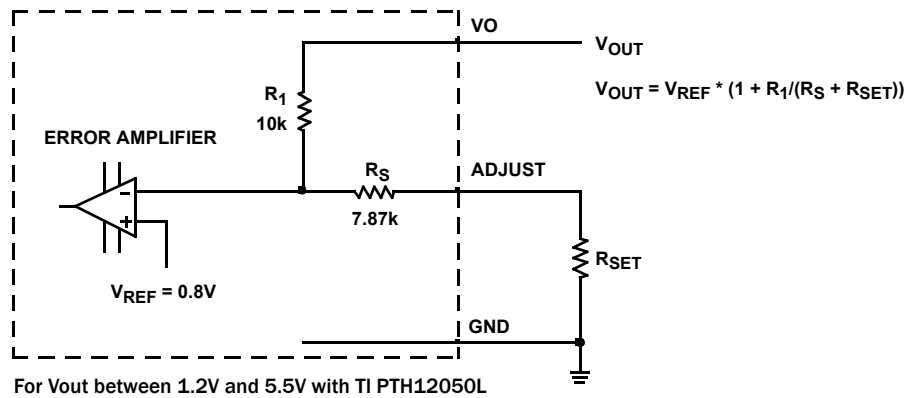


FIGURE 12. LOW OUTPUT VOLTAGE POLA MODULE CIRCUIT MODEL WITH DCP

Appendix E: DOSA DC/DC Converter Circuit Model

The circuit model for a DOSA DC/DC converter module is very similar to the POLA modules as shown in [Figure 13](#).

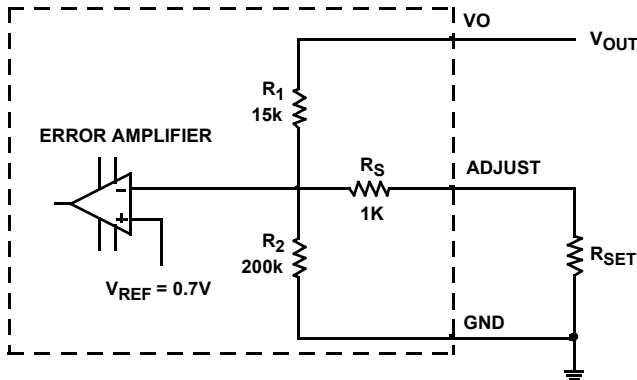


FIGURE 13. DOSA MODULE CIRCUIT MODEL WITH DCP

Appendix F: Vicor Generation 2 DC/DC Converter Circuit Model and Design Equations

The output voltage of a Vicor Generation 2 DC/DC converter module can be adjusted for trimming and margining purposes by using the circuit shown in [Figure 14](#). Resistor R_W sets the width of the adjustment range and resistor R_Y is used to center the adjustment range around its nominal output with the DCP set to

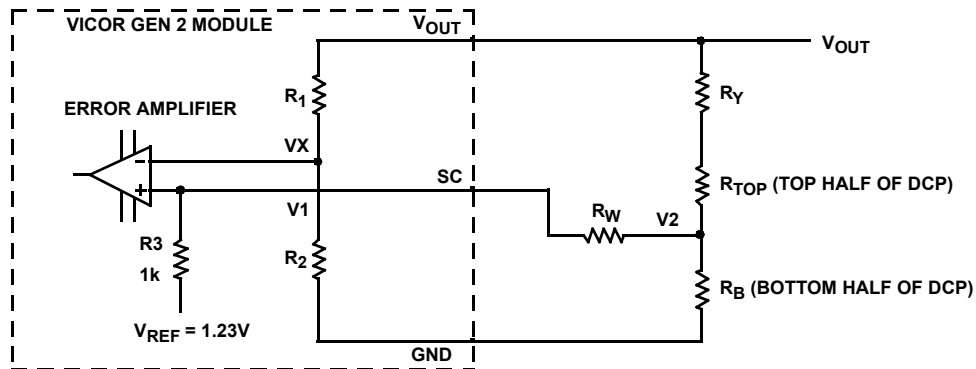


FIGURE 14. VICOR GENERATION 2 MODULE CIRCUIT MODEL WITH DCP

midscale. Because the DCP presents a “load” to the feedback network, the resistance of both sides of the DCP must be considered. For analysis, the equivalent circuit with node assignments is used in [Figure 14](#).

Summing Currents at V1 and V2 Node:

$$(V_{REF} - V1)/R_3 + (V2 - V1)/R_W = 0 \quad \text{Node V1}$$

$$(V1 - V2)/R_W + (V_{OUT} - V2)/(R_Y + R_{TOP}) + (0 - V2)/R_{bot} = 0 \quad \text{Node V2}$$

The error amplifier will force $V1 = Vx$

Resistors R_1 and R_2 are not shown on the datasheet or application notes; however, it is easy to determine the ratio R_1/R_2 based on circuit analysis when there is no trim applied.

With no trim applied to the SC pin

$$V_{nom} = V_{REF} * (1 + R_1/R_2) \quad \text{where } V_{nom} \text{ is the output voltage with no trim.}$$

$$R_1/R_2 = V_{nom}/V_{REF} - 1$$

Summing Currents at Vx Node

$$(V_{OUT} - Vx)/R_1 + (0 - Vx)/R_2 = 0$$

$$V_{OUT} = Vx * (1 + R_1/R_2)$$

Plugging R_1/R_2 from the No Trim Calculation

$$V_{OUT} = Vx * V_{nom}/V_{REF}$$

To calculate the output voltage with a DCP code, R_W and R_Y resistor values, the two node equations, $V1 = Vx$ and $V_{OUT} = Vx * V_{nom}/V_{REF}$ were programmed into TK Solver. The TK Solver rules sheet is available upon request.

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