

RESISTOR DIVIDER SPREADSHEET PROVIDES STANDARD RESISTOR VALUES FOR OPTIMAL CONVERTER OUTPUT-VOLTAGE ACCURACY

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INTRODUCTION

The resistive voltage divider is the most basic form of electronic circuit. It is used in nearly every analog application for voltage sensing, voltage biasing, undervoltage/overvoltage fault detection, reference setting, biasing networks, and more. For many applications, selection of the proper resistor divider values can achieve significant improvements without increasing system cost. However, because resistors are available in standard values spaced logarithmically in series, it can be a challenge to find the best solution for specific designs. Legacy tools to help designers find tight-tolerance solutions omit many of the options available. To help designers find the best resistive voltage divider for a specific design, an Allegro calculator is presented.

OVERVIEW OF RESISTOR DIVIDERS

A typical application of a resistor divider to sense output voltage in a DC-DC converter is shown in Figure 1. The feedback voltage (FB in Figure 1) is compared to a reference voltage and processed for closed-loop control as shown in Figure 2.

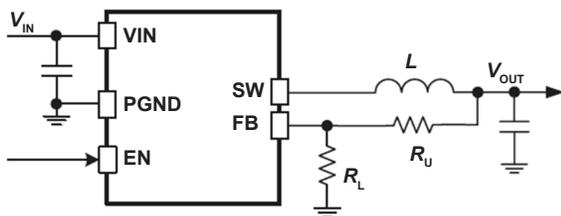


Figure 1: Typical feedback divider arrangement in DC-DC converters.

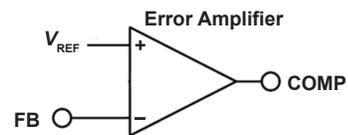


Figure 2: Error amplifier that compares feedback voltage of a DC-DC converter to a reference voltage.

RELATIONSHIP WITH OUTPUT VOLTAGE

In an ideal DC-DC converter, the output voltage is set by the resistor divider as:

Equation 1:

$$V_{OUT} = [(R_U + R_L) / R_L] \times V_{REF}$$

The error amplifier used to sense feedback voltage from the resistor divider is non-ideal and has a bias current, I_{FB} . Typically, the bias current of the error amplifier ranges from a few nA to 1 μ A. This current adds to the error in the output voltage.

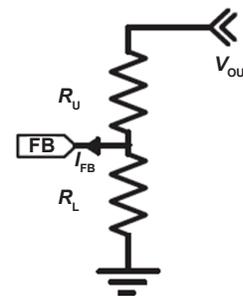


Figure 3: Feedback divider with biasing current.

Converter output voltage with bias current considered is given as:

Equation 2:

$$V_{OUT} = [(R_U + R_L) / R_L] \times V_{REF} + R_U \times I_{FB},$$

where, I_{FB} is defined as negative when current is coming out of the FB pin.

Some DC-DC converters, such as the Allegro [A8660](#)^[1]—a wide-input voltage, adjustable output, synchronous buck controller—trim the internal reference voltage to compensate for the bias current error for a known effective resistance. If external resistors are optimally selected for this value, the effect of bias current can be nulled. It is desirable to select an effective resistance close to this recommended value.

The effective resistance from the FB pin is given by:

Equation 3:

$$R_{eq} = (R_U \times R_L) / (R_U + R_L).$$

The output voltage with trimmed ICs is given by:

Equation 4:

$$V_{OUT} = [(R_U + R_L) / R_L] \times (V_{REF} - R_{eq} \times I_{FB}) + R_U \times I_{FB}.$$

Many modern applications require a DC-DC converter with a tightly regulated output voltage. Accuracy can be improved with tighter-tolerance components, but these components are usually more expensive. Selection of the proper resistor divider values can significantly improve output-voltage accuracy without increasing system cost.

RESISTOR DIVIDER SELECTION AND SELECTION TOOLS

In DC-DC converters, the accuracy of the output voltage depends on the feedback-divider ratio. Optimization of the feedback-divider ratio can be a challenge because resistors are available in standard values spaced logarithmically in series, where each series represents a standard tolerance. For example, the E96 series has a 1% tolerance, and the E24

series has a 5% tolerance (other series are subsets of these).

To help users determine the most appropriate resistor with the lowest tolerance, legacy tools are available to determine the optimal resistor divider values based on the 1% resistors available in the E96 series. [2],[3]

However, these legacy tools, which are suitable for an ideal error amplifier with zero bias current, consider only the E96 series, so they do not leverage all of the options available.

Some of the values in the E24 series differ from the E96 series. The E24 series resistors have become available with a 1% tolerance, which has given 18 additional values that are not available in the E96 series.

Use of the 1% tolerance line of the E24 series with the E96 series can improve the accuracy of an output-voltage setting. However, due to the nature of combined series, it is extremely difficult to achieve a universal formula to calculate the resistor divider. The Allegro *Resistor Divider Calculator Spreadsheet* has been developed to meet this need.

ALLEGRO RESISTOR DIVIDER CALCULATOR SPREADSHEET

To help users select resistors from the combined E96 and E24 series with 1% tolerance, Allegro created a spreadsheet (pictured in Figure 4) that uses VBA-based data and considers the effects of bias current and compensating trim to calculate optimal resistor divider values. Information to download and use the tool is provided in the sections that follow.

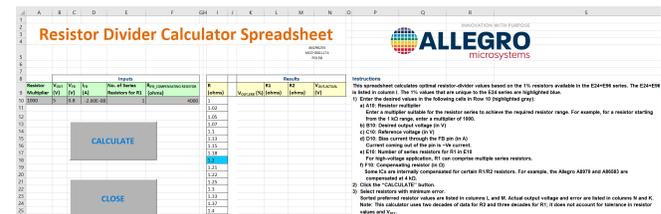


Figure 4: Resistor divider calculator spreadsheet.

[1] See <https://www.allegromicro.com/en/products/regulate/regulators/single-output-regulators/a8660>

[2] "Divide And Conquer The Resistive Divider" Karl R. Volk, EDN Online ID #12236, April 13, 2006. <https://www.electronicdesign.com/power-management/article/21775877/divide-and-conquer-the-resistive-divider>.

[3] "Excel Formula Calculates Standard 1%-Resistor Values" Bruce Trump, Christine Schneider, EDN Online ID #1480, January 21, 2002. <https://www.electronicdesign.com/technologies/components/article/21763411/excel-formula-calculates-standard-1-resistor-values>.

How to Download the Spreadsheet

The Allegro *Resistor Divider Calculator Spreadsheet* is available for download [here](#).^[4] This is a macro-enabled spreadsheet that is compatible with Microsoft Excel® format 2007 and later versions.

How to Use the Spreadsheet

To calculate values for R1 and R2:

- Enter the desired values in the cells shown:
 - B10: Output voltage (in V)
 - C10: Reference voltage (in V)
 - D10: Bias current (in A)
Note: I_{FB} is defined as negative current when current is coming out of pin FB.
 - F10: Recommended compensating resistor (in ohms, as given in the product datasheet); if none, set to 0.
 - E10: Number of series resistors for R1
Typically, only one resistor is used for R1. However, in high-voltage applications, multiple high-side resistors of the same value are often connected in series to meet safety requirements. If multiple series resistors are used, update cell E10.
 - A10: Resistor decade range for resistor R2.
Resistors are available in decades. For example, 1 kΩ, 10 kΩ, 100 kΩ, 1,000 kΩ, and so on. For example, if the minimum value for R2 is 10 kΩ, set the multiplier in cell A10 to 10,000. The spreadsheet considers two decades of values for R2 and three decades of values for R3, and it processes about 80,000 combinations of R1 and R2. Providing a suitable multiplier value limits processing to the practical limits of the spreadsheet.
- Click the “CALCULATE” button to run the VBA code in the background. It takes a few minutes to provide the values of R1 and R2 with the minimum output-voltage error arranged in ascending order.
 - R1 and R2 are provided in ohms and are listed in columns L and M, respectively.
 - Output voltage error is provided in percent and is listed in column K.
 - Actual output voltage for the given values of R1 and R2 is listed in column N.

- Select a suitable resistor with the preferred values that result in the minimum output voltage error.
- Click the “CLOSE” button to minimize file size while saving. This clears all the calculations and data stored in columns K to N, which significantly reduces saved file size.

Usage Example

The Allegro [ARG81800](#)^[5] is an automotive-qualified, wide-input-voltage, synchronous buck regulator with ultralow quiescent current. This regulator is capable of delivering up to 1 A of continuous output current. Resistor divider calculations for commonly used 3.3 V and 5 V outputs are shown in Figure 5.

ARG81800				
V_{REF}	0.8	V		
I_{FB}	-2.75E-08	A		
$R_{IFB,COMP}$	0	kΩ		

	V_{OUT}	R_U (k)	R_L (k)	$V_{OUT,ACTUAL}$	$V_{OUT,ERR\%}$
Design Example	3.3	301	95.3	3.318	-0.560
Suggested Values		330	105	3.305	-0.158
Design Example	5	732	137	5.056	-1.122
Suggested Values		845	160	5.002	-0.035

Figure 5: Spreadsheet calculations that yield high output voltage accuracy for the Allegro ARG81800 buck regulator.

CONCLUSION

Use of the Allegro *Resistor Divider Calculator Spreadsheet* presented here can help designers select suitable resistors with preferred values that result in the minimum output voltage error without adding system cost.

[4] See <https://www.allegromicro.com/-/media/files/design-tools/resistor-divider-calculator-spreadsheet.zip>

[5] See <https://www.allegromicro.com/en/products/regulate/regulators/single-output-regulators/arg81800>

Revision History

Number	Date	Description	Responsibility
-	December 10, 2021	Initial release	S. Wekhande

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