

How to Determine the Op-Amp Open-Loop Output Impedance

Applying phase compensation to amplifier circuits using op-amps requires knowledge about the open-loop output impedance of the device, Z_O . As this parameter is rarely specified in datasheets, this application note explains one of many ways to determine Z_O for a given capacitive load condition.

Loading the output of the non-inverting amplifier in Figure 1 with a large capacitance causes a gain peak in the frequency response. This is because C_L forms a pole with Z_O at frequency f_p , causing the unload open-loop gain, A_{ul} , to change its roll off from -20 to -40dB/decade (Figure 2). This section is denoted as the loaded open-loop gain, A_{ld} . At the frequency, where the closed-loop gain, $1/\beta$, crosses A_{ld} , the gain peak occurs. Therefore, this frequency becomes the peak frequency, f_{pk} .

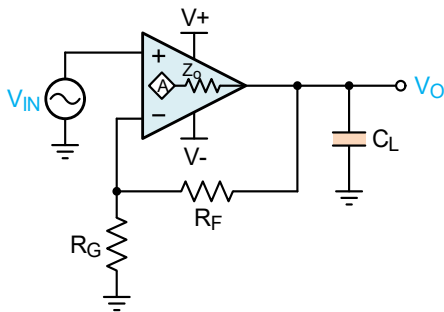


Figure 1.

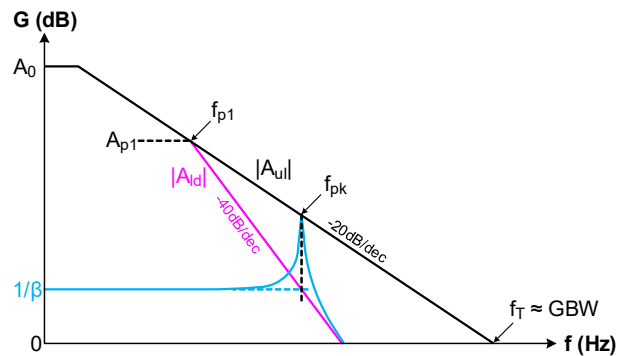


Figure 2.

To find the value for Z_O under this load condition, only two parameters must be known by the designer: f_{pk} , which can be measured with a network analyzer or oscilloscope, and f_T , which is the unity-gain bandwidth of the op-amp, and in most cases also the gain bandwidth, GBW : $f_T \approx GBW$.

As the open-loop gain at f_{p1} , denoted as A_{p1} , is equal for both roll offs, you can establish the constant gain-bandwidth equation for each slope:

$$\text{for the } -20\text{dB/dec roll off: } f_{p1} \cdot A_{p1} = f_T \Rightarrow A_{p1} = \frac{f_T}{f_{p1}}$$

$$\text{for the } -40\text{dB/dec roll off: } f_{p1}^2 \cdot A_{p1} = f_{pk}^2 \cdot 1/\beta \Rightarrow A_{p1} = \frac{f_{pk}^2}{f_{p1}^2 \cdot \beta}$$

$$\text{Setting both } A_{p1} \text{ terms equal and solving for } f_{p1}, \text{ gives: } f_{p1} = \frac{f_{pk}^2}{f_T \cdot \beta}$$

Then, substituting f_{p1} with $1/(2\pi Z_O C_L)$ and solving for Z_O , provides the open-loop output impedance:

$$\text{(EQ. 1) } Z_O = \frac{f_T \beta}{2\pi f_{pk}^2 C_L} \quad \text{with} \quad f_T \approx GBW \quad \text{and} \quad \beta = \frac{R_G}{R_G + R_F}$$

Revision History

Revision	Date	Description
1.00	May 10, 2022	Initial release.

IMPORTANT NOTICE AND DISCLAIMER

RENESAS ELECTRONICS CORPORATION AND ITS SUBSIDIARIES (“RENESAS”) PROVIDES TECHNICAL SPECIFICATIONS AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS OR IMPLIED, INCLUDING, WITHOUT LIMITATION, ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for developers skilled in the art designing with Renesas products. You are solely responsible for (1) selecting the appropriate products for your application, (2) designing, validating, and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. Renesas grants you permission to use these resources only for development of an application that uses Renesas products. Other reproduction or use of these resources is strictly prohibited. No license is granted to any other Renesas intellectual property or to any third party intellectual property. Renesas disclaims responsibility for, and you will fully indemnify Renesas and its representatives against, any claims, damages, costs, losses, or liabilities arising out of your use of these resources. Renesas' products are provided only subject to Renesas' Terms and Conditions of Sale or other applicable terms agreed to in writing. No use of any Renesas resources expands or otherwise alters any applicable warranties or warranty disclaimers for these products.

(Rev.1.0 Mar 2020)

Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,
Koto-ku, Tokyo 135-0061, Japan
www.renesas.com

Contact Information

For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit:
www.renesas.com/contact/

Trademarks

Renesas and the Renesas logo are trademarks of Renesas Electronics Corporation. All trademarks and registered trademarks are the property of their respective owners.