Instrumentation Amplifiers
Cascading Instrumentation Amplifiers for High Gain at High Bandwidth

Abstract
This application note explains cascading instrumentation amplifiers for high gain at high bandwidth.

Related Literature
For a full list of related documents, visit our website:
• ISL28533, ISL28534, ISL28535, ISL28633, ISL28634, ISL28635 device pages

1. Cascading Instrumentation Amplifiers
Although the prevailing number set in electronics is binary, a human-machine interface uses a decimal-number set. For this reason, designs often require the use of amplifiers with programmable gain steps in the power of 10. The ISL28634 monolithic instrumentation amplifier (Figure 1) has 9 digitally programmable gain settings, which are listed in Figure 2.

The device has high bandwidth at lower gains, but inevitably loses this bandwidth at a gain of 1000. If an application demands bandwidth in the range of 100kHz at a gain of 1000 and if offset and noise performance prevail over circuit complexity, the cascaded amplifier in Figure 3 fits the need.

Figure 1. ISL28634 Block Diagram

Figure 2. ISL28634 programmable Gain Settings

Figure 3. Cascaded Instrumentation Amplifier Achieves 136kHz Bandwidth at Gain of 1000
This composite instrumentation amplifier uses three cascaded ISL28634 devices. Each device has its G1 terminal fixed to ground; therefore, enables a gain change between 1 and 10 by turning the G0 terminal high or low. The three G0 terminals are designated with A0, A1, and A2, which are controlled through the GPIO of the local controller. The required logic states and their corresponding gain settings are listed in Figure 3.

Figure 4 shows that the bandwidth for the single INA at G = 10 (20dB) is 237kHz. This bandwidth is reduced to 2.37kHz at G = 1000 (60dB). Cascading three INAs, each working at G = 10, partially restores the bandwidth to 136kHz while operating at G = 1000.

Figure 5 depicts the corresponding, input-referred (RTI) voltage noise densities. Here, the single INA, at G = 10, has nearly twice as much low-frequency noise as the cascaded amplifier operating at G = 1000.

2. Revision History

<table>
<thead>
<tr>
<th>Rev.</th>
<th>Date</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td>May.18.20</td>
<td>Initial release</td>
</tr>
</tbody>
</table>
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.

© 2020 Renesas Electronics Corporation. All rights reserved.