

Where Do Reference Designs Come From?

Reference designs are circuit diagrams that appear on a datasheet (usually near the beginning). Where do reference designs come from? This seemingly simple question has led to a number of interesting conversations. The answers vary widely among product families and target audiences. If you've ever wondered how they are chosen and why, we have some answers for you.

First of all, if you wander into an engineer's cubicle and ask "Where do reference designs come from?" they will look at you strangely and probably make some off-hand comment like "They are just basic circuits." Pressing further, we find that there is no industry standard or governing methodology for choosing these circuits. Each engineer could only answer for the products he or she worked with, so let's try to bring those thoughts together.

In addition to being the primary technical reference, remember that the datasheet is also a sales and marketing tool. It is designed to show you how great an IC (integrated circuit) is and how simple it is to use. The direct trade-off of highlighting simplicity is providing all the details necessary to ensure successful operation. (If something is so easy to use, why would it need elaborate amounts of explanation?) This same trade-off appears in the reference design.

Let's start with a simple example; a voltage reference. This handy little chip will provide the bias voltage your system needs. How accurate or noisy this voltage may be depends on supply bypassing. The datasheet may include the supply bypass capacitors in the reference design. However, the proper types and values of these capacitors will depend on the frequencies in the system where it is operating. If it is a broadband system, multiple capacitor values in parallel would be best to overcome the resonant behavior of each component. (Resonance occurs between the capacitance and the parasitic series inductance of the layout and package.) All precision ICs need the protection bypass capacitors provide. So, whether they appear in the reference design or not, use bypass capacitors.

Now we've just mentioned the largest common variable in system design, layout. A simple circuit diagram, and therefore a reference design, does not usually take into account any parasitics generated by layout. This causes headaches for many applications engineers. Even when a sample layout is provided, customers must adapt the IC to fit in their system with their particular PCB layout. Part of the challenge (and the fun) of system design is making the appropriate choices and trade-offs for a successful system to come together.

Can a reference design represent all the situations where an IC will be used? The answer is yes...sometimes. It depends on how application-specific or general-purpose the IC is designed to be.

It's tougher to create the reference design for a general purpose device than an application-specific one. By the simple fact that it is general purpose, there are many different uses for the part. Companies want to show two things with their

reference design: how easy the part is to use and how to use it in your system. In this case, these desires are in conflict. Let's take an example: an op amp. Op amps can be used for amplifying, for filtering, for buffering and more. Which application should the engineer highlight in the datasheet? He or she could choose to do multiple reference designs. This is not always optimal since the reference design often becomes the evaluation board circuit. It is not cost-effective to have multiple evaluation boards for every possible application of every different product. Instead, most reference designs try to accommodate the top one or two applications.

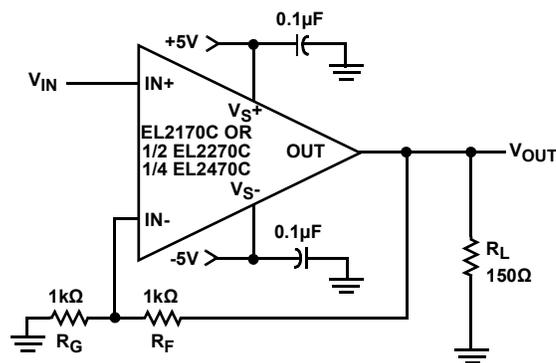


FIGURE 1. REFERENCE CIRCUIT FOR THE EL2170, A CURRENT-FEEDBACK OP AMP

Figure 1 shows how simple it is to hook up a general purpose op amp. (As long as you consider adding five external, passive components to be easy.) Let's discuss each of these external components. It is easiest to accept the presence of R_F and R_G , since they are needed to complete the feedback that stabilizes the amplifier and sets the gain. The next pair of components to consider are the two bypass capacitors connected between the supply pins and ground. Many system designers mistakenly remove these devices to save BOM cost or board space. This is rarely a good idea. Bypass capacitors protect the op amp from spikes and noise on the power supply lines. They are most effective when they are placed closer to the device. As a matter of fact, bypass capacitors should ideally accompany every IC in a system. The final component, R_L is the only one that might be optional. R_L represents the load resistance. When the load is connected, this resistor is not needed. However, if the load is not connected, then the resistor simulates actual operation so you can observe the op amp under similar conditions.

It is also important to notice that this reference design serves multiple devices. The EL2170 is a single op amp. The EL2270 is a dual version of the same part while the EL2470 is the quad version. This same reference circuit applies to all three versions of the part. Note, however, that only one pair of bypass capacitors is needed per IC. That means that the single device has 5 passive components; the dual will have 8 components, while the quad will have 14 components.

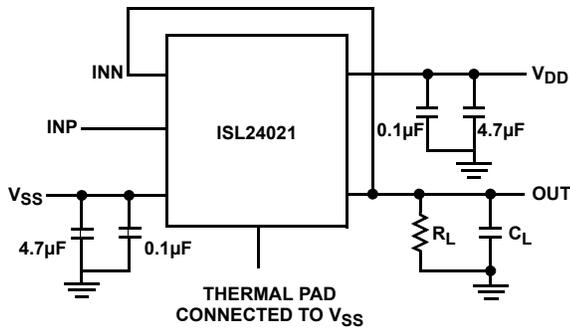


FIGURE 2. REFERENCE DESIGN TEST CIRCUIT OF INTERSIL'S ISL24021 RAIL-TO-RAIL, 1A OP AMP

A second reference design appears in Figure 2. Here we find an op amp hooked up in a buffer configuration (the output pin is connected to the inverting input). Instead of a triangle, which is the symbol of an op amp, the engineer chose to represent the IC with a box. This might be more user-friendly for a system designer that "just needs an op amp". Note that this is a higher-frequency part so there are 2 different capacitors recommended for each supply pin. The 4.7µF takes care of lower frequency noise while the 0.1µF capacitor addresses higher frequency signals on the power lines. As for loading, this time the load is modeled with a resistor and a capacitor in parallel. No surprise here since any higher-frequency system will be more sensitive to the capacitance on any signal path node (like the input and output, in this case).

Once a customer believes a device might work in his or her design, it should be tested. Again, the reference circuit comes in handy. Reference designs commonly include the basic test set-up. On the evaluation board, this allows the customer to verify critical parameters of a device. Sometimes a circuit is included in the datasheet that is labeled "Test Circuit." This clearly demonstrates the configuration under which the device's characteristics are guaranteed. Pay close attention to the small print included above and within the design specification table to check for specific testing configurations.

One final question, and possibly the most important: How do you know the reference design works? The ideal answer should be: because the engineer who wrote the datasheet built and tested it. Unfortunately, humans make mistakes, datasheets go through multiple revisions, and simplifications might limit the applications for which the reference design is reasonable. Nothing replaces your own tests in your own system. Get an evaluation board and hook it up. It's quick, easy and will give you the peace of mind that your system will come together successfully.

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