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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 lead 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.

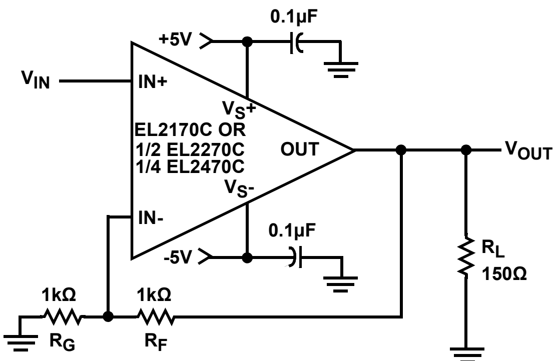

FIGURE 1. REFERENCE CIRCUIT FOR THE EL2170, A CURRENT-FEEDBACK OP AMP

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.

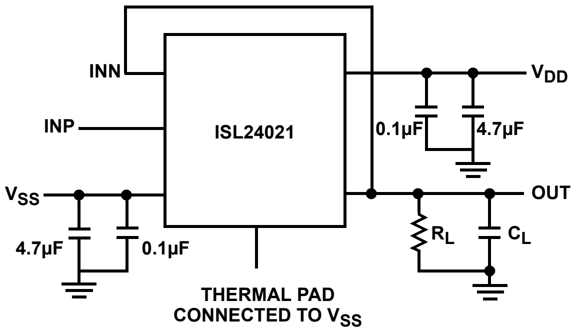

FIGURE 2. REFERENCE DESIGN TEST CIRCUIT OF INTERSIL'S ISL24021 RAIL-TO-RAIL, 1A OP AMP

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.