From August 2006 *High Frequency Electronics*

Guidelines for Using Manufacturer-Provided Reference Designs

Reference designs are usually the fastest way to incorporate a device into a new product, but attention is required to be certain that the design is not changed when added to a larger system

Reference designs have become a valuable part of a product designer's tool set for the creation of new products. The ability to replicate a proven layout with supporting components can save many hours of development time. However, there are many opportunities for problems to arise when translating the reference design into a larger system.

This tutorial article reviews the major pitfalls that engineers can experience during this process. Most of the issues are common, but we will try to point out some of the subtle ways that a reference design can be altered during the overall design process.

Figure 1 · Evaluation boards like this one for the LT5527 from Linear Technology typically are implemented using the reference design for the device.

Layout and Substrate Issues

Typically, the first design task is adding the reference design to the overall p.c. board layout. This is required early in the process to determine the amount of space needed for this portion of system.

One common problem during this part of the design is the desire (or need) to construct the circuit on a different substrate material. A reference design using FR4 will have substantially different properties when implemented on a PTFE board. Transmission line sections will have different impedances; parasitic reactances will change, as well. Different thicknesses of the same substrate as the original design will also have a major effect on circuit performance. One of the subtle factors is that the effective thickness is from the top layer to the ground plane, which is usually one of the internal layers of a multi-layer board. Also, any traces that are moved from the top layer to an embedded layer will then have a very different characteristic impedance. Some of the methods for dealing with different substrates are described in [1].

Component Issues

The selection of supporting components represents the most common changes to a reference design. Many well-meaning engineers have been surprised when the revised design does not work as expected after selecting different coupling or bypass capacitors, bias resistors or input/output matching components.

Modeling and simulation may be difficult with a complex multi-function device, which further complicates the process. Significant adaptation of the reference circuit, with different value components, may require empirical study. A technician may be able to replace the "standard" components on an evaluation board with the desired new parts. A few evaluation boards include pads for the addition of optional components, but this is not the norm.

Often, a manufacturer's applications engineering staff will be able to offer suggestions. After all, the creators of the reference design will have explored a number of choices in layout and component selection. They may have some insight into the particular variation you want to implement.

Most often, however, experience is the best guide. Engineers and technicians who have designed, built and tested many kinds of circuits will gain knowledge about component choices typically used to create or adapt a design for a different frequency range or matched to an impedance different from the common 50 ohms.

Figures 2 and 3 show a test circuit for a mixer IC and its Bill of Materials. The BoM includes some specific brands and model numbers, and has notations on some acceptable alternate part numbers as well. Pay close attention to the manufacturers' recommendations. Substitutions of components must be done with awareness of any changes in behavior. Be aware of variables like Q and self-resonant frequency (SRF) of inductors and large-value coupling/bypass capacitors. Temperature coefficients should match the reference design if your application is intended to operate over the full commercial, industrial or military temperature range.

Specialized components, such as the transformers in the example of Figures 2 and 3, require special attention. At a minimum, obtain test data that directly compares the proposed alternate to a sample of the specified part. Manufacturers may provide cross-references to competitors' parts, but often these are "functional equivalents" that are not identical in all respects.

Interface Issues

The portion of a reference circuit that cannot be completely provided by the manufacturer is the interface to external circuitry. Some devices are designed for a standard 50-ohm input and/or output impedance and can be "dropped into" a 50-ohm system with minimal concern for altered performance. However, there are many devices which, for reasons of performance, do not attempt to provide a 50-ohm match. Often, these are RFICs or MMICs that have an impedance that affects noise figure or intercept point, or that varies with the frequency of operation.

Also, the user's application may not be the same as the test circuit provided by the manufacturer, requiring that modifications be made to the published design. These "semi-reference" designs are common, and while they require additional design and testing, the manufacturer typically provides both data and applications support that can ease the process.

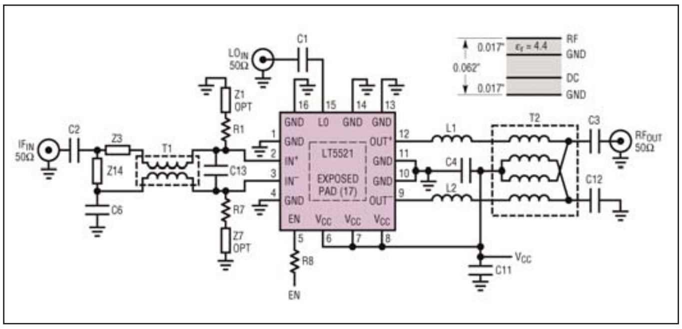

Figure 2 · Diagram of a device test circuit, also used for the devices' evaluation board. If the user's application is within the design limits of this circuit, it can also be used as a reference design for a portion of the larger system. ***(Linear Technology LT5521 used for this example)***

REF	f_{IF} = 250MHz, f_{RF} = 1.95GHz f_{LO} = 1.7GHz, V_{CC} = 5V	f_{IF} = 44MHz, f_{RF} = 1.045GHz f_{LO} = 1.001GHz, V_{CC} = 5V	f_{IF} = 250MHz, f_{RF} = 1.95GHz f_{LO} = 1.7GHz, V_{CC} = 3.3V
R1, R7	110Ω, 1%	110Ω, 1%	22.6Ω, 1%
Z14	10pF	120nH	10pF
Z3	0Ω	150pF	0Ω
L1, L2	2.7nH	10nH	2.7nH
T1	M/A-COM MABACT0010[3]	M/A-COM MABACT0010[3]	M/A-COM MABACT0010[3]
T2	M/A-COM ETC1.6-4-2-3	M/A-COM ETC1.6-4-2-3	M/A-COM ETC1.6-4-2-3
C1, C13	6.8pF	27pF	6.8pF
C3	82pF	3.9pF	82pF
C12	82pF	1nF	82pF
C2, C4, C6	1nF	1nF	1nF
C11	1µF	1µF	1µF
Z1, Z7	0Ω	0Ω	100nH
THIS COMPONENT CAN BE REPLACED BY PCB TRACE ON FINAL APPLICATION			
R8	10k	10k	10k

Note 1: Tabulated values are used for characterization measurements.
Note 2: Components shown on the schematic are included for consistency with the demo board.
If no value is shown for the component, the site is unpopulated.
Note 3: T1 also M/A-COM ETC1-1-13 and Sprague Goodman GLSW4M202. These alternative transformers have been measured and have similar performance.

Figure 3 · Bill of Materials for the test circuit of Figure 2. Note that some parts are listed by specific manufacturers' part numbers.

Summary

Reference designs are valuable aids that can speed the integration of a new component into a larger system. This tutorial notes the most common factors involved in the process of implementing a reference design. This process includes a combination of careful replication of the reference design, intelligent adaptation for specific applications, and, when appropriate, modeling and/or breadboarding to assure that the revised circuit is correct.

Reference

1. J. Capwell, W. Clausen, T. Weller, L. Dunleavy, "Accurate Models Simplify Reference Designs for RFIC Amplifiers," *High Frequency Electronics*, Nov. 2005.