Reducing PCB design costs: From schematic capture to PCB layout

By Tom Hendrick
Engineering Technician, Advanced Analog Products

Modern EDA software packages provide a host of tools that allow designers to draw schematics in order to produce printed circuit boards. Understanding the basic requirements of these tools and the interactions between them can help to reduce the cost of PCB designs.

Figure 1. Schematic library symbols

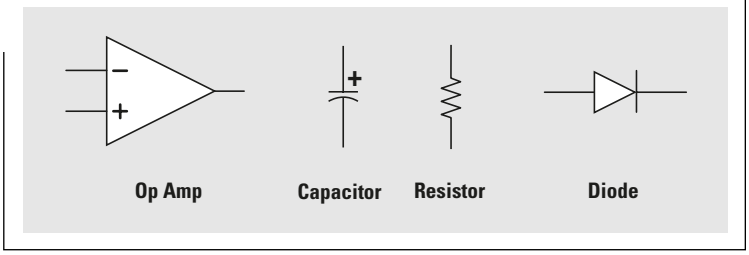
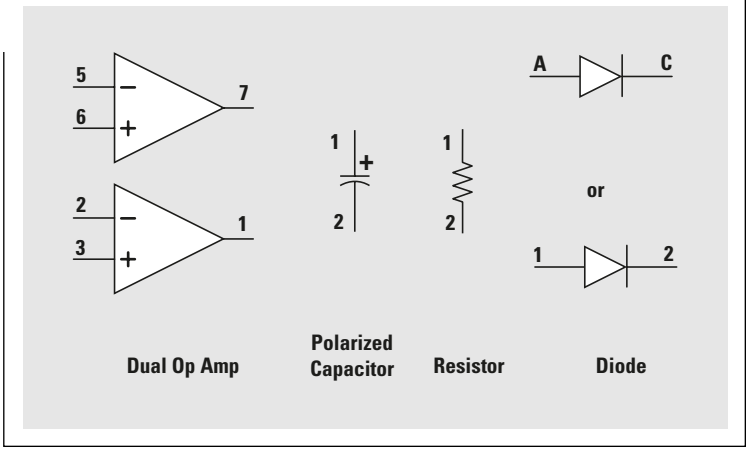


Figure 2. Component electrical pin numbers



The basics

Schematic capture packages contain various tools and features that make the process of entering a schematic and documenting a circuit easy on the designer. One common feature among popular schematic capture packages is an array of libraries. Another is the ability to output netlists that are compatible with various simulation and PCB layout packages. The schematic capture process creates a database of symbolized parts and a netlist describing the connections between the symbols.

PCB layout packages have their own suite of tools and features designed to streamline the creation, verification, and documentation of a physical printed circuit board. All the board designer needs to do is define the outline of the board, add footprints from a decal library, import the netlist, and route the connections. Netlist comparisons will verify that the board matches the schematic. Online error checking warns of open- or short-circuit conditions. Design rules can be set up to check things such as matched net lengths, routing stubs, and parallelism.

Sounds simple, doesn't it? Draw a schematic, output the netlist, and sit back to wait for your prototype assemblies. Simple, that is, until the call from the assembly shop tells you that a part does not match its footprint, or you spend hours tracking down a diode or capacitor that was laid out backwards. An understanding of the process that takes place when exporting a schematic netlist is necessary to ensure your board layout will be correct.

Schematic libraries

Schematic libraries are based on familiar symbols such as those shown in Figure 1.

The symbol libraries are generic by nature. They are intended as building blocks for various part types. Schematically speaking, the same resistor symbol can be used for a 1/8-watt surface mount or a 100-watt chassis-mount device. The op amp symbol could be a single device in a 5-pin SOT package or a dual device in an 8-pin DIP. To create a valid schematic part, these symbols must, at a minimum, have electrical pin numbers assigned and be saved in a part type library.

Quite often, this is the extent of the part type libraries supplied with the schematic capture tool (see Figure 2). Enough information is given to allow the designer to create a schematic, but information required to create a printed circuit board is missing. As with the symbol library, the vendor-supplied part type libraries are intended as a starting point for a customized user library.

Customizing a vendor-supplied library requires that the user assign attributes detailing the specific part to be used in the design. A generic vendor-supplied part type "resistor," for example, could be copied to a customized user library, be given a footprint attribute "1206," and then be renamed to part type "RES_1206_SMT." When this new part is called from the user library, it would always require that a 1206-size surface-mount footprint be used to represent this device on the printed circuit board.

PCB libraries

The PCB libraries are based on the footprints designated by industry standards. They usually include common surface-mount and through-hole devices. To create a footprint, or decal, pads are arranged in a specific pattern and designated with an electrical pin number. Figure 3 is

an example of some common footprints shipped with most PCB design tools.

As with the schematic symbol library, one PCB decal can be associated with many different part types. The layout database relies on the pin numbers defined in the schematic library for mapping to a footprint in the PCB library. This process allows two completely different 8-pin devices to use the same 8-pin PCB decal.

Understanding the importance of this problem becomes even more obvious when you consider parts such as diodes or electrolytic capacitors. A generic schematic part called "DIODE," for instance, could be assigned a PCB decal called "D0-41." If the diode is designated in the schematic library with electrical pin 1 as the anode and electrical pin 2 as the cathode, the associated D0-41 footprint must also have the same designations (see Figure 4). Having the pins reversed on the PCB footprint can cause serious problems that can be difficult to debug on an assembled board. Error checking will not catch this type of problem.

Figure 3. Example of common PCB footprints

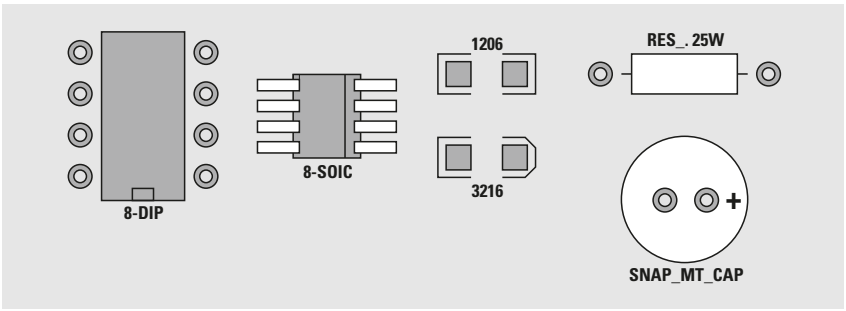
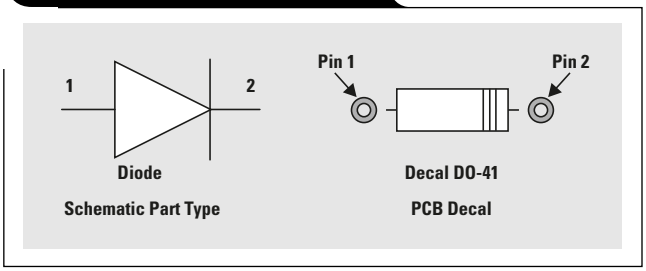


Figure 4. Diode designation



The netlist file

The netlist file is where the schematic and PCB databases come together. The output from a schematic database is formatted to meet the needs of a specific PCB layout package and contains several specialized sections.

The first section usually describes the PCB decals that are needed in the design. If a decal does not exist in the PCB library, the desired part cannot be placed on the board. All schematic part types must be assigned a valid PCB decal before the schematic netlist can be imported to the PCB design database. Most PCB design packages will immediately flag an error and stop processing the netlist file if a decal is missing.

The next section of the netlist file contains the connection, or "rubber band," information. If a decal cannot be found, there can be no connections to route. Other sections may include PCB routing directives, simulation directives, or detailed information for power and ground connections.

Save time and avoid errors

Avoid using different platforms to produce schematic and PCB designs. Most EDA vendors can provide bundled schematic capture and PCB layout packages that are designed to work together. These integrated packages provide a common shell that allows for easier verification of the schematic and board files, and makes processing engineering changes relatively painless. Integrated packages usually allow "back-annotation" as well, so that changes made in a PCB design can be reflected back to the schematic.

The use of a common library can help prevent problems. Develop a system where one regularly updated library serves the needs of all persons involved in design activities. Multiple people creating the same devices in individual libraries will only lead to errors and confusion at layout. If a new part needs to be constructed, build it in a central library so everyone can use it. Review all newly created parts and their associated PCB footprints for accuracy.

PCB layout tools will normally present an error or warning if the schematic part references a PCB footprint with fewer electrical pins than described in the schematic netlist. For example, if a 14-pin device were assigned to an 8-pin decal, there would be an error mapping pins 9 through 14 described in the schematic. If, on the other hand, a 14-pin decal is assigned to an 8-pin device, error flags are not necessarily raised. A PCB decal can have more pins than electrically represented in a schematic; mounting or alignment holes, for instance, are part of a decal. This type of error often goes unnoticed as well. It is usually found after the PCB is fabricated, when someone tries to mount a 14-pin device in a 16-pin decal.

Many companies use outside sources to design printed circuit boards. If an external design house provides your printed circuit board layouts, make sure your engineers are familiar with the tools they use. Sending out a netlist file in the correct format will save time and money. Share your libraries with your vendor so they can save time and avoid having to re-create parts. Create your schematic libraries so that they reference the PCB footprint libraries of your design house.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products	
Amplifiers	**amplifier.ti.com**
Data Converters	**dataconverter.ti.com**
DSP	**dsp.ti.com**
Interface	**interface.ti.com**
Logic	**logic.ti.com**
Power Mgmt	**power.ti.com**
Microcontrollers	**microcontroller.ti.com**
Applications	
Audio	**www.ti.com/audio**
Automotive	**www.ti.com/automotive**
Broadband	**www.ti.com/broadband**
Digital control	**www.ti.com/digitalcontrol**
Military	**www.ti.com/military**
Optical Networking	**www.ti.com/opticalnetwork**
Security	**www.ti.com/security**
Telephony	**www.ti.com/telephony**
Video & Imaging	**www.ti.com/video**
Wireless	**www.ti.com/wireless**

TI Worldwide Technical Support

Internet

TI Semiconductor Product Information Center Home Page
support.ti.com

TI Semiconductor KnowledgeBase Home Page
support.ti.com/sc/knowledgebase

Product Information Centers

Americas

Phone	+1(972) 644-5580	Fax	+1(972) 927-6377
Internet/Email	support.ti.com/sc/pic/americas.htm		

Europe, Middle East, and Africa

Phone			
Belgium (English)	+32 (0) 27 45 54 32	Netherlands (English)	+31 (0) 546 87 95 45
Finland (English)	+358 (0) 9 25173948	Russia	+7 (0) 95 7850415
France	+33 (0) 1 30 70 11 64	Spain	+34 902 35 40 28
Germany	+49 (0) 8161 80 33 11	Sweden (English)	+46 (0) 8587 555 22
Israel (English)	1800 949 0107	United Kingdom	+44 (0) 1604 66 33 99
Italy	800 79 11 37		
Fax	+(49) (0) 8161 80 2045		
Internet	support.ti.com/sc/pic/euro.htm		

Japan

Fax			
International	+81-3-3344-5317	Domestic	0120-81-0036
Internet/Email			
International	support.ti.com/sc/pic/japan.htm		
Domestic	www.tij.co.jp/pic		

Asia

Phone			
International	+886-2-23786800		
Domestic	Toll-Free Number		Toll-Free Number
Australia	1-800-999-084	New Zealand	0800-446-934
China	800-820-8682	Philippines	1-800-765-7404
Hong Kong	800-96-5941	Singapore	800-886-1028
Indonesia	001-803-8861-1006	Taiwan	0800-006800
Korea	080-551-2804	Thailand	001-800-886-0010
Malaysia	1-800-80-3973		
Fax	886-2-2378-6808	Email	tiasia@ti.com
Internet	support.ti.com/sc/pic/asia.htm		ti-china@ti.com

C011905

Safe Harbor Statement: This publication may contain forward-looking statements that involve a number of risks and uncertainties. These "forward-looking statements" are intended to qualify for the safe harbor from liability established by the Private Securities Litigation Reform Act of 1995. These forward-looking statements generally can be identified by phrases such as TI or its management "believes," "expects," "anticipates," "foresees," "forecasts," "estimates" or other words or phrases of similar import. Similarly, such statements herein that describe the company's products, business strategy, outlook, objectives, plans, intentions or goals also are forward-looking statements. All such forward-looking statements are subject to certain risks and uncertainties that could cause actual results to differ materially from those in forward-looking statements. Please refer to TI's most recent Form 10-K for more information on the risks and uncertainties that could materially affect future results of operations. We disclaim any intention or obligation to update any forward-looking statements as a result of developments occurring after the date of this publication.

Trademarks: All trademarks are the property of their respective owners.

Mailing Address: Texas Instruments
Post Office Box 655303
Dallas, Texas 75265

© 2005 Texas Instruments Incorporated