

Choosing Components: Part 1

INTRODUCTION

Electronic components are specified by their parameters. A parameter is some property of the component that has a numerical value, and describes one feature of the component's performance. The values of a given component's parameters are found in the manufacturer's data sheet and are usually called the "specs" (specifications).

For instance, the following is a partial list of specs for a resistor:

- tolerance: 5%, 1%, 0.1%, etc.
- wattage: 1/4 W, 1/2 W, 1 W, etc.
- material: carbon film, metal film, wire-wound, etc.
- temperature range: commercial (0 to 70 degrees C), military (-55 to 125 degrees C) , etc.
- temperature coefficient (tempco): given as percent/degree or ppm/degree
- physical dimensions: length, diameter, etc.
- form-factor: axial leads, radial leads, etc.
- MTBF (mean-time-before-failure): hours
- price: always a consideration

If something as simple as a resistor has that many specs, you can imagine how many a transistor or integrated circuit must have. The obvious question is: How do you choose a part? The answer is two-fold. First, know what specs a component has. Second, know which specs are important for your application.

The first part, knowing what specs a component has, is the easy one. For something as common as a resistor, you can find the information in an introductory text book. For any component, the best source of information is the manufacturer's data sheet. It used to be that you had to get the data sheets as hard-copy, often in the form of a data book. Now you can almost always go to a manufacturer's WEB site and download the data sheets.

It's the second part, knowing which specs are important for your application, that takes some analysis. A good source for this purpose are the application notes (ap-notes) that most component manufacturers supply, and which also can be found at the WEB site.

WHAT IS IMPORTANT

How do you know what's important? The answer is to understand what it is you're trying to do. If you understand what role a component plays in your design, you can identify most of the key parameters immediately. A few may not be obvious, but can usually be recognized when you test your breadboard.

For example, suppose you are building a "quick and dirty" 5-Volt power supply to use on your bench, and it uses an LED to indicate when it is on. You need to choose a resistor to limit the current in the LED. So what specs are important for that resistor? Well, certainly the value and wattage are important. But since you just want to see whether the LED is on or off, the tolerance of the resistor is not going to be critical. The worst tolerance you can find on a resistor is 20%, and that would be adequate. So a common 5% resistor will work fine.

Let's look at some of the other resistor specs:

- **Material:** since this is not a demanding application for a resistor, choose the most common, and lowest cost, device. That would be carbon film.
- **Temperature Range:** the supply is going to be on your bench, not in a tank. So you don't need a military temperature range, the commercial range is sufficient.

- **Tempco:** since the tolerance wasn't important in this application, then the drift in value due to temperature won't be an issue since it will have less impact than the tolerance.
- **Physical Dimensions:** once you have chosen the material, the size is mostly determined by the power rating.
- **Form-factor:** again, choose the most common, lowest cost, version: axial leads.
- **MTBF:** not a concern in this application. If the proper wattage is used, even common resistors are very reliable.

Some parameters, such as size and wattage, are interrelated. Higher wattage resistors are going to be physically bigger than lower wattage resistors of the same type. But a 2 Watt wire-wound resistor may be smaller than a 1 Watt carbon film resistor. Also, the dimensions of a 100 Ohm, 1/2 Watt carbon resistor will depend on whether it has radial leads or axial leads, or is a surface mounted device with no leads.

Some parameters depend on production considerations. We said to use a resistor with axial leads for that LED. The assumption was that your design was for a "one-off" project you're building by hand. If you were designing a commercial product for high-speed, high-volume production, then you would use a surface mount device. Why? Because high-speed, high-volume production is done by machines which can use surface-mount components more efficiently.

IDENTIFYING KEY PARAMETERS

The first step in choosing a device is to decide which parameters are crucial and which parameters are not. For the resistor example above, wattage was crucial but tolerance was not. We decided that by knowing what role that resistor had to play in the design. Now let's look at something more complicated than a resistor for an LED. Let's look at a bipolar junction transistor (BJT). If you have an Adobe reader, you can see a typical transistor data sheet at:

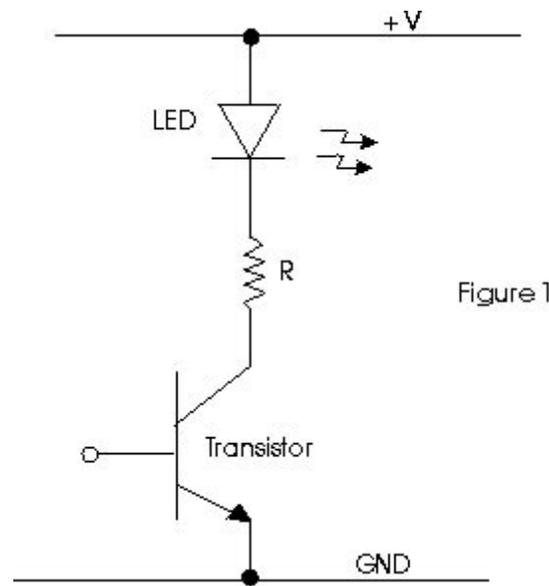
http://www.semiconductors.com/acrobat/datasheets/2N4401_4.pdf

To be able to view this document, [download](#) your free copy of Acrobat Reader software from the Adobe site.

Of all the parameters on a transistor data sheet, how do you identify the key parameters for your application? You do it by analyzing two things: first, what does this transistor do in the design, and second, what parameters relate to that job. While you know the role you want the transistor to play, components sometimes interact in ways that we didn't anticipate. So it is necessary to analyze just what the transistor is actually doing.

As for knowing how the specs relate to performance, look for those parameters that are expressed in the same terms, or units of measure, as the key role of the transistor. Start with the obvious things: the maximums for voltage, current, and power. Then move on to other parameters that are crucial to the application.

For example, suppose you want to use a transistor as a switch: either on or off (*see Figure 1*). When it is on, the transistor will conduct the most current through its collector. So you need to look at the spec for maximum collector current (MAX IC) which will be in Amps or milliAmps. When it is off, the transistor will have the maximum voltage at the collector. So you need to look at the spec for maximum collector voltage, sometimes called 'breakdown' voltage. You will find two maximum voltage specs on the data sheet: one for collector-to-emitter (VCE or VCEO) and one for collector-to-base (VCB or VCBO). Use the lesser of the two values.



Consider speed. If you are using the transistor to switch an indicator LED on and off, then speed is not important. But if you are using the transistor to switch an LED in a fiber-optic data transmission circuit, then speed is important and you need to look for parameters measured in units of time (microseconds or nanoseconds). Remember that frequency is the inverse of time, so parameters measured in Hertz may also be important.

Suppose you are interested in speed. So you look on a transistor data sheet and find the following four parameters: delay time t_d , rise time t_r , storage time t_s , and fall time t_f all specified in nanoseconds. You also find something called f_T given in megaHertz. If you know what they mean then you can determine if they are suitable for the application. If you don't know what they mean then you've got some homework to do, but at least you know what to look for. You can then refer to a textbook, the manufacturer's application notes (ap-notes), or use a search engine on the Internet to find what you need.

WHAT'S NOT SO IMPORTANT

For some parameters, the exact value is not important as long as it satisfies some minimum requirement. One such parameter is the current gain of a BJT, called h_{FE} or beta. Transistors with the same part number can have values of beta that span a range of 3-to-1 or more. What's more, the value of beta can change with temperature and even can change with collector current.

The way to deal with beta is to design the circuit both to work with the lowest expected value, and also to be insensitive to changes in value. For example, just about any BJT will have a beta greater than 20, so you could always take that as your minimum value. If the circuit is designed properly, then it will work with beta equal to 20, 50, 100, or higher.

DERATING

The term 'derating' is often used to refer to the practice of using a component with a higher rating than is actually required. This is commonly done with the maximum ratings for voltage, current, and power dissipation. Voltage, current, and power are 'stressors' that have a strong influence on failure rate (MTBF). The more stress, the sooner the failure.

A derating factor of 2 is commonly used. For example, suppose you determine that a transistor in your design must withstand 50 Volts maximum collector to emitter voltage, 100 mA maximum of collector current, and dissipate 500 milliWatts of power. If possible, you should choose a device with a MAX VCE of at least 100 Volts, a MAX IC of at least 200 mA and a maximum power dissipation of at least 1 Watt.

KNOWLEDGE AND EXPERIENCE

If all your projects come straight out of a 'cookbook', then all you need to pick the right components is a catalog. But if you are modifying a circuit, or designing your own circuit 'from scratch', then you will need to be familiar with the parameters of common components. One way to do that is by reading textbooks, application notes, and data sheets. But it is also necessary to build your designs and test them out.

Don't feel that you need to have analyzed every possible aspect of your design before you can build a breadboard or prototype. And don't feel that if a breadboard circuit doesn't work perfectly the first time that you've 'failed'. We usually learn more from our mistakes than we do from our successes. The purpose of a breadboard is to help you identify the key areas in your design by allowing you to make measurements on the actual components. You'll find that with experience you will get your designs up and running more quickly.

WHAT'S NEXT

In later parts of this series of Tech Tips we will look at some specific circuits and identify the key parameters of each component. We will look at tracking symptoms back to the problem part. And along the way, you should be able to see common themes in design, and to become more familiar with device parameters.