CIRCUIT CELLAR ONLINE

FEATURE ARTICLE

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Looking at the Specs

With this article, Gerard helps us answer some of the questions about one of the defining characteristics of most engineering projects, showing us that, when engineers, marketeers, and customers all have a common goal, they can get the most out of specifications. But, is it really possible for all three to come to an agreement? See what Gerard has to say.

Specifications are the defining characteristic of most engineering projects. Few other jobs hang by that word. But, how are specifications created? Who creates them? What do you do if you are faced with an impossible specification? What about safety issues? And remember, most engineering lawsuits are for products that fail specifications.

There are two sides to specifications, user and producer. Naturally, when you are a consumer buying a stereo amplifier, you examine the specifications to determine if it fits your needs and desires. Conversely, if you are a manufacturer, you define your product with specifications to give the consumer information about how the amplifier should perform. But, here is the underlying factor in the making of specifications: profit.

Specifications are used to compete against other products in the marketplace. It is good business to specify your product as attractively as possible. Otherwise it won't sell as well as it could. Thus, all specifications have an inherent conflict of interest. There is the need to be honest, as well as the need to sell the product.

ARE YOU FLEXIBLE?

Specifications are not black and white numbers. Of course, standard measurement techniques are used to reduce their flexibility. But, there will always be creative people who use loopholes in standard techniques to their benefit. Often, companies reward this creativity. After all, that employee has made it more attractive or perform better without actually changing the product. This clearly is a cost-effective approach to product enhancement.

Take this simple fictional example. You are designing a digital logic gate. The typical propagation delay for this class of logic is 5 ns, like yours. But, your company wants faster chips. Normally, the speed is tested with 20 pF of load. So, reduce the load to 10 pF, and the apparent propagation delay is reduced. In short, changing the testing procedure changes the performance. Or, you could change temperature, board layout, power supply voltage, or a dozen other variables. Being honest, you insist that the actual test setup be defined in the datasheet. How many consumers will notice the difference between the way you test it and the normal way of testing? Do you really compare such specification details?

This is called specmanship and is not considered good engineering practice. Put your chip in a specific circuit and measure the propagation delay. Then, put a competitor's chip in the same circuit and see if there really is a difference. This is the only way to compare propagation delay, but it's awkward and time consuming. In the previous example, there wouldn't be a difference.

But, take the marketing point of view for a moment. You have faster chips. They'll sell better. More sales means more profit, which means a stronger company. Obviously, this is a good deal.

Because the test procedure is completely defined in the datasheet, there is nothing dishonest or unethical. Nowhere is it said that your chip is faster than the competitor's. The specifications and test procedures are presented, and the user determines if they are appropriate for a particular use. Realistically, few users need the full speed of the gate anyway. So, the likelihood of a user complaining is small. And, if there is a complaint, the datasheet explains everything in detail.

This example shows the classic tug-of-war between marketing and engineering. It is important to realize that both are correct from their own point of view! There is nothing wrong about making your chip look good. Conversely, the chip isn't really any faster than the others on the market.

WHO'S THE BOSS?

This brings us to the topic of who defines the specifications. Generally, it is left to engineering to verify or test to the specifications. However, it is usually marketing that generates the specifications. This is not as odd as it sounds.

Marketing talks to the consumer. The consumer says, "I need a faster chip, one that switches in 3 ns." Perhaps the consumer will add, "The load is 10 pF." So, the company decides to create a chip that switches in 3 ns. It becomes your job to develop such a product.

Perhaps all that is needed is a different test with a load of 10 pF. Or maybe a completely new topography is needed. In either case, the specifications generated by engineering are the performance specifications, while marketing generates goal specifications. These are obviously different.

This doesn't mean that engineers can't also generate goal specifications. Often, a clever idea drives engineering research and development into improving the performance of a product.

When this happens, marketing is presented with a new product that it is supposed to sell. This can get marketing upset. They are supposed to spend time and effort, as well as their customer's time and effort, to learn about a new product. They could be selling other existing products, but now they have to try to sell a new and unfamiliar product to a customer who hasn't indicated any interest.

The other method is when marketing commits engineering to a customer's performance specifications for a product. Then, engineering gets upset. They are supposed to spend their time and effort developing a product to specifications that make no sense or are impossible.

The point is that marketing and engineering must work closely together. Otherwise, the whole company suffers. There is no alternative.

SO, WHAT ARE YOUR OPTIONS?

What do you do if you are presented with a project that requires impossible specifications? For example, let's say that marketing has promised to measure ±0.1°F with your standard embedded microcontroller. The problem is that the microcontroller has an 8-bit A/D and is specified as 0° to 200°, ±2°. Obviously going from 0 to 200 in 0.1 steps requires at least 11 bits (2048 steps).

There are a few things that you should remember, everything in marketing is negotiable, marketing has a potential sale, and marketing is not engineering. So, sit down, take a breath, and think things through. Examine all the options and possibilities. Remember that someone has told marketing this is what they want. But, who told them, an engineer or a manager? What application is this for? How much extra cost will be acceptable? What is the likely volume of sales?

After examining the problem in detail, you should have a meeting with marketing (or whoever gave you the specifications). First, show them the cost of adding an out-board A/D converter (software and hardware) and whatever else is needed to perform the task. Then explain why the existing system can't work. It is always good practice to give a solution first, even if it's unlikely to succeed. It shows that you are working on their problem, not dismissing it. Get as many details from marketing as possible. If it's possible, a technical discussion with the customer would be useful. Often, these impossible specifications are a result of miscommunication or wishful thinking.

In this case, the application was for monitoring the body temperature of zoo animals. Clearly the range of temperature is small, and an 8-bit A/D will resolve 0.1° from 95° to 105° (100 steps).

But wait! There is an important difference between resolution and accuracy. Determining the actual temperature (i.e., 98.6°) to ± 0.1 requires a precision sensor. The temperature sensors used in such a situation only provide absolute accuracy to ±2°. So, a real temperature of 100° could be measured as anywhere from 98° to 102°. This is not accurate. But, it turns out that the animals are generally healthy. So when the system is turned on, the first reading is the normal temperature. All that needs to be measured is a change from normal (accuracy refers to an absolute measurement; resolution refers to a relative measurement).

In short, by re-examining the problem, a small design change to the system allowed the standard microcontroller to be used. This makes marketing happy, the customer happy, and you get a hearty pat on the back. In general, when faced with impossible specifications, find a solution first. It may not need to be a great solution, but don't simply say, "It can't be done." Marketing and management view this as poor teamwork.

It may come to a point when it is impossible to achieve the specifications as presented. For example, use the onboard 8-bit A/D and measure 0.1° over 0° to 200° (without range-changing). In such a case, marketing and management are willing to ignore or falsify the specifications in order to make the sale. Although rare, this has happened (e.g., military programs that don't work). You will have to choose between your job and your character. Be careful not to get roped into being the scapegoat. It will eventually be discovered. Written documentation is vital in this situation.

If you are working for yourself, the situation may arise when the customer presents an almost working product that needs tweaking. This is tricky. Again, provide a solution for your customer and explain in detail why it is necessary. If you take the job, be sure to have everything detailed in writing. Often these customers don't understand the solution. If they did, their product would work.

WHAT ARE THE HAZARDS?

It is important to understand the difference between hard and soft specifications. Basically this is a measure of importance. Some specifications are more important than others. It is important that your voltmeter read the proper AC voltage at 60 Hz. It's not so important that it read properly at 200,000 Hz. Of course, your meter probably has a specified high-frequency limit. Have you ever tested that? Was it an important point in your decision to buy it? Probably not.

The most important (or most difficult) specifications deal with personal safety. It is absolutely critical that these specifications be conservative. What is the AC leakage current? What fuse rating is proper? Do you know how to properly specify a fuse? Are the power supply components rated properly? If not, an exploding filter capacitor or fire could result. If a part fails, will it cause the product to become a shock hazard? Will a person be at risk? Always search for possible dangerous situations. Most likely they won't occur, but you should be prepared.

For example, I was asked to design a custom doorbell to be installed by the user. It worked on the 16-VAC doorbell transformer, but I knew that someone somewhere was going to connect it to 110 VAC. So, I took a little extra time and designed the system to tolerate 110 VAC. It only required changing two quarter-watt resistors to half-watt parts.

Did you notice the change in perspective? I went from creating product specifications to identifying part specifications. This is another point. Specifications of a product depend on the specifications of the parts. Although obvious, it is surprising how often it is overlooked. I frequently see designers fail to specify a proper part, and then they wonder why the final product fails to meet expectations.

One of the most common and disturbing examples of this is in simple linear power supplies—a transformer, bridge rectifier, and capacitor. Many times the capacitor and rectifier are underrated. Suppose the transformer is 24 VAC. A 35-V filter capacitor should be okay, right? This is the standard 50% voltage overrating for power supply circuits. Wrong.

The unloaded voltage will almost certainly be greater than 35 V. Remember that the capacitor (without load) will charge up to the peak voltage. This is 1.414 times the rated (RMS) voltage, or 33.9 V. Also, the transformer is rated under load. Without load, the transformer output is 3 to 5 V greater than its nominal rating. Even after subtracting the rectifier diode voltage drops, the no-load voltage will still be greater than 35 V. And, don't think that there won't be occasions when the load will be removed. Don't you sometimes remove the load to check the power supply? How would you react if the power supply filter capacitor exploded when you did this? A 50-V capacitor is the minimum voltage acceptable. A 63-V rating would be better.

The PIV of the bridge rectifier should also be a minimum of 50 V, however, 100 V is better and doesn't cost much more. Just don't forget inrush current. Suppose the power supply provides 0.5 A. You choose a 1-A transformer. At powerup, the capacitor acts like a dead short, and the full power of the transformer goes through the diodes. This also occurs if there is a short circuit to the power supply. So, if you chose 1-A rectifiers for the 0.5-A supply, they could easily fail. Admittedly, diodes are rugged, but for a few pennies, safety and reliability can be enhanced.

I am always conservative when I design a power supply. Cutting corners here always seems to create problems later.

TO BE OR NOT TO BE SPECIFIED?

This article wouldn't be complete without some mention of software specifications (stop laughing). It is true that Microsoft has managed to create a powerful software monopoly without any specifications or performance guarantees for its operating system. Microsoft's "End User License Agreement" is remarkable reading, but the rest of us have to provide a product that works.

There seems to be a lack of specifications for software (as compared to hardware). With software, if it works, it must be okay. Part of the reason is that extensive testing of software is difficult. There are few standard tests and tools. Generating specialized software tests is difficult and expensive.

That said, it doesn't mean that software shouldn't be specified. Often, software is operationally specified. These software goal specifications are generated at the start of the project, defining what the software does. But, how do you know how well it works? There are a few numbers, like lines of code and execution speed, but these don't tell you much. Of course, there are hardware requirement specifications, which detail what is needed for the software to operate. These are important, but also don't indicate how well the software works.

It would be nice to have an index of complexity. For example, the ratio of branch instructions to in-line code or a MTTR (Mean Time to Repair) specification. Perhaps a comment to code ratio could be standardized. Unfortunately, I don't see this happening soon.

UNHAPPY CUSTOMERS

Most legal action happens because the customer feels that the product doesn't perform properly, failing specifications. "This clock doesn't keep time!" "The radio doesn't pick up my favorite station!" "The power supply keeps failing!" "I want my money back!"

There will always be unhappy customers. However, your product shouldn't make them that way. Proper specifications can go a long way to educate your customer about what to expect from your product. Unfulfilled expectations (realistic or not) are a major cause of customer dissatisfaction.

The spec sheet should define what the product needs to operate (voltage, frequency, etc), and what it produces (output power, distortion, etc). It should have the physical dimensions. It should state if other apparatus is needed for operation (AC adapter, microphone, etc). This is the absolute minimum for specifications.

At the next level are the softer specifications. These may not be absolutely necessary like the upper frequency response for a VOM. These are typical specifications that provide the user with guideline performance, rather than a guaranteed performance.

Try to place yourself in the user's point of view. What is important to know about your product? If you were buying it, what factors would you like to compare to your competitor's product. And, if your specification is poor in one area, you may consider not including it. In that regard, be careful not to over-specify your product. Don't force your product to meet a specification that isn't important. You don't want to spend time and money making your product conform to whimsical requirements (i.e., the color of the PC board or the number of detents on the volume control). Be sensible, understanding the conflicts of interest will help you create, use, and comprehend proper specifications. ■

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