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How To Select Bridge Rectifiers

by Jos van Loo, Taiwan Semiconductor Europe, Zorneding, Germany and Kevin Parmenter, Taiwan Semiconductor America, Chandler, Ariz.

Bridge rectifiers have been around for decades. Choosing to use a bridge rectifier in a design versus discrete rectifiers is often a tradeoff in terms of space, size, cost or whatever the case may be. Sometimes pc board space and the insertion of a single component into the board (versus four) are the most important issues, other times not. Sometimes power levels dictate the use of a packaged bridge rectifier. In this article we will assume that the choice to use a bridge rectifier rather than discretes has already been made.

Given that decision, what are electrical and mechanical specifications that need to be considered and what are the designer's options when selecting a bridge rectifier? In this article we will identify the relevant specifications, outline the options, and offer advice on how to navigate the specs, quality and cost considerations. Some of the common assumptions made about device cost versus device rating are wrong, and you can take advantage of the reality to improve reliability in your designs.

Size, Package and Power Rating

There are three-phase and single-phase bridge rectifiers dictated by the application. If additional alternative sources are desired, multiple single-phase bridge rectifiers can be used in a multiphase application. The available pc board space must be known and/or the power level needed—these will dictate the size and available package options for your PCB layout.

Typically, surface-mount devices are available for up to approximately 70-W applications and above that leaded package devices must be chosen. From 70 W to approximately 1000 W, SIP package devices are available. Above 1000 W chassis-mount devices are the preferred package up to and including devices with FASTON lugs for soldering or quick-connect push-on FASTON connectors. Fig. 1 shows the industry-standard bridge rectifier packages that are available.

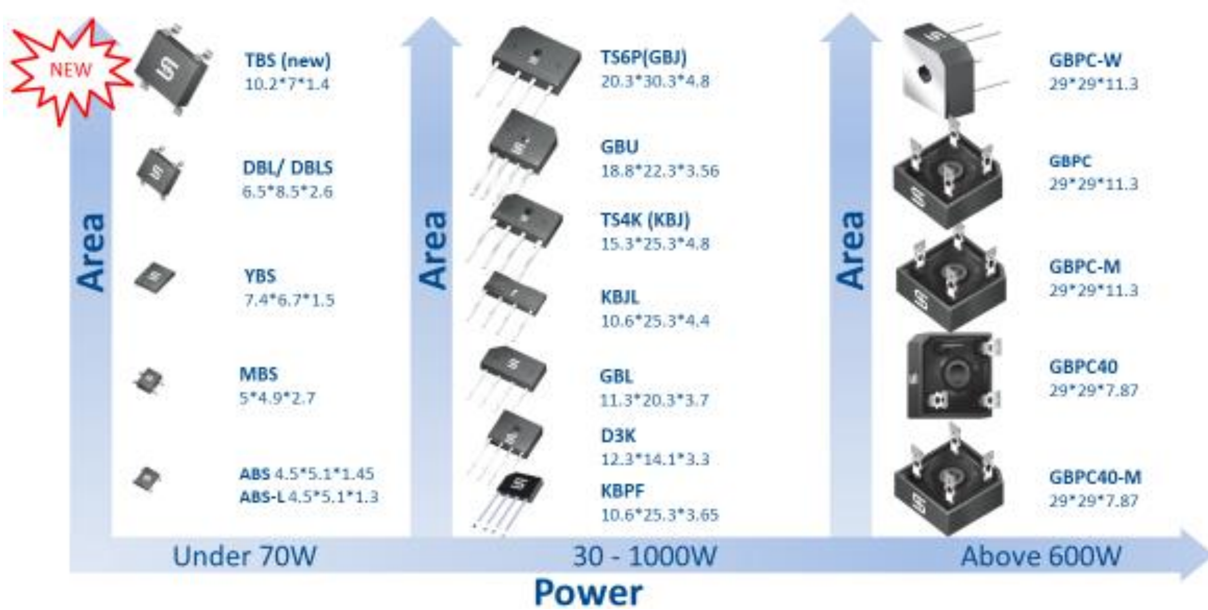

Fig. 1 Various industry-standard package types available for bridge rectifiers versus power levels and area.

Of course, these devices either benefit from or must have heat sinking methods applied including chassis mounting or augmentation by heatsinks. If power levels are high enough then convection cooling alone is not an option and conduction cooling must be applied to augment thermal performance of convection from the device and PCB thermal heatsinking.

Refer to the junction-to-case thermal resistance specification on the datasheet. Often, we will be asked for other thermal performance metrics and, the only thing a semiconductor supplier can control is the thermal resistance from junction-to-case. The application must consider keeping the die below 125°C in the package—a good design practice is to keep the die below 100°C for margin. Thermal modeling, transient thermal impedance modeling can be used to estimate how the device will perform in the intended application.

Often 3D CAD models are available for these devices to ease assembly drawings and PCB recommended pad layouts are often useful if your CAD package did not come pre-loaded with the pad layout for the bridge rectifier you are using as standard. Since power electronics designs are subject to much of the regulatory and safety isolation barrier requirements, and typically process high voltages and currents, some of the packages including the devices needing heat sinking should carry appropriate safety specifications. Look for UL certifications on the device you intend to use to make sure the isolation barrier can pass regulatory certifications and your supplier of the bridge rectifier can back up the claims.

Inrush Current Rating

It's also best to make sure that the device you choose has high inrush current specifications. Offline applications and power converters often have significant inrush surge current associated with the application because large bulk cap capacitor banks usually must be charged thus creating large inrush currents that the device must withstand repeatedly every time power is cycled. If the device in the application does not have a large enough die and quality construction to deal with the resulting transient thermal response the die can overheat and become damaged with high inrush currents. Therefore, be sure to select the highest inrush current part you can and discuss the internal construction of the bridge rectifier device with the manufacturer.

Lower cost or off-brand devices usually have smaller die size which is great for microprocessors and VLSI devices but not for power rectification. This is done for the manufacturer's sake, especially with off-brand devices, to allow the manufacturer to offer very low prices. The device may work for a while in the application but eventually fail due to the cheaper, smaller die. So, keep in mind the old saying: In the beginning there is price, but in the end there's cost.

As an example, if someone has to climb a roof or tower to replace your product, the warranty return and cost to you and your customer could be hundreds or thousands of dollars. In such cases, it's certainly not worth risking a product failure to save a little money on the bridge rectifier. Fig. 2 shows average current ranges versus standard available package types from sub-amp to tens of amps.

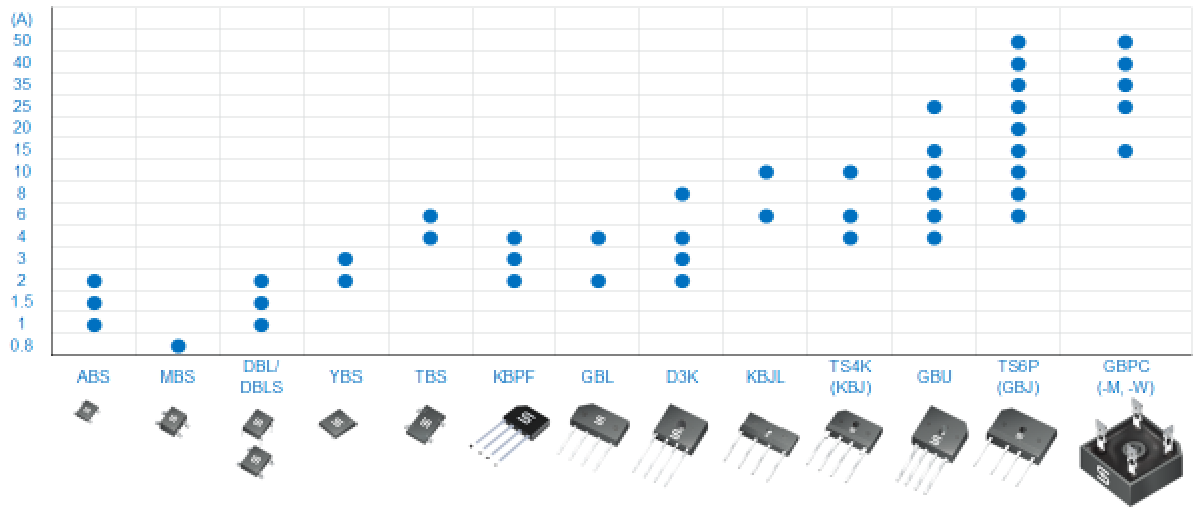

Fig. 2. Standard bridge overview—current ratings versus package type.

Quality Is Not A Given

Today everyone assumes quality is a given yet that's just not the case today. The mindset that "quality is free, six sigma, zero defects," which was a reality in many organizations during the 80s and 90s has been replaced with "is it the lowest price part and can I ship it today and make money?"

When looking for a bridge rectifier supplier, ask for quality and reliability information on the device you intend to use. If the processes and devices cannot hold up to the rigors of an AEC-Q automotive qualification and certification and/or they cannot provide a reliability report, it might be good to pass on that low-cost bridge rectifier from an obscure supplier.

Quality minded suppliers know that automotive standards set a high bar that satisfies the requirements of most applications, so they apply these standards broadly. As an example, currently, Taiwan Semiconductor (TSC) standardizes on automotive qualifications for all parts and has running quality levels at sub 4 parts per billion levels. So quality is assured and if the device in question is applied properly and operated within datasheet specifications, it will last decades in the application.

Voltage Drop And Device Recovery Options

Once the power level, average current and inrush current are known the next step is to figure the voltage drop needed in the application and to determine if something faster than the approximately 3 µs provided by general-purpose bridge rectifiers is needed in the application. For most ac offline applications, general-purpose standard rectifiers will be sufficient for the bridge rectifier. However some specialized applications will benefit from other types of rectifiers in the bridge such as fast recovery devices, high efficiency, superfast recovery and Schottky bridge devices: all of these are available as standard off-the-shelf parts.

Withstand Voltage

Another important consideration is of course the voltage withstanding rating. When used in a typical application such as a full-wave rectifier circuit feeding a capacitor the voltage on the capacitor will be approximately the peak value of the RMS ac voltage which can be found by multiplying the input voltage by the square root of 2.

For example, a 220-V rated input power supply would see a peak line voltage of approximately 300 V. We usually double this for margin, assuming that the bridge could experience twice the peak voltage as the highest voltage available which gives us approximately 600 V. But because of clamping of the varistor (or planar FET) during IEC surge testing you may need 800 or 1000 V. Also the mains in some developing countries is notoriously uncontrolled (beware exporting to India). So here a good margin is even more important.

This last point merits some additional consideration. AC mains and other places where bridge rectifiers are used often experience transients and surges. During testing of a product to meet IEC specifications the application will be subjected purposefully to both ESD transients, common-mode and differential peak transient voltages per IEC transient testing. IEC 61000-4-5 is common as are the IEEE C.62 ringing waveforms, input overvoltages of 300 Vac RMS and other tests.

Since engineers are under so much pressure to reduce cost it's often thought that it's economical to use the lowest-voltage bridge rectifier necessary and no higher. This is often a misinformed error. For example, consider that for decades the common 1N400X family has had the same electrical specifications (other than the reverse voltage rating) and the same low, low prices whether you choose a 1N4001, a 1N4007 or anything in between. So why not use a 1N4007 for everything including your 24-V low-voltage transformer secondary application?

The same advice applies for bridge rectifiers. Typically, there is no price penalty for using higher voltage devices of the standard recovery type. Usually, the manufacturer derives all its bridge rectifier models from a single wafer source rated for the highest voltage offered. So the lower-voltage models are simply downgraded versions. In other words, that 50- or 100-V bridge rectifier might actually be an 800- or even 1000-V device. However, some vendors take the parts that failed the high voltage specs and offer them as lower voltage models, which leads to potential reliability problems. Customers can avoid this problem by making sure the vendor performs PAT, part average testing (see the reference).

Standard recovery bridge rectifiers are available in voltages from 50 to 1000 V and higher. Specialty bridge rectifiers (Schottky, ultrafast etc.) typically have voltage ratings from 40 V to 1000 V. That being said, all things being equal, choose the highest available voltage device that has the same electrical specifications as the lower voltage versions. The demand and yield might be so good that the higher 800-V device costs the same or less than the 50- or 100-V device and your design will have more margin, longevity and survive hostile real world conditions for a longer service life. What's more, there will be a lower cost of ownership for your end customer's application.

Reference

"Secrets Of The Datasheet: What Rectifier Specs Really Mean" by Jos van Loo and Kevin Parmenter, How2Power Today, September 2019.

About The Authors

Jos van Loo is a technical expert on power semiconductors with more than 30 years' experience. In his role as technical support engineer at Taiwan Semiconductor Europe, Jos consults with customers on rectifiers, MOSFETs and power management ICs.

Kevin Parmenter is an IEEE Senior Member and has over 20 years of experience in the electronics and semiconductor industry. Kevin is currently director of Field Applications Engineering North America for Taiwan Semiconductor. Previously he was vice president of applications engineering in the U.S.A. for Excelsys, an Advanced Energy company; director of Advanced Technical Marketing for Digital Power Products at Exar; and led global product applications engineering and new product definition for Freescale Semiconductors AMPD -

Analog, Mixed Signal and Power Division. Prior to that, Kevin worked for Fairchild Semiconductor in the Americas as senior director of field applications engineering and held various technical and management positions with increasing responsibility at ON Semiconductor and in the Motorola Semiconductor Products Sector. He holds a BSEE and BS in Business Administration.

For further reading on designing with rectifiers, see the How2Power Design Guide, and locate the Component category and select "Diodes and Rectifiers."