SECTION 12

Rectifier Assemblies

VMI designs and manufactures custom rectifier assemblies for specific requirements. This section is intended to provide the user with 1) general background information on certain diode and rectifier assembly characteristics, and 2) basic guidance in identifying specific application requirements necessary for the design of a custom rectifier assembly. At the end of this section, a design specification form is provided.

Outline of Rectifier Design Process:

I. Assembly Type

- *single phase bridge*
- *three phase bridge*
- *center tap (positive or negative)*
- *doubler*
- *special configuration*

II. Electrical Operating Conditions

- *input voltage*
- *output current*
- *operating frequency/pulse waveform*
- *transient conditions*

III. Physical Characteristics

- *package size*
- *mounting*
- *terminations*

IV. Environmental Conditions

- *high altitude*
- *chemical exposure*
- *humidity*
- *extreme temperatures*

RECTIFIER ASSEMBLIES

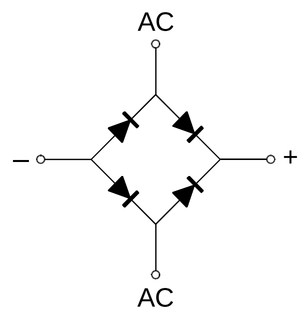
Design Guide

I. Assembly Type

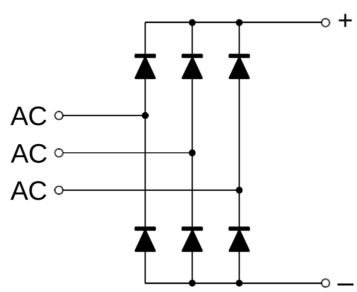
The following schematics show the types of rectifier assembly elements typically encountered. It is not uncommon to have combinations of these circuit types within the same package. In such cases, it is important to specify the electrical characteristics of each element as well as the interconnections and/or isolation requirements between elements.

FIGURE 1:

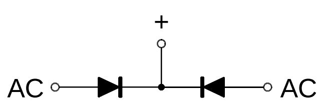
Single Phase Bridge



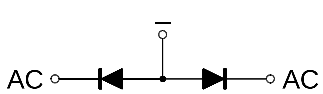
Three Phase Bridge



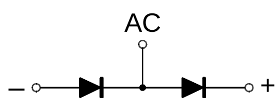
Positive Center Tap



Negative Center Tap



Doubler



Specify...

- single phase bridge
- three phase bridge
- center tap (+/-)
- doubler
- special configuration

ASSEMBLY

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II. Electrical Operating Conditions

Custom rectifier assembly electrical requirements can be specified in many different ways. To develop a design that will meet performance requirements and provide high reliability, it is important to know about the currents, voltages and operating frequencies or pulse wave shapes, to which the individual legs of the assembly would be subjected during operation. When applicable, this information needs to account for transient effects as well.

Electrical Operating Conditions: Input Voltage

The input voltage to the assembly (including known or expected transient conditions) must be identified to determine what diode(s) is best suited for the application. This is based primarily on the maximum reverse working voltage (V_{RWM}) rating.

In a particular application, it is possible to allow for additional margin by using diodes with higher reverse voltage ratings. However, as the reverse voltage capability of a diode increases, the forward voltage drop increases. This may result in undesirable forward power dissipation in the junction.

VMI diodes are tested for minimum PIV using a rectified 60Hz reverse voltage with carefully controlled reverse current limiting.

Electrical Operating Conditions: Output Current

In any rectifier assembly, one of the more important design considerations is heat dissipation. In many applications, the power dissipated due to the forward voltage drop is typically the greatest contributor to junction heat generation.

Electrical Operating Conditions: Output Current (continued)

The forward voltage drop is a function of the silicon resistivity, the number of junctions and the level of forward current. As the forward current in the diode increases, the forward voltage drop also increases in a non-linear manner.

The output current from the assembly (including known or expected current transient conditions) must be known to address heat dissipation in the assembly. Various factors, including diode junction size, diode type, heat sink provisions and/or special mounting requirements all contribute to the thermal impedance of the assembly, and therefore its ability to dissipate the heat generated.

Since the forward voltage decreases as the junction temperature rises, most thermal design calculations for forward power dissipation use the V_F data at 25°C as a worst case value. If the assembly is mounted to a cold plate, it is important to know the maximum output current at the maximum controlled cold plate temperature.

Electrical Operating Conditions: Operating Frequency/Pulse Waveshape

Another potentially significant source of heat generation in an assembly is caused by reverse recovery losses. Reverse current flowing through the diode during its transition from forward conduction to reverse blocking mode causes reverse recovery losses.
The speed at which the diode recovers into its steady-state voltage blocking mode is related to the amount of stored charge in the silicon junction and the rate at which the applied reverse voltage changes.

Identify...

- reverse working voltage (V_{RWM})
- forward voltage (V_F)
- reverse recovery time (T_{RR})
- forward current (I_F)

ELECTRICAL

<u>Electrical Operating Conditions: Operating Frequency/Pulse Waveshape (continued)</u>

As the voltage switching frequency increases and/or as the rate of rise of reverse voltage decreases, the reverse recovery losses are increased for a given diode. For this reason, it is particularly important to identify the frequency and waveform characteristics of the applied voltage.

In some applications, faster diodes are necessary to reduce the reverse losses. However, reduced reverse recovery time comes at the expense of added forward voltage drop, causing additional forward power dissipation. It is important also to note that the reverse recovery time increases as the junction temperature of the diode increases. If a diode is not fast enough for the application, the reverse recovery losses can cause the junction temperature to increase, corresponding in a further increase in reverse recovery time, thereby adding to the reverse recovery losses. Such a condition is known as thermal runaway and results in subsequent diode failure.

<u>Electrical Operating Conditions: Transient Conditions</u>

It is also important to specify any known or expected transient voltage or current conditions to which the assembly may be subjected. Voltage or current levels, along with transient duration and frequency of occurance are important factors to evaluate when determining the best possible design for the application.

III. Physical Characteristics

Physical Characteristics: Size

One of the benefits of using custom rectifier assemblies is that the customer can usually specify the size and shape of the package. The customer may also specify special physical characteristics desired for the application provided such specifications do not compromise design constraints. Actual design of the package size/shape must account for adequate cooling and voltage isolation issues.

Clearly defining the dimensions and tolerances is necessary. When the specific shape and/or size is not defined, as much information as possible should be provided, regarding the enclosure where the part will be installed and/or the customer's preferred physical characteristics. Typically, packaging that is "as small as possible" is desired. However, an indication of preferences and expectations, with respect to package size, will aid in the development of a suitable package design.

Physical Characteristics: Mounting

The preferred end-application mounting or installation provisions need to be specified. Through holes, integral threads, encapsulated inserts, pcb mount and suspension are some examples of mounting techniques.

Physical Characteristics: Terminations

Custom rectifier assemblies can have a large variety of terminations. Some possibilities include quick disconnect (see Figure 3), turret terminals (see Figure 4), and leads or bus wire (see Figure 5).

Specify...

- package size
- mounting provisions
- terminations

PHYSICAL

Physical Characteristics: Terminations (continued)

Other termination possibilities include high voltage leads/connectors, inserts, pcb pins, contact pads or combinations of these configurations. Special terminal plating requirements should also be noted.

FIGURE 3:
Quick Disconnect Terminal Rectifier Assembly

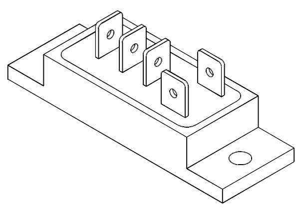


FIGURE 4:
Turret Terminal Rectifier Assembly

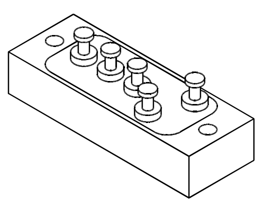
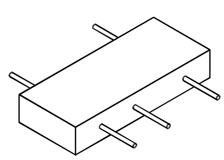


FIGURE 5:
Leaded Rectifier Assembly



IV. Environmental Conditions

Properties of dielectric materials used in encapsulating the components of the assembly as well as those used to overpot an assembly in its installation are greatly influenced by environmental effects. Basic environmental conditions such as operating and storage temperature ranges, in which the rectifier will be required to operate need to be defined. However, other special conditions, if applicable, need to be identified for proper design.

Environmental Conditions: High Altitude

High altitudes can amplify what would, at lower altitudes, be relatively benign design issues. For example, some dielectric materials will outgas in low pressure or vacuum installations causing degradation of the dielectric and/or contamination from insulating film deposition. Also, corona problems will generally vary non-linearly with increased altitude.

Environmental Conditions: Chemical Exposure

The level of exposure an assembly receives to various chemicals should be identified. Many applications use dielectric oils or gases to surround the custom rectifier assembly. While these materials can provide excellent isolation, reduced corona effects, minimal mechanical stresses, and usually good cooling, they can also damage or degrade some encapsulants and remove assembly labeling. As such, materials compatibility must be addressed during the design stage.

Identify...

- high altitude
- chemical exposure
- humidity
- extreme temperature

ENVIRONMENT

Environmental Conditions: Humidity

Environments with high humidity can sometimes cause certain types of dielectric materials to absorb moisture. Also, humidity severely limits the voltage isolation capabilities of air-insulated applications. As a result, it may be necessary to overpot, or otherwise insulate any exposed high voltage connections.

Environmental Conditions: Extreme Temperatures

Assembly exposure to very high or very low temperature extremes requires special consideration. This is due to the electrical and mechanical effects of materials used in the assembly construction. For example, very high temperature extremes, such as in excess of 150°C, can sigificantly reduce the voltage isolation capabilities of some encapsulants. Additionally, high temperatures can induce significant mechanical stresses, due to mismatches in material thermal expansion coefficients. (see Table 1):

TABLE 1:

Temperature Range	Material Availability
25°C to 75°C	Excellent
75°C to 125°C	Good
125°C to 175°C	Fair
175°C to 225°C	Poor
>225°C	Rare

Environmental Conditions: Extreme Temperature (continued)

Similarly, very low temperature extremes can induce mechanical stresses due to material thermal expansion mismatches. Low temperatures can also cause radical changes in the physical characteristics of the encapsulant, making it brittle, or causing the encapsulant to exhibit non-linear shrinkage effects. (seeTable 2)

TABLE 2:

Temperature Range	Material Availability
-40°C to +25°C	Excellent
-55°C to -40°C	Good
-65°C to -55°C	Fair
<-65°C	Rare

RECTIFIER ASSEMBLY

Design Specification Sheet

Company:		Customer P/N:	
Engineer(s):		VMI Part Number:	
Telephone:		Fax:	
Due Date:		Qty/Usage/Time Span:	
Target Price:		Program/Application:	
Quantity to Quote:		Assembly Type:	

Input Voltage: (pk-pk)	
Output Voltage:	
Max Transient Voltage:	
Output Current:	
Operating Frequency:	
Max Surge Current:	
Size (Max/Preferred):	
Mounting:	
Terminations:	
Non-Op Temp:	
Operating Temp:	
Other:	

Special Requirements:	

(Attach/Provide a Sketch)