

## Smart troubleshooting pinpoints rectifier failures

### Application Note



### Testing Functions Case Study

**Measuring tools:** Fluke 189 Digital Multimeter

**Operator:** Golden Valley Electric Association

**Tests conducted:** What tests?

The Golden Valley Electric Association's generating capacity of 228 megawatts, along with its 2,566 miles of transmission and distribution lines and its 31 substations, enables it to supply electric power to approximately 90,000 residents of Alaska's interior region. As part of a team including 12 wiremen and 23 linemen, James Gengler helps keep this system spinning like a top. Occasionally, that task requires the performance of a miracle worker, he says, but more often it involves getting the upper hand on power supply rectifiers.

"Our focus on rectifiers is the result of the need for clean direct current to maintain the charge on backup batteries at each of our substations," he says. To keep an eye on the utility's systems, Gengler relies on a Fluke 189, a high-accuracy (0.025 % DC), handheld digital multimeter (DMM). On occasion, he also finds that the graphic display of a handheld Fluke digital oscilloscope (DSO) can assist in spotting problems on rectifier outputs.

### Diodes and capacitors: A rectifier's critical components

As the key components of rectifiers, diodes and capacitors play an important role in Gengler's work. Let's take a look.

#### Half-wave rectifiers

"In the first example, we will use a capacitor in parallel with load and acting as an input filter," notes Gengler. (See Figure 1.) "The problem here is that there is no voltage across the load. That means the circuit is open, and the question is

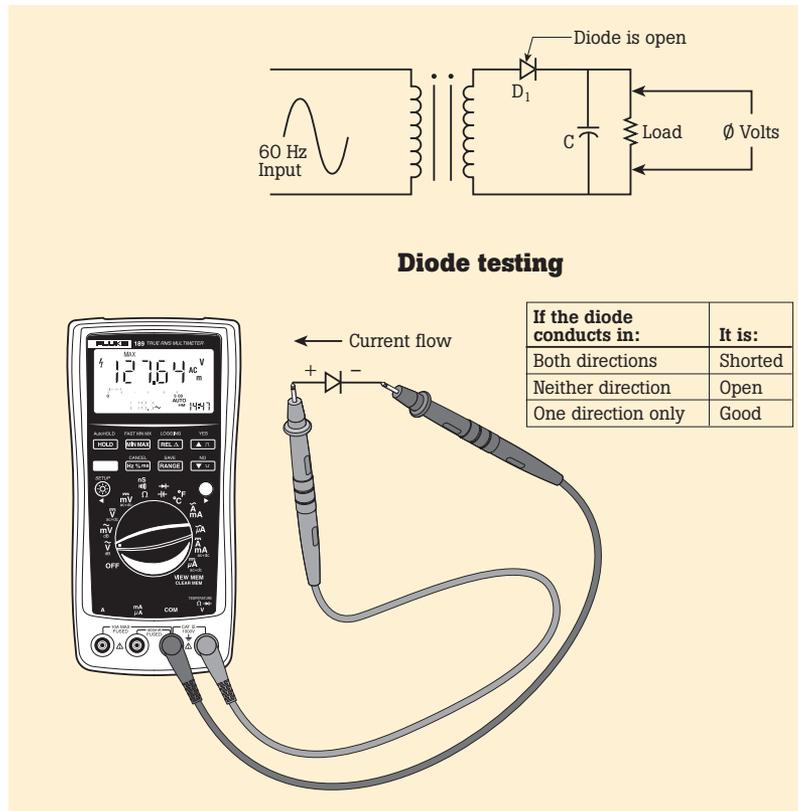


Figure 1. Half-wave rectifier with failed diode.

whether the diode has failed—and is operating as an open switch, thereby and killing power to the circuit. The DMM shows zero volts.

To confirm Gengler’s hypothesis that the diode is open, he first removes the diode from the circuit. “Now, we place the DMM in the Diode Test mode and measure across the diode by placing the negative lead on the negative side of the diode, and the positive lead on positive side of the diode. There is no audible tone across the diode when the diode is biased if it is open. The DMM will display infinite resistance, O.L. (for over load, meaning the resistance is so significant it cannot be read), or a high mega ohm value indicative of reverse break down voltage, which the diode is not specifically designed to do, causing failure.

“Now reverse the DMM leads and note the DMM reading. If the meter reads a high resistance value and no tone in either direction, you know that that the diode is bad.

Gengler cites the three possible states of a diode and how to identify them. If the diode conducts in only one direction, it is good. If it conducts in both directions, it is shorted. If it conducts in neither direction, it is open.

**Full-wave rectifiers**

Next, Gengler applies the basics to a common type of full-wave rectifier. (See Figure 2.) As in the previous example, the full-wave rectifier is connected to a load and uses the same capacitor-input filter.

“Let’s examine the circuit in its entirety. First, we establish that the circuit receives an ac source of 60 Hz—this is confirmed by a DSO that we have installed across the circuit. This 60 Hz signature also shows a significant ripple<sup>1</sup>, a phenomenon created by the charging and discharging of the capacitor-input filter.”

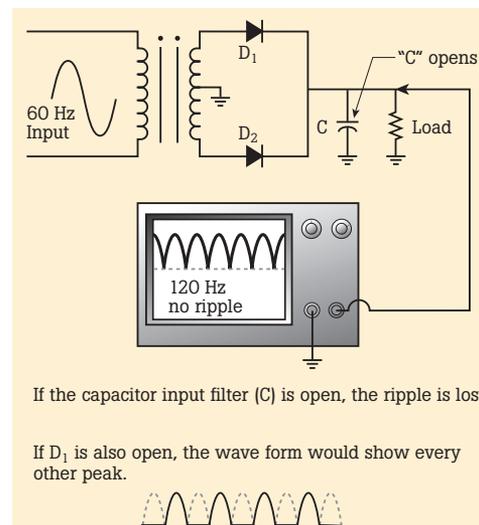
Is this frequency and ripple pattern an indication of a problem?” he asks. “Yes, in a full-wave rectifier, rectified dc or

pulsating dc is created. This is accomplished through the functioning of the diodes. If diode D<sub>1</sub> is open, current will conduct through the load only during the negative half-cycle of the input signal. The open will prevent current through the load on the positive half-cycle.

“If both diodes are operating properly, the negative wave cycles of the ac are ‘flipped,’ creating a second, or extra, positive wave cycle. This creates a frequency output that is double the input frequency.”

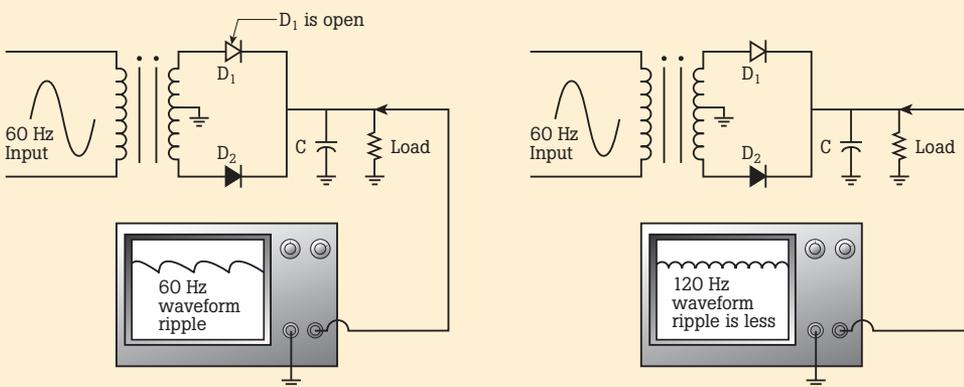
What would the oscilloscope indicate if the capacitor-input filter was also open? Refer to the example in Figure 3.

<sup>1</sup>“**Ripple**” or “**ripple voltage**” refers to the amount of ac voltage mixed with the rectifier’s dc output. When the desired goal is pure dc, ripple voltage is undesirable.



**Figure 3.** Full-wave rectifier with failed input capacitor.

“Whether diode D<sub>1</sub> is functioning properly or not, one can easily determine if the capacitor-input filter is open,” he says. “If the capacitor fails, the ripple effect is lost, causing a significant failure in the filtering action of the rectified DC output.”



**Waveform with D<sub>1</sub> open**

With D<sub>1</sub> open, D<sub>2</sub> conducts only the negative half-cycle of the input. The open D<sub>1</sub> prevents current flow on the positive half-cycle.

**Waveform with D<sub>1</sub> functioning properly**

If the open D<sub>1</sub> is replaced with a properly functioning diode, the waveform should have a frequency of 120 Hz because both the negative and positive half-cycle are conducted.

**Figure 2.** Full-wave rectifier with failed diode.

"In this case, the filtered full-wave voltage will have less ripple than the half-wave voltage," says Gengler. "This is because the capacitor discharges less during the shorter intervals created between the full-wave pulses. In this respect, bridge rectifiers are no different from full-wave rectifiers. The affects of diodes and capacitor-input filters in the two cases are the same."

### Diode failures

"Diodes fail if a circuit condition exists that allows the diode to reach a reverse breakdown voltage," says Gengler. "In most cases, the result is an open, but it may also be a short.\* A shorted diode in a bridge rectifier circuit would more than likely burn open because of sufficiently high current that would exist during one half of the input cycle. (See Figure 4.) The amount of current in the shorted diode would cause it to open, and the other diode in series with it might also fail open."

If both diodes open, no voltage will develop across the load. "In such a case," he says, "a shorted capacitor would cause an excess of current through the diodes and burn all four diodes open."

\*Some diodes, called Zeners, are designed to operate in the reverse breakdown voltage region.

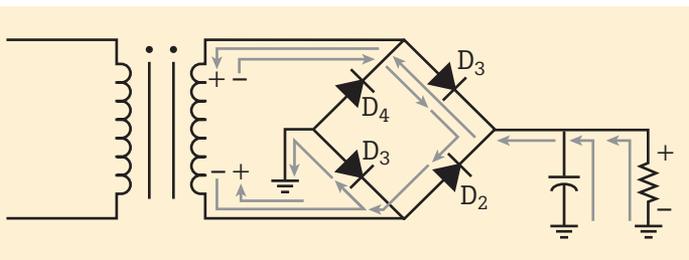


Figure 4. Bridge rectifier with multiple diode failures.

**Gengler's final thought:** "For testing rectifiers, make sure you have a good DMM in your toolbelt. DMMs such as the Fluke 189 are equipped with the specialized functions you need for your toughest testing challenges."

Gengler offers one final tip: "Do not use the DMM's resistance (ohms) mode to measure a diode. This setting lacks the proper voltage to bias a diode, which, in turn, can give a false

open indication for most diodes. And note that diodes are commonly made of germanium or silicon, and each has a different biasing voltage—typically 0.5 V to 0.7 V."

### Half-wave rectifiers

A half-wave rectifier allows one half of an ac waveform to pass through to the load. Its output is a variable, or pulsed, dc signal. See Figure 5.



Figure 5. Half-wave rectifier circuit.

### Full-wave rectifiers

In order to rectify ac power so as to use both half-cycles of the sine wave, a different rectifier circuit configuration must be used. Such a circuit is called a full-wave rectifier. Its output is also a pulsed dc signal, but at twice the frequency of the half-wave signal. See Figure 6.

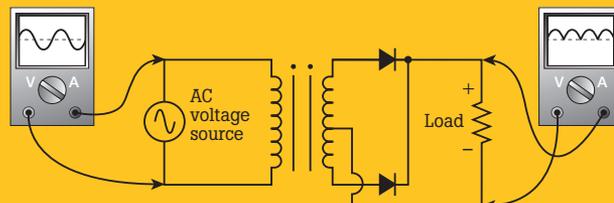


Figure 6. Full-wave rectifier circuit (center-tap design).

**Fluke.** Keeping your world up and running.

**Fluke Corporation**  
PO Box 9090, Everett, WA USA 98206

**Fluke Europe B.V.**  
PO Box 1186, 5602 BD  
Eindhoven, The Netherlands

**For more information call:**  
In the U.S.A. (800) 443-5853 or  
Fax (425) 446-5116  
In Europe/M-East/Africa (31 40) 2 675 200 or  
Fax (31 40) 2 675 222  
In Canada (800)-36-FLUKE or  
Fax (905) 890-6866  
From other countries +1 (425) 446-5500 or  
Fax +1 (425) 446-5116  
Web access: <http://www.fluke.com>

©2005 Fluke Corporation. All rights reserved.  
Printed in U.S.A. 5/2005 2453099 PublD 10937-eng