Observing & Measuring The In-rush Current Of A Power Supply, or Why Rectifier Diodes Sometimes Go Poof

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Purpose:

A half-wave rectifier is often used as a power supply in inexpensive, low-power circuits. Its output is unregulated DC with a quasi-sawtooth ripple voltage proportional to the load current. The single diode can be damaged by excessive reverse voltage, often due to a transient on the power line, or it can be damaged by a large in-rush current at the time of turn-on. A diode can fail in two ways: becoming an open circuit (symptoms are clear: the circuit goes dead) and becoming a short circuit (symptoms MAY be clear: the circuit gives off smoke, the filter capacitor gets hot and may explode, the transformer primary acts as a fuse and becomes an open, or a fuse blows).

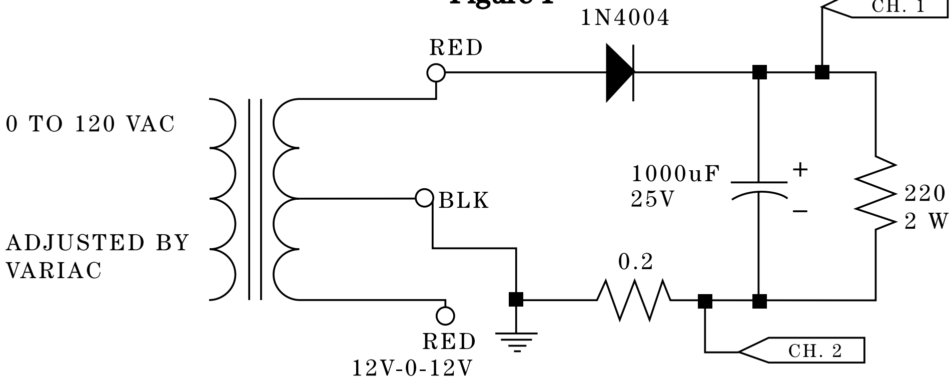
Equipment Required:

- HP 54600 - Series Oscilloscope

Circuit Explanation:

This experiment uses a variable autotransformer (Variac) feeding a 120V/12V-0-12V step-down power transformer in a closed metal box. Two secondary terminals (12V RMS) are connected to a breadboard with the circuit. There is a 0.2ohm current-sensing resistor in series with the return wire to the transformer; this allows the diode current to be measured. By putting the oscilloscope in single-shot mode, and by triggering on the rise of voltage on Channel 2, the voltage across the sensing resistor (which is proportional to diode current) can be captured when the switch feeding the transformer primary is first thrown.

Figure 1



To observe the steady-state DC output voltage with its ripple, Channel 1 is connected to the top of the load resistor and the oscilloscope is used in a conventional repetitively-triggered mode. The automatic measurement capabilities of the oscilloscope can be used to quantify the peak, average and RMS values of an unfiltered rectifier.

Procedure A - Observing And Measuring Peak Diode Current After Turn-on:

1) Refer to the information in Figure 2 for oscilloscope control settings, and adjust your oscilloscope accordingly.

2) Rotate the transformer box output control fully clockwise (maximum, (or approximately equal to)13 VRMS). Turn on the transformer output by throwing the toggle switch up. The sweep of the oscilloscope should be triggered once, and a new trace recorded (see Figure 2 for a typical display). You will have to press the **Run** hardkey after each trigger to "arm" the sweep again.

3) Press the **Stop** hardkey, then press the **Display** hardkey followed by the **Vectors On** softkey. Vectors On essentially "connects the dots", giving a better display of the trace for Channel 2. Notable is the large amplitude of the first current pulse, due to the filter capacitor being uncharged initially. The first current pulse must bring the capacitor up from 0 V to very near full voltage (about 18 V), while subsequent pulses must only recharge the capacitor to replenish the charge that was drained out when the output voltage drooped (creating ripple voltage) during the prior 16.7 ms period of the 60 Hz supply voltage. In Figure 2, the peak current is 1.344 V/0.2 ohm = 6.72 A, while in steady-state operation (the 6th pulse) the peak current has dropped to 0.225 V/0.2 ohm = 1.125 A.

Procedure B - Observing And Measuring DC Output Voltage And P-P Ripple Voltage:

1) Keep the circuit and the probe locations as they were in procedure A. Change the oscilloscope settings as indicated in Figure 3. The **Average** softkey, under the **Display** hardkey menu, was used here to remove some noise on both traces.

2) See Figure 3. Measure the average (DC value) and the peak-peak (ripple) voltage of Channel 1. Channel 2 shows the peak current pulses in steady state are 210.9 mV/0.2 ohm = 1.05 mA.

3) In Figure 4, the Channel 1 V/Div has been decreased to expand the ripple voltage display. With the 220 ohm as the load, the p-p ripple is just over 2 div, or 1 Vpp. This trace is saved to memory 1 using the **Trace** hardkey and the **Save to Mem1** softkey. Then, a second load resistor (270 ohm) is placed parallel with the 220 ohm; the lower trace shows that the average value has dropped and the ripple voltage has increased (to 1.937 Vpp).

Measure the parameters indicated in the table below, for your circuit with two different load conditions.

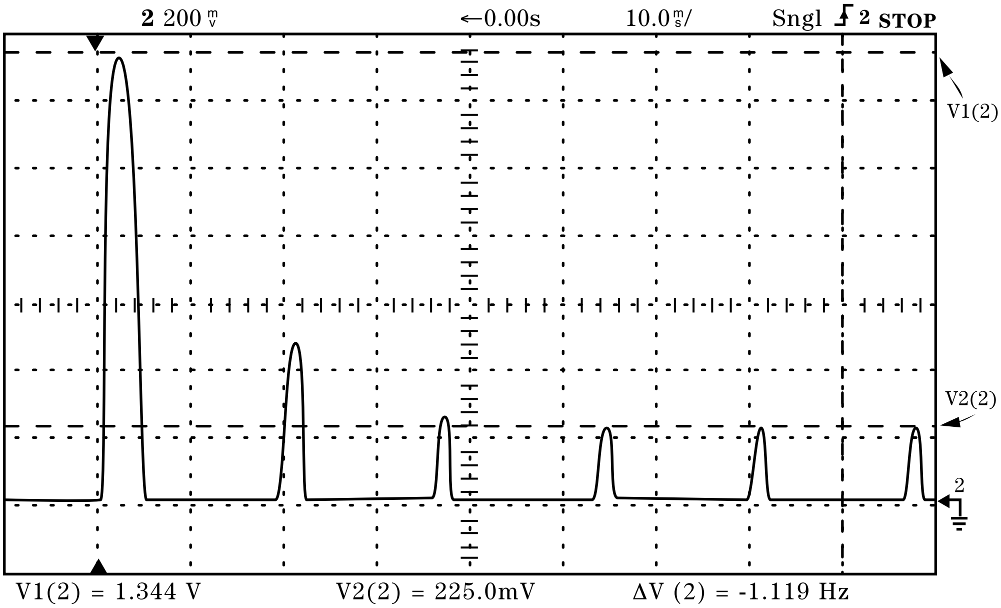
Load	Average (DC) Load Voltage (V)	Ripple Voltage (Vpp)
220 ohm		
220 ohm || 270 ohm		

Procedure C - Automatic Measurement Of Peak-peak, Average And Rms Voltage:

1) Turn down the supply voltage to 0 V. Change the circuit by removing the filter capacitor, and keep the probe locations as they were in procedures A & B. Set the supply voltage for maximum output. Change the oscilloscope settings as indicated in Figure 5.

2) Measure the peak-peak voltage (which equals the maximum voltage, since Vmin = 0 V), the average (or DC value of) voltage, and the RMS voltage for your unfiltered rectifier.

Peak-peak Voltage	Average Voltage	RMS Voltage



	State	Volts/Div	Position	Couplg	BW Lim	Invert	Probe
Chan 1	Off	500.0mV	-17.39 V	DC	Off	Off	10:1
Chan 2	On	200.0mV	-593.7mV	DC	Off	Off	1:1
Chan 3	Off	100.0mV	0.000 V	DC	---	---	1:1
Chan 4	Off	100.0mV	0.000 V	DC	---	---	1:1

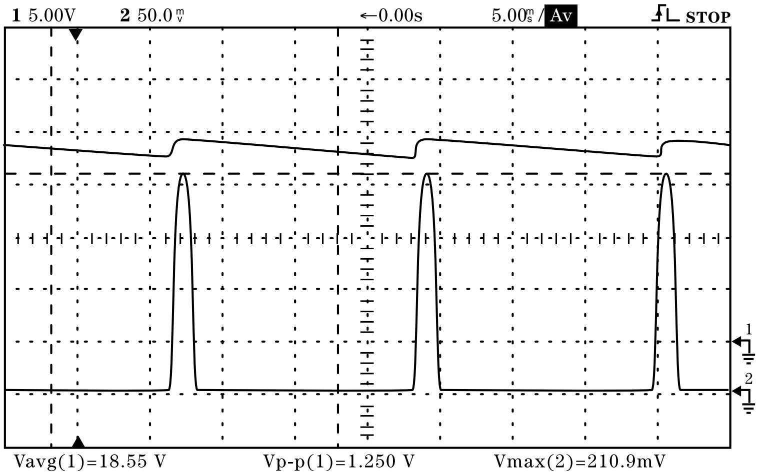
	Mode	Main Time/Div	Main Delay	Time Ref	Delayed Time/Div	Delayed Delay
Horizontal	Single	10.00ms/	0.000 s	Left	-------------	-------------

Trigger	Mode	Source	Level	Holdoff	Slope	Couplg	Reject	NoiseRej
	Normal	Ch 2	1.794 V	200.0ns	Pos	DC	Off	Off

Display Mode: Normal

Cursors: t1=-25.00ms t2=25.00ms V1(2)=1.344 V V2(2)=225.0mV

Figure 2 - Diode Current vs. Time,
Showing Large First-Cycle In-rush Current



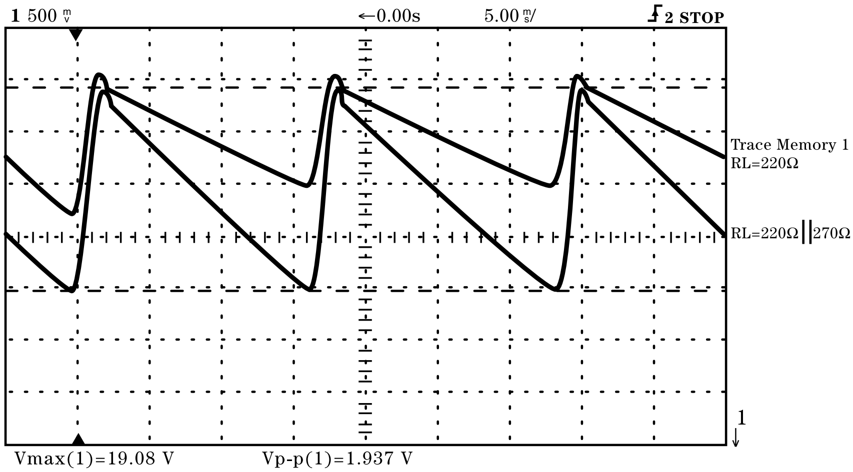
	State	Volts/Div	Position	Couplg	BW Lim	Invert	Probe
Chan 1	On	5.000 V	-10.00 V	DC	Off	Off	10:1
Chan 2	On	50.00mV	-148.4mV	DC	Off	Off	1:1
Chan 3	Off	100.0mV	0.000 V	DC	---	---	1:1
Chan 4	Off	100.0mV	0.000 V	DC	---	---	1:1

	Mode	Main Time/Div	Main Delay	Time Ref	Delayed Time/Div	Delayed Delay
Horizontal	Normal	5.000ms/	0.000 s	Left	-------------	-------------

Trigger	Mode	Source	Level	Holdoff	Slope	Couplg	Reject	NoiseRej
	Auto	Line	115.6mV	200.0ns	Pos	DC	Off	Off

Display Mode: Average # Average: 8

Figure 3 - Filtered Rectifier Output Voltage (Ch.1)
and Diode Current Pulses (Ch. 2)



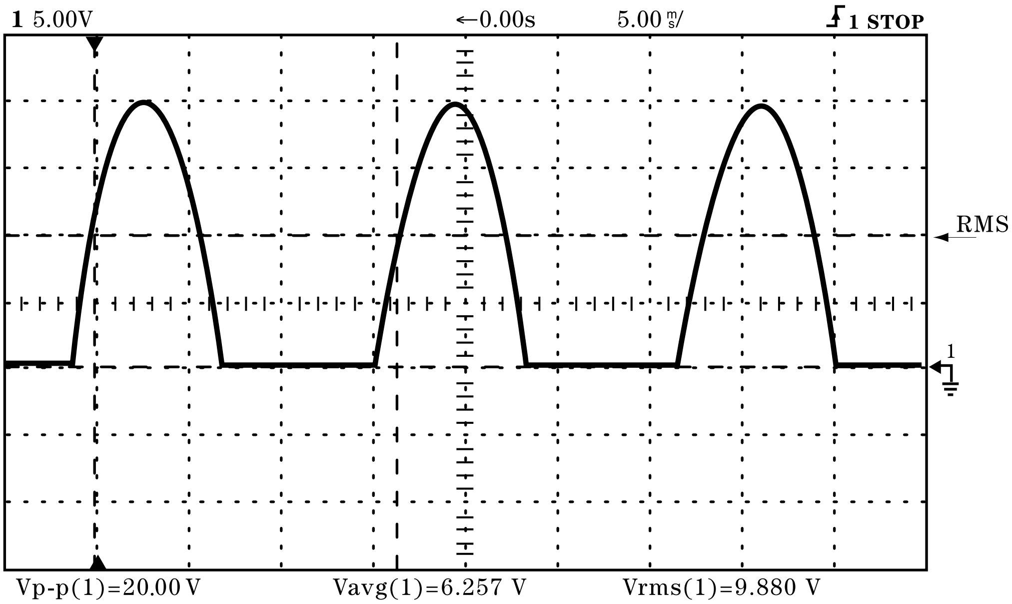
	State	Volts/Div	Position	Couplg	BW Lim	Invert	Probe
Chan 1	On	500.0mV	-17.67 V	DC	Off	Off	10:1
Chan 2	Off	100.0mV	-303.1mV	DC	Off	Off	1:1
Chan 3	Off	100.0mV	0.000 V	DC	---	---	1:1
Chan 4	Off	100.0mV	0.000 V	DC	---	---	1:1

	Mode	Main Time/Div	Main Delay	Time Ref	Delayed Time/Div	Delayed Delay
Horizontal	Normal	5.000ms/	0.000 s	Left	-------------	-------------

Trigger	Mode	Source	Level	Holdoff	Slope	Couplg	Reject	NoiseRej
	Auto	Ch.2	103.1mV	200.0ns	Pos	DC	Off	Off

Display Mode: Normal

Figure 4 - Filtered Rectifier Output Voltage
For Two Different Load Resistors (Using Trace Memory)



	State	Volts/Div	Position	Couplg	BW Lim	Invert	Probe
Chan 1	On	5.000 V	-5.000 V	DC	Off	Off	10:1
Chan 2	Off	100.0mV	0.000 V	DC	Off	Off	1:1
Chan 3	Off	100.0mV	0.000 V	DC	---	---	1:1
Chan 4	Off	100.0mV	0.000 V	DC	---	---	1:1

	Mode	Main Time/Div	Main Delay	Time Ref	Delayed Time/Div	Delayed Delay
Horizontal	Normal	5.000ms/	0.000 s	Left	-------------	-------------

Trigger	Mode	Source	Level	Holdoff	Slope	Couplg	Reject	NoiseRej
	Normal	Ch.1	9.844 V	200.0ns	Pos	DC	Off	Off

Display Mode: Normal

Figure 5 - Unfiltered Rectifier Output Voltage, With Automatic Voltage Measurements