# Electronics I. laboratory measurement guide

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## *3. Measurement: Diodes and rectifiers*

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In this session we are going to measure forward and reverse characteristics of diodes and the operation of half-wave and full-wave rectifier circuits.

This measurement needs asymmetric power supply, that is, a single power supply unit (one of the controllable outputs of the unit). <u>Set up a current limit of 30mA before starting the measurement, and don't change this value throughout the session.</u>

The rectifier diode used is type **1N4007**. The Zener-diode is type **BZX5V1** (with breakdown voltage of 5.1V). Find their connection info in the picture below. As seen, the cathode (K) is usually denoted with a strip on one end of the package.


*Figure 2.1: Connection of 1N4007  Si diode (left), and of the Zener-diode (right)*

## <u>2.0 Mandatory homework</u>

1. Calculate the expected current values in exercise 2.1 if the supply voltage is: 2V , 6V, 12V, 18V. Apply the known approximation for the diode forward voltage.

2. Calculate the expected current values in exercise 2.2 if the supply voltage is: 1V , 8V, 12V, 18V.

3. Calculate the expected output voltage of the Graetz-type rectifier in exercise 2.4 if the transformer's secondary voltage is 8Vrms.

## 2.1 Measurement of forward characteristics of normal Si diode

**2.1.1** Build the circuit seen in ***figure** 2.2*. This will be used to measure the forward characteristics of the diode. (The reverse characteristics of the normal diode is not measured, because its breakdown voltage can be several hundred volts.) The value of **R** resistor is **1kΩ**.

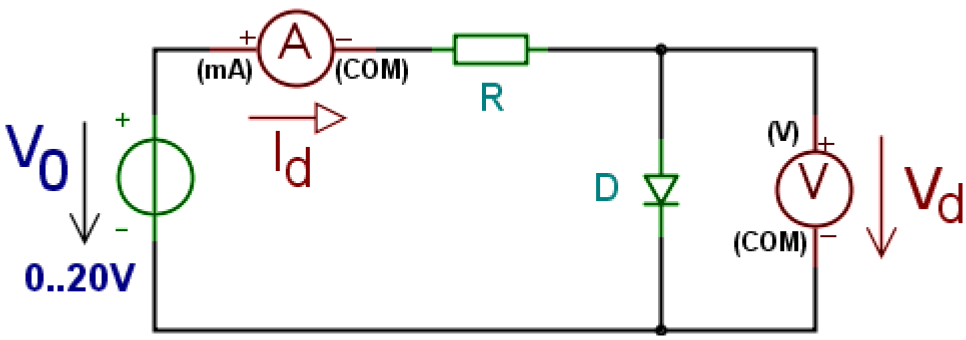


*Figure 2.2 Circuit for measuring forward characteristics*

**2.1.2** Use the current and voltage meters in 3 decimal digit precision setup (the current meter in mA setup, the voltage meter in V setup with 3 digits after the decimal point).

The current meter will measure the diode's current (because the voltmeter's internal resistance can be considered infinite relative to the diode's); the voltmeter measures the diode's voltage, these two are needed for the characteristics. The proper setup of the circuit can be tested by setting up a power supply voltage of several volts, in this case the voltage meter should show the forward diode voltage learned in our theoretical studies.

The resistor **R** protects the diode and also allows us to set up the I and V values in higher precision. Fill the following table with measurement data!

| $V_0$ [V] | 0.3 | 0.5 | 0.7 | 0.9 | 1.1 | 1.3 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $V_D$[mV] | | | | | | | | | | | | | | | | | | | |
| $I_D$[mA] | | | | | | | | | | | | | | | | | | | 1.0 |

In the lab report, draw a $V_D$-$I_D$ graph with linear scales and draw the forward characteristics.

Calculate the reverse current $I_0$ from the diode equation, use $I_D$ and $V_D$ values from the forward part where $I_D$>1mA. Using more than one pair of values allows you to average, thereby decreasing the effect of measurement error.

**2.1.3*** For the last column of the table, try to set up 1mA of diode current as precisely as possible, and measure the voltage in this case. Then, remove the diode and measure it using the multimeter's diode function! (The multimeter uses 1mA current generator to measure the diode, thus the measured voltage should be approximately equal to what you measured with 1mA.)

## 2.2 Measurement of reverse characteristics of Zener-diode

**2.2.1** Build the circuit according to ***figure 2.3*** to measure the Zener-diode **BZX5V1**. The type name shows us that is has 5.1V breakdown voltage. Therefore we are going to measure in more detail around this value. The circuit is similar to the previous, except the Z-diode is connected in reverse. **R** is still **1kΩ**. (Note that the forward characteristics of Zener-diodes are similar to normal diodes, also these are not used in that region, therefore we are not measuring it in greater detail, only in a few points.)

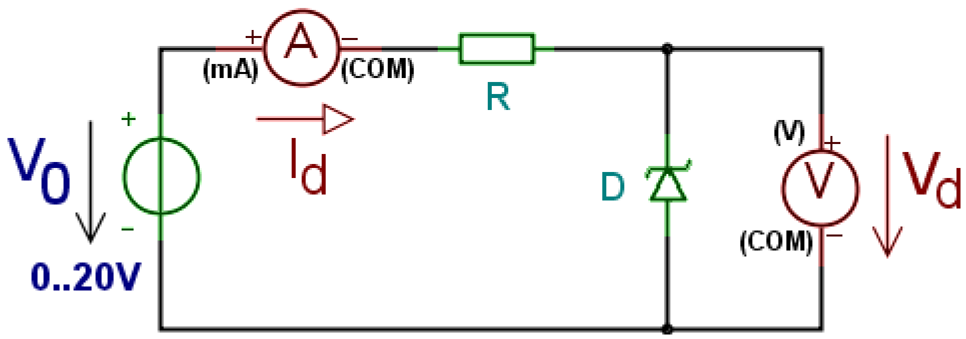


*Figure 2.3: Measurement circuit for reverse characteristics of Zener-diodes*

Though in this setup you are going to measure positive values, please draw the graph in the 3rd quarter of the coordinate system (that is, negative V and I), as the values are part of the reverse region of the characteristics.

| $V_0$ [V] | 1 | 2 | 3 | 4 | 4,5 | 4,7 | 4,9 | 5,1 | 5,3 | 5,5 | 5,7 | 6 | 7 | 8 | 10 | 12 | 14 | 16 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $V_D$[V] | | | | | | | | | | | | | | | | | | | |
| $I_D$[mA] | | | | | | | | | | | | | | | | | | | |

**2.2.2** Reverse the connection of the Zener-diode. That is, connect it in forward bias! With a quick measurement, prove that the forward characteristics are similar to the normal diode!

| $V_0$ [V] | 0.5 | 1 | 1.5 | 2 | 2.5 | 3 |
|---|---|---|---|---|---|---|
| $V_D$[V] | | | | | | |
| $I_D$[mA] | | | | | | |

Use the previous coordinate system and its 1st quarter (positive I and V) to draw the forward region!

## 2.3 Half-wave rectifier circuit

In this exercise we won't need the power supply and the multimeters. The input voltage will come from a transformer. This transformer has no on-off button, therefore only connect it when you are certain the circuit is built properly and ready for measurement. Also, when you make any changes in your circuit, first disconnect the input to avoid any accidental short circuits.

The waveform of the transformer may not be a perfect sinewave. It is because the ferrite core goes into saturation; the output waveform is distorted. It poses no problem, as our goal is to rectify, that is, to change it to DC (direct current).

Absolute ripple is the difference of the maximum and minimum of the output signal. Relative ripple is the absolute ripple divided by the maximum value (that is, normalized), expressed in percentage. Remember that the AC input is usually given as effective value, while for the rectifier the peak value is important.

Use the **1N4007** diode in this circuit.

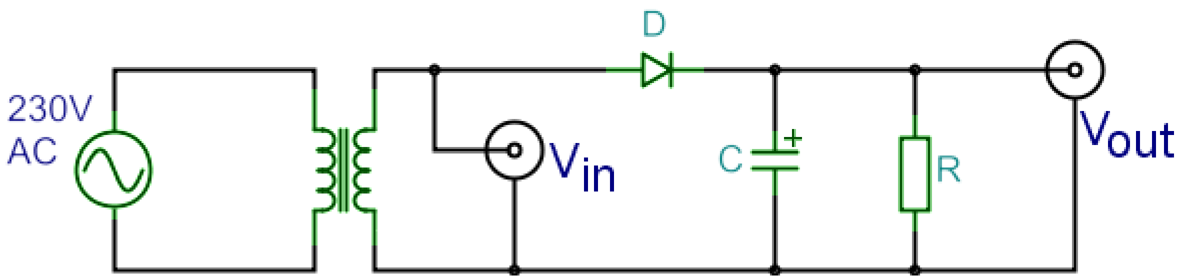


*Figure 2.4 Half-wave rectifier circuit.*

**2.3.1** First connect the transformer's output signal to the oscilloscope and note the main parameters of the signal (esp. peak value).

**2.3.2** Build the circuit from ***figure 2.4***. The R load resistor's value is **3.6kΩ**. Connect the signal $V_{in}$ to channel 1 of the oscilloscope, this is the input of the circuit. Connect $V_{out}$ to channel 2 of the oscilloscope, this is the output. (When using digital oscilloscope, take care to set up Edge mode for the trigger!) <u>First don't connect the **C** capacitor in the circuit.</u>

**2.3.3** Configure the sec/div setting on the scope according to the 50Hz mains frequency (it is practical to set the sec/div timebase to about 1/4 of the period T of the examined signal). Change the V/div setting according to the voltage shown on the transformer. Set both Ch1 and Ch2 channels to DC coupling and set their GND level to the same value. Mesure and draw the signals in your report, with proper relative magnitudes and phases, and explain them. How much lower is the output's peak value than the input's?

**2.3.4** Repeat the measurement with the **C=2.2µF** buffer capacitor in place! Take care of the polarity. Electrolythic capacitors are sensitive to polarity, if connected in reverse, they may explode (on the capacitor the negative pole is noted with a strip or arrow or similar). Measure and calculate absolute and relative ripple!

**2.3.5** Repeat the previous measurements with **C=10µF** capacitor! Compare the results with the previous exercise!

## 2.4 Measurement of Graetz type full-wave rectifier circuit

The input and output of the Graetz circuit are not directly connected, therefore we can not measure both input and output voltages at the same time using traditional oscilloscopes, because the shielding (the outer part of the connector) of both scope channels is grounded. Therefore we are only measuring the output voltage. The input voltage is the same as in the previous measurement, anyway. The load resistor is **3.6kΩ**.

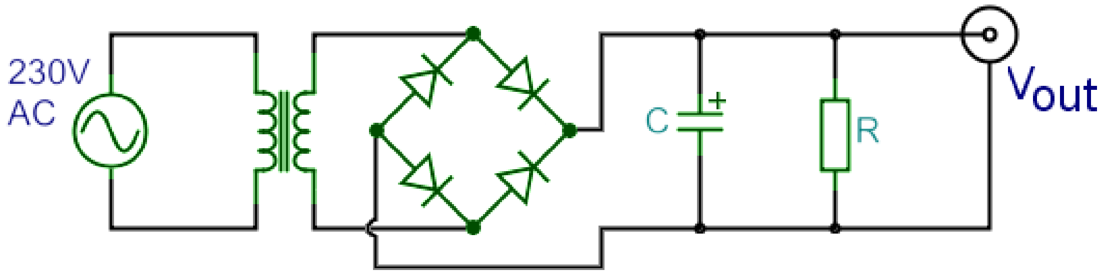


*Figure 2.5 Graetz-type full-wave rectifier*

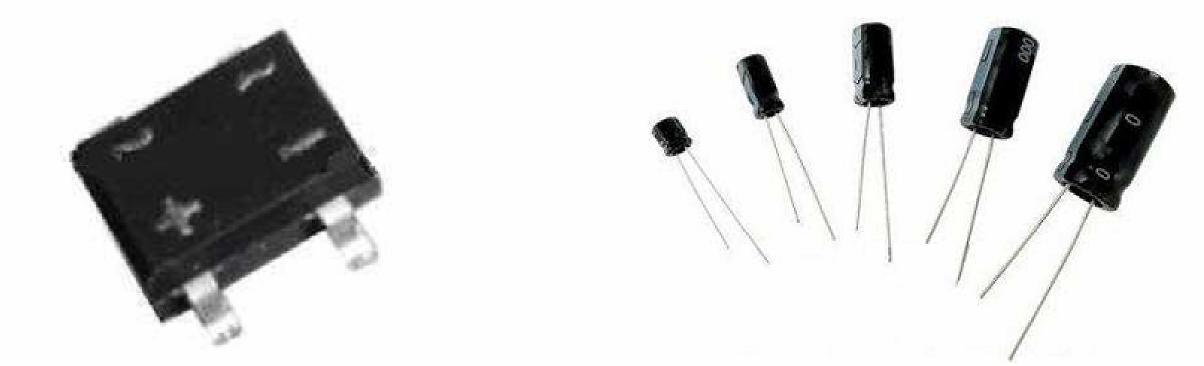

*Figure 2.6 Left: Integrated Graetz bridge; Right: Electrolytical Capacitors*

**2.4.1** Build the circuit of ***figure 2.5***. Connect $V_{out}$ to the scope. For ease of construction, an integrated Graetz package (containing the four diodes) is available, which has four pins, corresponding to the four nodes of the circuit (the rhombus in the figure). The positive output is noted with a + sign on the top of the package, next to it is the negative output, the other two indicated with a wave (~) are the AC inputs. First don't connect the **C** capacitor, only the **R** load resistor.

**2.4.2** Measure the output signal on the oscilloscope (in DC coupling), note the peak value and period time. How much smaller is the peak value than the input and why?

**2.4.3** Repeat the measurement after connecting a **C=2.2μF** capacitor. Measure the absolute and relative ripple. Compare the results with the half-wave rectifiers and explain!

**2.4.4** Repeat the measurement with **C=10μF** capacitor.

## 2.5 Questions for lab entry test

1. Draw the forward characteristics of a rectifier diode!
2. Draw the reverse characteristics of a Zener diode!
3. Write down the diode equation and name the variables and constants in it!
4. Draw a half-wave rectifier circuit (with input and load connected)!
5. Draw the output waveform of a half-wave rectifier with and without a buffer capacitor, if the input in sinusoidal!
6. Draw a Graetz type rectifier, with input transformer!
7. Draw the output waveform of a Graetz rectifier with and without a buffer capacitor, if the input in sinusoidal!
8. Why is the output voltage of rectifiers smaller than the input and by how much?
9. What is the absolute and relative ripple of rectifiers?
10. How can you decrease the ripple of rectifiers?