BASIC OF ELECTRONICS Introduction to the Measuring Exercises- PC16

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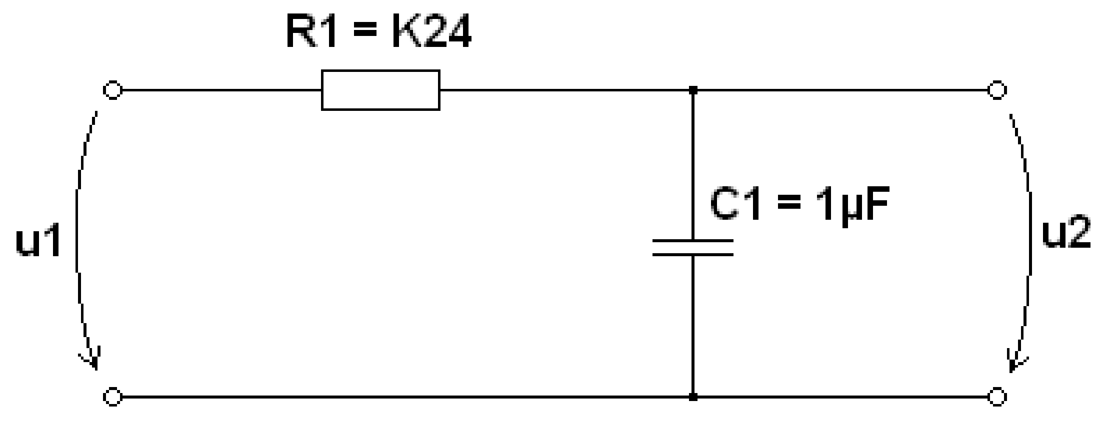
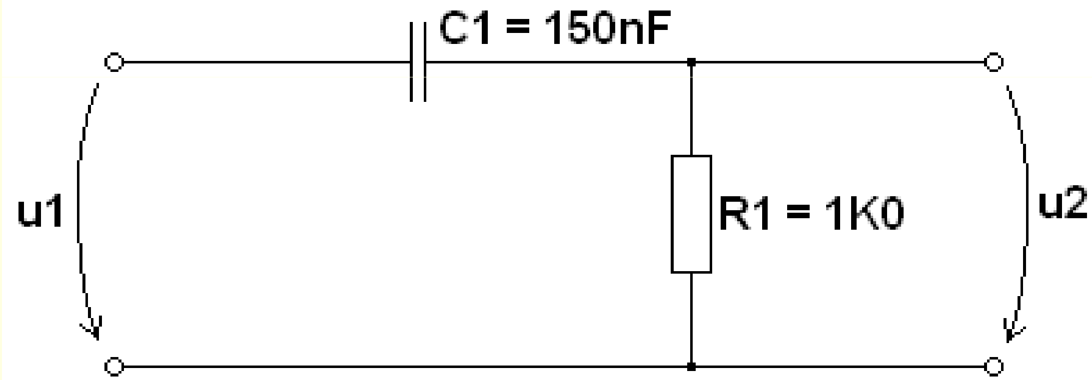
Measurements- Exercises

- **1.1 Exercise 1- Differentiator and Integrator**
- **1.2 Exercise 2- V-A characteristic of diode & Transistor Characteristics curves**
- **1.3 Exercise 3- Half- wave rectifier**
- **1.4 Exercise 4- Operational Amplifiers circuits**

Exercise 1- Integrator and Differentiator



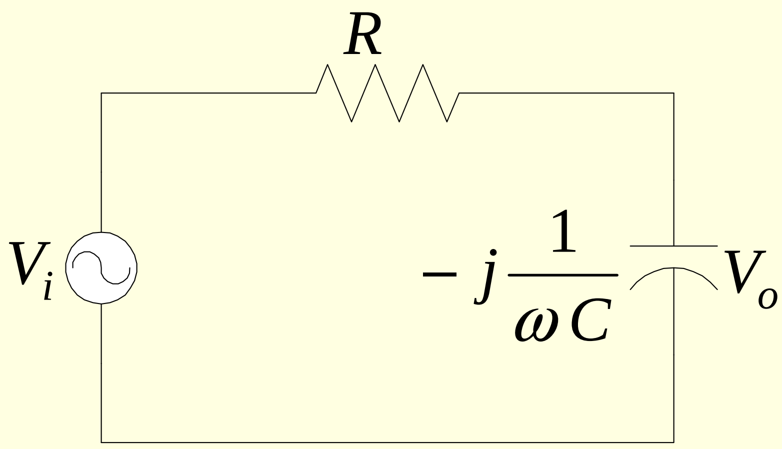


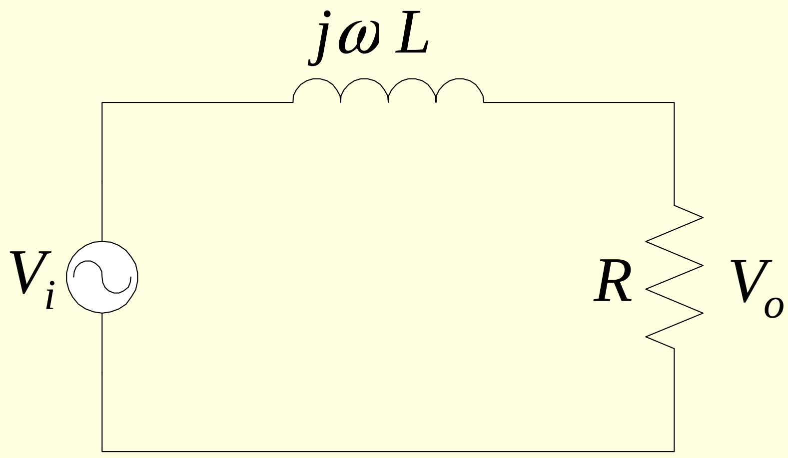
Tasks:

- 1.) To measure the amplitude- frequency characteristics of integrator and differentiator
- 2.) To measure the response of differentiator and integrator when the applied signal is a periodic square wave with different parameters (amplitude, DC, frequency ($f= 1/T$)- $\tau < T$, $\tau \approx T$, $\tau > T$)

Exercise 1- Integrator

Low pass Filters are used to pass low-frequency sine waves and attenuate high frequency sine waves. The ***cutoff*** frequency ω_c is used to distinguish the passband ($\omega_c > \omega$) from the stopband ($\omega_c < \omega$). An elementary example of passive lowpass filter is given below.





Exercise 1- Integrator

$$\frac{V_0}{V_i} = \frac{1}{1 + j\omega RC} \qquad (1) \qquad\qquad \frac{V_0}{V_i} = \frac{1}{1 + j\omega \frac{L}{R}}$$

$$\frac{|V_o|}{|V_i|} = \frac{1}{\left[1 + (\omega RC)^2\right]^{1/2}} \qquad (2) \qquad\qquad \frac{|V_o|}{|V_i|} = \frac{1}{\left[1 + \left(\omega \frac{L}{R}\right)^2\right]^{1/2}}$$

$$\theta = -\tan^{-1} \omega RC \qquad (3) \qquad\qquad \theta = -\tan^{-1} \omega \frac{L}{R}$$

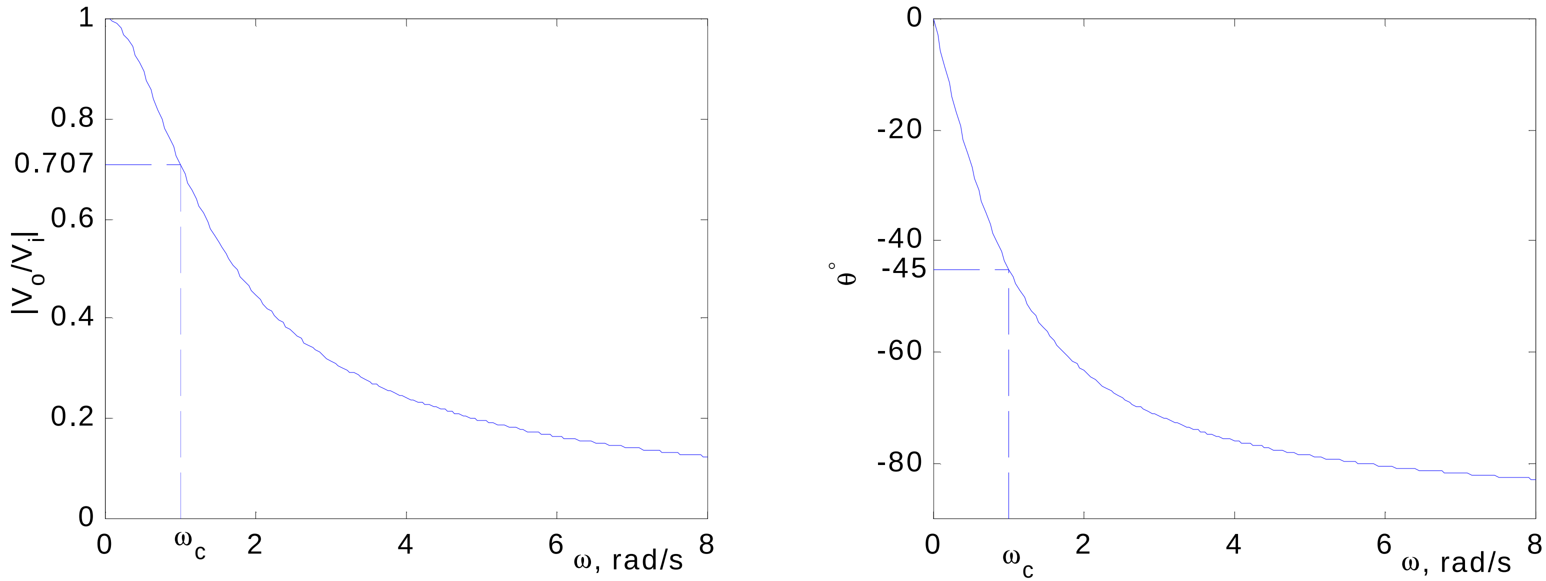
At cutoff frequency Gain $= 1/\sqrt{2}$. Substituting in (2) result in

$$\omega_c = \frac{1}{RC} \qquad (4) \qquad\qquad \omega_c = \frac{R}{L}$$

From (3), we see that the phase angle at cutoff frequency is -45°

The ratio V_0/V_i is shown by $H(j\omega)$, and is called the ***frequency response transfer function***. The gain versus frequency, and the phase angle versus frequency known as the *frequency response* is as shown.

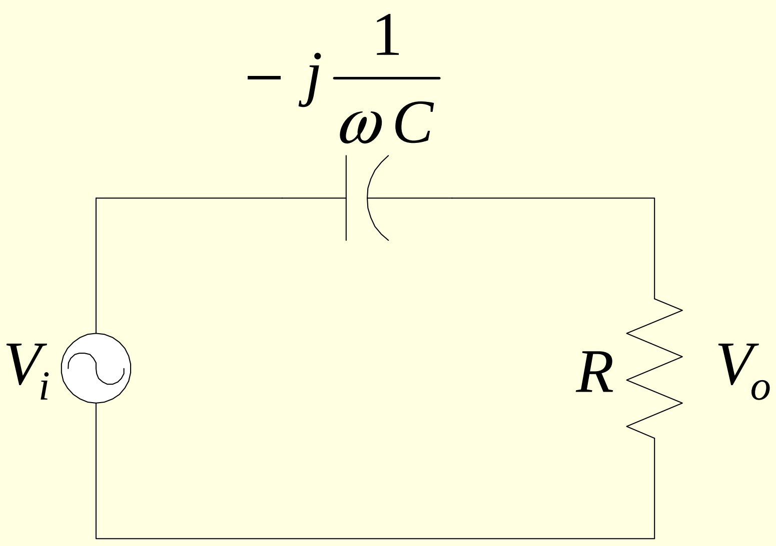
Exercise 1- Integrator

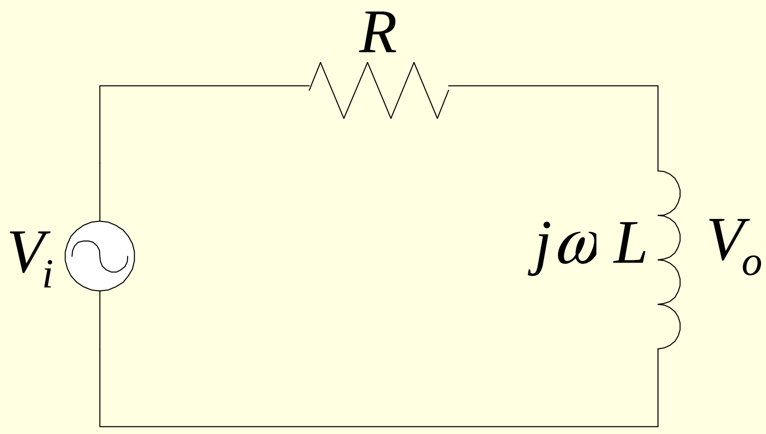


The ratio V_0/V_i is shown by $H(j\omega)$, and is called the ***frequency response transfer function***. The gain versus frequency, and the phase angle versus frequency known as the ***frequency response*** is as shown.

Exercise 1- Differentiator

High pass Filters are used to stop low-frequency sine waves and pass the high frequency sine waves. The ***cutoff*** frequency ω_c is used to distinguish the stopband ($\omega_c > \omega$) from the passband ($\omega_c < \omega$). An elementary example of two passive highpass filter is given below.





Exercise 1- Differentiator

$$\frac{V_0}{V_i} = \frac{\omega \mathrm{RC}}{\omega RC - j1} \qquad (5) \qquad \frac{V_0}{V_i} = \frac{\omega \frac{L}{R}}{\omega \frac{L}{R} - j1}$$

$$\frac{|V_o|}{|V_i|} = \frac{\omega RC}{\left[(\omega RC)^2 + 1\right]^{1/2}} \qquad (6) \qquad \frac{|V_o|}{|V_i|} = \frac{\omega \frac{L}{R}}{\left[\left(\omega \frac{L}{R}\right)^2 + 1\right]^{1/2}}$$

$$\theta = \tan^{-1} \frac{1}{\omega \mathrm{RC}} \qquad (7) \qquad \theta = \tan^{-1} \frac{R}{\omega L}$$

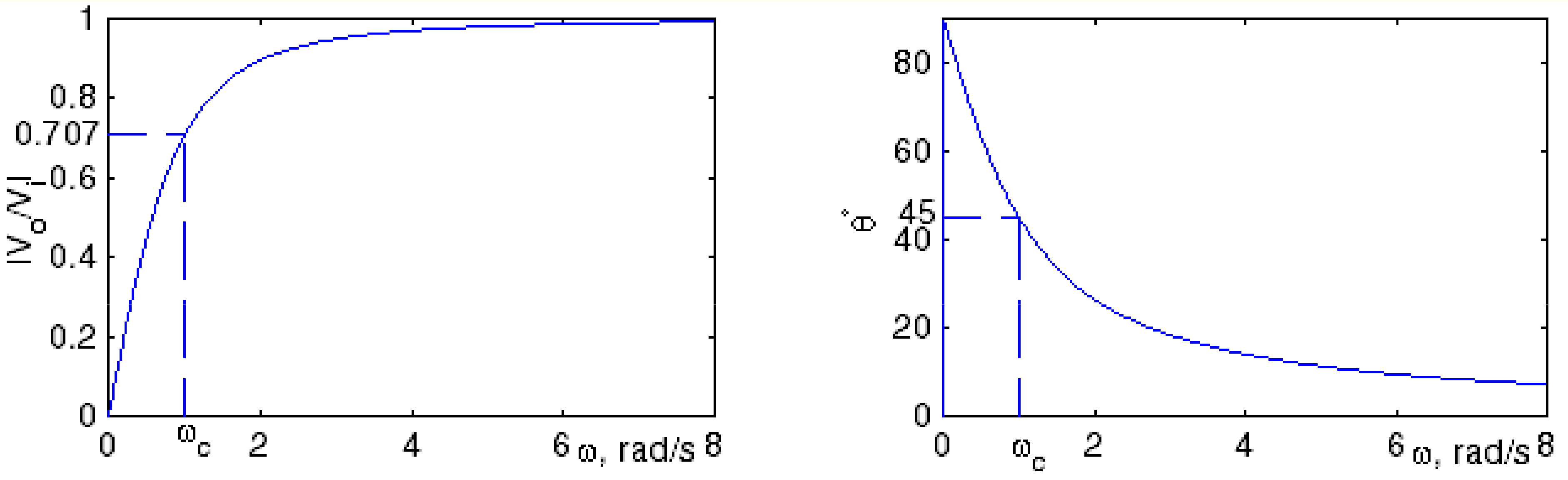
At cut off frequency Gain $= 1/\sqrt{2}$. Substituting in (6) result in

$$\omega_c = \frac{1}{RC} \qquad \omega_c = \frac{R}{L}$$

From (7), we see that the phase angle at cutoff frequency is 45°

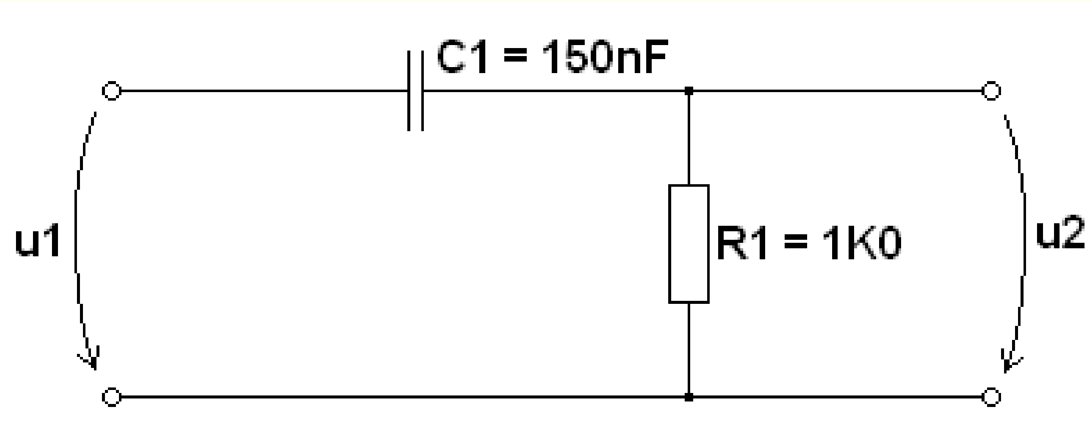
The ratio V_0/V_i is shown by $H(j\omega)$, and is called the ***frequency response transfer function***. The gain versus frequency, and the phase angle versus frequency known as the *frequency response* is as shown.

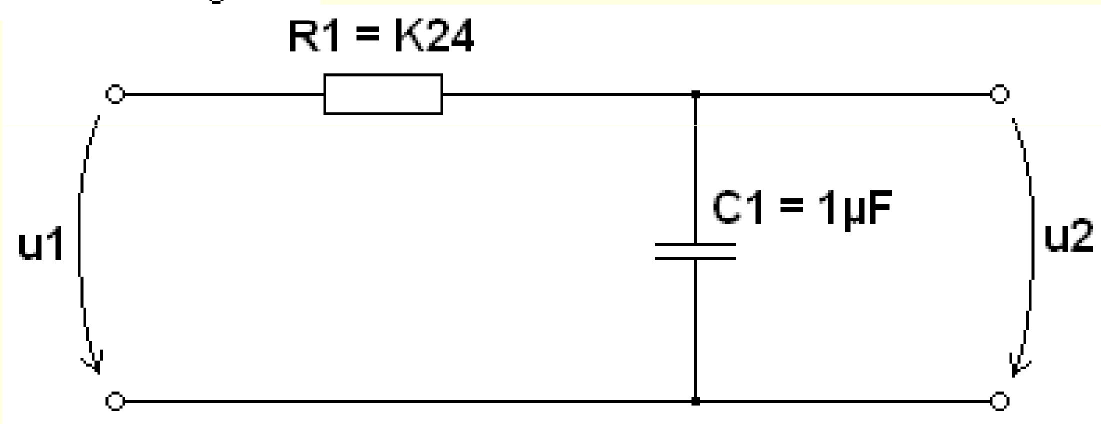
Exercise 1- Differentiator



The ratio V_0/V_i is shown by $H(j\omega)$, and is called the ***frequency response transfer function***. The gain versus frequency, and the phase angle versus frequency known as the ***frequency response*** is as shown.

Exercise 1- Differentiator and Integrator





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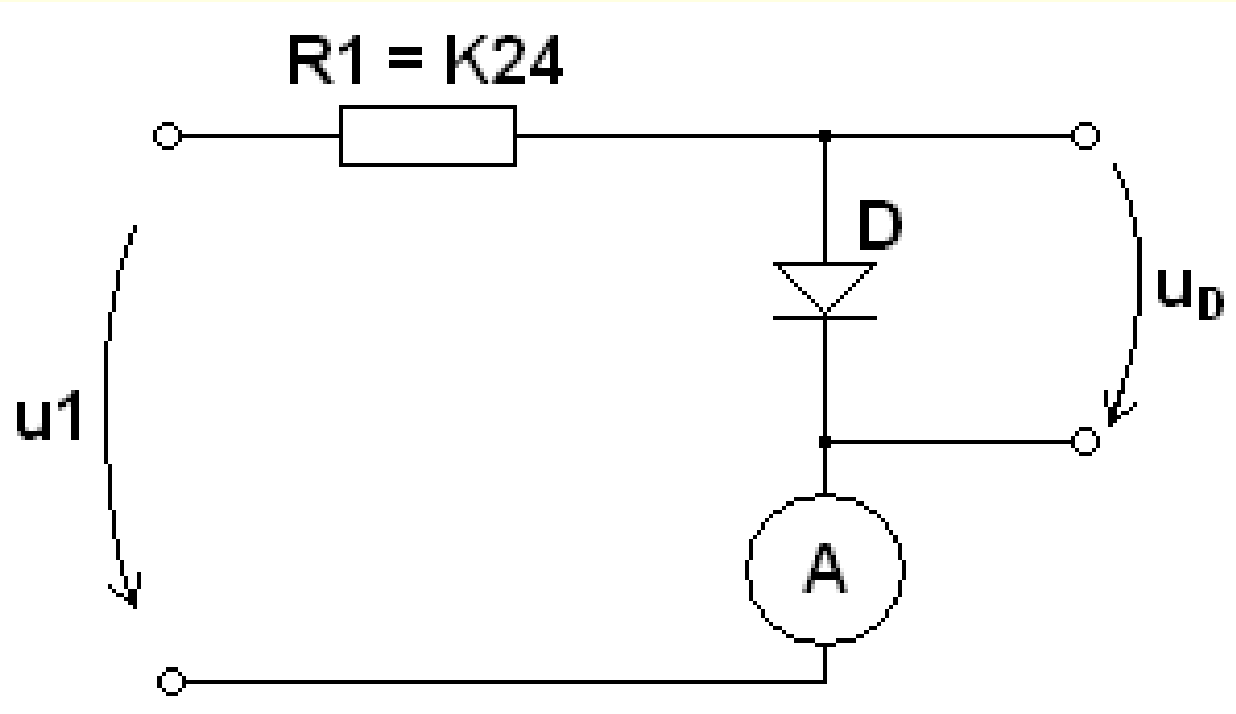
Exercise 2- V-A characteristic of diode



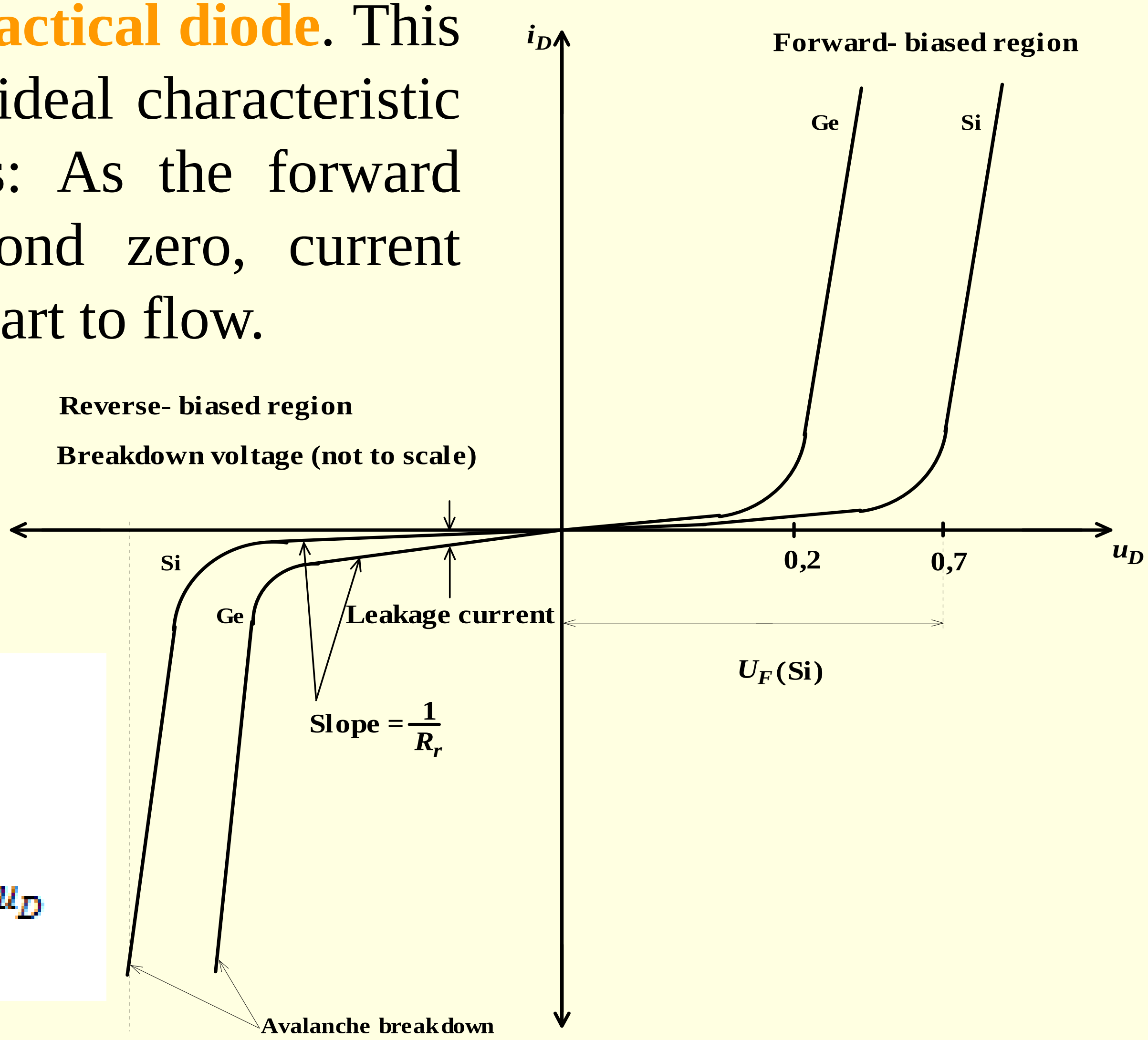
D- general, LED, Zener diode (ZD)

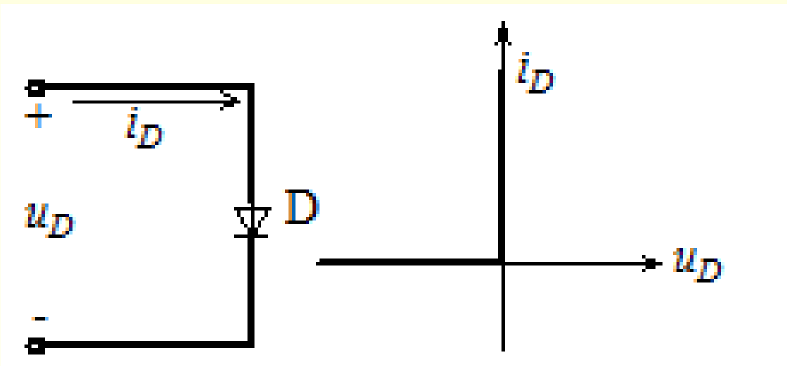
Tasks:

- 1.) Measure the V-A characteristics of diode (for input voltage u1)
- 2.) Find the quiescent operating point (Q- point : for input voltage u1=3V)

Exercise 2- V-A characteristic of diode

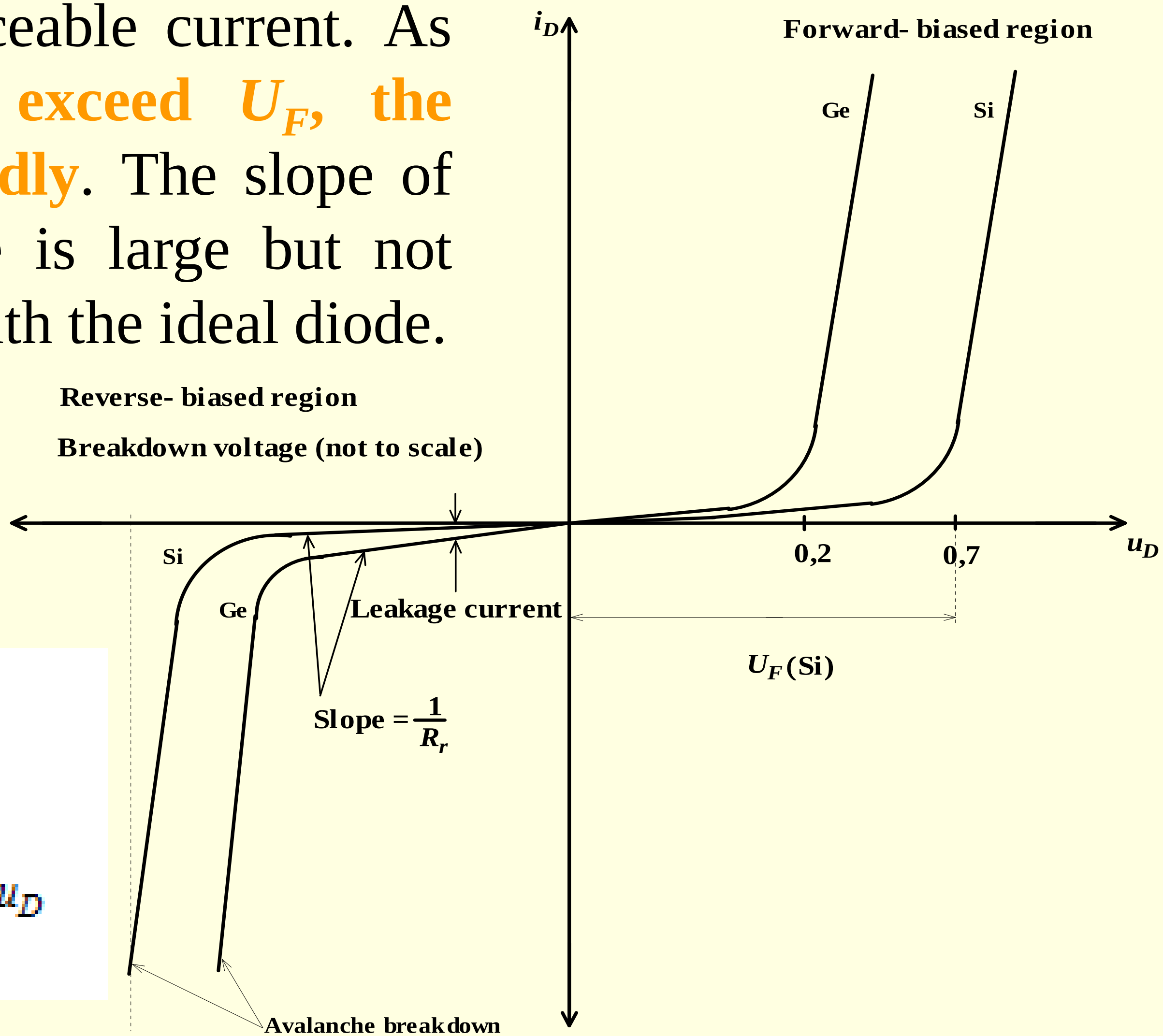
- Figure illustrates the **operating characteristics of a practical diode**. This curve differs from the ideal characteristic in the following ways: As the forward voltage increases beyond zero, current does not immediately start to flow.

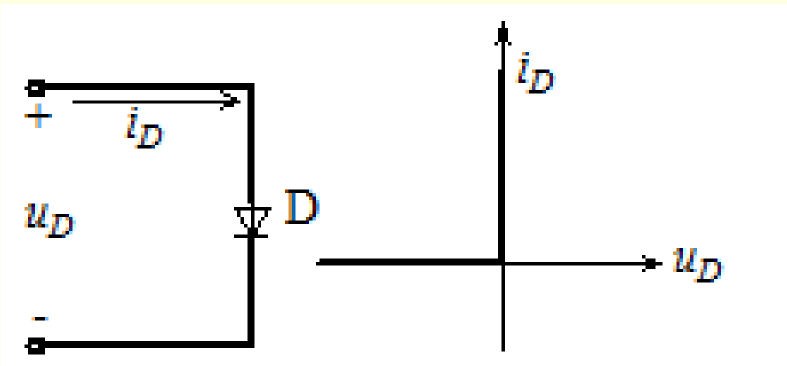




Exercise 2- V-A characteristic of diode

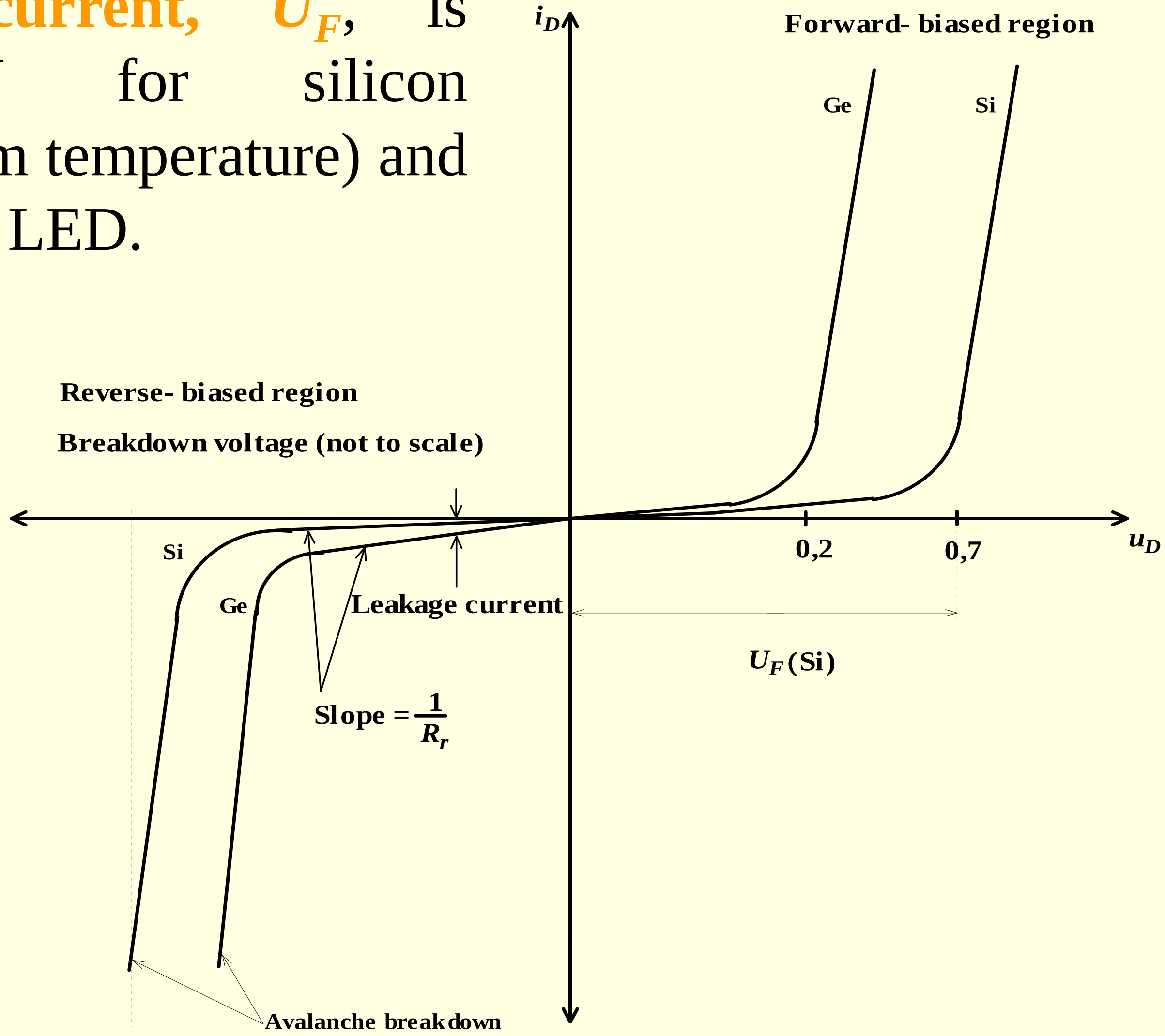
- It takes a minimum voltage, denoted by U_F, to obtain any noticeable current. As **the voltage tries to exceed U_F, the current increases rapidly**. The slope of the characteristic curve is large but not infinite, as is the case with the ideal diode.





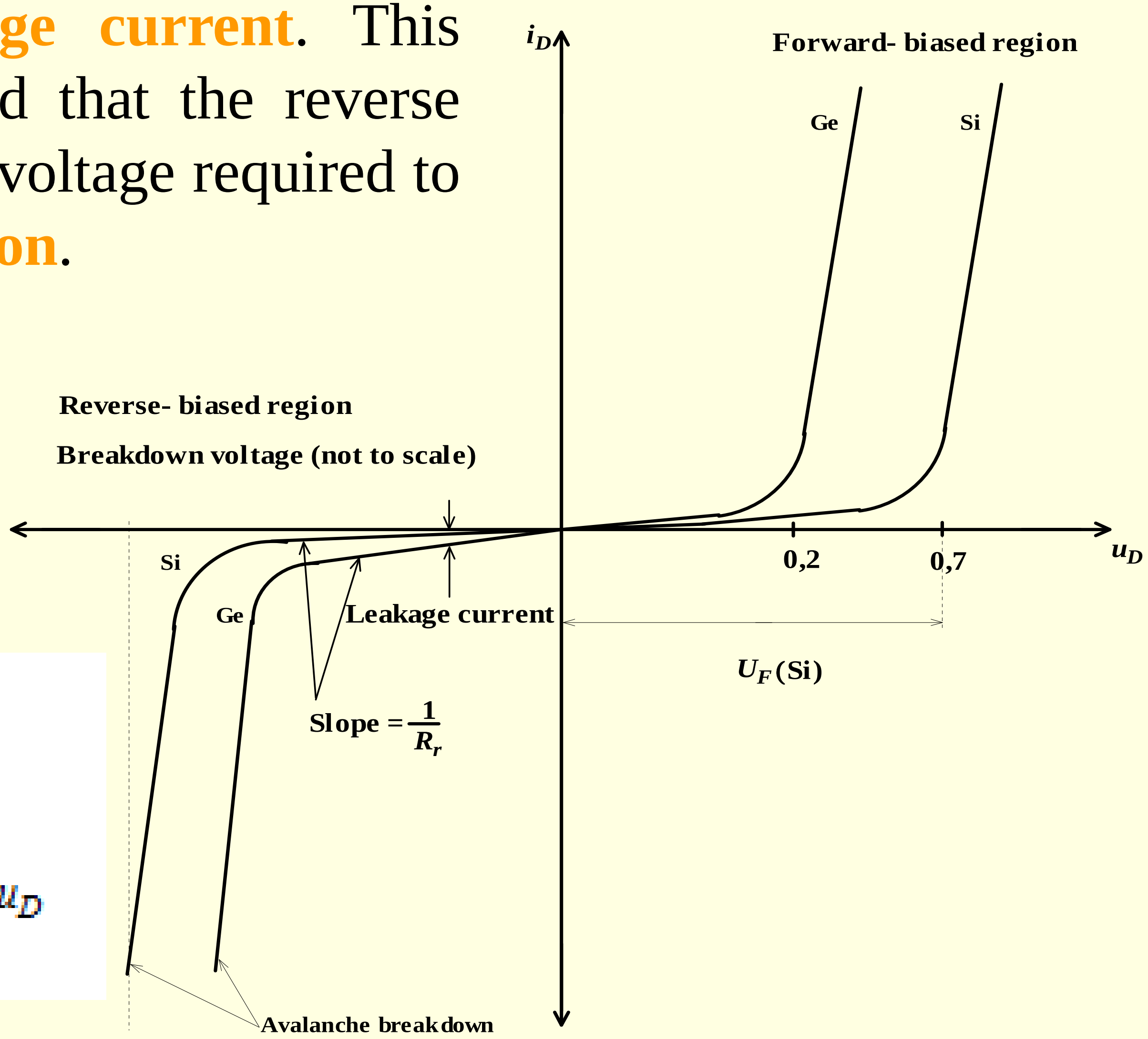
Exercise 2- V-A characteristic of diode

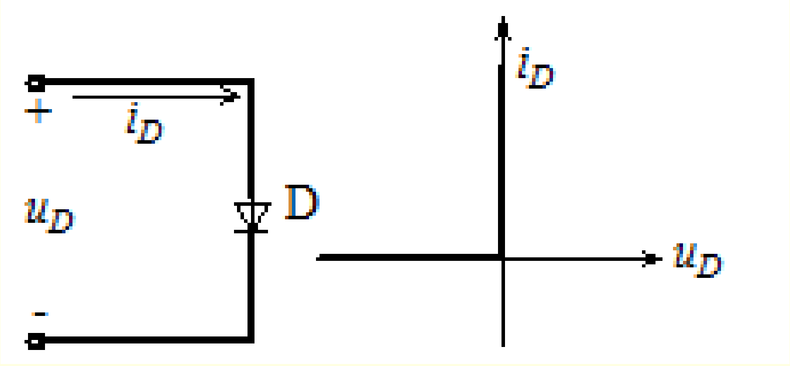
- **The minimum voltage required to obtain noticeable current, U_F,** is approximately 0.7V for silicon semiconductors (at room temperature) and approximately 1.4V for LED.



Exercise 2- V-A characteristics of diode

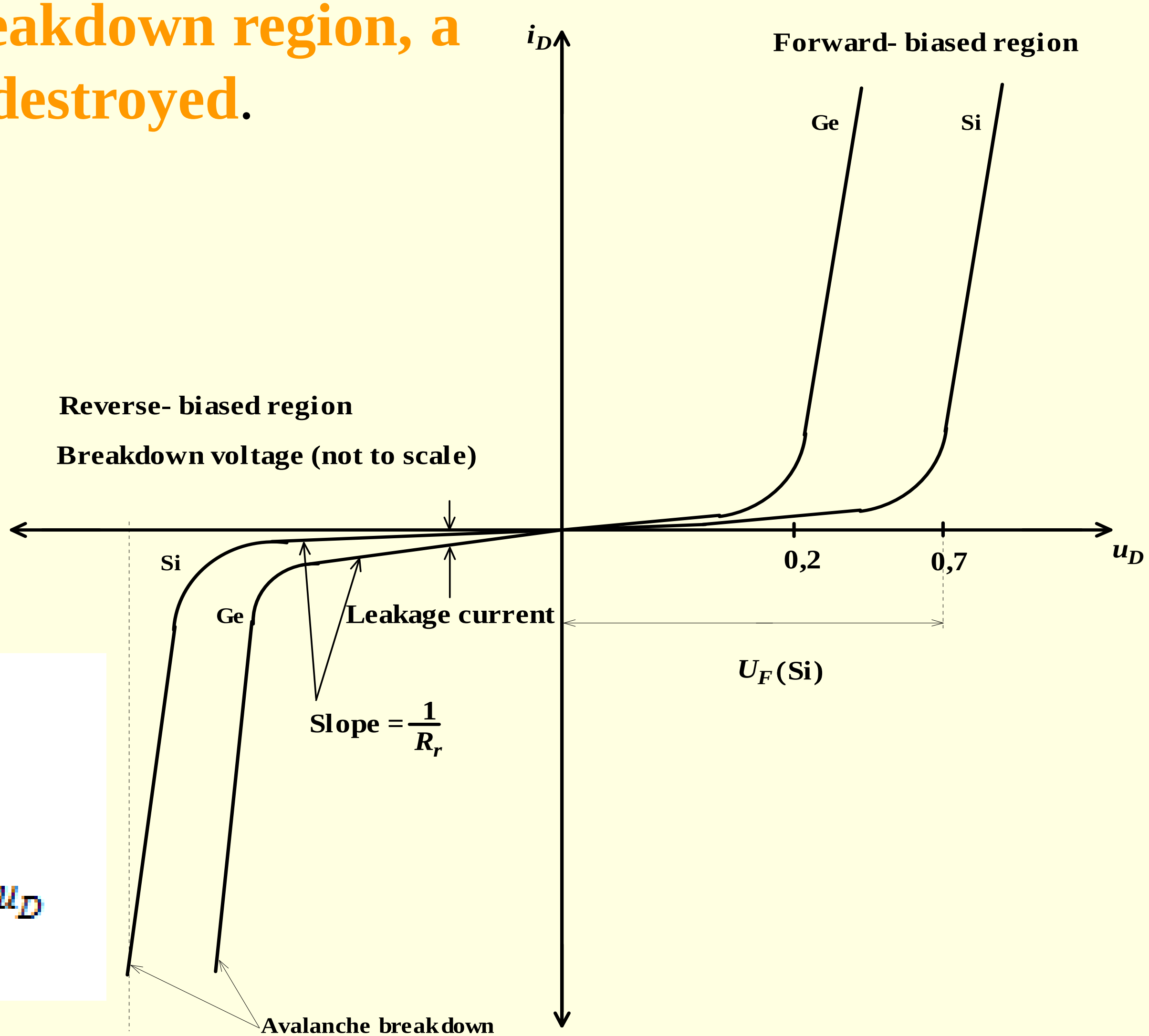
- When the diode is **reverse-biased, there is some small leakage current**. This current occurs provided that the reverse voltage is less than the voltage required to **break down the junction**.

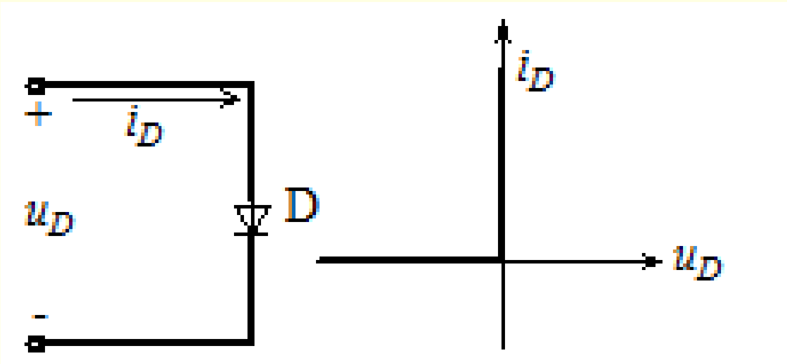




Exercise 2- V-A characteristic of diode

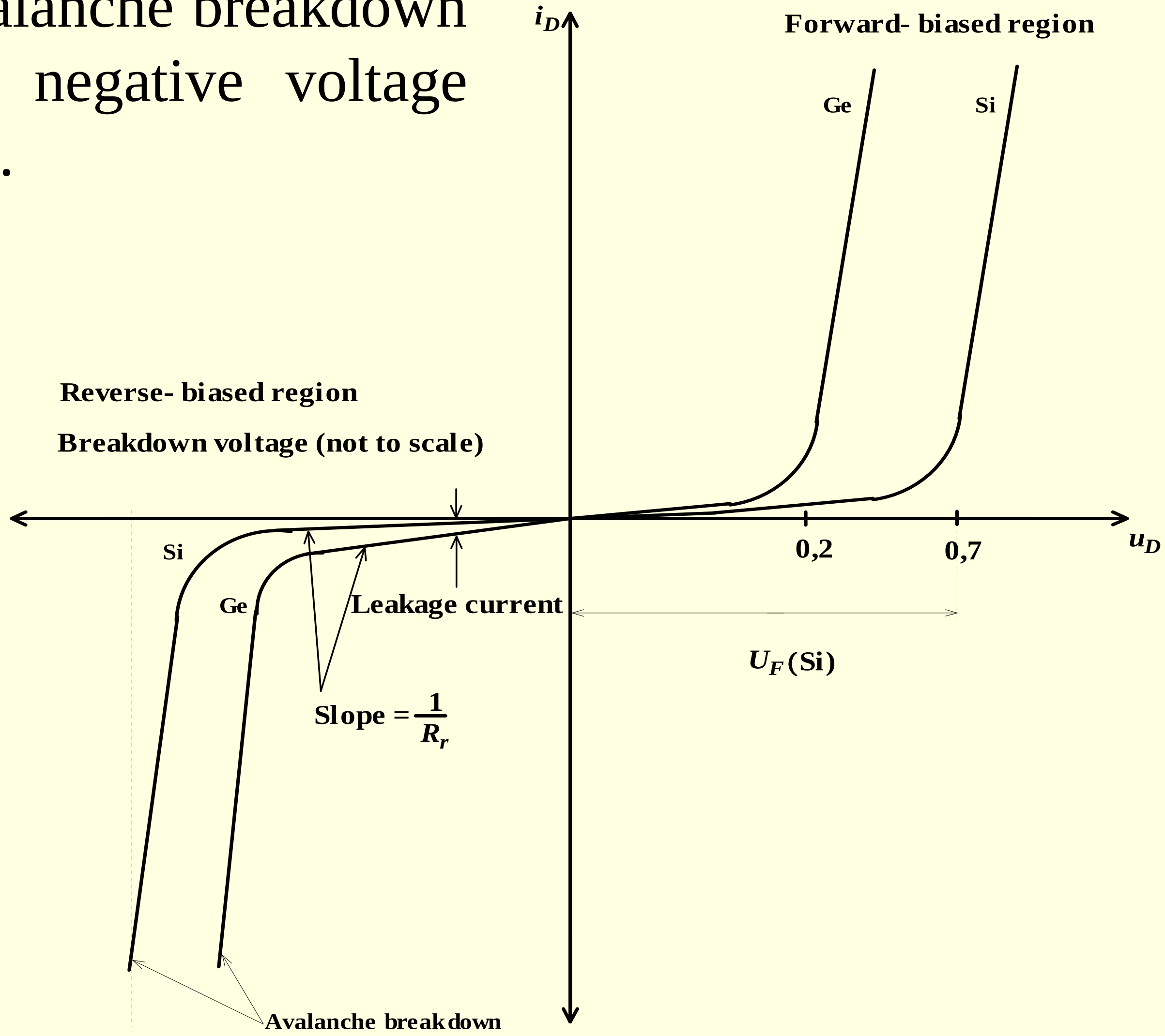
- If the negative voltage becomes large enough to be **in the breakdown region, a normal diode may be destroyed**.





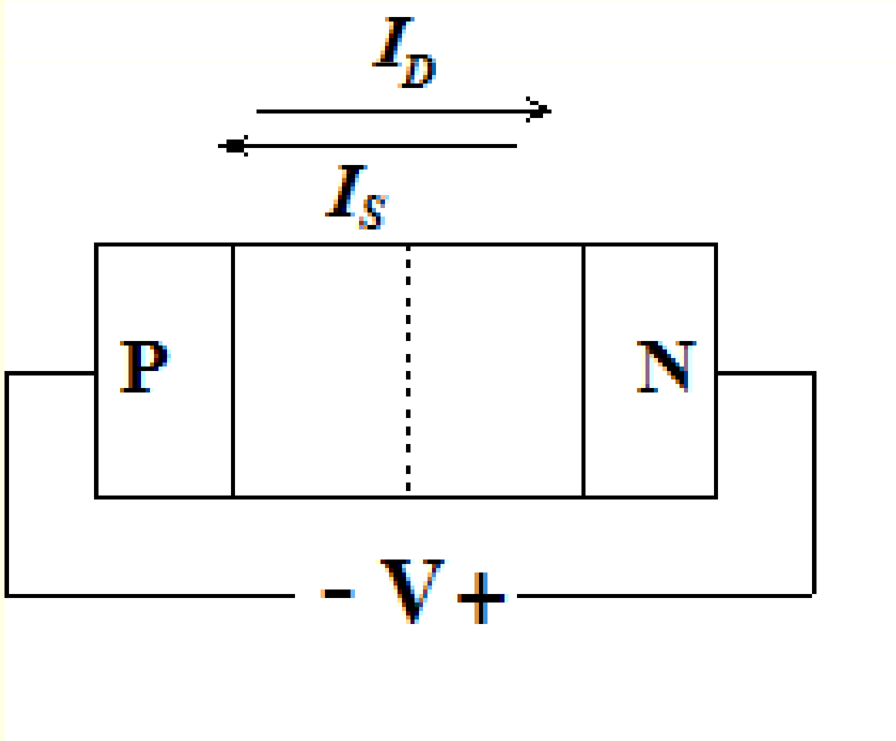
Exercise 2- V-A characteristic of diode

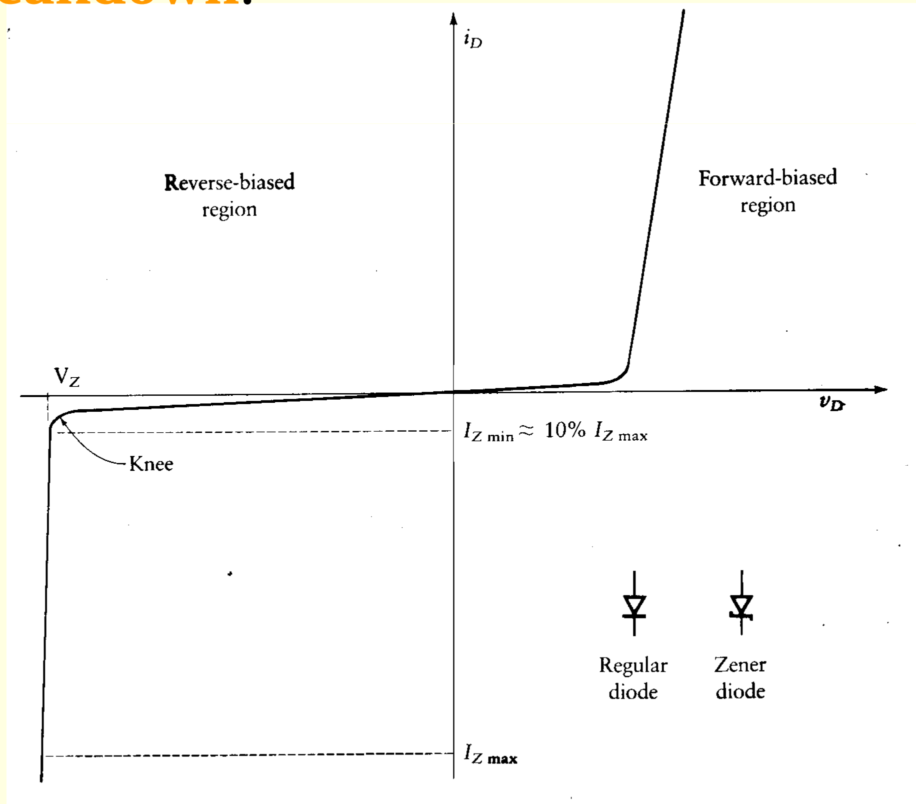
- **The curve is not to scale** in the reverse-biased region as the avalanche breakdown is usually at a large negative voltage (typically 50V or more).



Exercise 2- V-A characteristic of diode

- The damage to the normal diode at breakdown is due to the avalanche of electrons, which flow across the junction with little increase in voltage. The large current can cause destruction of the diode if excessive heat builds up. This breakdown is sometimes referred to as the **diode voltage breakdown**.

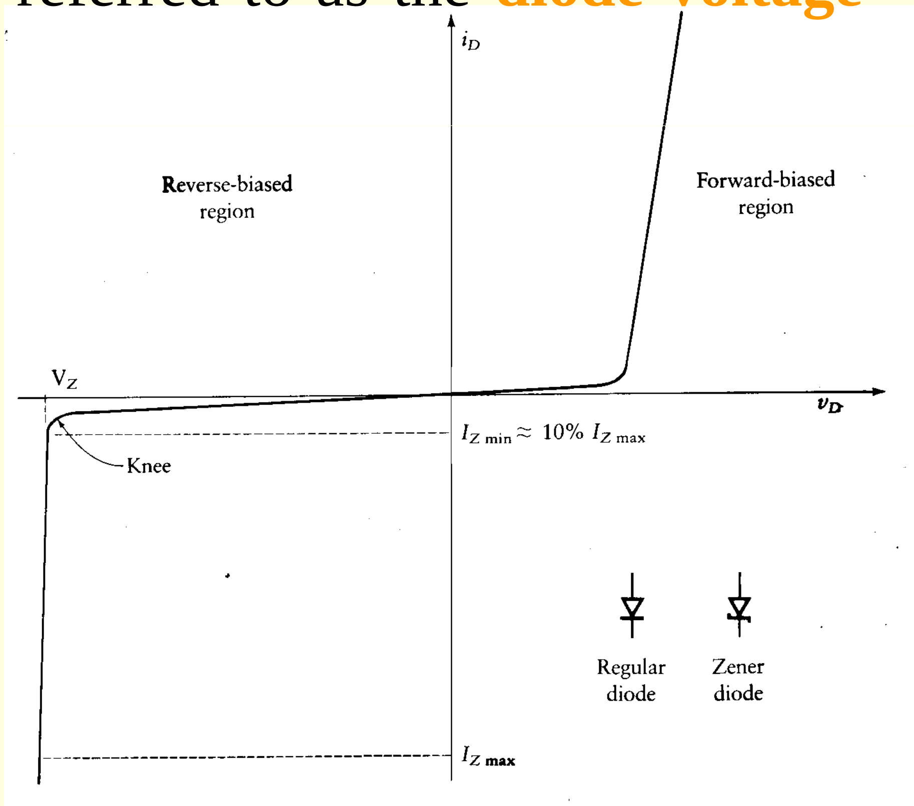




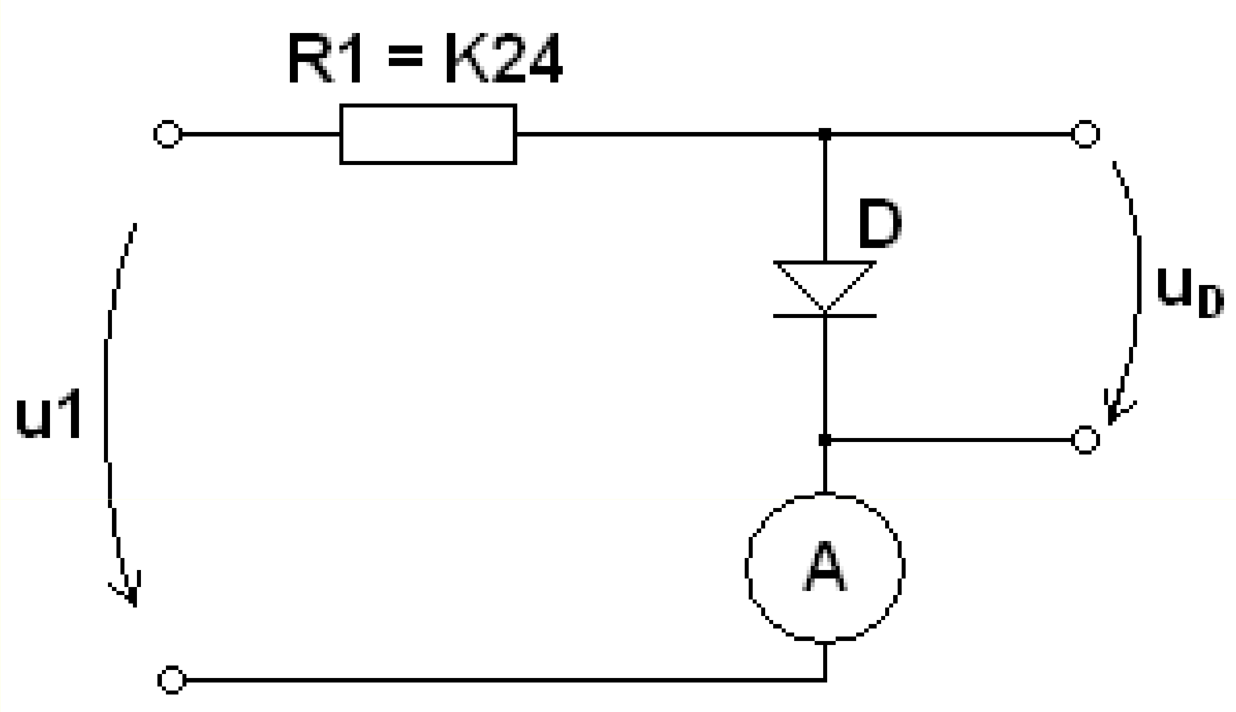
Exercise 2- V-A characteristic of diode

- The damage to the normal diode at breakdown is due to the avalanche of electrons, which flow across the junction with little increase in relative high voltage of the electric field. The large current can cause destruction of the diode if excessive heat builds up. This breakdown is sometimes referred to as the **diode voltage breakdown**.

- Diodes can be constructed to utilize the breakdown voltage to simulate a voltage-control device/ source. The result is a **Zener diode**.



Exercise 2- V-A characteristic of diode



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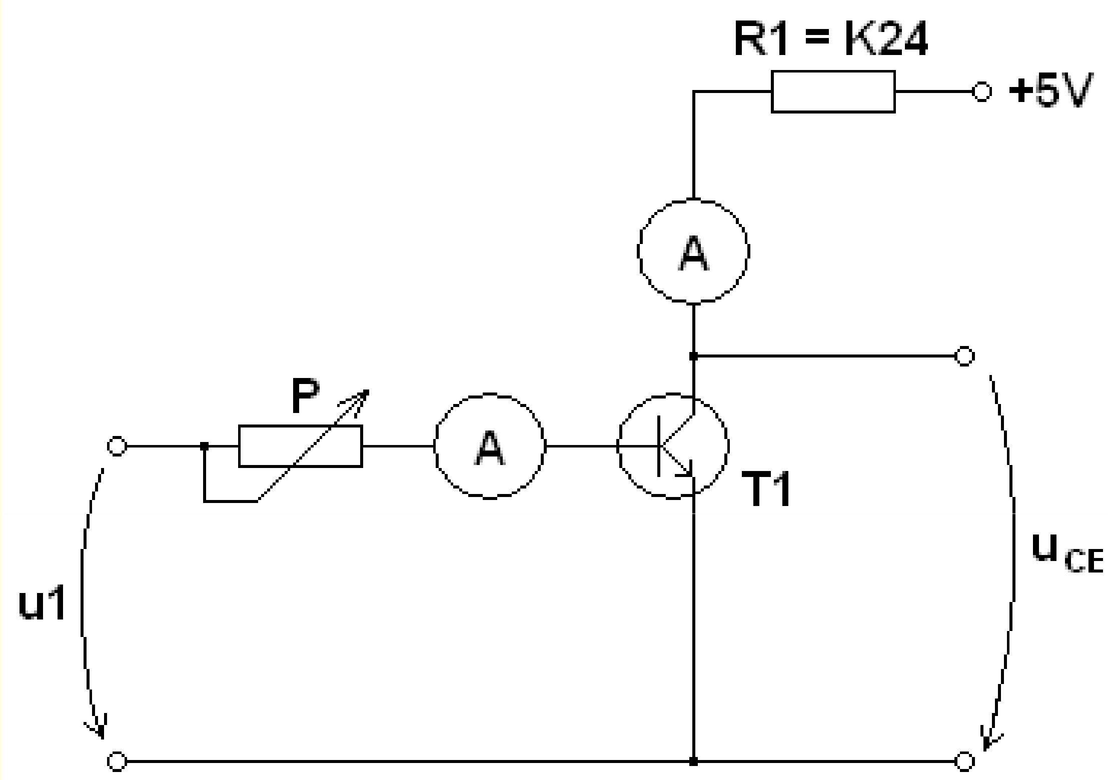
Exercise 2-Transistor Characteristics curves

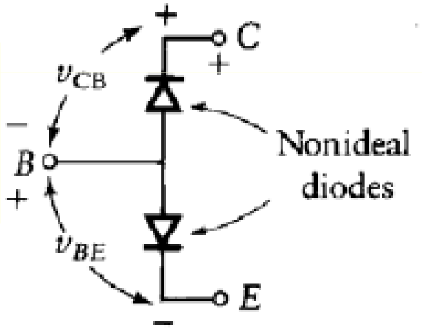


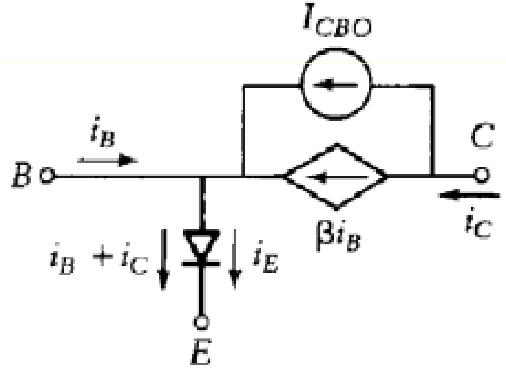
Tasks:

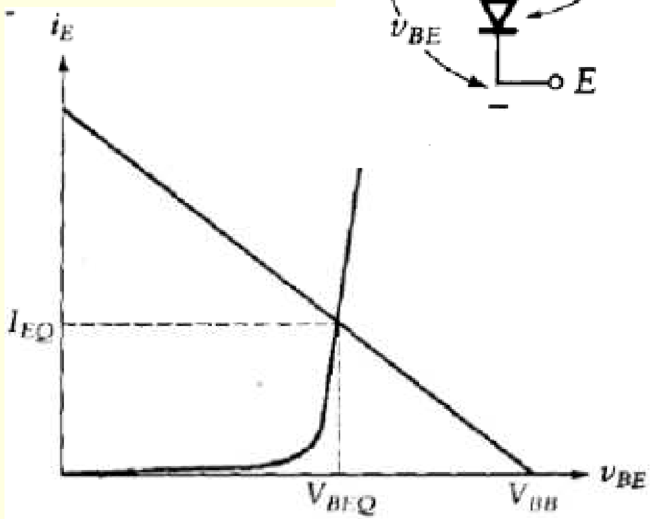
- 1.) Measure the input characteristic of transistor (Emitter- base)
- 2.) Measure the output characteristics of transistor (Collector-emitter), where base current is a parameter

Exercise 2-Transistor Characteristics curves

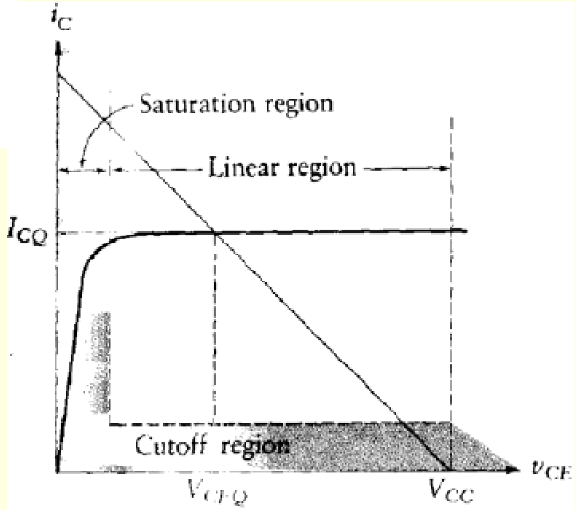
Since the transistor is a nonlinear device, one way to define its operation is with a series of characteristic curves in a manner similar to that used for diodes at least three variables. Therefore, *parametric curves* are usually used to describe transistor behavior. Figure 2.10 shows two typical plots. Figure 2.10(a) shows the emitter current as a function of the voltage between base and emitter when v_{CE} is held constant. Note that, as we might have expected, this curve is similar to the curve for a diode, since it is the characteristic of the current in the single junction.







(a) Emitter-base characteristics



(b) Collector-emitter characteristics

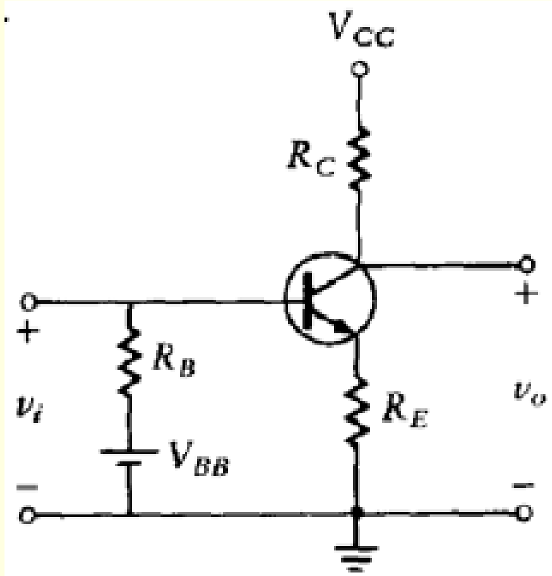
Exercise 2-Transistor Characteristics curves

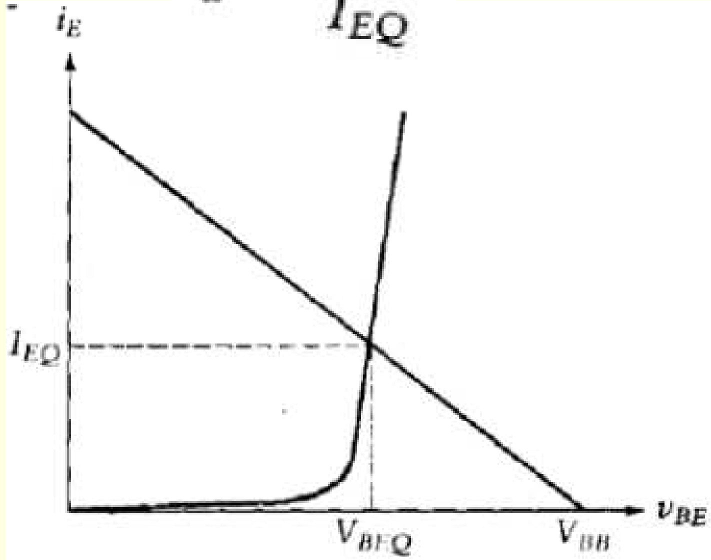
A load line is drawn using the two axis intercepts. When $i_E = 0$, $v_{BE} = V_{BB}$. The other intercept is found by setting $v_{BE} = 0$. The point where the load line crosses the i_E versus v_{BE} curve is called the *quiescent point*, or simply *Q-point*. The slope of the load line is $-1/(R_E + R_B)$. That is, the equivalent resistance seen by the base and emitter terminals is simply $R_E + R_B$. The slope of the characteristic curve is $1/r_d$, where r_d is the *dynamic resistance* of the transistor emitter-base junction. This slope can be calculated

the derivative of equation (1.1) and performing appropriate simplifications, we find the dynamic resistance to approximately equal

$$r_d \approx \frac{0.026}{I_{EQ}}$$

$$i_D = I_0\left(\exp\left(\frac{q \cdot u_D}{n \cdot k \cdot T}\right) - 1\right)$$





(a) Emitter-base characteristics

where I_{EQ} is the emitter current at the Q-point.

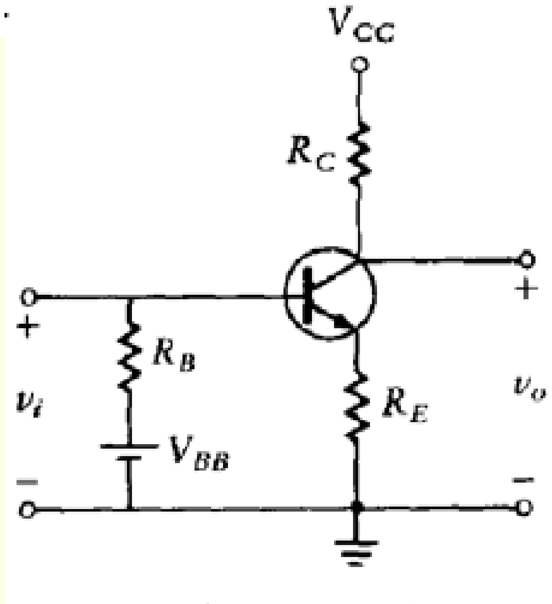
Exercise 2-Transistor Characteristics curves

Since $i_B = i_C/\beta$, the base-emitter junction is similar to that of a diode. Therefore, for the forward-biased junction,

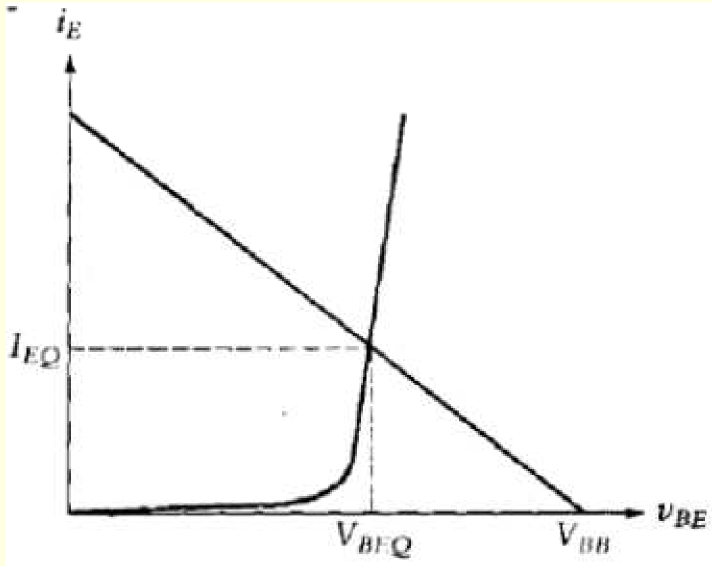
$$i_B \approx \left(\frac{I_o}{\beta}\right) \exp\left(\frac{v_{BE}}{nV_T}\right)$$

we use $n = 1$ and $nV_T = 26$ mV for silicon transistors.

A straight-line extension of the characteristic curve would intersect the v_{BE} axis at 0.7 V for silicon transistors, 0.2 V for germanium, and 1.2 V for gallium arsenide devices.



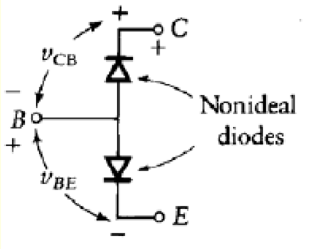
(a) Common emitter

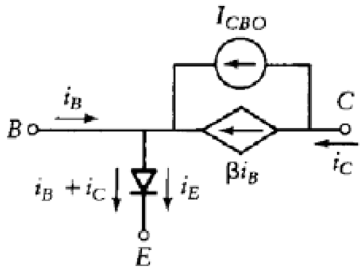


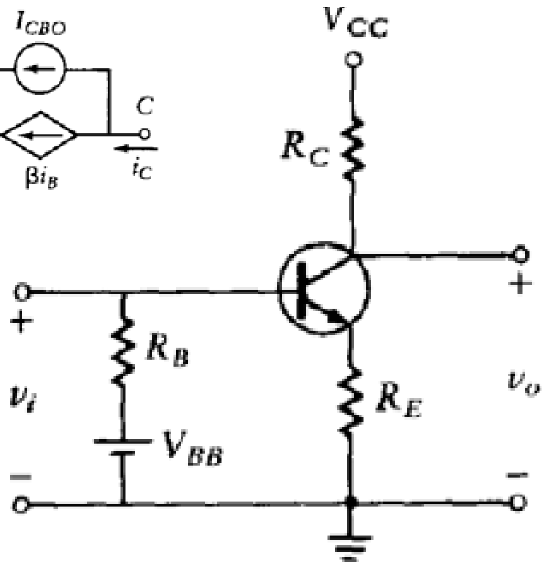
(a) Emitter-base characteristics

Exercise 2-Transistor Characteristics curves

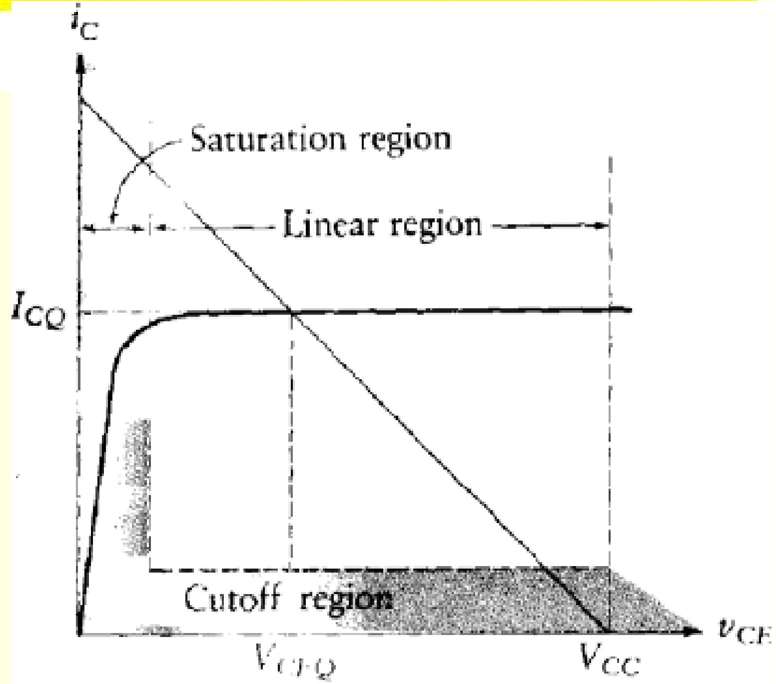
If we now hold i_B constant, the collector-emitter junction is defined by the curve of i_C versus v_{CE} shown in Figure 2.10(b). As can be seen from this typical curve, the collector current is almost independent of the voltage between the collector and the emitter, v_{CE}, throughout the "linear range" of operation. When i_B is close to zero, i_C approaches zero in a nonlinear manner. This is known as the *cutoff region* of operation. For the section of the characteristic curves where v_{CE} is near zero, i_C is maximum. This region, known as the *saturation region*, is also not usable for amplification because of nonlinear operation.







(a) Common emitter



(b) Collector-emitter characteristics

Exercise 2-Transistor Characteristics curves

Transistor characteristic curves are parametric curves of i_C versus v_{CE}, where i_B is a parameter. Figure 2.11 shows an example of a family of such curves. Each transistor type has its own unique set of characteristic curves.

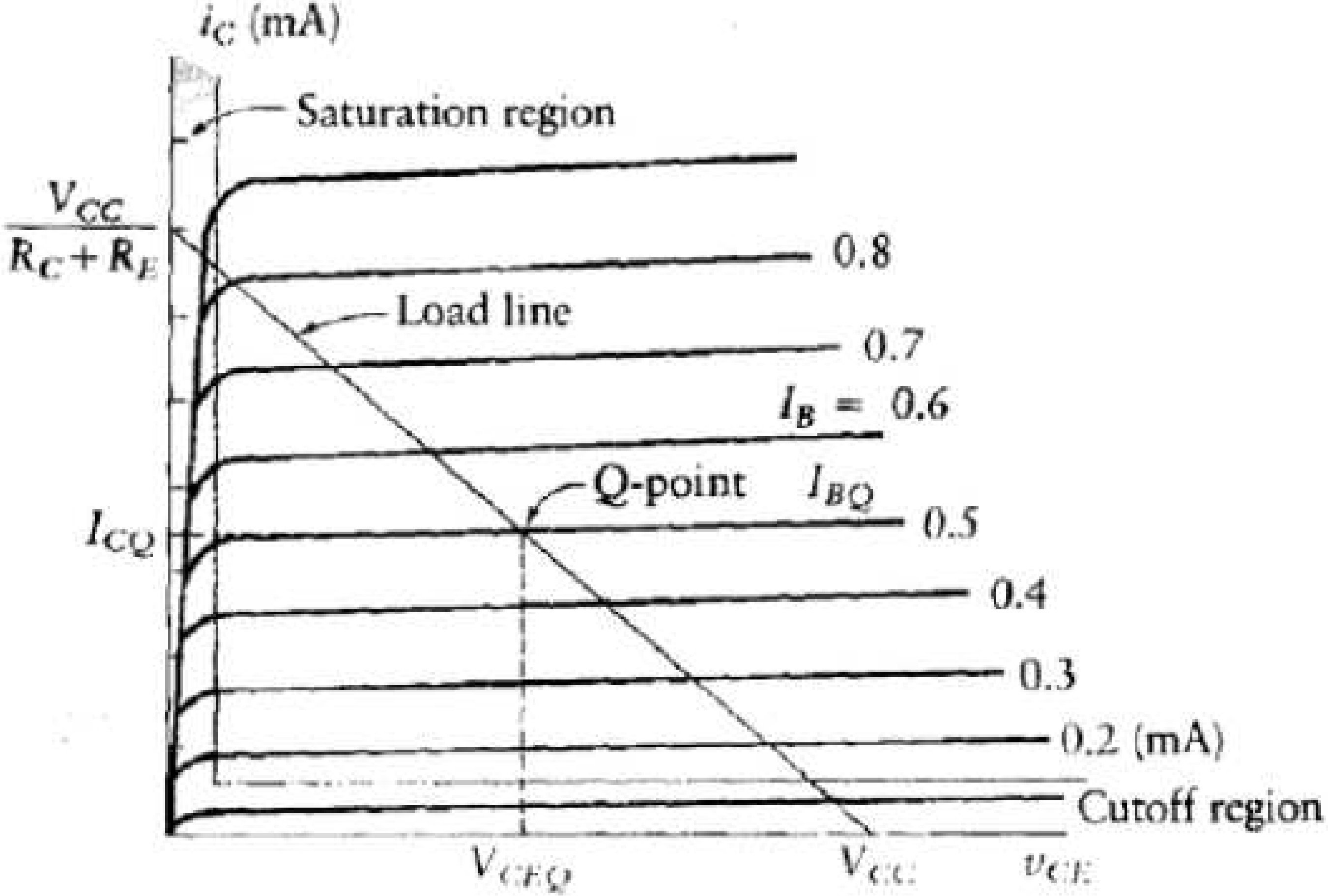


Figure 2.11 Family of transistor characteristic curves.

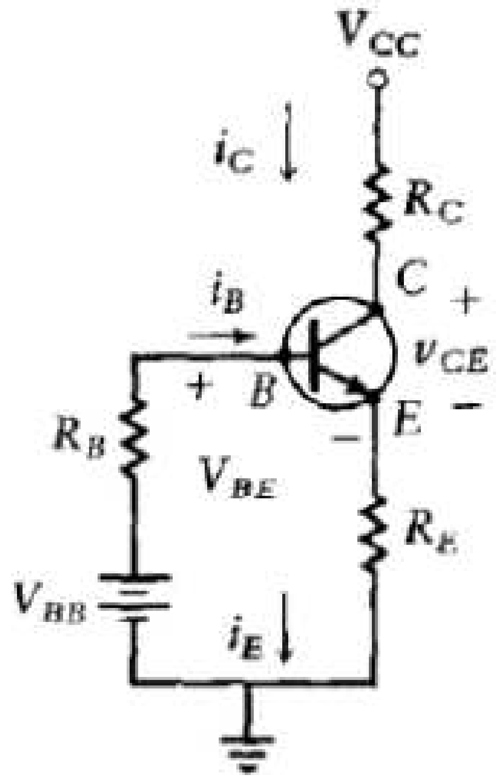
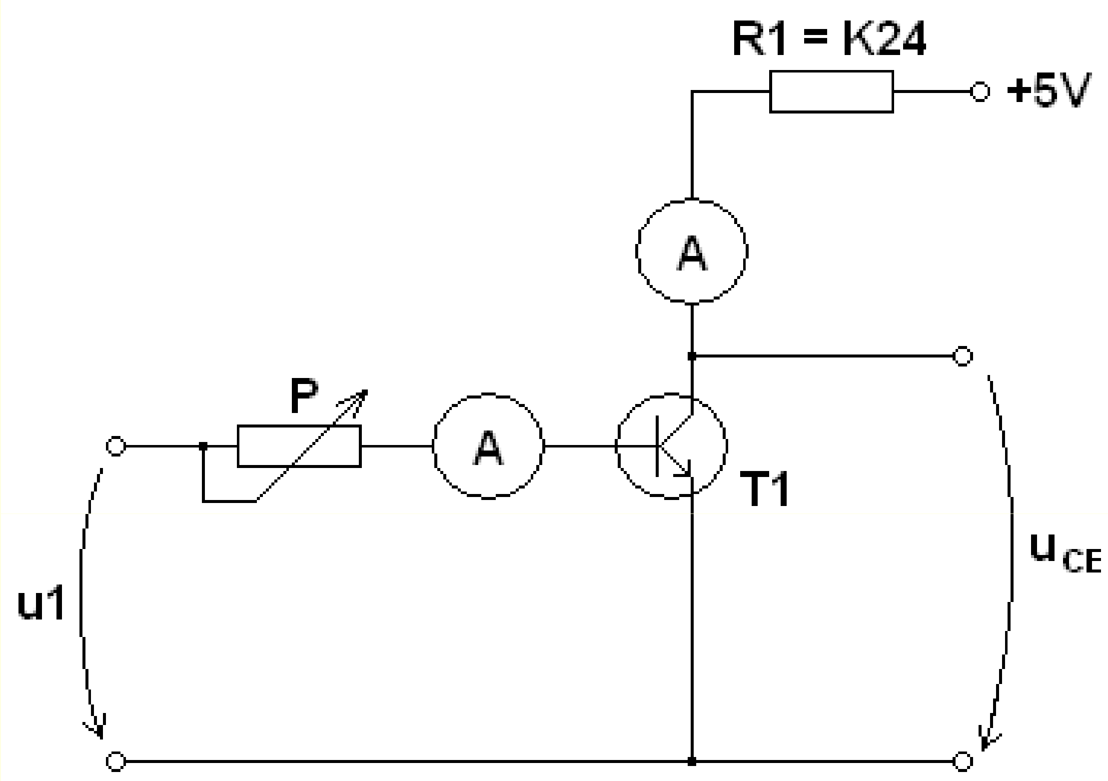


Figure 2.12 Simple transistor circuit.

Exercise 2-Transistor Characteristics curves



Tasks:

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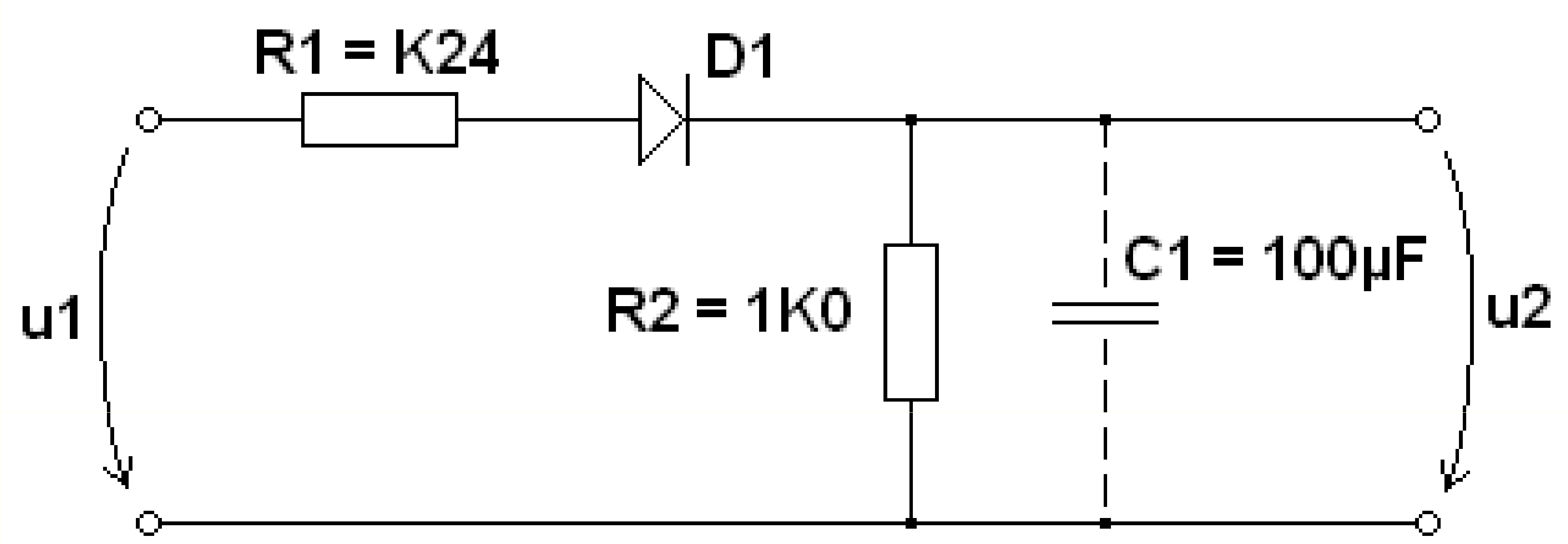
- 2.) Measure the output characteristics of transistor (Collector-emitter), where base current is a parameter

Exercise 3- Half- wave rectifier



Tasks:

- 1.) Measure the static transfer characteristic of half- wave rectifier u2=f(u1)
- 2.) Measure the output waveform of half- wave rectifier in time domain with (and without) capacitor C1, for different parameters of input periodic signal (for different frequency)

Exercise 3- Half- wave rectifier

- Within this exercise we will familiar with the diode configuration to perform useful function- **rectification**- major application of the diode

Rectification

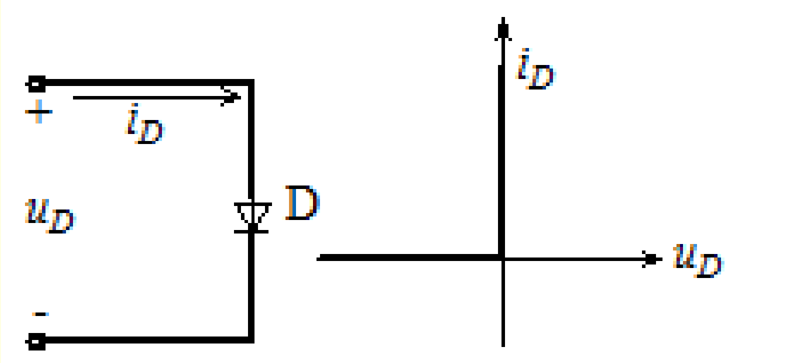
We are now ready to see how the diode is configured to perform a useful function. The first major application we consider is that of *rectification*.

Rectification is the process of turning an alternating signal (ac) into one that is restricted to only one direction (dc). Rectification is classified as either *half-wave* or *full-wave*.

Exercise 3- Half- wave rectifier

Half-Wave Rectification

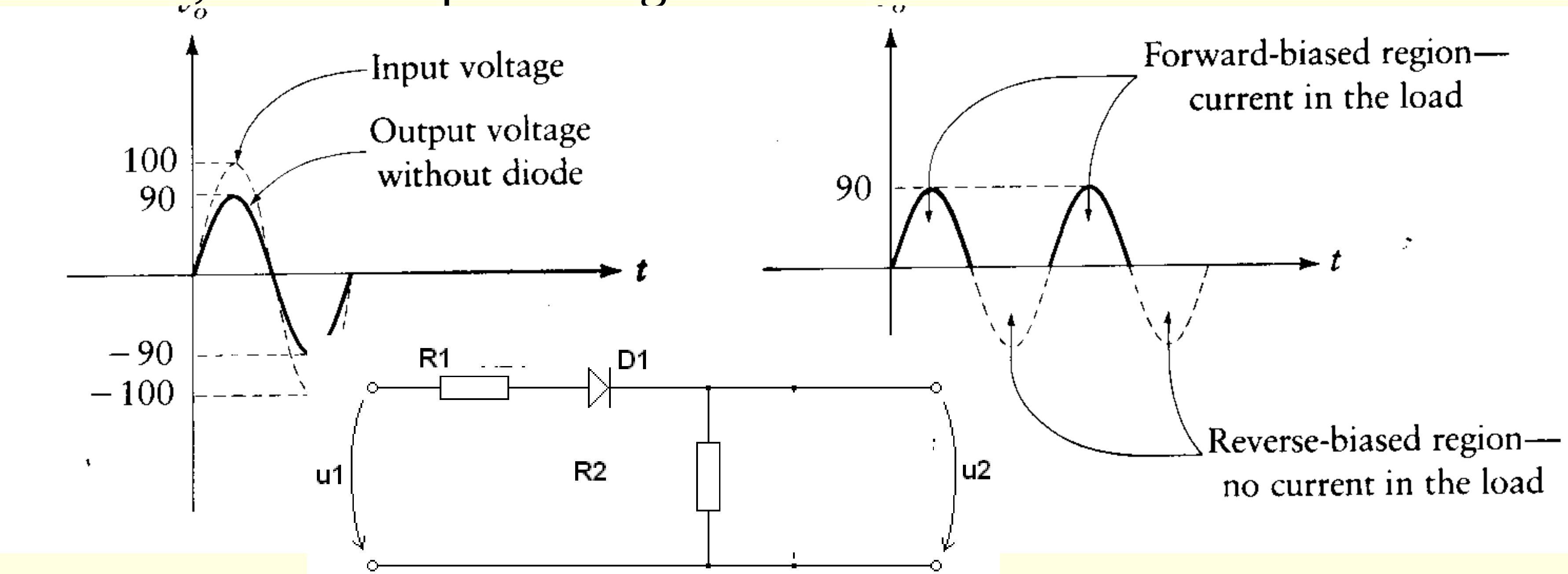
- Since an ideal diode can sustain current flow in only one direction, it can be used to change an ac signal into a dc signal.
- The task of our exercise is measure a simple half-wave rectifier circuit:
  - When the **input voltage is positive**, the diode is forward-biased and can be replaced (assume it is ideal) by a short circuit.
  - When the **input voltage is negative**, the diode is reverse-biased and can be replaced by an open circuit (provided the voltage does not get sufficiently negative to break down the diode).



Exercise 3- Half- wave rectifier

Half-Wave Rectification

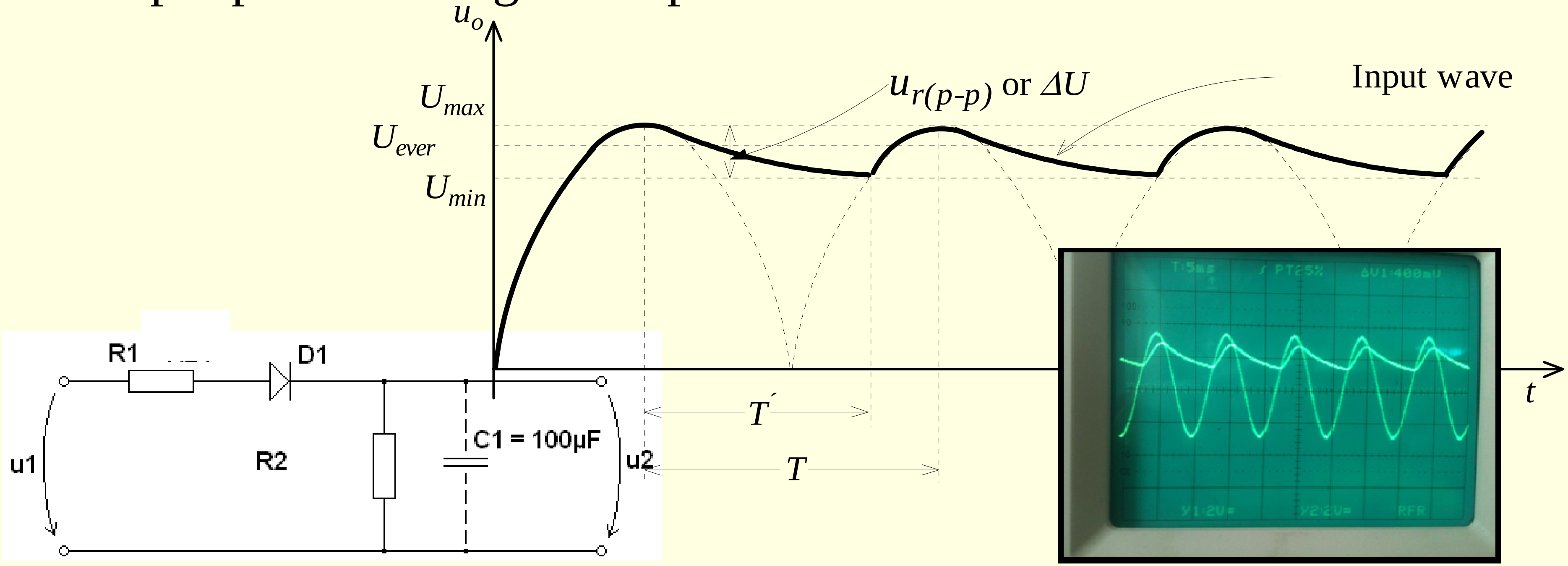
- Figure shows an example of the output waveform assuming a 100V amplitude sinusoidal input, R_1=10Ω, and R_2 = 90 Ω.
- When the diode is **forward-biased,** the output voltage across the load resistor R2 can be found from the voltage divider relationship R1&R2. Alternatively, in the **reverse-biased** condition, the current is zero, so the output voltage is also zero.



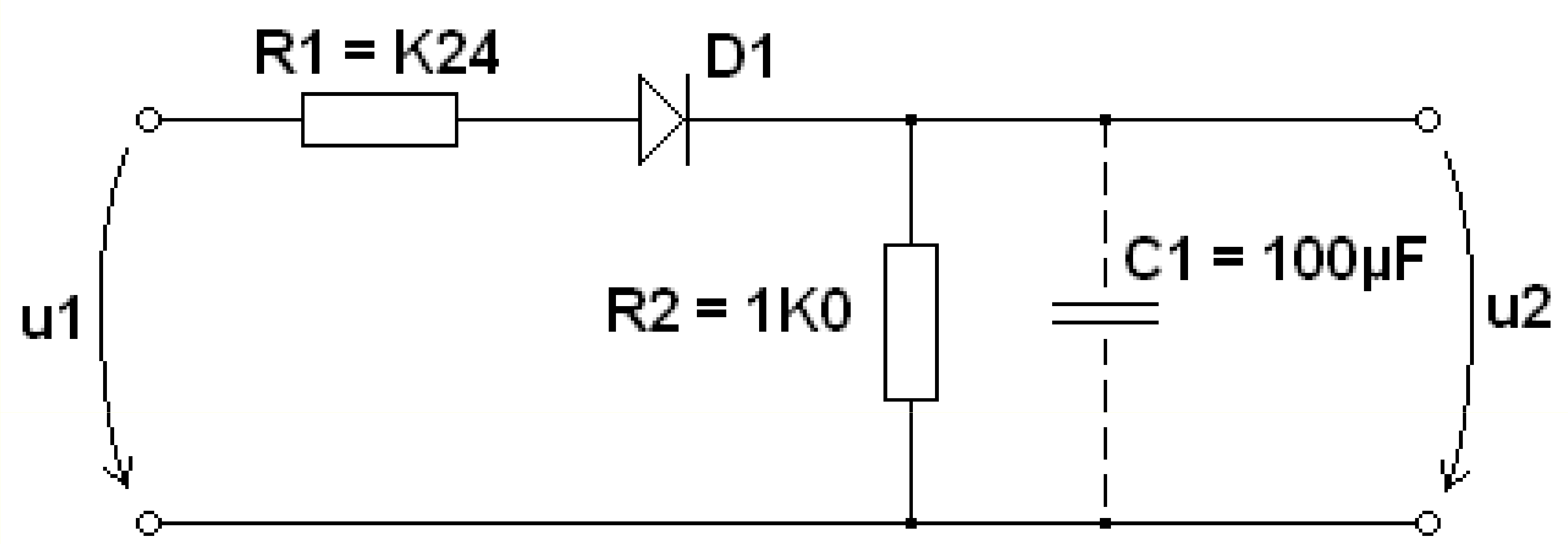
Exercise 3- Half- wave rectifier

Half-Wave Rectification

- The half-wave rectifier can be used to create an **almost-constant dc output** if the resulting waveform is filtered. We note that the half-wave rectifier is not very efficient. During one-half of each cycle, the input is completely blocked from the output. If we could transfer input energy to the output during this half cycle, we would increase output power for a given input- **full- wave rectifier**.



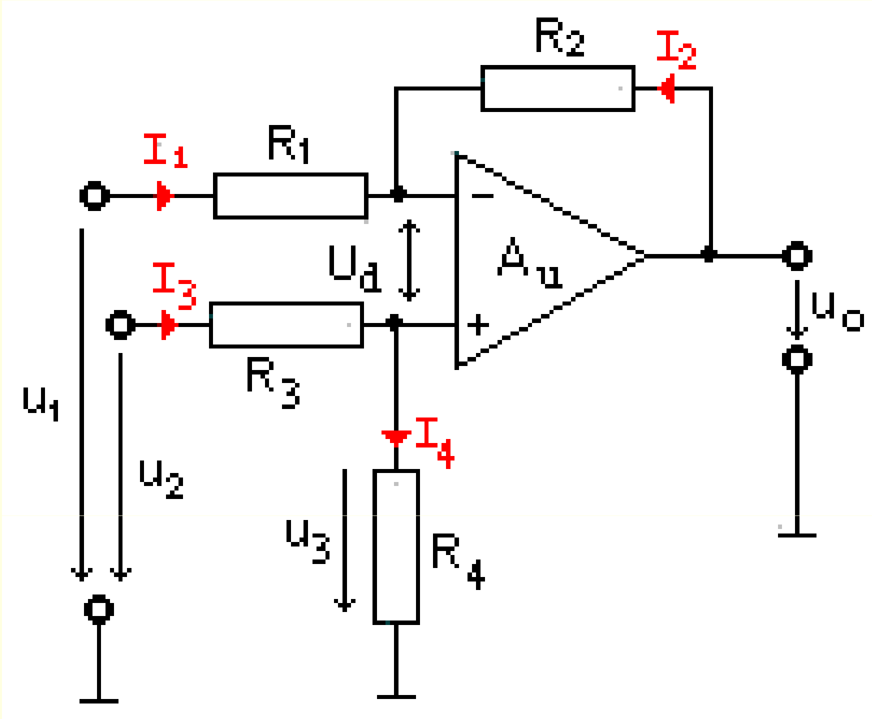
Exercise 3- Half- wave rectifier



Tasks:

- 1.) Measure the static transfer characteristic of half- wave rectifier u2=f(u1)
- 2.) Measure the output waveform of half- wave rectifier in time domain with (and without) capacitor C, for different parameters of input periodic signal (for different frequency)

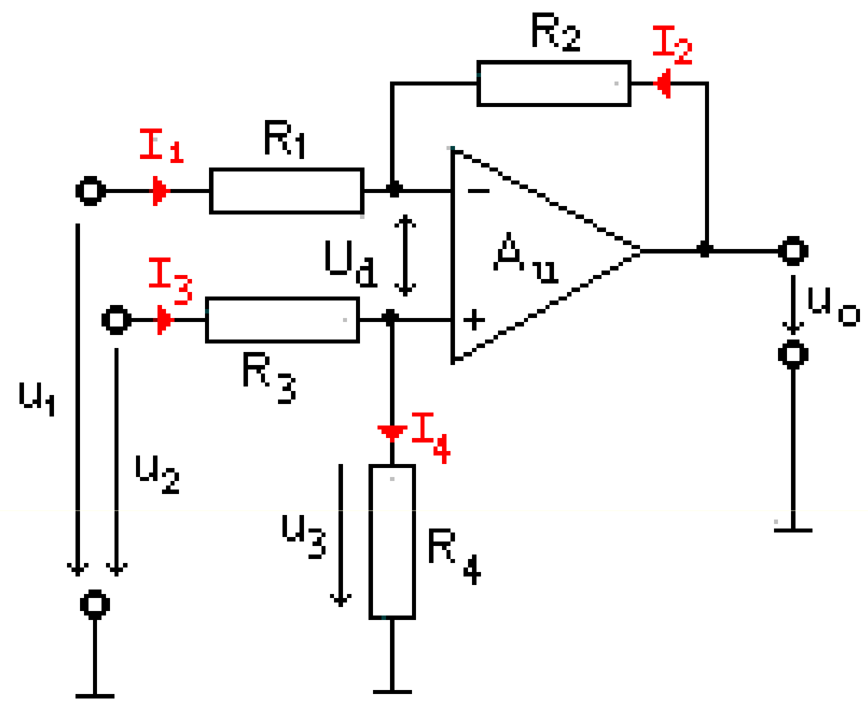
Exercise 4- Operational Amplifiers circuits



Tasks:

- 1.) Measure the output waveform of inverting amplifier in time domain, for different parameters of input periodic signal (frequency) and different values of feed- back resistor *R2*. Find the gain of the circuit for particular values of *R2*.
- 2.) Measure the output waveform of noninverting amplifier in time domain, for different parameters of input periodic signal (frequency) and different values of *R2*. Find the gain of the circuit for particular values of *R2*.
- 3.) Measure the DC transfer characteristic of inverting and noninverting amplifier for particular values of *R2*.

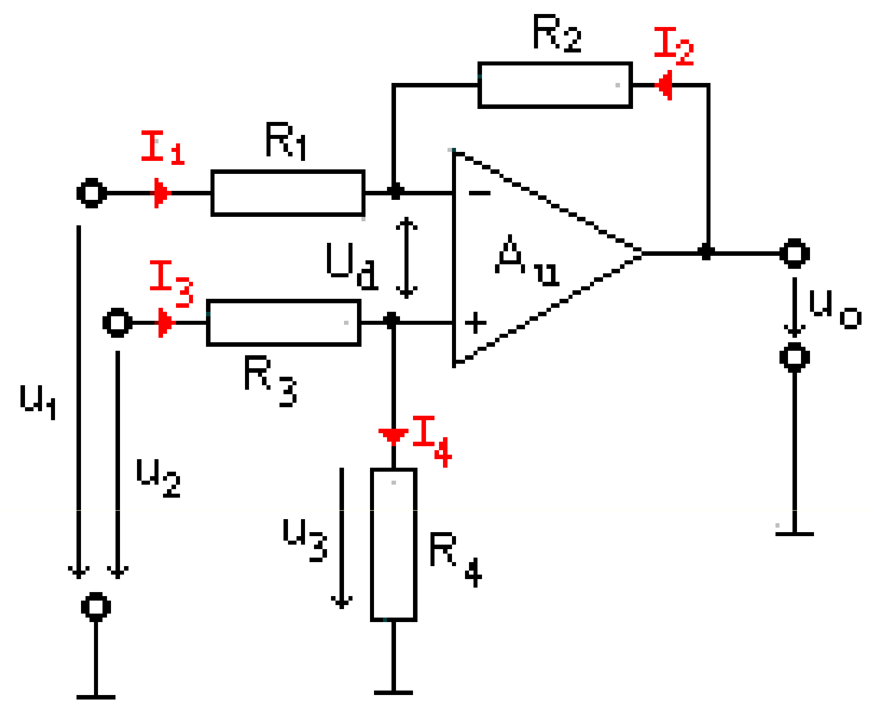
Exercise 4- Operational Amplifiers circuits



The ideal operational amplifier is characterized as follows:

1. Input resistance, $R_{\text{in}} \to \infty$
2. Output resistance, $R_o = 0$
3. Open-loop voltage gain, $G \to \infty$
4. Bandwidth $\to \infty$
5. $v_o = 0$ when $v_+ = v_-$ (i.e., the common-mode gain is zero and the CMRR approaches infinity)

Exercise 4- Operational Amplifiers circuits



Analysis Method

We use two important ideal op-amp properties:

1. The voltage between v_+ and v_- is zero, or $v_+ = v_-$.
2. The current into both the v_+ and v_- terminal is zero.

We develop a step-by-step procedure to analyze any ideal op-amp circuit as follows:

1. Write the Kirchhoff node equation at the noninverting terminal, v_+.
2. Write the Kirchhoff node equation at the inverting terminal, v_-.
3. Set $v_+ = v_-$ and solve for the desired closed-loop gains.

When performing the first two steps, remember that the current into both the v_+ and v_- terminal is zero.

Exercise 4- Inverting OA

Figure 8.3(a) illustrates an inverting amplifier with feedback, and Figure 8.3(b) shows the equivalent-circuit form of this inverting amplifier. We wish to solve for the output voltage, v_o, in terms of the input voltage, v_a. Let us follow the step-by-step procedure of Section 8.1.1.

1. Kirchhoff's node equation at v_+ yields

$$v_+ = 0$$

2. Kirchhoff's node equation at v_- yields

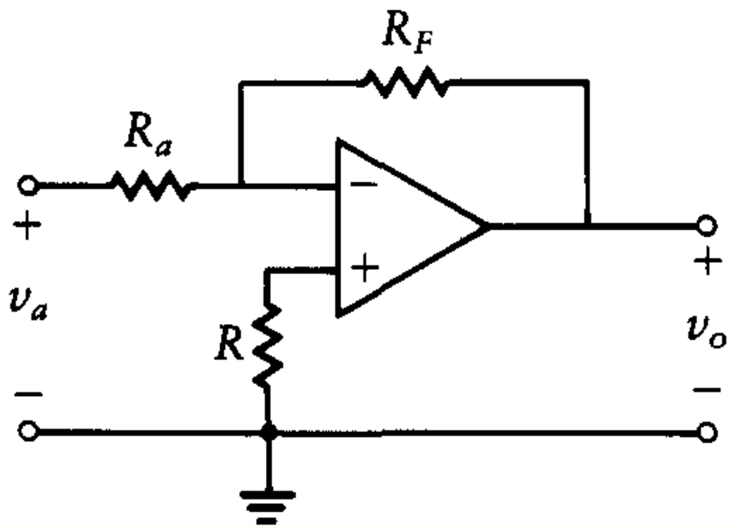
$$\frac{v_a - v_-}{R_a} + \frac{v_o - v_-}{R_F} = 0$$

3. Setting $v_+ = v_-$ yields

$$v_+ = v_- = 0$$

We now solve for the closed-loop gain as

$$\frac{v_o}{v_a} = \frac{-R_F}{R_a}$$



Exercise 4- Noninverting OA

The operational amplifier can be configured to produce either an inverted or noninverted output. In the previous section we analyzed the inverting amplifier, and in this section we repeat the analysis for the noninverting amplifier, which is shown in Figure 8.5. To analyze this circuit, we again follow the procedure of Section 8.1.1:

1. Write a node equation at the v_+ node to get

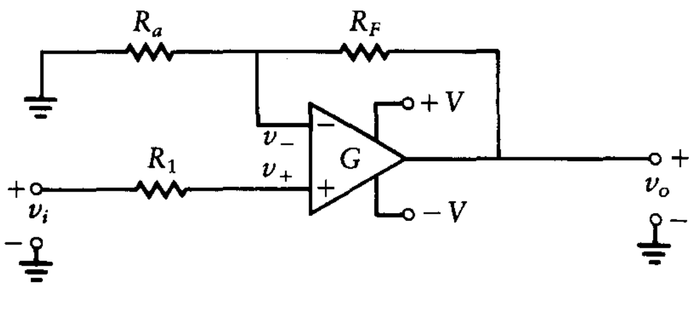
$$v_+ = v_i$$

2. Write a node equation at the v_- node to get

$$\frac{v_- - 0}{R_a} + \frac{v_- - v_o}{R_F} = 0$$

3. Set $v_+ = v_-$, and substitute for v_-, since

$$v_+ = v_i = v_-$$



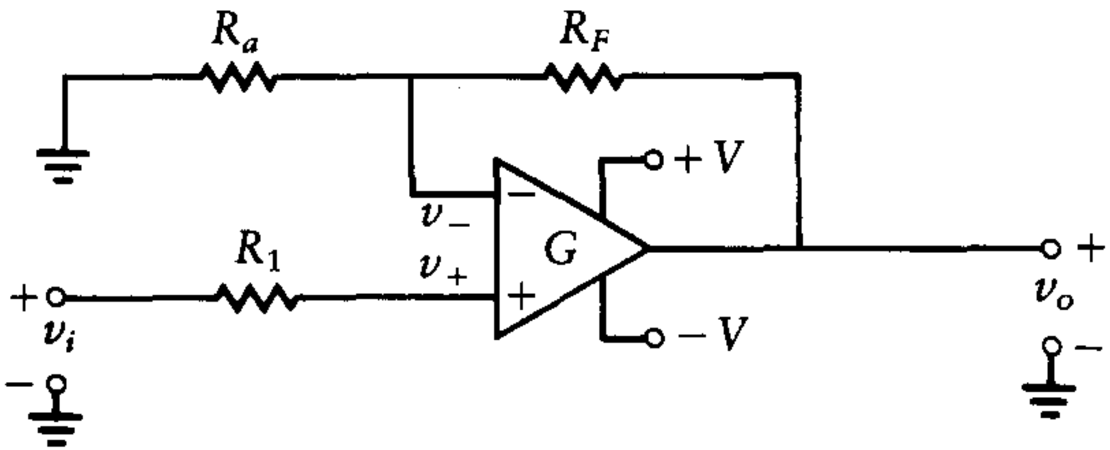
$$\frac{v_o}{v_i} = \text{?}$$

Exercise 4- Noninverting OA

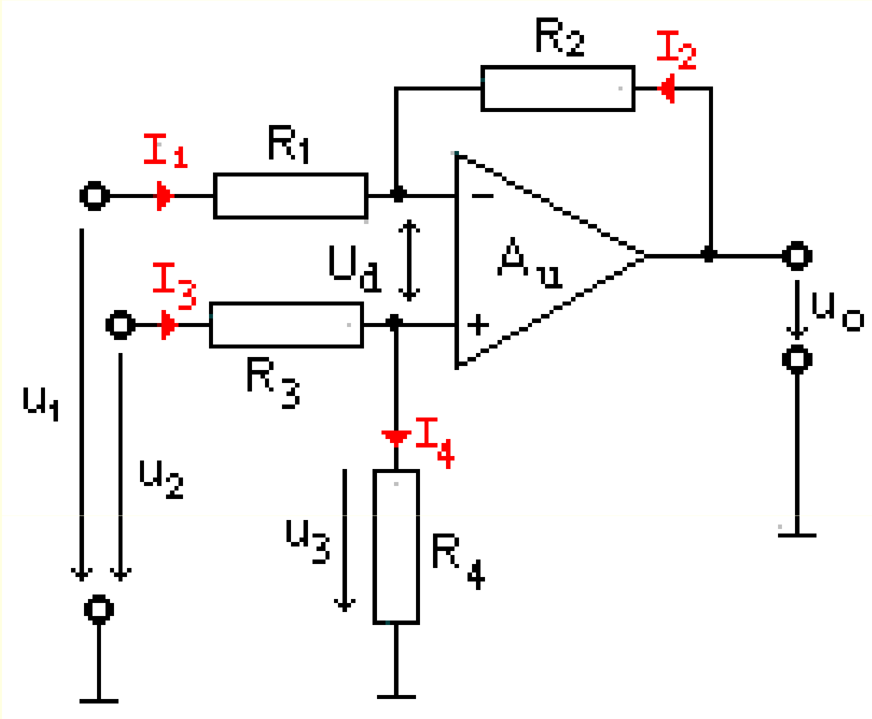
Solving for the gain, we obtain

$$\frac{v_o}{v_i} = 1 + \frac{R_F}{R_a}$$

Figure 8.5 Noninverting amplifier.



Exercise 4- Operational Amplifiers circuits

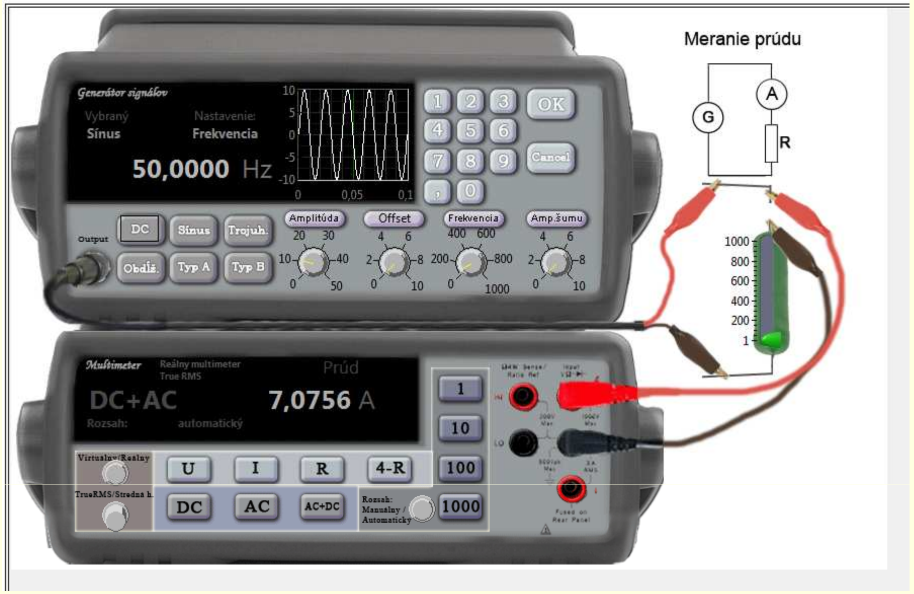


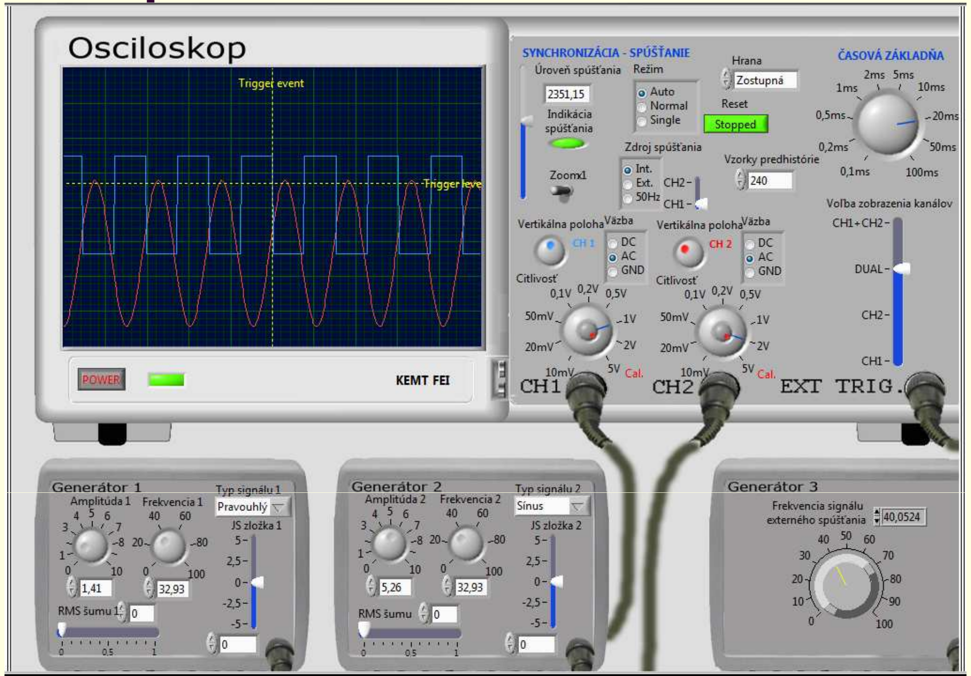
Tasks:

- 1.) Measure the output waveform of inverting amplifier in time domain, for different parameters of input periodic signal (frequency) and different values of feed- back resistor *R2*. Find the gain of the circuit for particular values of *R2*.
- 2.) Measure the output waveform of noninverting amplifier in time domain, for different parameters of input periodic signal (frequency) and different values of *R2*. Find the gain of the circuit for particular values of *R2*.
- 3.) Measure the DC transfer characteristic of inverting and noninverting amplifier for particular values of *R2*.

Equipments

http://meas-lab.fei.tuke.sk/pracoviska.html





- 1.) Multimeter (http://www.wisc-online.com/objects/ViewObject.aspx?ID=eng802)
- 2.) Generator (http://www.ee.usyd.edu.au/tutorials_online/topics/labintro/wav.html)
- 3.) Oscilloscope (http://www.slideshare.net/prasadpawaskar/prasad-5700898)
- 4.) Power supply (http://www.ee.usyd.edu.au/tutorials_online/topics/labintro/dc.html)