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EXAM GUIDELINES **(Answers submitted that do not follow to what is indicated in these guidelines will not be graded)**

- The exam lasts **a maximum of 3 hours**.
- The exam consists of these instructions and **a case study divided into 5 sections**, distributed over 4 sheets (7 pages).
- The score and estimated completion time are indicated in the title of each section of the exam.
- **It is mandatory to write the name, surname and group** in which the student is enrolled **on this first page of the exam statement (EXAM GUIDELINES), at the beginning of it**.
- Along with the statement, **each student will have blank sheets** to answer **all parts of the exam**, and to carry out calculations and drafts. **All these sheets must include the name, surname and group of the student, at the beginning of the exam**.
- **All parts of the exam will be answered on blank sheets**. **Section 4** must also include **the Bode Plot Diagram** available at the end of the exam statement, with the student's name, surname and group, even if it is blank.
- **Each section will be answered on separate sheets**.
- At the end of the exam, the student **MUST DELIVER THE EXAM STATEMENT and AT LEAST 1 SHEET FOR EACH SECTION, WITH THE PART TITLE AND YOUR ANSWER (even if the answer to the section is blank)**.
- **IN ALL THE ANSWERS TO THE QUESTIONS OF THE EXAM IS MANDATORY TO INCLUDE AN EXPLANATION** (THE DIRECT APPLICATION OF FORMULAS WITHOUT DEDUCTION OR EXPLANATION IS NOT VALID, EXCEPT THOSE EXPRESSLY INDICATED IN THE STATEMENT) **AND THE JUSTIFICATION OF ALL THE APPROXIMATIONS CARRY OUT** FOR THE REQUESTED CALCULATIONS.
- Each question **must be answered in a clear, clean and orderly manner**, avoiding amendments and crossing-outs in the exam answers.

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We want to set-up a wireless communication system for audio signals by using an infrared diode laser and a photodiode. The whole scheme of the system is shown in Figure 1. The system has an audio generator from the output voltaje v_{o1}, an emitter circuit with the infrared diode laser, a detector circuit with the condition electronics fot the photodiode with the output signal v_{o3} and a PLL where in Its output signal (v_{o4}) we obtain the level of the voltage depending on the frequency of the audio signal received, which allows to identify the musical note that has been sent.

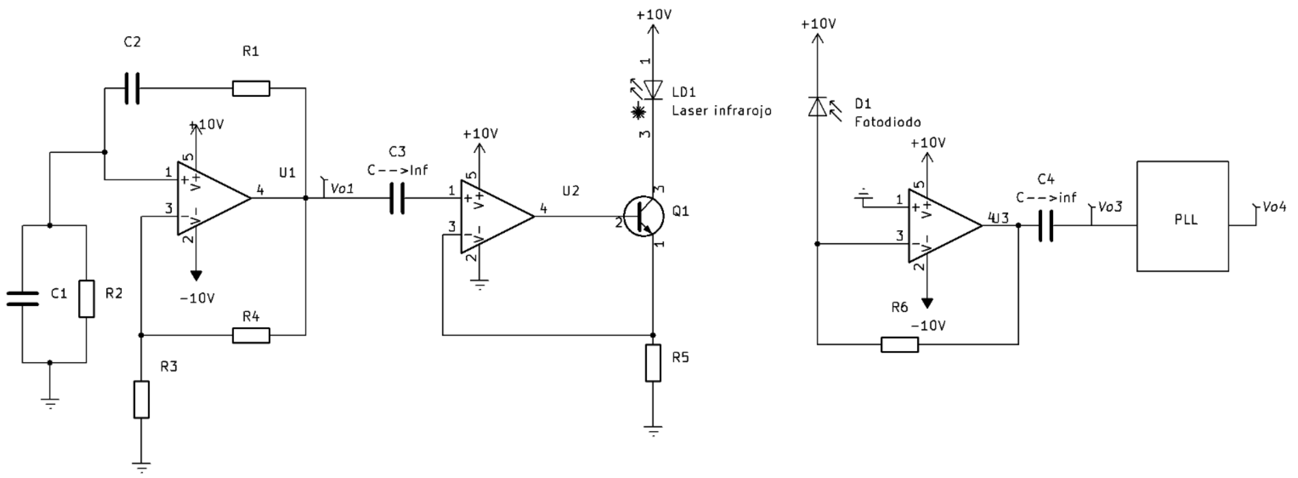

Figure 1

Data:

Vo1: Audio Signal to be transmitted (Input Signal in the Emitter)

Vo3: Audio Signal received (Output Signal in the Receiver)

Vo4: Variable Continuos Voltage Signal depending on the received musical notes

U1, U2, U3: Opamps with $R_i \rightarrow \infty$, $R_0 \rightarrow 0$, $A_v \rightarrow \infty$

Emitter: $R_5 = 110\Omega$, $r_{\pi 1} = 500\Omega$, $g_{m1} = 1.5 A/V$

Detector: $R_6 = 20k\Omega$

In the different Sections of this case study of the exam, It will be analyzed with detail each of these blocks.

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SECTION 1 (40 minutes, 2.5 points)

The characteristics of the electronics to generate audio signals are related to the 5th and the 6th Octaves starting by the **1st LA (440Hz)** and **including the 2nd LA on the next Octave in 880Hz until the 3rd LA corresponding to 1760 Hz.**

Please, answer the following questions:

1. The circuit that generates the Vo1 voltage is an Oscillator. What oscillator is this?.
2. Obtain the loop gain of the oscillator and deduce the starting-up and the frequency oscillation of the oscillator.
3. Calculate the values of the components of the oscillator to get the signal frequencies of the audio generator, Vo1, that could varied between the acoustic frequencies corresponding to the 2 indicated Octaves (between 440Hz to 1760Hz). What kind of components you need to adjust?.
4. Propose an scheme of the oscillator by adding a limiter of the output audio signal amplitude, Vo1, with a value of 2.5 V_{pp}. It is not necessary to include the values of the components of the amplitude limiter, but to make a proposal of the scheme that has to be implemented.
5. Deduce what will be the minimum Gain Bandwidth Product (GxBW) and the Slew Rate (SR) values that must have the Operational Amplifier in order to get that the audio signal generator works fine.

SECTION 2 (15 minutes, 1.5 point)

Electronic Characteristics of the Driver for the optical emitter (Infrared Diode Laser).

Answer the following questions:

6. Represent the scheme of the small signal at medium frequencies of the driver circuit for the diode laser. (Take into account that the equivalent resistance of the diode laser r_{laser} is 200Ω).

7. What is the feedback topology in the circuit that uses the Transistor Q_1 and what is the transfer function that it stabilizes?. Justify the answer.

8. If the signal that we get from the audio signal generator is 2.5V_{pp}, obtain the amplitude in A_{pp}, of the modulation current that is applying to the diode laser. Suppose that in the Q_1 feedback circuit A'β>>1.

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SECTION 3 (40 minutes, 2 points)

Electronic characteristics of the receiver (conditioning circuit of the photodiode)

Answer the following questions:

9. Demostrate that in the conditioning circuit of the photodiode there is negative feedback.
10. Represent the A' and β networks of the conditioning circuit.
11. Calculate the value of the gain of the A' network as well as for the β network.
12. Calculate the value of the gain of the amplifier at medium frequencies (v_{o3}/i_F).

SECTION 4 (30 minutes, 2 points)

Assuming for simplicity that the frequency response of the A' network can be obtained with the expresión (with the unities corresponding to the feedback topology of the electronic receiver):

$$A'(jf) = \frac{-20 \cdot 10^3}{\left(1+j\frac{f}{100kHz}\right)\cdot\left(1+j\frac{f}{1MHz}\right)\cdot\left(1+j\frac{f}{fp_{CF}}\right)}$$

Where f_{pCF} is the pole introduced by the equivalent capacity of the photodiode (C_F=1pF)

<u>Answer the following questions:</u>

13. Determine the frequency of the pole introduced by the parasitic capacity of the photodiode f_{pCF}. Justify clearly your response.

14. Determine If the feedback amplifier of the receiver is unstable. Justify clearly your response.

<u>Notes:</u>

- Consider that in the question 13 the frequency of the pole introduced by the parasitic capacity of the photodiode, is f_{pCF}=10MHz.

- You have a Bode plot at the end of the statement of this case study exam. The student must deliver the Bode plot with his name, surnames and with his tuition group.

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SECTION 5 (30 minutes, 2 points)

The scheme of Figure 2 represents **the Block Diagram of the PLL which is located at the output voltage, Vo3, of the receiver circuit in Figure 1** in order to process the Audio Signals between the 2 octaves corresponding to the 5th and the 6th octaves.

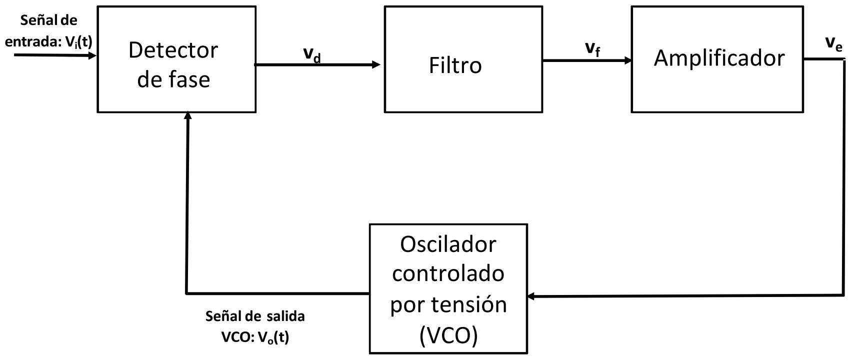

Figure 2

DATA:

- Transfer Function of the Filter F(s)=1.
- Free oscillation frequency of the VCO, fr = 880Hz.
- Gain of the VCO, Ko= $4\pi\cdot10^3$. (rad/s)/V.
- Gain of the phase detector (Gilbert Cell: vd =Kd($\phi-\pi/2$), Kd = $1/(4\pi)$ V/rad).
- Gain of the Amplifier, Av=1

Answe the following questions:

15. Represent the equivalent scheme of the PLL locked and obtain the transfer function $v_e/\Delta\omega_i$ ($\Delta\omega_i=\omega_i-\omega_{fr}$).

16. Reasonably infer what type of PLL It is (first or second order) and calculate the value of Its time constant.

17. Calculate the frequency range $\mathbf{f}_i$, of the audio signals at the input of the PLL in order to get the PLL Locked.

18. Obtain the output voltaje of the amplifier v_e, for the following values of the frequencies at the PLL $v_{i\,(t)}$ such as f_{i1}=880 Hz and f_{i2}=1100 Hz. Obtain as well the phase shifts $\phi_{\varepsilon1}$ y $\phi_{\varepsilon2}$ between $v_{i(t)}$ and $v_{o(t)}$ for the 2 cases studied before.

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