IN3170, spring 2023, mandatory laboratory exercise 2: Common source gain vs I_{bias} (deadline 12-Apr-2023, 14:15!)

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change log	
9-Mar-2023	Clarified the Ampère meter and resistive divider in figure 1. Added link to HTML GPIB instrument guide.

Abstract

In this lab we shall investigate how biassing (i.e. choosing the DC point of operation) influences the gain and bandwidth of a simple common source amplifier.

This is the second in a series of three lab tasks that will be graded and will count 40% towards the final grade. The first lab is only be 'pass' or 'fail'and the students are required to pass this lab assignment to be admitted to the exam. The second and third labs will get a score of between 0% and 100% and will each count 20% towards the course score. The deadline in the title is a hard deadline! Do not miss it! Plan to submit well ahead of the deadline! We will use devilry.ifi.uio.no for submission of you lab report.

1 Report and Group Assignments

1.1 Requirements for the Lab Report (read carefully!)

You are required to execute the tasks and answer all the questions posed below and to submit a report on your work. The report needs to be explaining clearly what you have done, how you have done it, what the results were and what you conclude from them. A good basic rule for any scientific writing is that a document should provide sufficient detail for someone reading it to be able to replicate the results that are presented. Make sure to answer all

questions! Supply the report with drawings of the circuits (including the values of the components and parameters you used where appropriate, e.g. bias voltages/currents, component sizes etc.) and measurement setups! Show your measurements in graphs! Use labels in the schematics that you draw, such as M_1, M_2 (M is often used fro labelling CMOS transistors), $opamp_1$, I_1, V_1 etc. You should then use those labels in your text, since it is much easier to write: 'transistor M_1 in figure 1' than 'the transistor third from the top and second from the left in the righthand side circuit in figure 1'. **MANDATORY when assembling a circuit in the lab**: Include a photograph of your circuit into the report!

1.2 Graded Mandatory Group Assignments

Note that this is part of the course's exam and strict rules apply as described in the document https://www.uio.no/english/studies/examinations/compulsory-activities/mn-ifi-mandatory.html . The page explains the significance of mandatory assignments in a course and in particular group assignments. It also specifies your responsibility to not plagiarize anybody else's work and that you are required to conduct and understand your own experiments and obtain your own results, while you are still allowed and encouraged to exchange advice and experiences also between groups.

Each group must deliver a written lab report using the Devilry online submission system **before** the **hard** deadline indicated in the title. Note that you can submit multiple times and the last submission before the deadline will be graded, so it might be a good idea to plan to submit preliminary versions well before the deadline. The points given for this lab assignment will determine if the lab assignment is accepted or rejected. You will need to pass this lab assignment in order to be admitted to the exam. The next two lab assignments will be weighted as 20% of the total score of the course, i.e. your final grade.

Each task is labelled with how many points it will contribute towards the score.

2 Lab Rules

2.1 Safety

Voltages over 40 Volt can in some cases be harmful, even though it usually requires more than that. The lab equipment is thus not able to provide voltages higher than 36V. Do not use equipment other than that provided in the lab! If a part of the skin is covered with a conductive fluid or is pierced and exposed to such voltages, a current could bypass the "insulator" of the skin and run through the body. If this current passes through the heart it can cause fibrillations or even cardiac arrest. Even higher more extreme currents could also give rise to internal burns. If this happens to anybody or something else happens in the lab, seek medical help immediately: heart fibrillations can last and cause trouble

long after the incident. Also notify the person in charge of the lab.

Some electronic components can explode if they are exposed to high currents. This is important to remember when working with electrolytic capacitors. However, none of the capacitors provided in the lab are electrolytic capacitors. Never bring your own electronic components into the lab!

2.2 Conduct

Good routines are necessary to make the work in the lab effective and safe:

- Food and drinks are prohibited from every lab.
- In general everybody is responsible for keeping the lab tidy.
- Always turn off the power supply before you start adding and/or removing components.
- Use an ESD protection wrist strap when handling ICs and other sensitive components.(ESD: electrostatic discharge)
- Always clean up after using equipment and tools:
  - Turn off all equipment, except for lab computer.
  - Throw away cutoffs and vacuum clean the desk, chair, and floor if nessesary.
  - Place all components you have used back to their respective places. (Do this while you work, if you have a component you don't use anymore, put it back.)
- When you leave; the desk should be clean and ready for the next group.
- Read the information posters in the lab describing what to do in case of fire or medical emergency.

3 Task

3.1 Tools

See lab 1 for a description of the tools, both software and equipment in the lab!

For the GPIB instruments there is now a short guide to get started, mostly copied from lab 1, but with a *constantly updated list of known issues* here: https://www.uio.no/studier/emner/matnat/ifi/IN3170/v23/materiale/lab-gpib-instrument-guide.html

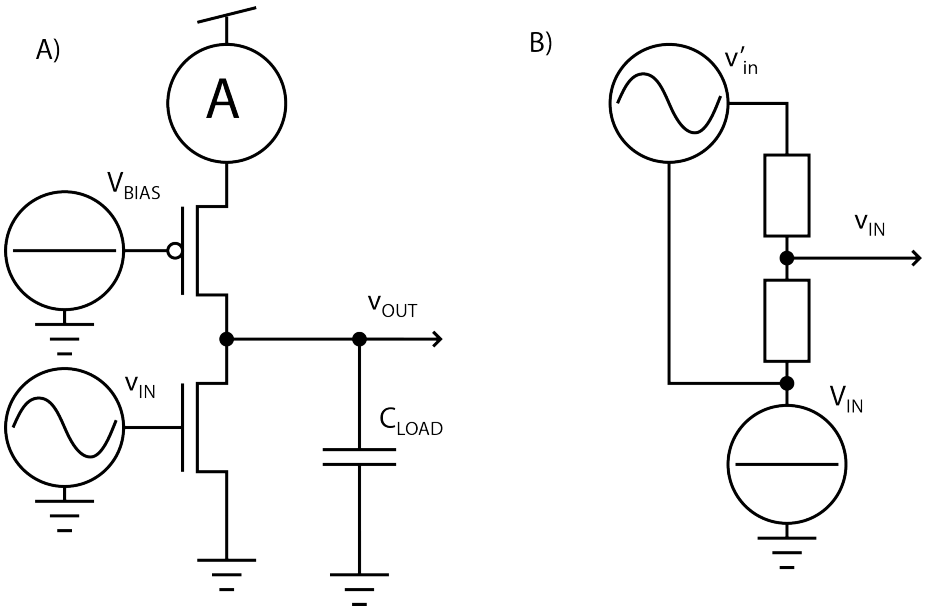


Figure 1: A) a CS gain stage setup that measures the bias current. NOTE: the circle with an A is an ampère METER, not a current source. B) a variant to set up the input with a resistive divider to manage to provide low amplitude AC input if necessary to avoid ending up outside the linear range of the amplifier. E.g. if your signal source's resolution is 10mV but the gain you want to measure is 200, then the output will 'jump' 2V for a minimum step at the input. This is then a very bad resolution on your y-axis. With a resistive divider with for example two equal resistors you will be able to reduce that minimum step from 10mV to 5mV, with the top resistor being 3 times larger, the step is reduced to 2.5mV etc.

3.2 Tasks

Task 1 (8p): Using the IC in the lab labelled CD4007UBE containing 6 transistors (data sheet on the course web-page under 'resources': cd4007ub.pdf), build a common source (CS) gain stage like described in figure 1 A). You shall measure its gain A for different biassing voltages/currents. You will thus verify figure 7.14 in the book that shows intrinsic gain ot a transistor vs. drain current, i.e. biassing current. The depicted relationship also holds true for a CS gain stage. Use a Vdd of 10V. Note that for measureing DC gain C_{load} is not really essential but it might reduce some of the noise.

There are (at least) two different methods to measure a DC gain of an amplifier. How will you go about to measure the gain in your setup? Describe clearly what you do, what values you measure (show graphs and mark the points you use!) and how you measure and compute the CS DC gain!

Both the methods the lecturer is thinking about will require that you can change the input in small enough steps such that the output does not saturate at Vdd or Gnd for just the one smallest step you are able to control at the input. So the higher the gain, the smaller the steps you need at the input. So report how small you make your steps and argue whether it is small enough to achieve a reasonable accuracy of the measured gain. If the device you use as source for the input has not enough resolution for that you might employ the scheme in figure 1 B) to down-divide the instrument output with a resistive divider. Use resistors of a few kΩ so that your source does not need to provide more than 1mA to produce the required voltage, and an appropriate resistor ratio. Explain the relation of v'_{IN} and v_{IN}. Verify the resulting v_{IN}, i.e. that it actually is what you think it is. Be wary of moving v_{IN} too fast: it might need time to settle.

Record the gain and bias current for at least 5 settings of V_{BIAS} and draw a plot like figure 7.14. Try to choose the biasses to cover both weak and strong inversion! As the data sheet does not tell us what the actual threshold voltages of the transistors are, can you somehow still get some indication of where the threshold voltages V_{tn} and V_{tp} are? Try to get at least an estimate and explain how you came by that estimate: you may simply measure it or try to deduce it from the measurements you are already doing. Make an argument for which point in your plot are in weak inversion and which ones are in strong inversion.