Laboratory report

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| Subject of the exercise: | Testing instrumentation amplifiers (Exercise 6.) |
| **Date:** | <year>. <month>. <day> |
| **Students name:** | <name 1> <name 2><name 3> |
| **Course and group No.** | Course: <Course No>, <Group No.> |
| **Supervisors:** | <name 1>, <name 2> |
| **Desk No.:** |  |

**All solutions to the exercises have to be explained and justified.**

**A separate file on the homepage (M6\_measurement\_results\_distancelearning.docx) contains the measurement results that have to be evaluated during the measurement. The values, oscilloscope screenshots, etc. have to be copied to the report and explained. The personalized measurement result can be selected according to your Neptun code from the file M6\_measurement\_results\_distancelearning.docx.**

**There are some notations that are different in the laboratory guide and in the videos. In these cases we indicated all of these compatible notations at the tasks.**

Measurement Tasks

**1. Analysis of the DC properties**

1.1. Measuring and setting the input offset.

*General instructions can be seen in the following video:*

<https://web.microsoftstream.com/video/9b8b3357-d879-4d13-89e4-399ea26f3a31?list=studio>

|  |  |
| --- | --- |
| E41 | *R11* is [,,,] , value, tolerance*R12* is [,,,] , value, tolerance*R21* is [,,,] , value, tolerance*R22* is [,,,] , value, tolerance |

1.1.1. Having short-circuited the resistances *R21* and *R22,* measure with the DC voltmeter the output voltage of the amplifier, then adjust it by means of the potentiometer POFSET to zero.

*You can see in the following video how the offset can be adjusted by the potentiometer:*

<https://web.microsoftstream.com/video/c44823de-a060-4740-b944-f5bd8251caf0?list=studio>

Leave the inputs of the amplifier free and make the measurement with a resolution of at least 10 μV.

*Please select your measurement result from M6\_measurement\_results\_distancelearning:*

**Ukioffset\_0 = µV**

Explain here how the offset should be adjusted. Please give a short comment about the remaining output offset (**Ukioffset\_0**).

Hint: the P\_offset potentiometer is connected to OFFSET N1 and N2 nodes as denoted in the TL071 schematic, seen on page 3 of the laboratory guide.

1.1.2. Remove the short-circuits one-by-one and repeat the measurement of the output voltage. From the measured data determine by calculation the input (bias) current and offset current of the amplifier.

*You can see in the following video how the short circuits are removed, and how the output voltage changes:*

<https://web.microsoftstream.com/video/756ed12c-3a63-436f-becd-7f1c1bcc49c9?list=studio>

Measured values from *M6\_measurement\_results\_distancelearning*:

Hint: notations of the lab guide and the video are different, see the clarification below.

When the  *R21* is 1 M Ω, then *Vout* = *Ukioffset\_1 = U-kiOff =* … mV

When the  *R22* is 1 M Ω, then *Vout* *= Ukioffset\_2 = U+kiOff =* … mV

Calculate the following parameters:

Hint: the formula in the video gives only the value of the input currents. Determine the correct direction of them! Are they flowing into, or out of the OPA?

*Ibias+* = *Ibe+* = …

*Ibias-* =*Ibe-* = …

*Ioffset* = …

*Ibias* =…

1.2.1. Set a voltage gain of about *Av*=100. Having connected the resistances *R11* and *R12* to ground, measure the output offset voltage, calculate the actual reduced input offset voltages of the inverting and the non-inverting amplifiers. Then – using the potentiometer POFSET – adjust the output offset voltage to zero.

*Explanation about input offset voltage calculation can be seen here:*

<https://web.microsoftstream.com/video/5629da9a-2e68-4022-966d-fb9f35179d58?list=studio>

Measured values from *M6\_measurement\_results\_distancelearning*:

When the  *R11* and *R12* are on the ground, then *Vout = Ukioffset =* … mV

*Vreduced\_input* = $U\_{offs}^{-}$ =…(for inverting input)

*You can see in the following video how the offset voltage is adjusted, and the long-term behavior of the offset voltage:*

<https://web.microsoftstream.com/video/739c5570-e6c5-4ad6-ba62-05d895a82b0f?list=studio>

Write here the method and personal observations about offset voltage adjusting, and also summarize your experiences about the stability of the offset voltage.

1.3. Measurement of gain of inverting amplifier at center frequency (**Ube** = **10 mVpp,** **f0 = 1 kHz sine wave**).

You can see here a video about the measurement setup:

<https://web.microsoftstream.com/video/95728a9c-861d-46f0-a8b7-7e658b5af854?list=studio>

1.3.1. Please draw the block diagram of the measurement. Don’t forget about the presentation of the instrument settings.

Block diagram:

Instrument settings:

1.3.2. Please select your measurement result from *M6\_measurement\_results\_distancelearning*

Measurement result:

1.3.3. Measure the gain according to the selected measurement result.

Write here the gain measurement. Don’t forget about the sign of the gain. Please also explain the results and compare with the expected value.

**1.4. Determining the Slew Rate and the maximum output voltage**

1.4.1. Connect a square-wave signal of 20 kHz on the input of the amplifier and increase it so that the amplifier becomes overdriven. Measure the maximum output voltage swing (Voutpp [V]) and the slope of the output signal (SR [V/μs]).

*You can see a video about the slew rate measurement:*

<https://web.microsoftstream.com/video/5c90061f-9bb6-4250-9ce5-2da4fde11c22>

1.4.2. Please draw the block diagram of the measurement. Don’t forget about the presentation of the setting of the instruments.

Block diagram:

Instrument settings:

1.4.3. Please select your measurement result from *M6\_measurement\_results\_distancelearning*

Measurement result:

1.4.4. Measure the slew rate according to the selected measurement result.

Measurement result and explanation. Comparison with datasheet value.

Hint: you are expected to determine the SR value from the measured signal. Consider the voltage change and the time taken only in between the 10%...90% of the total voltage change. Accurate readings can be performed by drawing horizontal and vertical measurement lines.

**1.5. Measurement of large-signal bandwidth of the amplifier.**

1.5.1. Please calculate the large-signal bandwidth of the amplifier at Uout = 10 Vpeak (7.07 VRMS) output voltage using the slew rate value in 1.4.4!

*You can see here the video about large-signal bandwidth calculation:*

<https://web.microsoftstream.com/video/20be2434-6bba-4b0d-bdc2-68c762139461?list=studio>

1.5.2. Please select your measurement result from *M6\_measurement\_results\_distancelearning*

Measurement result:

1.5.3. Measure the large-signal bandwidth fkv according to the selected measurement result. Measure the gain at fkv: A(fkv)

Measurement result and explanation.

Gain calculation. Why is it different than the gain given in 1.3.3?

**2. Analysis of the dynamic features**

*We will use the OSCBODE software for the measurement. The following video presents how this software can be used:*

<https://web.microsoftstream.com/video/7b09135d-ce4e-4dda-ba9c-5632af419d53>

**2.1. Measuring the Bode plot of an inverting amplifier (*Av(f))***

2.1.1. Connect the output of the sine-wave generator to the inverting input of the instrumentation amplifier and connect the non-inverting input to ground. Measure input and output voltages and the phase shift of the amplifier with an oscilloscope. Make the measurement in the following way: at a frequency of 1 kHz set an output voltage 7 VRMS(0 dB) using the AC voltmeter, then changing the frequency in the range 1 Hz – 1 MHz in 1-2-5-10 steps, measure the effective value of the input and the output voltages and the phase shift. On the base of the measured data calculate and plot the Bode diagram of the inverting amplifier.

*You can see here a video about Bode diagram measurement:*

<https://web.microsoftstream.com/video/3ca6a164-c0fa-4594-a21f-c3288add8013?list=studio>

Please draw the block diagram of the measurement. Don’t forget about the presentation of the setting of the instruments. Write down also your personal experiences according to the video.

Block diagram:

Instrument settings:

2.1.2. Please select your measurement result from *M6\_measurement\_results\_distancelearning.* The referenced Excel files are on the homepage of the measurement. In the Excel file please use the dataset belonging to the inverting amplifier, and according to the data (**f, Uout, Uin, Phase**) please plot the gain (dB) and phase characteristics on a logarithmic frequency scale.

Measurement result and interpretation:

Hints: Do not forget the axis titles and units! What type of notable points can be read from the Bode plot?

**2.2. Measuring the common mode gain of an instrumentation amplifier (*Avc(f)*)**

2.2.1. Apply a short circuit between the inputs of the instrumentation amplifier and give a sine-wave of 3 Veff between the short circuit and the ground. Measure the input and output voltages using an oscilloscope and an AC voltmeter

Please draw the block diagram of the measurement. Don’t forget about the presentation of the setting of the instruments.

Block diagram:

Instrument settings:

2.2.2. Please select your measurement result from *M6\_measurement\_results\_distancelearning.* Please calculate the common mode gain of the amplifier.

Measurement result, gain calculation and interpretation:

2.2.3. Please select your measurement result from *M6\_measurement\_results\_distancelearning.* The referenced Excel files are on the homepage of the measurement. In the Excel file please use the dataset belonging to the common mode gain, and according to the data (**f, Uout, Uin, Phase** ) please plot the gain (dB) characteristics on a logarithmic frequency scale in the 10 Hz – 10 MHz range.

Measurement result and interpretation:

Hints: Do not forget the axis titles and units! Compare the results with the Bode plot of the inverting amplifier!

**2.3. Measuring the Bode diagram of a non-inverting instrumentation amplifier (*A(f)v*)**

Connect the output of the sine-wave generator to the non-inverting input of the instrumentation amplifier and connect the inverting input to ground. Measure the input and output voltages and the phase shift of the amplifier by means of an oscilloscope and an AC voltmeter.

Please draw the block diagram of the measurement. Don’t forget about the presentation of the setting of the instruments.

Block diagram:

Instrument settings:

2.3.1. Please select your measurement result from *M6\_measurement\_results\_distancelearning.* The referenced Excel files are on the homepage of the measurement. In the Excel file please use the dataset belonging to the non-inverting amplifier, and according to the data (**f, Uout, Uin, Phase** ) please plot the gain (dB) and phase characteristics on a log frequency scale.

Measurement result and interpretation:

Hints: Do not forget the axis titles and units! What type of notable points can be read from the Bode plot?