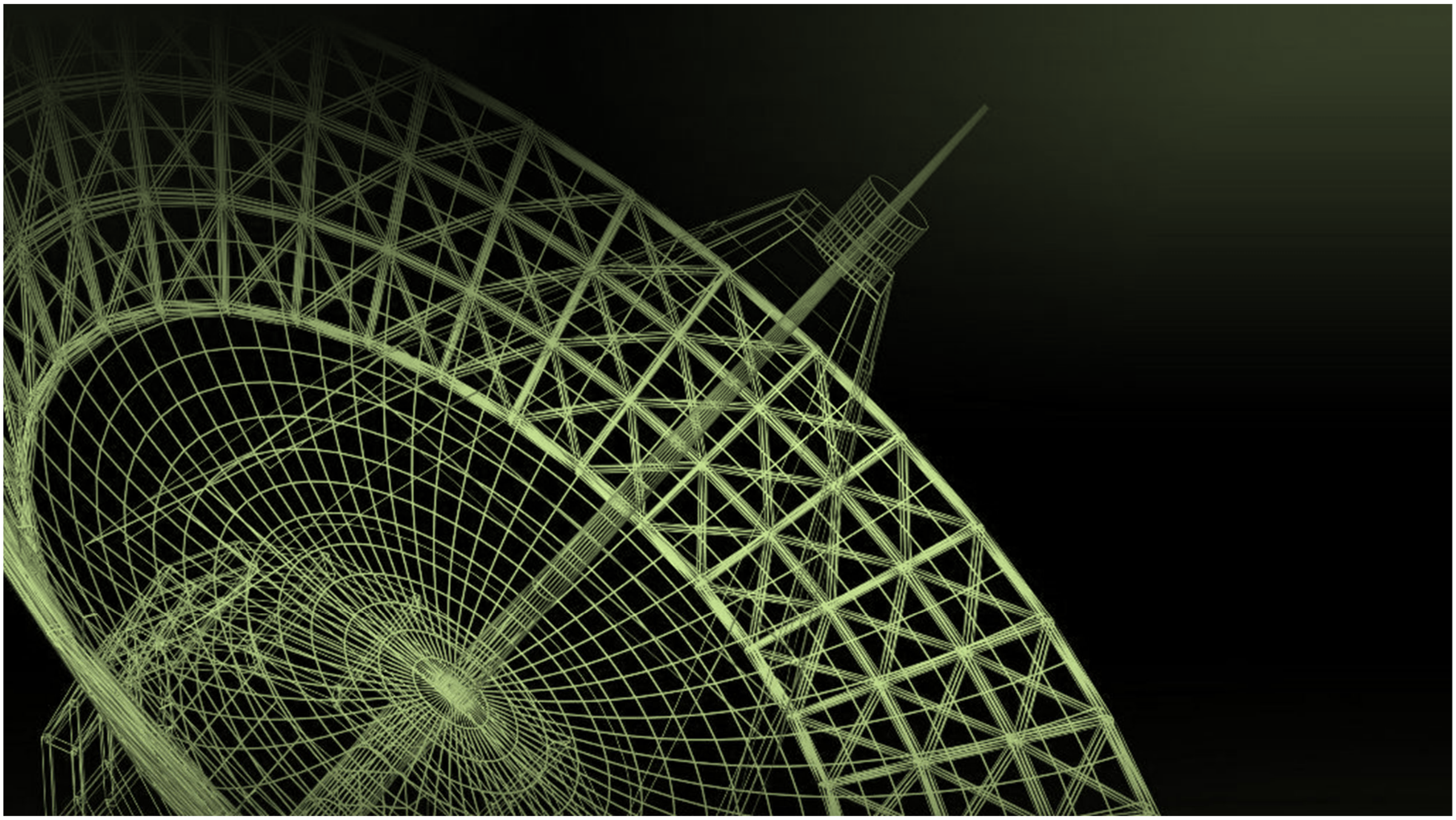
جامعة بيرزيت



Birzeit University
Faculty of Engineering & Technology

ENEE 4113
Communication Laboratory

First Semester 2023-2024

Table of Contents

Lab Safety Instructions and Rules

General Behavior

- Never work in the lab alone, always have another qualified person in the area do not use any equipment unless you are trained and approved as a user by your instructor or staff. Ask questions if you are unsure of how to operate something.
- Perform only those experiments authorized by the instructor. Never do anything in the lab that isn’t called for in the lab procedures or by your instructor. Carefully follow all instructions, both written and oral. Unauthorized experiments are prohibited.
- Don't eat, drink, or smoke, in the laboratory
- Please don’t yell, scream, or make any sudden loud noises that could startle others who are concentrating on their work.
- When you are done with your experiment or project, all components must be dismantled and returned to proper locations.
- Dress properly during all laboratory activities. Long hair, dangling jewelry, and loose or baggy clothing are a hazard in the laboratory. Long hair must be tied back and dangling jewelry and loose or baggy clothing must be secured.
- Keep aisles clear and maintain unobstructed access to all exits, fire extinguishers, electrical panels.

First Aid & fire

- First aid equipment is available in the lab, ask your instructor about the nearest kit.
- Fire extinguisher are available in the lab, ask your instructor about the nearest one to your lab.

Electricity

- Do not handle electrical equipment while wearing damp clothing (particularly wet shoes) or while skin surfaces are damp.
- Never bend or kink the power cord on an instrument, as this can crack the insulation, thereby introducing the danger of electrical shocks or burns.
- Know where the stop button, main switch or other device for stopping the apparatus is located

Machines and moving parts

- In order to avoid the possibility of injuries, it is important that the students be aware of their surroundings and pay attention to all instructions.
- Deal with caution with rotating machines, fans pumps compressors, motors etc. don’t touch any of the rotating parts; shafts, or blades.
- Read and understand operation instructions before turning on the machines, do not turn machine till you instructed by the instructor or the technician.

Hot surfaces and burns

- Do not touch hot surfaces; hot plates boilers, heating elements machines etc.

Introduction

The Communication Laboratory is one of the most important Laboratories that engineering students will take since it will enhance the theoretical knowledge gained in classes through a series of experiments.

In addition to practical experiments, students will have to prepare for the lab through simulation and calculation of the systems under test. Students will work in groups to enhance communication and team work skills; they are also required to write a report to illustrate and interpret results and draw conclusions and observations.

In most experiments prior knowledge of the theoretical material is assumed.

Objective

- **To test the analog modulation techniques (AM):**
  1- Amplitude Modulation:
    a- Normal Amplitude Modulation (Normal AM).
    b- Double side-band Suppressed Carrier Amplitude Modulation (DSB-SC).
    c- Single side-band Amplitude Modulation in its both forms:
      i. Suppressed Carrier (SSB-SC).
      ii. Residual Carrier (SSB-RC).
  2- Angle Modulation:
    a- Phase Modulation (PM).
    b- Frequency Modulation (FM).
- **To test the analog to digital and digital to analog on communication systems:**
  1- Pulse Amplitude Modulation and Demodulation (PAM).
  2- Pulse Code Modulation including:
    a- Quantization.
    b- Coding and encoding.
- **To discover the 5 quantization methods:**
  1- Uniform (Linear) Quantization.
  2- Non-Uniform (μ-Law) Quantization.
  3- Difference Pulse Code Modulation (DPCM).
  4- Linear Delta Modulation (LDM).
  5- Digital Coded Delta Modulation (DCDM).

- **To test digital communication techniques:**
  1- Amplitude shift keying (ASK).
  2- Frequency shift keying (FSK).
  3- Phase shift keying (PSK).
- **To Report the experiments and to develop necessary skills to deliver experiment findings in a scientific and precise way.**

Laboratory Instructions

- Each Student should prepare for the lab by reviewing the theoretical background and simulating the Modulation technique using MATLAB Simulink and submit the material of the prelab before the start of the laboratory session.
- Students will work in groups of 2-3 students maximum.
- Each group should prepare a report and submit it at the beginning of next lab session.
- Reports should be original and contain the basic required elements detailed below, any copy from any source will result in a zero grade and proper academic punishment.
- During the laboratory session it is required to have an experimental setup checked and approved by the instructor before starting data collection.
- Data sheet should be signed by the instructor before you leave the laboratory, otherwise your report will not be accepted
- Smoking, eating, drinking and use of cell phones is not allowed during the laboratory session

Report Writing

An experiment report is an important tool to communicate the experiment results and findings to others and it should be organized and written in a way to provide information about the experiment and its results and conclusions. The report should contain calculations and explanations of the results and a neat and clear way. The report should contain the following parts:

1. Cover page

It should contain the experiment name, date and name of experimenters.

2. Abstract

This section provides a brief summary explaining the aim of the experiment, the methods used and the main results.

3. Theory

This section should include any relevant theory along with mathematical formulas, the following should be considered when writing the theory section:

- Avoid copying from lab manual.
- Summarize the theory in your own words.
- Explain symbols in the mathematical formulas.

4. Procedure

This section describes in detail the way the experiment was conducted. This is very important so that anyone who reads it should be able to re-produce the experiment and its results. In this section what was measured and how it was measured should be provided.

5. Data and Calculations

Measurement data should be recorded in clear and readable fashion, the data should be provided in tables when possible and the following notes should be considered:

- Data should be written in ink and signed by the TA or Instructor.
- Data should have units.
- Calculation should be performed to get the required quantities from measured ones.
- Simulation results should be included where applicable.

6. Conclusions

This section presents the final result with the uncertainty associated with it. The conclusion should be based on evidence and does not reflect how the experimenter feels about the experiment. The conclusion should contain answers to the following questions:

- Is the result acceptable?
- What is the behavior of graphs/plots?
- What are the possible sources of error?
- Were there any major experimental complications?
- How the result can be improved in the future if the experiment is repeated?

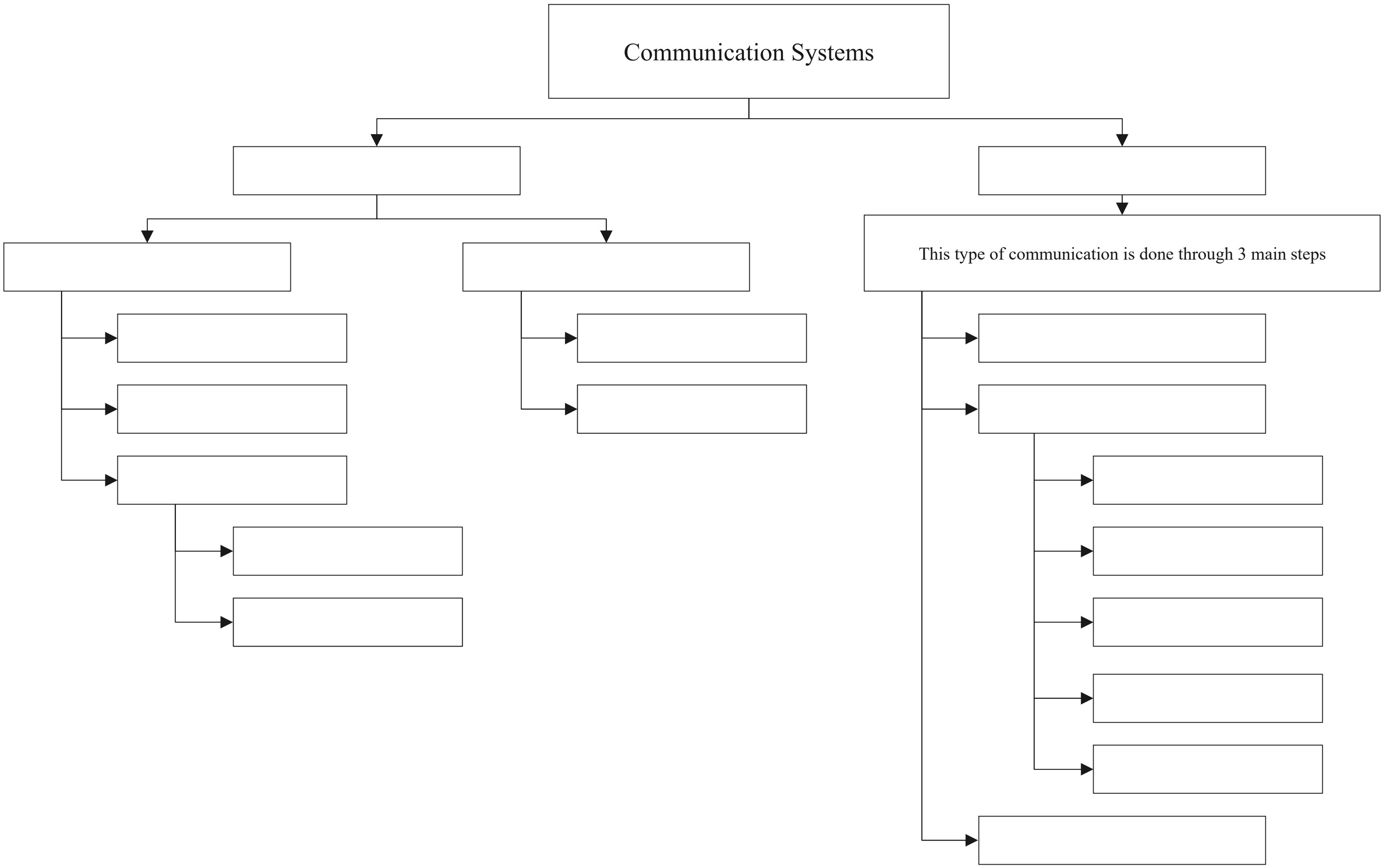
Report Grading Guidelines

The laboratory report grade will depend on the following:

- Is the report written well and in good English?
- Does the theory contain the necessary illustrative figures? Are these figures meaningful and clear?
- Do data and calculated quantities have corrected units?
- Are calculations made correctly?
- Does the report contain all information to reproduce the experiment?
- Is the result correct and consistent with what is expected?
- Are the graphs complete, correct and properly labeled (title, axis labels)?
- Does the conclusion show insight and indicate ways for future improvements in the experiment?
- Are all elements of the report included?
- Is the report submitted on time?

Topic	Description	Specified Mark	Total Mark
Cover page	- Birzeit University Logo. - Faculty, department and Lab name. - Experiment Name and Report number. - Student name and number. - Group members names and numbers - Section number. - Instructor. - Date and place.	---	0.5
Abstract	- Are all the objectives included and the expected results are summarized?	---	0.5
Tables	- Table of Content.	0.3	0.8
	- Table of figures and List of Tables	0.3	
	- All the figures and tables have descriptive names.	0.2	
Theory	- The theory includes the content of the experiment and is related to all its parts.	1	1.5
	- Rephrase from references and summarize what's related to the experiment.	0.5	
Procedure and data analysis	- All the parts are done in the report.	0.5	4.5
	- All the parts have the data collected and the simulation results.	0.5	
	- All the parts are discussed perfectly.	2.5	
	- Are the practical results compared with the theoretical ones?	1	
Conclusion	- The main objectives are included.	0.25	0.5
	- The learnt results are included.	0.25	
References	- Theory and Figures are referenced	---	0.5
File organization	- Font: **Times New Roman**, size = **12** - Line spacing: **1.5** and **justified** - Figure and table names: size = **10**	0.6	1.2
	- Titles: Size = **14** and **Bold** - Subtitles: Size = **12** and **Bold**	0.2	
	- Page border (**Box type**) - Page numbering: From the Abstract till the List of tables in Roman format (I, II, III, …). And from the theory till the last page in Arabic format (1, 2, 3, …)	0.4	

At the end of this lab the student should be able to fill the following flow chart



Analog Communication

Experiment #1:

Normal Amplitude Modulation and Demodulaiton

Prelab:

Theoretical Prelab:

Review the theoretical background of the Normal Amplitude Modulation and Demodulation (Please give a detailed view on the mathematical (equations) side).

Software Prelab (Simulink Matlab):

Signals information for this prelab section:

Message signal:

$$m(t) = 0.85\cos\,(2\pi(1000)t)$$

Carrier signal:

$$c(t) = 1\cos\,(2\pi(15k)t)$$

Modulator sensitivity (k):

$$k = \text{varies according to the modulation index}$$

- Block Simulation (Matlab Simulink):

  Build a full simulation block diagram of the ***<u>modulation and the demodulation</u>*** of the Normal AM that shows both the ***<u>time and frequency</u>*** domains. The diagram must show (message, carrier, modulated and demodulated) signals. Use ***<u>two</u>*** demodulation methods (coherent and envelope detector). Take into consideration to run your diagram for ***<u>3 modulation indices</u>*** ($\mu<1$, $\mu=1$, $\mu>1$). <u>Show the parameters you have used in each block.</u>

<u>Note: Comment and discuss each result scientifical</u>

Objective:

Generally, to transform the Normal Amplitude Modulation (Normal AM) theoretical knowledge into a practical one. This will include:

- To be familiar with signals basics like:
  - What is a real signal generator? What parameters can be adjusted using it?
  - What is a frequency oscillator?
  - What is the effect of a filter on the signal?)
  - What is the spectrum? Does it differ between the sine and the cosine signals?
- To be familiar with the communication basics like:
  - What is the difference between the message and carrier signals? Are they always sinusoidals?
  - What is the difference between the modulating and the modulated signals?
  - What is the modulator sensitivity?
  - What is the Coherent Demodulation? What is its problem?
  - What are the effects of changing the message parameters on the modulated signal?

Procedure: *[You Should Talk the Results in Time & Spectrum]*

Part one: Normal Amplitude Modulation

Section 1.1: Time Domain

3- Message Signals:

In this experiment the message signal of the Normal AM will be a sinusoidal message. To generate this signal set the function generator to: sine, Vss = 4 V and fm = 2 kHz. Plot the message signal in the time domain using the Cassy Lab software for 5 cycles and **take a picture** of the wave.

Note: Vss is the peak to peak amplitude.

4- Carrier Signal:

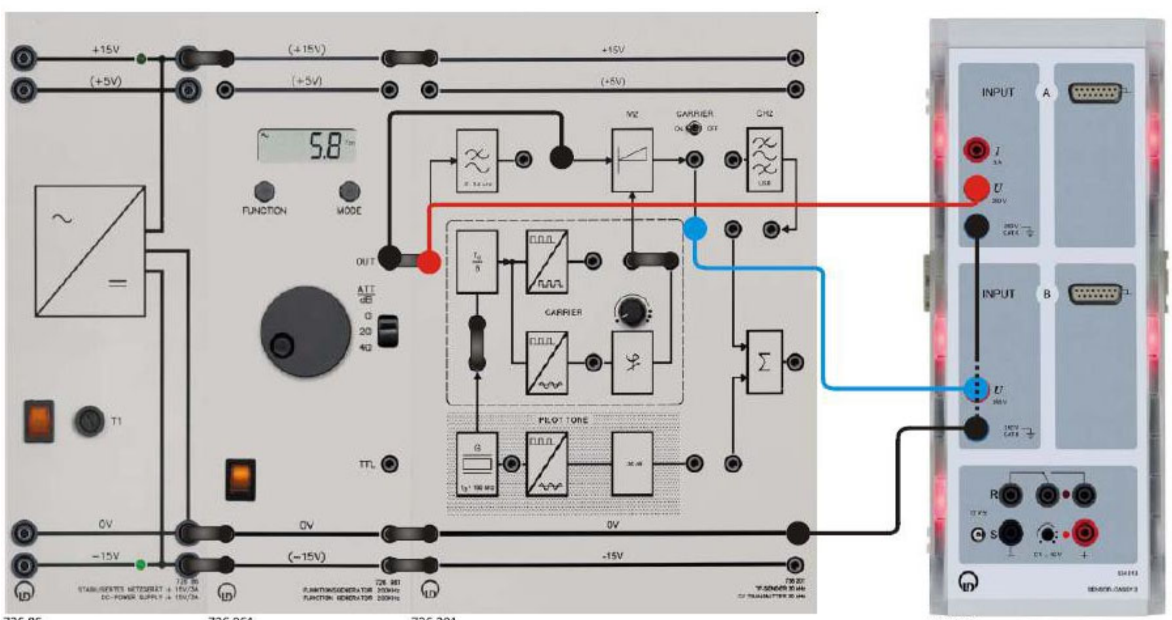
The carrier in this experiment is generated using a pulse frequency oscillator of 160kHz. After that it is entered to a frequency division block to out a 20kHz pulse signal. The toolkit gives two options for generating the carrier: square wave carrier or a sinusoidal wave. Plot the sinusoidal carrier using the Cassy Lab software and determine its characteristics and **take a picture** of the wave.

Carrier amplitude Ac = _________.

Carrier Frequency Fc = _________.

5- Modulated signal

Assemble the components as shown in the figure below:



726 86 DC-Power Supply ±15/3A | 726 961 Function Generator 200 kHz | 736 201 CF Transmitter 20 kHz | 524 013 SENSOR-CASSY 2

Set the toggle switch to **CARRIER ON** (This is to sum the carrier after multiplication of the message and carrier to produce the normal AM signal) to generate the modulated signal (s(t)). Remember:

$$s(t) = \left(1 + km(t)\right)c(t) = c(t) + km(t)c(t)$$

Plot the output signal of the modulator (s(t)) and the message signal (m(t)) at the same time on the Cassy Lab wave. On the Cassy Lab screen shift the message signal (m(t)) to the upper or lower envelope curve of the modulated signal (s(t)). **Take a picture** of the wave.

Write a description of the modulated signal in terms of the message signal:

____

____

Calculate/Find the modulation index (μ):

____

Calculate the modulator sensitivity (k):

____

Determining the effect of varying the frequency (fm) and the amplitude (Am) of the message signal:

1. The effect of changing the frequency: Keep Vss = 4V and change the message frequency to 1kHz and 3kHz (**Take a picture** of the wave in each case). ***Measure the modulation index.***

Write your observations:

____

2. The effect of changing the amplitude: Keep fm = 2kHz and change the message Vss to 2V and 6V (**Take a picture** of the wave in each case). ***Measure the modulation index for both values.***

Write your observations:

____

____

____

LPF phase shift effect: Repeat this section of the experiment but this time feed the modulating signal m(t) via **the low pass (LP) filter** before the modulator. Plot the message signal before and after the filter and observe the plots. (**Take a picture** of the wave).

What do you observe? what happens to the phase shift?

____

____

Change the message frequency to 7kHz. What do you observe? Will that affect the Modulated signal?

____

Section 1.2: Frequency Domain (Spectrum)

In this section set the Cassy Lab in FFT mode. To do this go to:

Settings > Calculator > FFT > choose input channel (FFT of)

Finally, adjust the Interval and observe the x-axis range

iii. Message Signals:

What is the spectrum of a sinusoidal signal?

____

Does the cosine spectrum differ from that of the sine?

____

Return the function generator to: sine, V_{SS} = 4 V and fm = 2 kHz. Plot the message signal spectrum using the Cassy Lab then **take a picture** of the impulse. (Adjust the x-axis range to be suitable for the plot)

Note: To get a perfect impulse, decrease the interval time and increase the measuring time.

Try to change the message frequency and observe what happens to the impulse. (Adjust the x-axis range to be suitable for the plot)

iv. Carrier Signal:

Repeat the spectrum measurement for the sinusoidal carrier signal. Plot the carrier signal spectrum using the Cassy Lab then **take a picture** of the impulse. (Adjust the x-axis range to be suitable for the plot).

Now plot the spectrum of the square carrier signal. **Take a picture** of the impulses (Adjust the x-axis range to be suitable for the plot).

What do you observe? Whey the square carrier have more pulses?

____

____

What is the spectrum of the square train?

____

v. Modulated signal

Return the function generator to: sine, V_{SS} = 4 V and fm = 2 kHz and the carrier to the sinusoidal form. Feed the message signal into the lowpass filter then connect its output to the modulator block. Plot the modulated signal spectrum using the Cassy Lab then **take a picture** of the impulses. (Adjust the x-axis range to be suitable for the plot).

Write your observations:

____

____

Repeat the part but this time for m(t) as **Sine**, V_{SS} = 4V and fm = 3 kHz. This time feed the message signal m(t) directly (without the lowpass filter) into the modulator. Why?

Compare the results from the two observations by answering the following questions:

How does the Upper Side Impulse respond as a function of the signal frequency fm?

What about the Lower Side Impulse?

Determine the transmission bandwidth of the normal amplitude modulation signal based on the measurements.

Generalize your results for a randomly taken message signal.

Determine the modulation index μ from the various spectra. (Take proper measurements)

Find the power of each impulse side in addition to the carrier impulse, then calculate the power efficiency.

When the power efficiency is maximized? Prove it experimentally

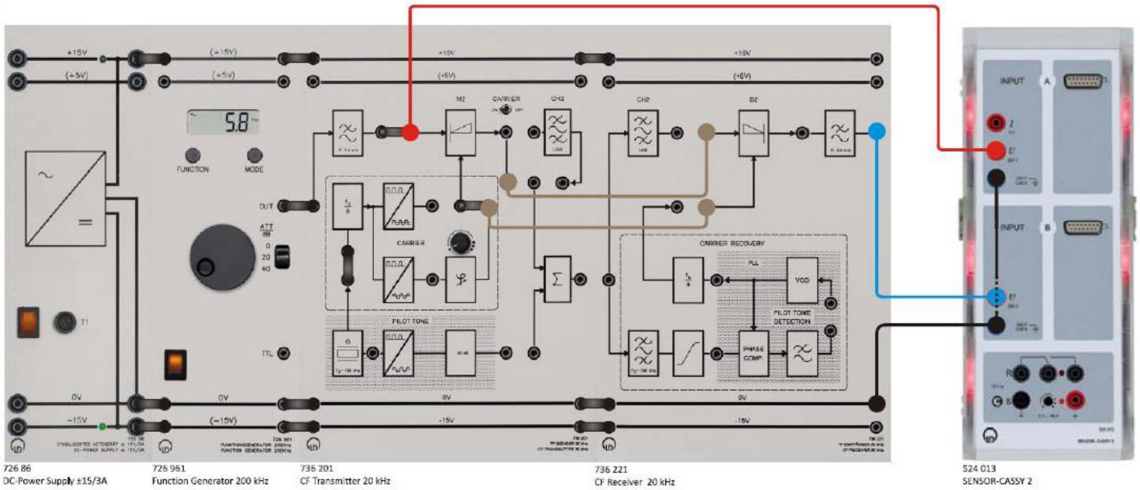
Part Two: Normal Amplitude Demodulation

Section 2.1: Time Domain

1. Coherent Demodulation

Assemble the components as shown. Make sure that the function generator is set to:

sine, V_{SS} = 4V and fm = 2 kHz.



Set the phase controller (**φ**) to the left (Min value = 0°). Feed s(t) signal directly into the demodulator (do not use any filter while transmitting it). Using a wire feed a sinusoidal carrier signal into the auxiliary carrier input of the demodulator.

Why does this step is done?

____

____

Plot the message signal m(t) as well as the demodulated signal on the Cassy Lab. One time before the output filter and another after it. **<u>Take a picture</u>** of the waves.

Why the receiver output filter is used? Prove the need of it mathematically

____

____

2. Non-Coherent Demodulation

Now to study the effect of non-coherence, feed the modulator with a sinusoidal carrier from the pin before the phase shifter and feed the demodulator with the carrier from the pin after the phase shifter. Change the carrier phase from the phase shifter (**φ**).

What do you conclude?

____

When does the output completely disappears?

____

Section 2.2: Frequency Domain (Spectrum)

In this section set the Cassy Lab in FFT mode. To do this go to:

Settings > Calculator > FFT > choose input channel (FFT of)

Finally, adjust the Interval and observe the x-axis range

Repeat all the three demodulation schemes and observe the demodulated signal in the frequency domain

1. **Coherent Demodulation**

   Plot the spectrum of the message signal with the demodulated signal and compare them. **Take a picture** of the impulses. (Adjust the x-axis range to be suitable for the plot).

2. **Non-Coherent Demodulation**

   Plot the spectrum of the message signal with the demodulated signal and compare them. **Take a picture** of the impulses. (Adjust the x-axis range to be suitable for the plot).

   What happened to the demodulated impulse? Does it disappear at some moment?

   ____

   ____

   ____

Post lab Questions: (Homework Questions)

Question 1: Write the Normal AM modulated signal Equations:

Normal AM:

Question 2: How to extract the message signal from the Normal AM?

Normal AM:

Question 3: A message signal with the form of

$$\boldsymbol{m(t) = 2sin(500\pi t)}$$

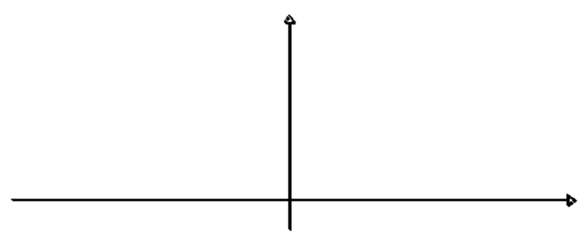
has to be modulated in both Normal AM and the DSB using a carrier with the form of:

$$\boldsymbol{c(t) = 1sin(10k\pi t)}$$

Draw the time domain and the frequency domain representations for both modulation techniques assuming the modulator sensitivity to be 0.5:

- Time domain AM

2. Frequency Domain AM



Question 4: Draw the PLL internal parts in details then explain how it works.

Drawing:

Explanation:

Experiment #2:

Double-side and Single-side Band Modulation

Prelab:

Theoretical Prelab:

Review the theoretical background of both Amplitude Modulation and Demodulation of the Double-side suppress carrier and Single-side band methods (Please give a detailed view on the mathematical (equations) side).

Software Prelab (Simulink Matlab):

Signals information for this prelab section:

Message signal:

$$m(t) = 0.85\cos\,(2\pi(1000)t)$$

Carrier signal:

$$c(t) = 1\cos\,(2\pi(15k)t)$$

- Block Simulation (Matlab Simulink):

  Build a full simulation block diagram of the ***modulation and the demodulation*** of the ***DSBsc*** that shows both the ***time and frequency*** domains. The diagram must show (message, carrier, modulated and demodulated) signals. Show the parameters you have used in each block.

  Build a full simulation block diagram of the ***modulation and the demodulation*** of the ***SSBsc upper or lower*** that shows both the ***time and frequency*** domains. The diagram must show (message, carrier, modulated and demodulated) signals. Show the parameters you have used in each block.

Note: Comment and discuss each result scientifically.

Objectives

Generally, to transform the Double-side and Single-side bands modulation methods theoretical knowledge into a practical one. This will include to be familiar with the communication basics like:

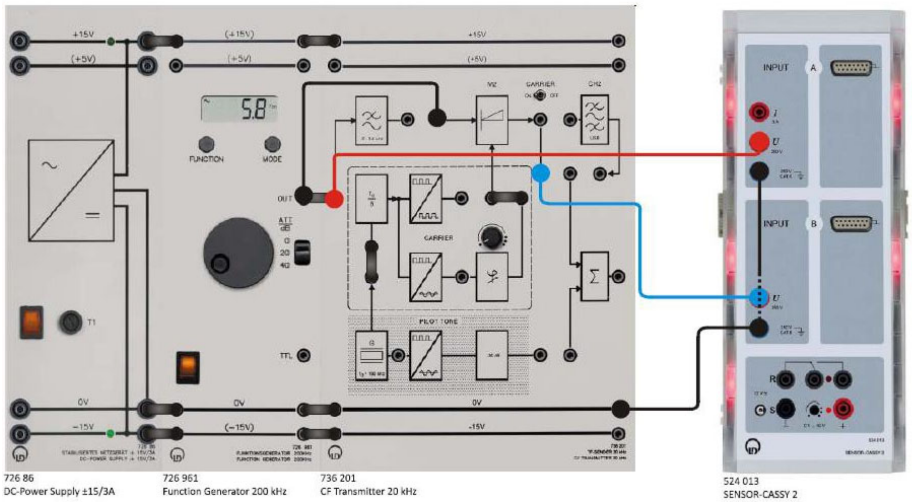
- How to create DSBsc?
- What are the types of SSB and how they differ? (SSBsc)
- How to create both types of SSB?
- Study the demodulation of these methods practically.
- Are they both affected by non-coherent problem?

Procedure *[You Should Talk the Results in Time & Spectrum]*

Part one: Double-side band suppressed carrier amplitude Modulation

Section 1.1: Modulation (Time and Frequency domains)

Assemble the components as shown in the figure below:



Set the toggle switch to **CARRIER OFF** (This is to neglect the carrier sum after multiplication of the message and carrier) to generate the modulated signal (s(t)).

Remember: $s(t) = m(t)c(t)$

Time Domain:

The message signal of the DSB will be a sinusoidal message Vss = 4V and fm = 2 kHz Plot the output signal of the modulator (s(t)) and the message signal (m(t)) at the same time on the Cassy Lab wave. On the Cassy Lab screen shift the message signal (m(t)) to be an envelope curve of the modulated signal (s(t)). **<u>Take a picture</u>** of the time wave.

Write a description of the modulated signal in terms of the message signal:

____

____

Determining the effect of varying the frequency (fm) and the amplitude (Am) of the message signal:

1. The effect of changing the frequency: Keep Vss = 4V and change the message frequency to 1kHz and 3kHz (**<u>Take a picture</u>** of the wave in each case).

   Write your observations:

   ____

2. The effect of changing the amplitude: Keep fm = 2kHz and change the message Vss to 2V and 6V (**<u>Take a picture</u>** of the wave in each case).

   Write your observations:

   ____

   ____

   ____

Frequency Domain (Spectrum)

In this section set the Cassy Lab in <u>FFT</u> mode. To do this go to:

Settings > Calculator > FFT > choose input channel (FFT of)

Finally, adjust the Interval and observe the x-axis range

Modulated signal

Return the function generator to: sine, Vss = 4 V and fm = 2 kHz and the carrier to the sinusoidal form. Feed the message signal into the lowpass filter then connect its output to the modulator block. Plot the modulated signal spectrum using the Cassy Lab then **<u>take a picture</u>** of the impulses. (Adjust the x-axis range to be suitable for the plot).

Write your observations:

____

____

Repeat the part but this time for m(t) as **Sine**, Vss = 4V and fm = 3 kHz. This time feed the message signal m(t) directly (without the lowpass filter) into the modulator. Why?

____

Compare the results from the two observations by answering the following questions:

How does the Upper Side Impulse respond as a function of the signal frequency fm?

What about the Lower Side Impulse?

Determine the transmission bandwidth of the normal amplitude modulation signal based on the measurements.

Generalize your results for a randomly taken message signal.

Find the power of each impulse side in addition to the carrier impulse, then calculate the power efficiency.

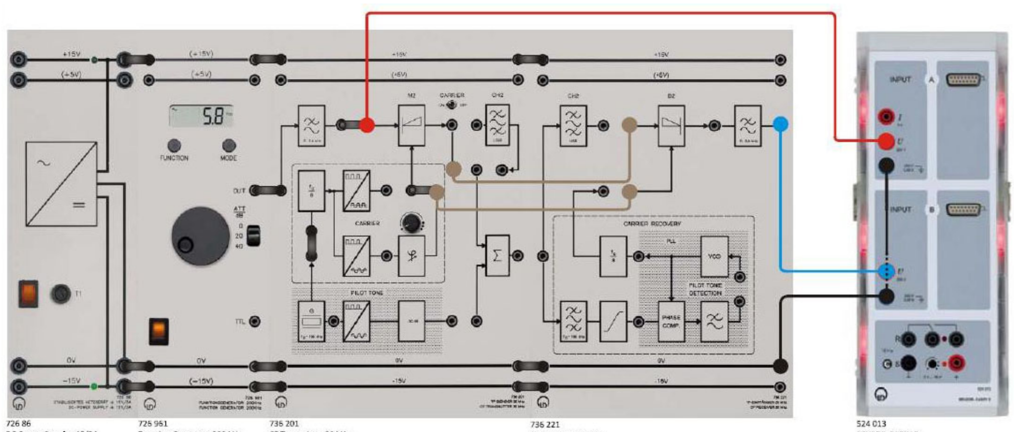
Section 1.2: Demodulation

Time Domain

1. **Coherent Demodulation**

Assemble the components as shown. Make sure that the function generator is set to:

sine, Vss = 4V and fm = 2 kHz.



Set the phase controller (φ) to the left (Min value = 0°). Feed s(t) signal directly into the demodulator (do not use any filter while transmitting it). Using a wire feed a sinusoidal carrier signal into the auxiliary carrier input of the demodulator.

Why does this step is done?

Plot the message signal m(t) as well as the demodulated signal on the Cassy Lab. One time before the output filter and another after it. **<u>Take a picture</u>** of the waves.

Why the receiver output filter is used? Prove the need of it mathematically

____

____

2. **Non-Coherent Demodulation**

Now to study the effect of non-coherence, feed the modulator with a sinusoidal carrier from the pin before the phase shifter and feed the demodulator with the carrier from the pin after the phase shifter. Change the carrier phase from the phase shifter (**φ**).

What do you conclude?

____

When does the output completely disappears?

____

Section 2.2: Frequency Domain (Spectrum)

In this section set the Cassy Lab in <u>FFT</u> mode. To do this go to:

Settings > Calculator > FFT > choose input channel (FFT of)

Finally, adjust the Interval and observe the x-axis range

Repeat all the three demodulation schemes and observe the demodulated signal in the frequency domain

1. **Coherent Demodulation**

Plot the spectrum of the message signal with the demodulated signal and compare them. **<u>Take a picture</u>** of the impulses. (Adjust the x-axis range to be suitable for the plot).

2. **Non-Coherent Demodulation**

Plot the spectrum of the message signal with the demodulated signal and compare them. **<u>Take a picture</u>** of the impulses. (Adjust the x-axis range to be suitable for the plot).

Part two: Single-side band amplitude Modulation and Demodulation

One way to generate a Single-side band modulation is by filtering the upper or the lower side of either the Normal AM or the DSBsc modulation schemes. As filters in real life are not ideal, filtering each modulation scheme will result in a SSB modulation type. Filtering the ***<u>Normal AM</u>*** with a non-ideal filter will results in a type called ***<u>SSB residual carrier</u>***, it got this name since the carrier component will not completely filtered and there will be a residual carrier component. However, filtering the ***<u>DSBsc</u>*** signal will result in the ***<u>SSB suppressed carrier</u>*** type which hasn't a carrier component.

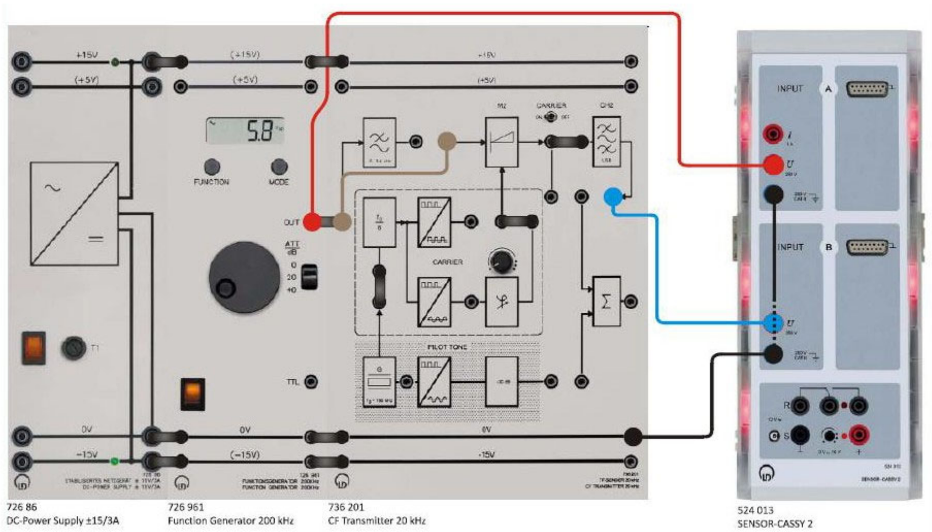
Section 2.1: Single-side band Suppressed carrier

2.1.1: Modulation

Modulation

Assemble the components as shown. Make sure that the function generator is set to:

sine, Vss = 4V and fm = 2 kHz.



Set the toggle switch to **CARRIER OFF (why?)**

____

Time Domain:

Plot the output signal of the modulator (s(t)) and the message signal (m(t)) at the same time on the Cassy Lab wave. **Take a picture** of the time wave.

Write a description of the modulated signal in terms of the message signal:

____

____

Determining the effect of varying the frequency (fm) and the amplitude (Am) of the message signal:

1. The effect of changing the frequency: Keep Vss = 4V and change the message frequency to 1kHz and 3kHz (**Take a picture** of the wave in each case).

Write your observations:

____

2. The effect of changing the amplitude: Keep fm = 2kHz and change the message Vss to 2V and 6V (**Take a picture** of the wave in each case).

Write your observations:

____

Frequency Domain (Spectrum)

In this section set the Cassy Lab in FFT mode. To do this go to:

Settings > Calculator > FFT > choose input channel (FFT of)

Finally, adjust the Interval and observe the x-axis range

- **Modulated signal**

  Return the function generator to: sine, $V_{SS} = 4$ V and fm = 2 kHz. Feed the message signal into the lowpass filter then connect its output to the modulator block. Plot the modulated signal spectrum using the Cassy Lab then **take a picture** of the impulses. (Adjust the x-axis range to be suitable for the plot).

  Write your observations:

  ____

  ____

  Repeat the part but this time for m(t) as **Sine**, $V_{SS} = 4$V and fm = 3 kHz. This time feed the message signal m(t) directly (without the lowpass filter) into the modulator. Why?

  ____

  Compare the results from the two observations by answering the following questions:

  How does the Upper Side Impulse respond as a function of the signal frequency fm?

  ____

  What about the Lower Side Impulse?

  ____

  Determine the transmission bandwidth of the normal amplitude modulation signal based on the measurements.

  ____

  ____

  ____

  ____

  Generalize your results for a randomly taken message signal.

  ____

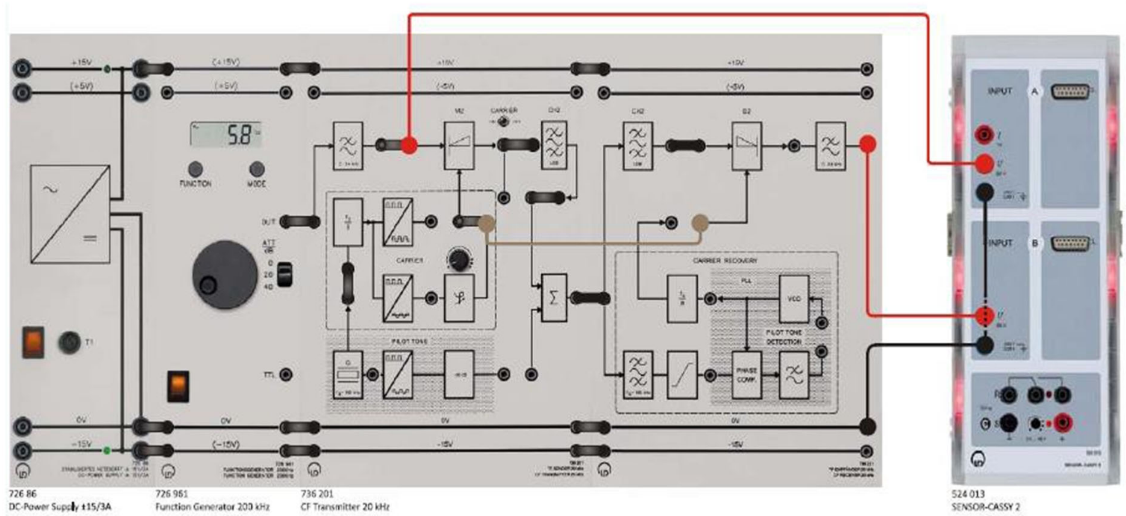
2.2.2: Demodulation

Time Domain & Frequency Domain

1. Coherent Demodulation

Assemble the components as shown. Make sure that the function generator is set to:

sine, V_{SS} = 4V and fm = 2 kHz.



Set the phase controller (**φ**) to the left (Min value = 0°). Feed s(t) signal directly into the demodulator (do not use any filter while transmitting it). Using a wire feed a sinusoidal carrier signal into the auxiliary carrier input of the demodulator.

Why does this step is done?

Plot the message signal m(t) as well as the demodulated signal on the Cassy Lab. One time before the output filter and another after it. **<u>Take a picture</u>** of the waves.

Why the receiver output filter is used? Prove the need of it mathematically

---

---

2. Non-Coherent Demodulation

Now to study the effect of non-coherence, feed the modulator with a sinusoidal carrier from the pin before the phase shifter and feed the demodulator with the carrier from the pin after the phase shifter. Change the carrier phase from the phase shifter (**φ**).

What do you conclude?

When does the output completely disappears?

---

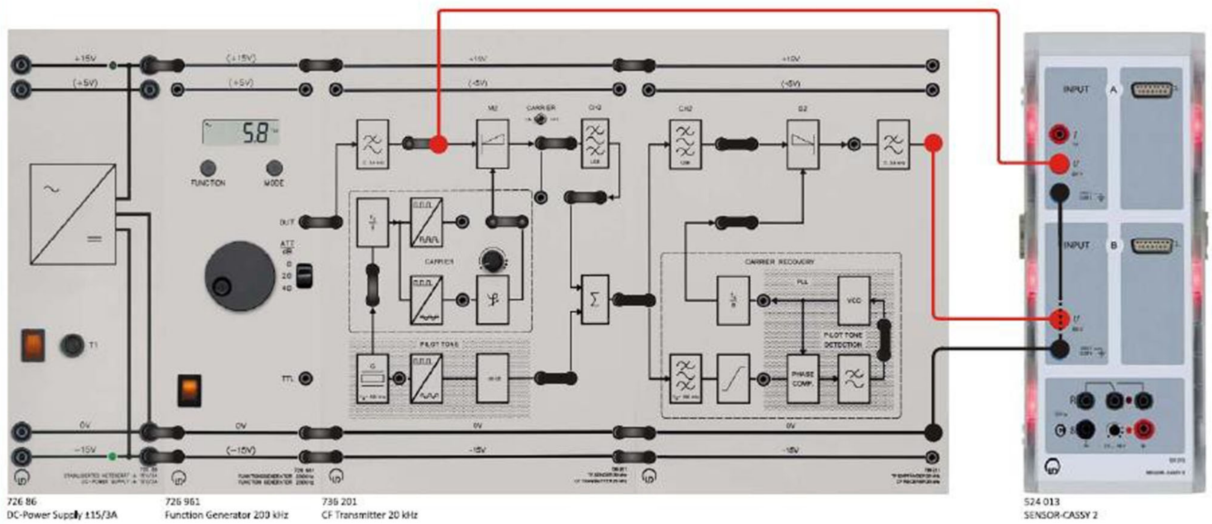
3. **Phase Locked Loop (PLL) Coherent Demodulation**

Another way of coherent demodulation is to use the Phase Locked Loop (PLL). This loop is located at the receiver, it accepts an attenuated version of the carrier and recreates a full carrier signal to be used in the demodulation process.

Assemble the components as shown. Make sure that the function generator is set to:

sine, V_{SS} = 4V and fm = 2 kHz.

Make sure to use the square carrier signal (This is because the PLL is generating a square carrier)



1- Sketch the pilot tone of the transmitter and the recovered signal in the receiver at the output of the PLL circuit. **Take a picture** of the waves.

Are they the same? ____

2- Plot the message signal m(t) as well as the demodulated signal on the Cassy Lab. One time before the output filter and another after it. **Take a picture** of the waves.

Does the demodulation process success by using the PLL?

____

Post lab Questions: (Homework Questions)

Question 1: A message signal with the form of

$$m(t) = 2sin(500\pi t)$$

has to be modulated in All the Amplitude modulation techniques: Normal AM, DSB and SSB using a carrier with the form of:

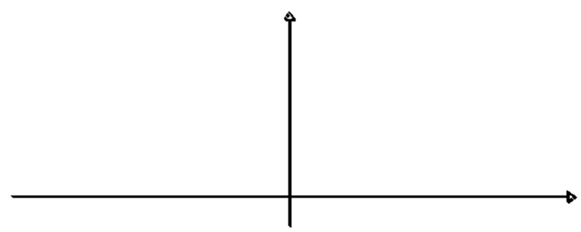
$$c(t) = sin(5k\pi t)$$

Draw the time domain and the frequency domain representations for both modulation techniques.

<u>The filter gain at f = 2.5k equals 0.2</u>

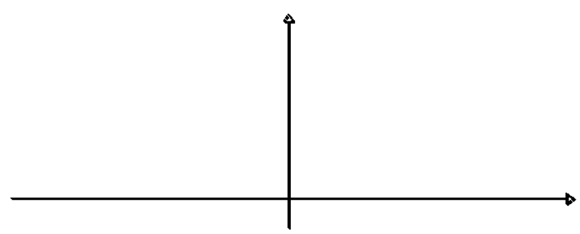
Time domain DSB

Frequency Domain DSB



Time domain SSB-SC

Frequency Domain SSB-SC



Time domain SSB-RC

Frequency Domain SSB-RC

Experiment #3:

Noise in Normal AM and DSB

Prelab:

Theoretical Prelab:

Review the theoretical background of the signal to noise ratio of the analog communication systems.

Objectives

To be able to calculate the signal to noise ratio (SNR) for both the double-side and the single-side band modulation methods. Moreover, to calculate the figure of merit which is a concept that evaluates the transmission process while dealing with the noise. The SNR will be found for the modulation (transmission) process and for the demodulation process.

Procedure

Part 1: Displaying the DSB-SC Modulation with Noise in Time and Frequency:

4. Set the kit of the DSB-SC modulation.
5. Send a message signal with frequency = 2 kHz, Vss = 4V
6. Add the noise channel to the kit and insert the modulated signal s(t) to one of its inputs.
7. Choose 3 different levels of noise (e.g., 0dB, -12dB and -30dB) and plot the modulated message signal at the input of the noise channel and at the output of it for the chosen noise levels. Notice the effect of the added noise to the modulated signal.
8. Plot the same signals in the frequency domain, show 50kHz spectrum.

Part 2: Calculating the power of the modulated and demodulated signals.

- **Power in the modulated DSB-SC signal:**
  1. Set the noise in the channel to 'OFF'.
  2. Plot the modulated DSB-SC signal s(t) in the frequency/time domain.
  3. Find the max voltage amplitude of the modulated signal s(t).
  4. Apply the following equation to find the power of the modulated signal (P_{DSB}):

$$P_{DSB} = (A_{DSB})^2$$

Where, A_{DSB} is the max voltage of the upper **or** the lower pulses of the modulated signal. And record the answer in Table.1

6- **Power in the modulated SSB-SC signal:**

7- Repeat the same steps in (1), but this time for the SSB.

8- Apply the following equation to find the power of the modulated signal (P_{SSB}):

$$P_{SSB} = \frac{(A_{SSB})^2}{2}$$

Where, A_{DSB} is the max voltage of the upper **or** the lower pulses of the modulated signal (Frequency/Time). And record the answer in Table.1

9- **Power in the demodulated DSB-SC signal:**

10- Set the noise in the channel to 'OFF'.

11- Connect the carrier to the demodulator to perform coherent demodulation.

12- Plot the demodulated signal at the output of the LPF.

13- Apply the following equation to find the power of the demodulated signal ($P_{DeM\text{-}DSB}$):

$$P_{DeM-DSB} = \frac{(A_{DeM-DSB})^2}{2}$$

Where, $A_{DeM\text{-}DSB}$ is the max voltage of demodulated signal in the time domain. And record the answer in Table.1

14- **Power in the demodulated SSB-SC signal:**

15- Repeat the same steps in (3), but this time for the SSB.

$$P_{DeM-SSB} = \frac{(A_{DeM-SSB})^2}{2}$$

And record the answer in Table.1

Part 3: Calculating the Signal-to-Noise Ratio of the DSB-SC

This part will be done in the **frequency domain.**

3- Set the noise of the channel to 0dB.

4- Disconnect the DSB-SC from the noise channel. (By doing this only the noise will be shown at the output of the channel).

5- Plot the output of the noise channel in the frequency domain.

6- From this spectrum, the noise power (N_{power}) can be calculated as follows:

$$N_{power} = (S)(BW_N)$$

Where S is the average noise level in the frequency domain, and it is calculated by:

$$S = \frac{(A_N)^2}{2}$$

Where A_n is the max average noise voltage.

BW_N is the bandwidth occupied by s(f) "It is approximately 5 kHz from 17.5k to 22.5k". However, since the noise generator generates random noise an enhancement to the BW calculation must be done as follows:

$$BW_N = \left\lceil \frac{BW_{s(t)}}{\Delta f} \right\rceil$$

Where $BW_{s(t)}$ is the bandwidth of the noise of s(f) and Δf is the separation between two consecutive impulses. Note that the ceiling of the answer must be taken.

Therefore, the final noise power N_{power} can be calculated as:

$$N_{power} = \frac{(A_N)^2}{2} \left\lceil \frac{BW_{s(t)}}{\Delta f} \right\rceil$$

Record the value in Table 1.

Now the SNR will be calculated after inserting the noise to the LPF:

c- Plot the noise spectrum at the output of the LPF.

d- Repeat the same steps used in calculating N_{power} to calculate the noise power N_{LPF} after the filter

$$N_{LPF-DSB} = \frac{(A_N)^2}{2} \left\lceil \frac{BW_{LPF}}{\Delta f} \right\rceil$$

e- Repeat the same steps used in calculating N_{power} to calculate the noise power N_{LPF} after the filter

$$N_{LPF-SSB} = \frac{(A_N)^2}{2} \left\lceil \frac{BW_{LPF}}{\Delta f} \right\rceil$$

Table.1: power of each modulated and demodulated signal

Power	DSB	SSB
Modulated signal Power (W)		
Demodulated signal Power (W)		
Modulated Noise Power (W)		
Demodulated Noise Power (W)		

Signal to Noise Ratio (SNR) Calculation:

6- Calculate the Signal-to-noise (SNR1) ratio at the output of the transmission line using:

$$SNR_1 = \frac{P_{DSB-Mod}}{N_{power}} \qquad SNR_1 = \frac{P_{SSB-Mod}}{N_{power}}$$

7- Calculate the Signal-to-noise (SNR2) ratio at the output of the Low Pass Filter using:

$$SNR_2 = \frac{P_{DSB-DeM}}{N_{LPF-DSB}} \qquad SNR_2 = \frac{P_{SSB-DeM}}{N_{LPF-SSB}}$$

8- Compare between SNR_1 and SNR_2 and find the figure of merit for the DSB-SSB.

$$\gamma = \frac{SNR_2}{SNR_1}$$

Table.2: Final answers

	DSB	SSB
SNR-Modulation $SNR_1 = \frac{P_{s(t)}}{N_{power}}$		
SNR-Demodulation $SNR_2 = \frac{P_{DeM}}{N_{LPF}}$		
Figure of Merit $\gamma = \frac{SNR_2}{SNR_1}$		

Compare between the DSB and the SSB:

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Compare the ideal case of each modulation method with the practical results:

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Experiment #4:

Frequency Modulation

Pre-Lab Work

Theoretical Prelab:

Review the theoretical background of the Frequency modulation.

1. State the Frequency Modulation (FM) modulated signal equation.
2. How to extract the message signal from the modulated signal theoretically. "This can be done by differentiating the modulated signal then applying an envelope detector, and finally subtracting the DC value." Prove it mathematically.

Software Prelab:

Consider the frequency modulated signal:

$$s(t) = \cos(2\pi(20k)t + 6\sin(1000\pi t))$$

Build a Simulink model in a MATLAB Simulink that [***Take plots in time and frequency domains*]:**

1. Extract the message signal m(t) from s(t). ***[by hand solution]***.
2. Plot 5 cycle from message signal m(t) and s(t) versus t. ***[by Simulink]***.
3. Differentiate s(t) with respect to t and plot ds(t)/dt. Notice how this operation transforms an FM waveform into an AM waveform. ***Write your observation and conclusions.*** ***[by hand then use Simulink to observe your result]***.
4. Apply ds(t)/dt to an ideal envelope detector, subtract the dc term and show that the detector's output is linearly proportional to m(t). ***Write your observation and conclusions.*** ***[by hand solution].***
5. Extract message signal by using phase-locked loop (PLL). ***[by Simulink].***
6. Extract the message signal by using the envelop detector. ***[by Simulink].***

Objectives

Generally, to transform the Frequency Modulation (FM) theoretical knowledge into a practical one. This will include:

- To be familiar with the communication basics like:
  - How to perform the Frequency modulation and demodulation method.
  - What is the FM modulator sensitivity?
  - The carrier zero crossing concept.
- To be familiar with signals basics like:
  - What characteristics a low pass filter can have?
  - What is the pre-emphasis and when it is used?

Procedure *[You Should Talk the Results in Time & Spectrum]*

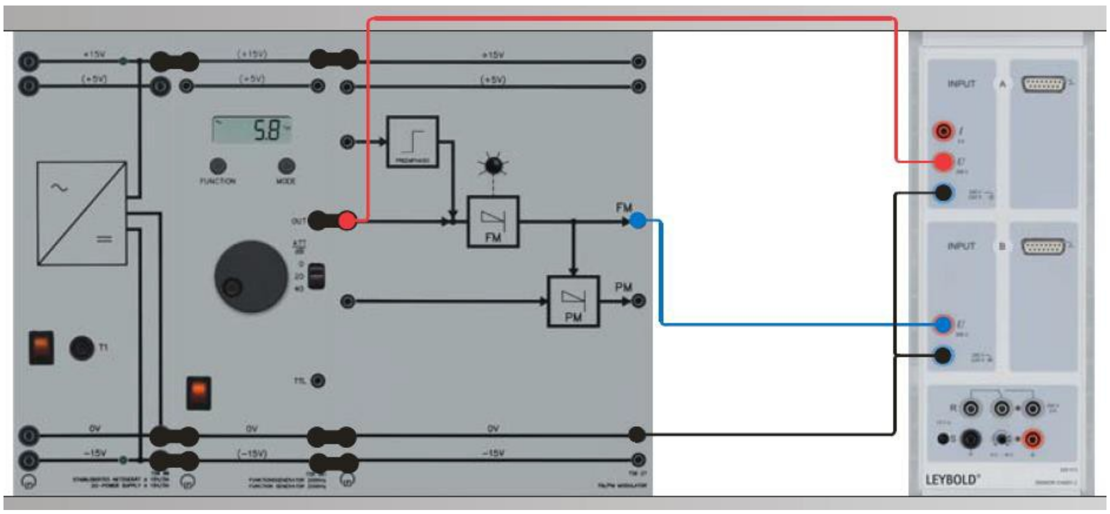
Part 1: Modulation

Section 1: Time Domain

1.1: Displaying the FM signal in the time domain

Assemble the components as shown in the figure. Set the function generator to generate a sinusoidal message signal with Vss = 20V and fm = 1kHz. Set the carrier knob to the min value and start the measurement. **Take a picture of the wave.**

Note: Show only one message period.



Does the modulated signal frequency changes with respect to the message amplitude? ____________

Can you give an explanation of what is happing?

___

___

Section 2: Frequency Domain (Spectrum)

In this section set the Cassy Lab in FFT mode. To do this go to:

Settings > Calculator > FFT > choose input channel (FFT of)

Finally, adjust the Interval and observe the x-axis range

2.1: Setting the carrier frequency to exactly 20kHz

Set the function generator to give a **Vss = 0V** message signal. Now the modulated signal s(t) is representing the carrier signal alone. **How? Prove it by equation.**

___

___

In the frequency domain observe the carrier impulse and adjust it (using the carrier knob) to be on the 20kHz frequency x-axis point.

2.2: The Characteristic of the FM Modulator

The objective of this part is to determine the modulator sensitivity constant k_f in Hz/V

Remember: The instantaneous frequency $f_i(t)$ of the FM modulator is related to the message signal by: $f_i(t) = f_c + k_f m(t)$

What will happen if the message signal is set to be constant?

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Using the 20 kHz carrier signal, modulate a **DC-signal** message signal starting with -10V. After that determine the carrier frequency from the spectrum. Increment the DC voltage in steps of 2V and repeat the measurement of the carrier frequency filling the following table.

Message Voltage	Carrier Frequency	Message Voltage	Carrier Frequency
-10		2	
-8		4	
-6		6	
-4		8	
-2		10	
0			

Determine the coefficient of the FM modulator k_f:

____

____

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Determining of the frequency deviation for a 10V message signal

The frequency deviation depends on the coefficient of the FM modulator and the amplitude of the modulating signal**.** Using this relationship, determine the frequency deviation for a 10V message signal.

$$\Delta f = k_f A_m$$

____

____

2.3: Displaying the FM signal spectrum

2.3.1: Sinusoidal Message signal

With the same kit setup, use a **sinusoidal** signal with V_{SS} = 20V and fm = 3000Hz as the message signal m(t). Make sure its DC offset is 0V. Plot the modulated signal spectrum using the Cassy Lab then **take a picture** of the impulses. (Adjust the x-axis range to be suitable for the plot)

Repeat the measurement for a message signal V_{SS} = 20V and fm = 200Hz. plot the modulated signal spectrum using the Cassy Lab then **take a picture** of the impulses. (Adjust the x-axis range to be suitable for the plot)

Compare changes in the spectrum for different m(t) frequency.

2.3.2: Square Message signal

Use a message signal with **square wave** signal, V_{SS} = 20V, duty cycle 50% and fm = 200Hz. Plot the modulated signal spectrum using the Cassy Lab then **take a picture** of the impulses. (Adjust the x-axis range to be suitable for the plot)

Compare changes in the spectrum for different m(t) types.

2.4: Determining the zero carrier crossings

Recall that the spectral component at the carrier frequency is proportional to the Bessel function term $J_0(\beta)$. Thus, there are certain values of β that make $J_0(\beta)$ = 0. The first three values are:

$\beta = 2.4048$ $\quad\quad$ $\beta = 5.5201$ $\quad\quad$ $\beta = 8.6537$

Zero crossing (now it can be seen as varying β) can be achieved by either varying the message amplitude (while holding the frequency constant) or by varying the frequency (while holding the amplitude constant).

2.4.1: Varying the message amplitude while keeping the frequency constant

Assume the following cases:

16- A message with a constant frequency of 100Hz.

Calculate the first three values of the message amplitude that will result in zero carrier crossing. Fill them in the following table.

Modulation index (β)	2.4048	5.5201	8.6537
Amplitude (V)			

Use a sinusoidal signal with V_{SS} = 0V and fm = 100Hz of the function generator as the modulating signal m(t). Slowly Increase the amplitude of the message. Plot the modulated signal spectrum using the Cassy Lab then **take a picture** of the impulses. (Adjust the x-axis range to be suitable for the plot) Observe the decay of the carrier impulse. Record the values of the amplitudes when the carrier impulse disappears.

1st carrier decay at amplitude = ___________

Compare the theoretical values that were found before. What can you conclude?

____

____

____

2.4.2: Varying the message frequency while keeping the amplitude constant.

17- A message with a constant amplitude of 10V.

Calculate the first three values of the message frequency that will result in zero carrier crossing. Fill them in the following table.

Modulation index (β)	2.4048	5.5201	8.6537
Frequency (Hz)			

Use a sinusoidal signal with V_{SS} = 20V and fm = 1kHz of the function generator as the modulating signal m(t). Slowly reduce the frequency of the message. Plot the modulated signal spectrum using the Cassy Lab then **take a picture** of the impulses. (Adjust the x-axis range to be suitable for the plot) Observe the decay of the carrier impulse. Record the values of the amplitudes when the carrier impulse disappears.

1st carrier decay at frequency = ___________

Compare the theoretical values that were found before. What can you conclude?

____

____

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____

Part 2: FM Demodulation

Section 1: Time domain FM demodulated signal

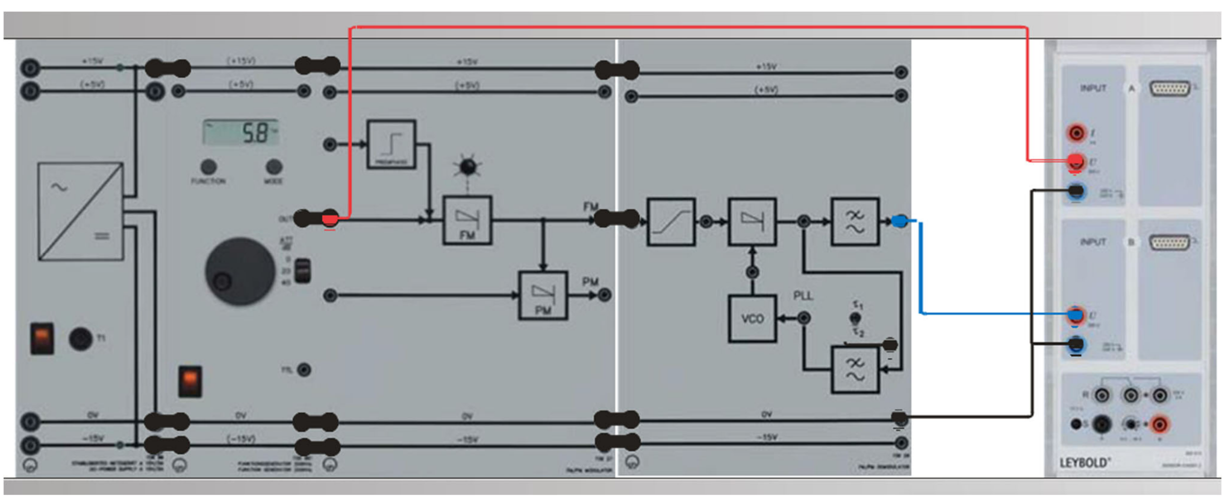
Use a **sinusoidal** message signal m(t) with V_{SS} = 10 V and f_m = 500 Hz. Set the loop filter of the FM demodulator to τ2. Plot both the message and demodulated signals. **Take a picture** of the waves. Does the PLL demodulator works for the FM?

____

Section 2: Studying the effect of the receiver loop filter

The receiver of this experiment is implemented so that two receiver loop filters can be used. Each filter is representing a lowpass filter with a special gain-bandwidth characteristics. So that the objective of this section is to compare the message signal with the demodulated signal when the gain of the loop filter is varied between the two loop filters.

Assemble the components as shown below.



2.1: Studying Loop filters τ_1 and τ_2 without pre-emphasis

In this section set the Cassy Lab in FFT mode. To do this go to:

Settings > Calculator > FFT > choose input channel (FFT of)

Finally, adjust the Interval and observe the x-axis range

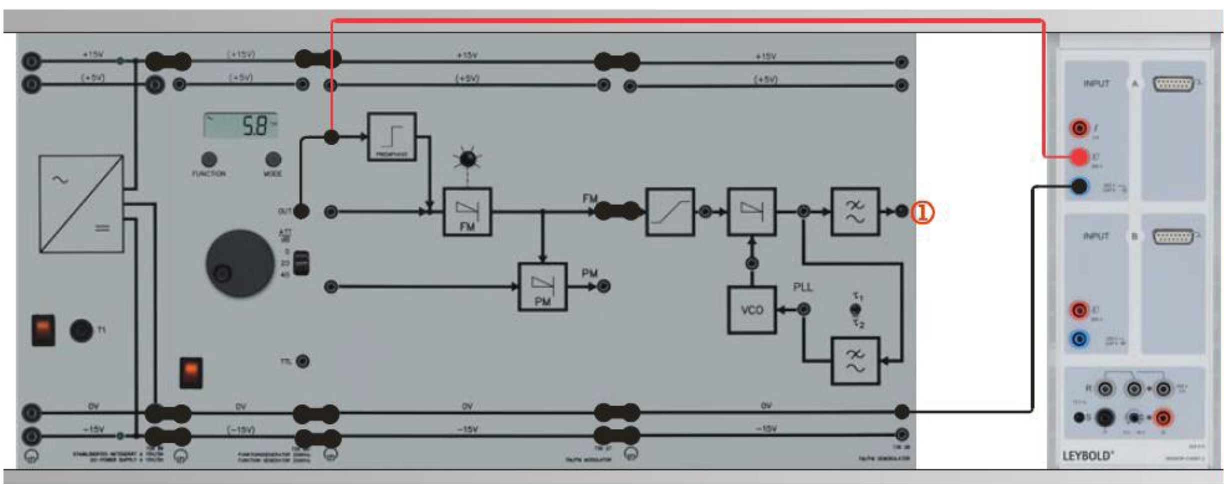
Use a sinusoidal modulating signal m(t) with V_{SS} = 4V and starting with fm = 500Hz. Determine the amplitude of the demodulated signal using the spectrum for each loop filter. **Record the values into the table.** Plot Ad/Am versus fm on the chart below.

Without the Pre-emphasis						
Message Frequency (Hz)	500	1000	1500	2000	3000	4000
A_d using τ_1 filter						
A_d using τ_2 filter						

2.2: Studying Loop filters τ_1 and τ_2 with pre-emphasis

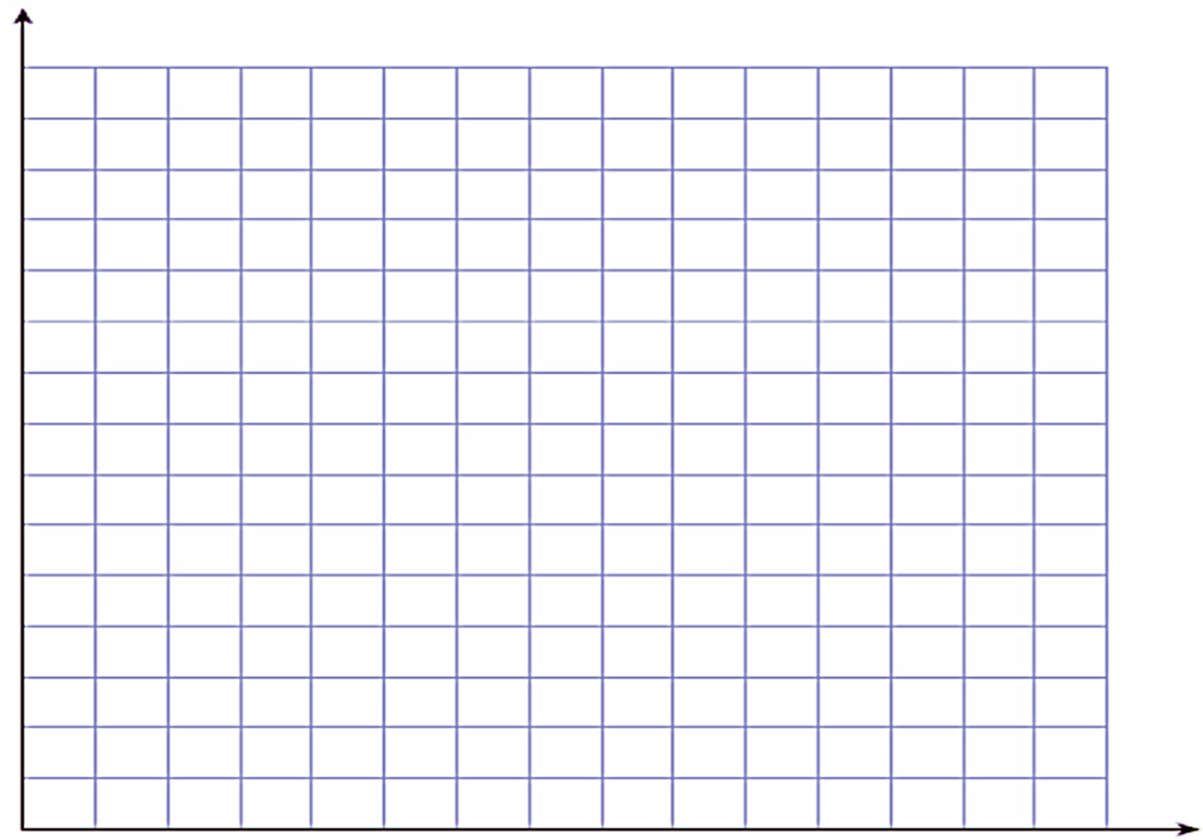
Pre-emphasis is the process of amplifying its input signal if it is at a specific range of frequency (Usually high frequency).

Assemble the components as shown.



Use a sinusoidal modulating signal m(t) with V_{SS} = 4V and starting with fm = 500Hz. Determine the amplitude of the demodulated signal using the spectrum for each loop filter. **Record the values into the table**. Plot Ad/Am versus fm on the chart below.

With the Pre-emphasis						
Message Frequency (Hz)	500	1000	1500	2000	3000	4000
A_d using τ_1 filter						
A_d using τ_2 filter						

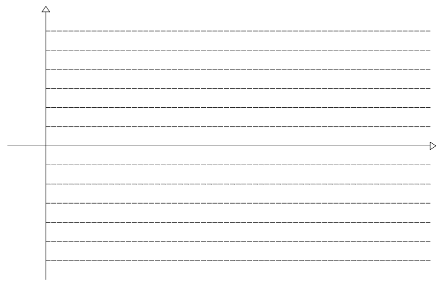


What are the different characteristics between the two loop filters?

How does the Pre-emphases affect the filters responses?

Post-Lab Assignment

Question 1: Draw a sinusoidal message signal of frequency = 2kHz and Amplitude = 2V, with the modulated signal of the FM modulation s(t) in the time domain (Note carrier frequency = 20kHz and amplitude = 1).

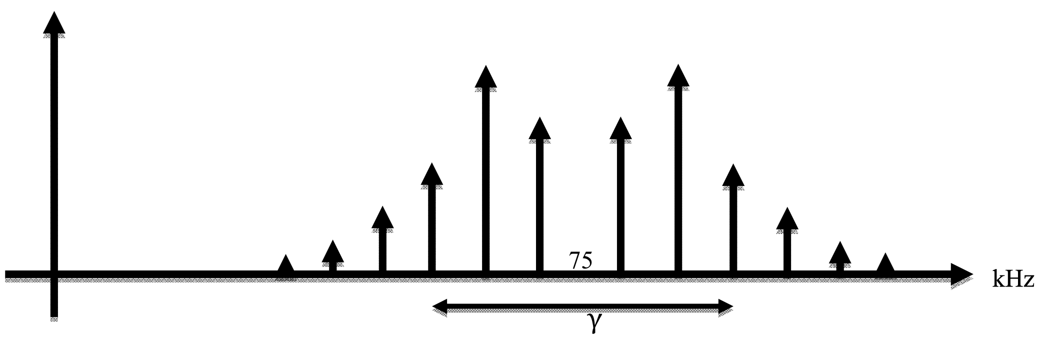


Question 2:

In a frequency modulation experiment with a carrier frequency = 75kHz, a sinusoidal message signal in the form of:

$$m(t) = A_m \cos(\omega_m t)$$

was modulated through an FM modulator that has the sensitivity k_f = 120 Hz/V. The modulated signal spectrum was found to be:



It was found that the range of frequencies (γ) shown in the spectrum equals 6 kHz.

d- What is the frequency of the message signal?

f_m = ___________________

e- Find the value of the modulation index:

β = ___________________

f- Find the Amplitude of the message signal:

A_m = ___________________

g- Write the Frequency modulated signal s(t).

S(t) = ____

Question 3: When is deemphasis used in FM demodulation? How does it function?

Experiment #5:

Phase Modulation

Objectives

Generally, to transform the Phase Modulation (PM) theoretical knowledge into a practical one. This will include:

- To be familiar with the communication basics like:
  - How to perform the Phase modulation and demodulation method.
  - What is the PM modulator sensitivity?
- To be familiar with signals basics like:
  - What characteristics a low pass filter can have?

Software Prelab:

Consider the frequency modulated signal:

$$s(t) = \cos(2\pi(20k)t + \pi \cos(1000\pi t))$$

Build a Simulink model in a Matlab Simulink that [***Take plots in time and frequency domains***]**:**

1. Extract the message signal m(t) from s(t). ***[by hand solution]***.
2. Plot 5 cycle from message signal m(t) and s(t) versus t. ***[by Simulink]***.
3. Differentiate s(t) with respect to t and plot ds(t)/dt. Notice how this operation transforms an PM waveform into an AM waveform. ***Write your observation and conclusions.*** ***[by hand then use Simulink to observe your result]***.
4. Apply ds(t)/dt to an ideal envelope detector, subtract the dc term and show that the detector's output is linearly proportional to m(t). ***Write your observation and conclusions.*** ***[by hand solution].***
5. Extract message signal by using phase-locked loop (PLL) and by envelop detector. ***[by Simulink].***

Procedure *[You Should Talk the Results in Time & Spectrum]*

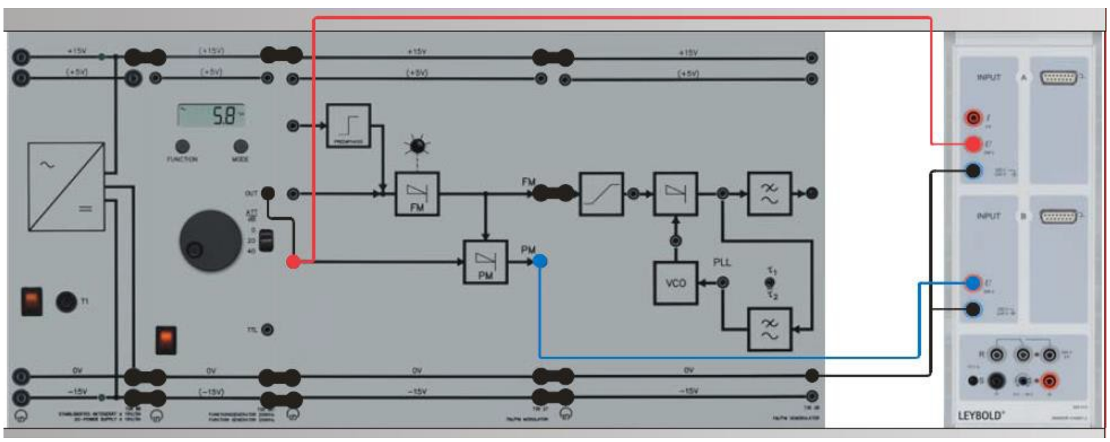
Part 1: PM Modulation

Section 1: Time Domain

1.1: Displaying the FM signal in the time domain

Assemble the components as shown in the figure. Set the function generator to generate a sinusoidal message signal with Vss = 2V and fm = 1kHz. Set the carrier knob to approximately 20kHz.

Load the CASSY Lab 2 example PM_TDscope.labx and start the measurement. **Take a picture of the wave.**



Does the modulated signal phase changes with respect to the message amplitude? ____________

Can you give an explanation of what is happing?

____

____

Section 2: Frequency Domain (Spectrum)

In this section set the Cassy Lab in FFT mode. To do this go to:

Settings > Calculator > FFT > choose input channel (FFT of)

Finally, adjust the Interval and observe the x-axis range

2.1: The Characteristic of the FM Modulator

The objective of this part is to determine the modulator sensitivity constant k_p in °/V

Using the 20 kHz carrier signal, modulate a **DC-signal** message signal starting with -1V. Load the CASSY Lab 2 example PM_TD.labx.

After that Determine the phase shift Δt (μs) between the carrier oscillations of the FM and PM output. Increment the DC voltage in steps of 0.2V and repeat the measurement of the carrier frequency filling the following table.

Message Voltage	Δt (μs)	Message Voltage	Δt (μs)
-1		0.2	
-0.8		0.4	
-0.6		0.6	
-0.4		0.8	
-0.2		1	
0			

Determine the coefficient of the PM modulator k_p. Hint: use the following equation:

$$\Delta\theta = \frac{\Delta t}{T_c} 360° = (\Delta t)(f_c)360°$$

2.2: Displaying the PM signal spectrum

With the same kit setup, use a **sinusoidal** signal with V_{SS} = 2V and fm = 3000Hz as the message signal m(t). Make sure its DC offset is 0V. Plot the modulated signal spectrum using the Cassy Lab then **<u>take a picture</u> [in time and frequency]** of the impulses. (Adjust the x-axis range to be suitable for the plot)

Repeat the measurement for a message signal V_{SS} = 2V and fm = 200Hz. plot the modulated signal spectrum using the Cassy Lab then **<u>take a picture</u> [in time and frequency]** of the impulses. (Adjust the x-axis range to be suitable for the plot)

Compare changes in the spectrum for different m(t) frequency.

How different is the spectrum of the PM signal from that of the FM signal?

Part 2: PM Demodulation

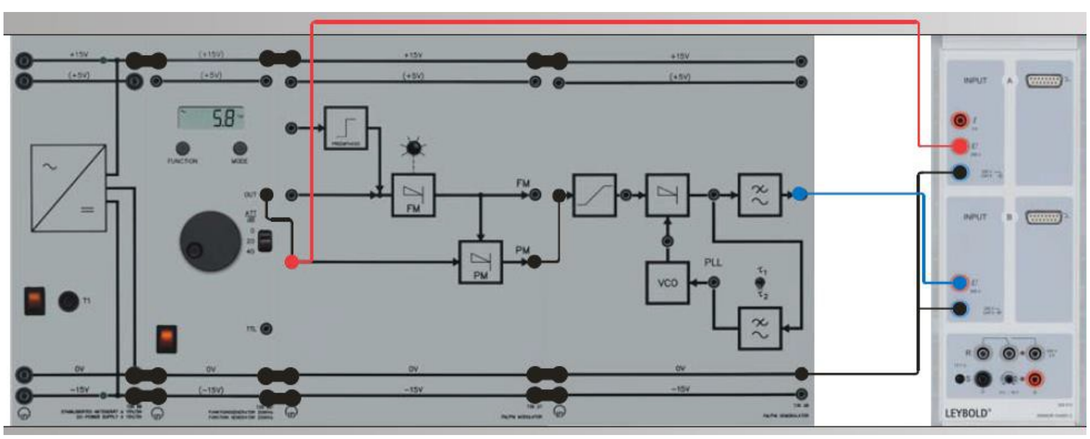
Section 1: Time domain PM demodulated signal

Use a **sinusoidal** message signal m(t) with $V_{SS} = 2$ V and $f_m = 500$ Hz. Set the loop filter of the PM demodulator to $\tau 2$. Plot both the message and demodulated signals. **Take a picture** of the waves. Does the PLL demodulator works for the PM?

Section 2: Studying the effect of the receiver loop filter

The receiver of this experiment is implemented so that two receiver loop filters can be used. Each filter is representing a lowpass filter with a special gain-bandwidth characteristics. So that the objective of this section is to compare the message signal with the demodulated signal when the gain of the loop filter is varied between the two loop filters.

Assemble the components as shown below.



2.1: Studying Loop filters τ_1 and τ_2 without pre-emphasis

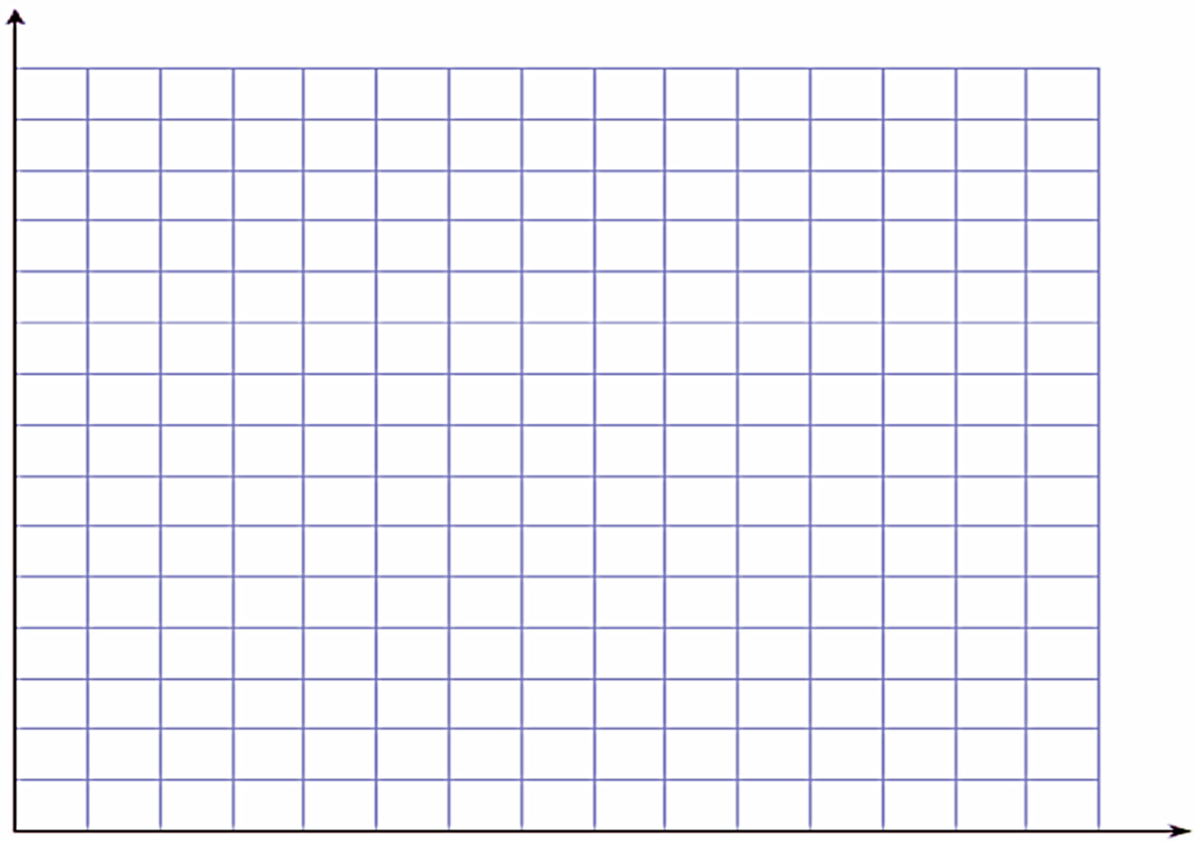
In this section set the Cassy Lab in FFT mode. To do this go to:

Settings > Calculator > FFT > choose input channel (FFT of)

Finally, adjust the Interval and observe the x-axis range

Use a sinusoidal modulating signal m(t) with V_{SS} = 2V and starting with f_m = 500Hz. Determine the amplitude of the demodulated signal using the spectrum for each loop filter. **Record the values into the table.** Plot Ad/Am versus fm on the chart below.

Without the Pre-emphasis						
Message Frequency (Hz)	500	1000	1500	2000	3000	4000
A_d using τ_1 filter						
A_d using τ_2 filter						



What are the different characteristics between the two loop filters?

____

____

____

____

Post-Lab Assignment

Question 1:

In a phase modulation experiment, different DC signals were fed to the modulator and the phase between the modulated signal and the carrier was observed for each. The following table shows the obtained results:

DC voltage (V)	-0.9	-0.6	-0.3	0	0.3	0.6	0.9
Time difference (μs)	-18	-12	-6	0	6	12	18

The amplitude of the used carrier was set to 2V. After that, the same PM modulator was used to modulate a message signal that has the following representation:

$$m(t) = 4\cos(1000\pi t)$$

- When a DC voltage = 0V was passed through the modulator, it was found that the frequency of the modulated signal S(t) is equal 15 kHz. What is the frequency of the original carrier?

  fc = ___________

- Find the value of the Phase modulator sensitivity.

  kp = ___________

- Write the Phase modulated signal s(t).

  S(t) = ____

- Draw the modulated signal in the time and frequency domain. (Note: draw only one cycle of the message signal).

Analog To Digital Converter

Experiment #6:

Pulse Amplitude Modulation (Sampling)

Objectives

The main aim of this experiment is to transform the theoretical knowledge about the: pulse train spectrum, sampling, Nyquist rate and aliasing, the effect of the sampling pulses on the communication system and finally the time division multiplexing with the cross talk.

Pre-Lab Work

Theoretical Prelab:

Review the theoretical background of the Sampling theorem and the pulse amplitude modulation. Make sure to review all the topics included in the experiment.

Software Prelab:

Build a full system that describes all the parts [1,2,3 and 4] of this experiment using MATLAB Simulink. Starting from generating the pulse train in the ***time and frequency domains***. Then building a PAM ***(Natural Sampling and Flat-Top Sampling)*** modulation and demodulation models with all the test cases in the experiment and finally make ***aliasing*** in modulation and demodulation system as it is requested in part four of the experiment. The Final system should be around this system:

Procedure *[You Should Talk the Results in Time & Spectrum]*

Part 1: Time and Frequency Characteristics of pulse train

In this part, various pulse signals will be studied in the time and the frequency domains.

1. Select a **pulse train** at the function generator with:

   Freq = 1 kHz, V_{SS} = 10 V and duty cycle = 10%.

2. Start the measurement.
3. Show the pulse train in the time domain **(Show 5 cycles and take a picture of the output).**
4. Show the pulse train in the frequency domain **(Choose a suitable measuring time so that the spectrum become clear and take a picture of the output).**

Answer the following questions:

Where is the zero crossings in the envelope of the pulse spectrum?

____

- Calculate and talk the measurements of the **spectral** and **time** characteristics for the same frequency and amplitude for different duty cycles 20%, 30%, 40, 50% and 90%. **(Choose a suitable measuring time so that the spectrum become clear and take a picture of the output). [Talk at least one results from the table]**

Fill the table:

Duty Cycle (%)	20	30	40	50	90
Zero Crossing (kHz)					

Answer the following questions:

5. Why do pulse trains require large transmission bandwidths?

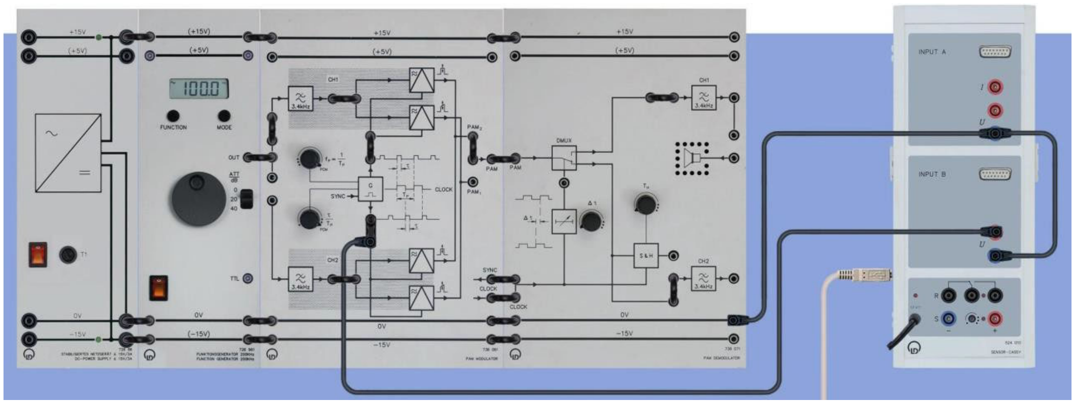
   ____

6. What is the structure of the spectrum of a pulse train and its envelope?

   ____

Part 2: Characteristics of Pulse Amplitude Modulation (PAM)

In this part a square signal will be used to sample the message signal. To carry out this experiment, assemble the components as shown below. (Neglect Sync Pin)



1. Adjust the sampling frequency (f_p) knob to its max value.
2. Adjust the duty cycle (τ/T_P) knob to its max value.
3. Connect Cassy UA1 to the Clock generator output (G).
4. Adjust the sampling frequency to 5000 Hz.

To adjust the sampling frequency of the clock generator:

7. Start an FFT analyzer measurement.
8. Choose a suitable Measuring time so that the spectrum becomes clear.
9. Slowly reduce the pulse frequency (f_p), until the spectral line of the fundamental pulse appears at (f_0 = 5000 Hz) the second pulse must appear at ($3f_0$ = 15 kHz) and so on. **(Choose a suitable measuring time so that the spectrum become clear and take a picture of the output).**

After adjusting the sampling frequency, now it is the time to investigate the Time and the Frequency characteristics of the Pulse Amplitude Modulation.

Study the effect of the channel filter (CH1):

To study the effect of any filter, a signal of a specified amplitude and frequency is passed through the filter. Then the output signal of the filter is compared with the original one.

1. Set the function generator to:

Sine wave, Freq = 500 Hz and Vss = 10V

2. Connect the Cassy sensor UA1 to the input message signal.
3. Connect the Cassy sensor UB1 to the output signal of the CH1 filter.
4. Start the measurement. **(Show 5 cycles and take a picture of the output).**

Answer the following question:

What is the gain of the filter at the 500 Hz?

Display the Pulse Amplitude Modulated signal s(t) of PAM1 in the time and frequency domains:

1. Set the function generator to:
    a. Sine wave, Freq = 500 Hz and Vss = 10V
2. Connect the Cassy sensor UA1 to the output signal of the CH1 filter.
3. Connect the Cassy sensor UB1 to the PAM1 output.
4. Start the measurement. **(Show 5 cycles and take a picture of the output).**

Determining the effect of the duty cycle on the PAM in the time domain:

1. Reduce the duty cycle of the clock generator to the min value.
2. Start the measurement. **(Show 5 cycles and take a picture of the output).**

Display the Pulse Amplitude Modulated signal s(t) of PAM1 in the Frequency domain:

3. Use the same connection that was used to study the time domain of PAM1.
4. Set the duty cycle of the clock generator to the max value.
5. Connect Cassy sensor UA1 to the clock generator output.
6. Show the PAM1 output in the frequency domain. **(Choose a suitable measuring time so that the spectrum become clear and take a picture of the output).**

Determining the effect of the message frequency on the PAM in the Freq domain:

1. Change the message frequency to 1kHz and 2kHz respectively
2. For every frequency **(Choose a suitable measuring time so that the spectrum become clear and take a picture of the output).**

Determining the effect of the duty cycle on the PAM in the Freq domain:

1. Set the message frequency back to 500Hz
2. Change the duty cycle of the clock generator to 10% and 30%.
3. For every duty cycle **(Choose a suitable measuring time so that the spectrum become clear and take a picture of the output).**
4. After finishing this part return the duty cycle to 50%.

    Display the Pulse Amplitude Modulated signal s(t) of PAM2 in the time domain:

5. Set the function generator to:

    Sine wave, Freq = 500 Hz and Vss = 10V

6. Connect the Cassy sensor UA1 to the output signal of the CH1 filter.
7. Connect the Cassy sensor UB1 to the PAM2 output.
8. Start the measurement. **(Show 5 cycles and take a picture of the output).**

Determining the effect of the duty cycle on the PAM in the time domain:

9. Reduce the duty cycle of the clock generator to the min value.
10. Start the measurement. **(Show 5 cycles and take a picture of the output).**

Display the Pulse Amplitude Modulated signal s(t) of PAM2 in the Frequency domain:

Use the same connection that was used to study the time domain of PAM2.

1. Set the duty cycle of the clock generator to the max value.
2. Connect Cassy sensor UA1 to the clock generator output.
3. Show the PAM2 output in the frequency domain. **(Choose a suitable measuring time so that the spectrum become clear and take a picture of the output).**

Determining the effect of the message frequency on the PAM in the Freq domain:

4. Change the message frequency to 1kHz and 2kHz
5. For every frequency **(Choose a suitable measuring time so that the spectrum become clear and take a picture of the output).**

Determining the effect of the duty cycle on the PAM in the Freq domain:

6. Set the message frequency back to 500Hz
7. Change the duty cycle of the clock generator to 10% and 30%.
   For every duty cycle **(Choose a suitable measuring time so that the spectrum become clear and take a picture of the output).**
8. After finishing this part return the duty cycle to 50%.

Part 3: Characteristics of Pulse Amplitude Demodulation

Display the message signal and the demodulated signal using PAM1:

1- Set the clock generator frequency to its max value.

2- Set the function generator to:

Sine wave, Freq = 500 Hz and Vss = 10V

3- Connect the Cassy sensor UA1 to the input signal of the CH1 filter.

4- Connect the Cassy sensor UB1 to the output of the demodulator filter of CH1.

5- Start the measurement. **(Show 5 cycles and take a picture of the output).**

Determining the effect of the duty cycle on the PAM in the time domain:

6- Change the duty cycle of the clock generator to 10% and 30% respectively.

7- (Show 5 cycles and take a picture of the output of each duty cycle).

Part 4: Aliasing in the Time and the Frequency Domains

Display the message signal and the demodulated signal using PAM1 in the time domain:

1. Set the clock generator frequency to 5000 Hz.
2. Set the duty cycle to 50%.
3. Set the function generator to:
4. Sine wave, Freq = 3000 Hz and Vss = 5V
5. Connect the Cassy sensor UA1 to the output signal of the CH1 filter.
6. Connect the Cassy sensor UB1 to the PAM1 modulator.
7. Start the measurement. **(Show 5 cycles and take a picture of the output).**
8. Connect the Cassy sensor UB1 to the output of the demodulator filter of CH1.
9. Start the measurement. **(Show 5 cycles and take a picture of the output).**

Display the message and the demodulated signals using PAM1 in the frequency domain:

Use the same message settings that was used to study the time domain of PAM1.

1- Connect the Cassy sensor UA1 to the output of the clock generator.

2- Connect the Cassy sensor UB1 to the PAM1 modulator.

3- Start an FFT measurement. **(Choose a suitable measuring time so that the spectrum become clear and take a picture of the output).**

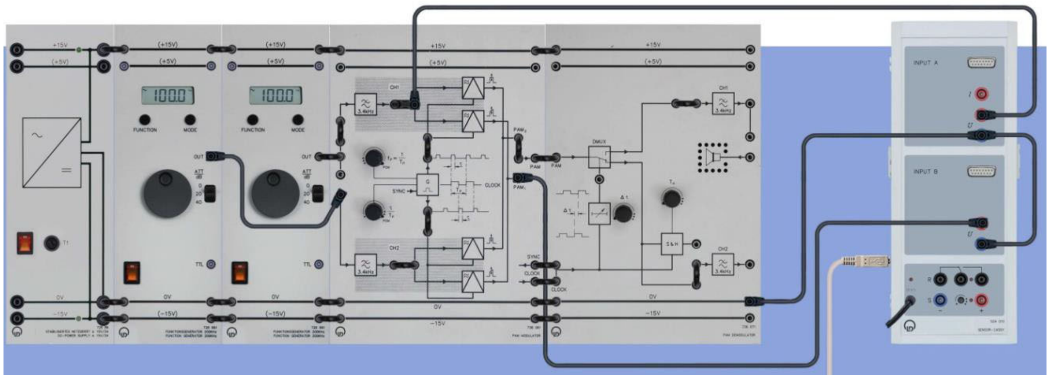
4- Connect the Cassy sensor UB1 to the output of the demodulator filter of CH1.

5- Start the measurement. **(Show 5 cycles and take a picture of the output).**

Part 5: PAM Time Multiplex

The objective of this part is to learn how to transmit and receive two signals over one common channel by using the concept of time division multiplexing.

To carry out this experiment, assemble the components as shown below. (Neglect Sync Pin)



Display the time characteristic of the time multiplex signal.

1- Set the sampling frequency f_P to the max. And the duty cycle to its max value.

2- Set the first function generator to:

Triangle, f_{M1} = 200 Hz, V_{SS} = 5 V

3- Set the second function generator to:

Sine, f_{M2} = 300 Hz, V_{SS} = 10 V.

4- Connect the CASSY sensor UA1 to the triangle message channel CH1.

5- Connect the CASSY sensor UB1 to Output PAM modulator PAM1.

6- Start the measurement by pressing F9. **(Show 5 cycles and take a picture of the output).**

7- Connect the CASSY sensor UA1 to the sine message channel CH1.

8- Start the measurement by pressing F9. **(Show 5 cycles and take a picture of the output).**

9- Connect the CASSY sensor UA1 to the demodulator filter CH1.

10- Connect the CASSY sensor UB1 to the demodulator filter CH2.

Cross Talk (Δt) left/middle

When the system fails to maintain synchronization, cross talk results. Here, a portion of the first message $m_1(t)$, appears at the output designated for the second message signal $m_2(t)$, and vice versa.

1- Keep the same connections of the message signals

2- Observe the effect of cross talk as the phase shift Δt changes in both the time and the frequency domains. **(Show 5 cycles and take a picture of the output). (Choose a suitable measuring time so that the spectrum become clear and take a picture of the output).**

1- Set the first function generator to:

Triangle, f_{M1} = 200 Hz, V_{SS} = 10 V

1- Set the second function generator to:

Sine, f_{M2} = 300 Hz, V_{SS} = 10 V.

Observe the effect of cross talk as the phase shift Δt changes in both the time and the frequency domains. **(Show 5 cycles and take a picture of the output). (Choose a suitable measuring time so that the spectrum become clear and take a picture of the output).**

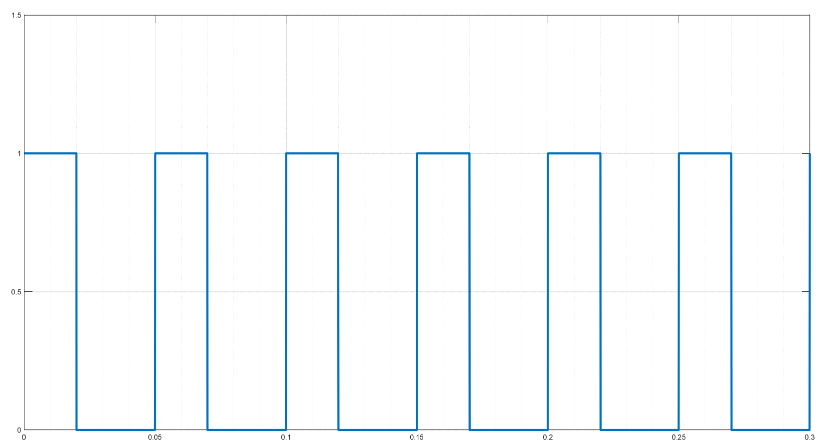
Post-Lab Assignment

Question 1:

1- Find the duty cycle of the clock shown in the figure below.

2- Find the fundamental frequency of the clock.

3- Plot the signal in the frequency domain and determine the zero crossing of the signal.



Question 2:

In a 2-user TDM communication system, two messages are required to be transmitted in the same channel.

$$m_1(t) = 20\,\mathrm{tri}(2000\pi t) \qquad\qquad m_2(t) = 10\,\mathrm{tri}(1000\pi t)$$

A clock generator with duty cycle = 50% was used.

1- Draw the block diagram of the full TDM system showing all the required components.

2- Draw the time domain representation of the PAM signal in the channel.

3- Draw the reconstructed message signals from user No.1 and user No.2.

4- Design the gain of the filter so that the reconstructed message signals will be the same as the original ones.

Experiment #7:

Pulse Code Modulation (Quantizers and Encoders)

Objectives

This experiment transforms the theoretical knowledge of the Characteristics of different types of full system Quantizers (Uniform and Non-uniform) and Encoders. Moreover, it will study the characteristics of the compressor and expander quantizers each alone. And finally, the resolution of each quantization types will be compared.

Pre-Lab Work

Theoretical Prelab:

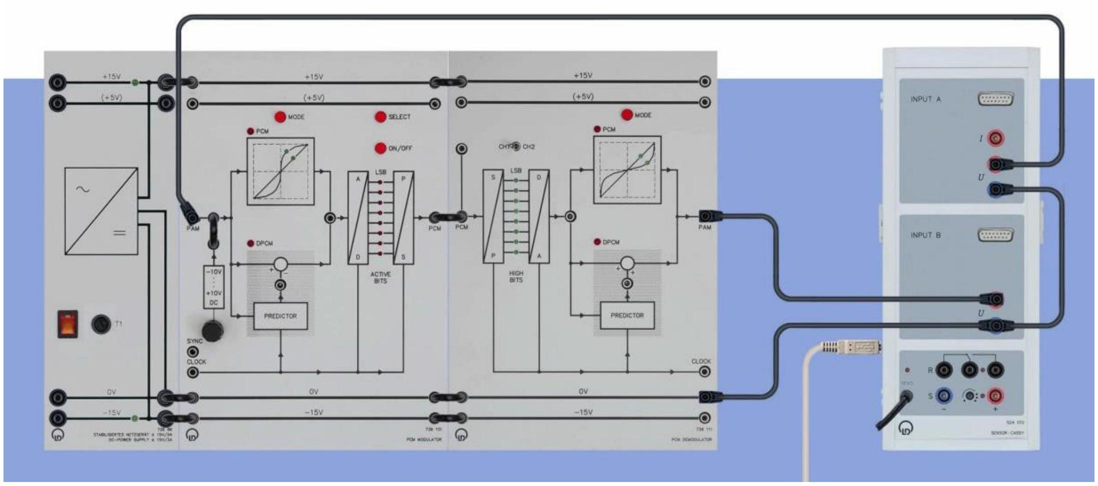
Review the Quantizers characteristics (Uniform and non-uniform (μ-law) in addition to the compressor and expander quantizers. Also, review the Encoding methods (Signed binary, Gray, and Folded Binary)

Procedure

Part One: Linear Quantization: (Characteristic of linear Quantizer with DC input)

The objective of this part is to obtain the **input-output characteristics** of a uniform linear quantizer with a given number of quantization levels $L = 2^8$

To carry out this experiment, assemble the components as shown below.



1. Set both the PCM modulator and PCM demodulator Panels to: linear quantization.
2. Activate all A/D converter 8-bits.
3. At the PCM modulator input, set the variable DC voltage to -10V.
4. Load the CASSY Lab 2 example Quant.labx.

5. Slowly turn-up the potentiometer knob increasing the input DC voltage.
6. Note that the input voltage is slowly rising from –10 V to +10 V. This input voltage is displayed as voltage UA1. The output voltage (after quantization) is displayed as voltage UB1.
7. After recording the quantization characteristics; stop the measurement by pressing F9.

   Take a picture of the characteristic curve.

Part Two: Non-linear Quantization: (Characteristic of Non- linear Quantizer with DC input)

The objective of this part is to generate the **input-output characteristics** of a non-uniform with a given number of quantization levels $L=2^8$)

1. Keep the connection the same as it was used in the first part.
2. Set both the PCM modulator and PCM demodulator Panels to: Non-linear quantization.
3. Repeat the measurement as mentioned in Part 1 (i.e., by slowly rising the potentiometer voltage from –10 V to +10 V and observing the resulting output voltage).

   Take a picture of the characteristic curve.

Part Three: Compressor / Expander characteristic

The objective of this part is to obtain both the characteristic of the compressor at the transmitting side and the expander at the receiving side.

Keep the connection the same as it was used in the first part.

Compressor Characteristics

1. To investigate the Compressor characteristic, set the PCM modulator Panel to Non-linear Quantization and the PCM demodulator panel to Linear Quantization.
2. Repeat the measurement as mentioned in Part 1 (i.e., by slowly rising the potentiometer voltage from –10 V to +10 V and observing the resulting output voltage).

   Take a picture of the characteristic curve.

Expander Characteristics

3. To investigate the Expander characteristic, set the PCM modulator Panel to Linear Quantization and the PCM demodulator panel to Non-linear Quantization.
4. Repeat the measurement as mentioned in Part 1 (i.e., by slowly rising the potentiometer voltage from –10 V to +10 V and observing the resulting output voltage).

   Take a picture of the characteristic curve.

Part Four: Quantizer Resolution for both linear and non-linear quantizer

The objective of this part is to observe the effect of **reducing the number of bits** needed to represent each quantized sample on the characteristic of both the linear and the non-linear quantizer)

1. Reduce the resolution from 8 to 5 bits: For this deactivate the three least significant bits (**LSB**) of the PCM modulator.
2. Keep the connection the same as it was used in the first part.

Linear – Linear Quantizer:

3. Set both the PCM modulator and PCM demodulator Panels to: Linear quantization.
4. Repeat the measurement as mentioned in Part 1 (i.e., by slowly rising the potentiometer voltage from –10 V to +10 V and observing the resulting output voltage).

   Take a picture of the characteristic curve.

   Discuss the difference between the 8-bit and the 5-bit coder.

Non-Linear – Non-Linear Quantizer:

5. Set both the PCM modulator and PCM demodulator Panels to: Non-Linear quantization.
6. Repeat the measurement as mentioned in Part 1 (i.e., by slowly rising the potentiometer voltage from –10 V to +10 V and observing the resulting output voltage).

   Take a picture of the characteristic curve.

   Discuss the difference between the 8-bit and the 5-bit coder.

Non-Linear – Linear Quantizer:

7. Set the PCM modulator panel to Linear and PCM demodulator panel to Non-Linear quantization.
8. Repeat the measurement as mentioned in Part 1 (i.e., by slowly rising the potentiometer voltage from –10 V to +10 V and observing the resulting output voltage).

   Take a picture of the characteristic curve.

   Discuss the difference between the 8-bit and the 5-bit coder.

Linear – Non-Linear Quantizer:

9. Repeat the same steps as before while changing the PCM modulator panel to Non-Linear and PCM demodulator panel to Linear quantization.

Part Five: Encoding

In this part you will be required to obtain the representation levels of the linear quantizer and the binary representation corresponding to the various levels.

1. Keep the connection the same as it was used in the first part.
2. Set both the PCM modulator and PCM demodulator Panels to: linear quantization.
3. Activate all bits (i.e.: 8 bits).
4. Activate CH2 in the demodulator encoder.
5. Load the CASSY Lab 2 example Code.labx.

Note: For this part, only instantaneous recorder windows of (UA1 & UB1) are used to compare corresponding input and output voltages. (i.e.: do not close recorder windows as no plots will be required)

6. Repeat the measurement as mentioned in Part 1 (i.e., by slowly rising the potentiometer voltage from –10 V to +10 V and observing the resulting output voltage).
7. Vary the DC voltage UA1 with the potentiometer knob recording the values in a table. Note the **output voltage UB1** of the PCM demodulator **and** the **corresponding bit pattern** (green LEDs i.e.: 110...01 etc.). [Record consecutive values for bit pattern changes]

Input voltage (UA1)	Output Voltage (UB1)	Bit pattern
-9 V		
-7 V		
-5 V		
-3 V		
-1 V		
0 V		
1 V		
3 V		
5 V		
7 V		
9 V		

Explain the bits functionality to indicate polarity. What encoding technique is used?

Post-Lab Assignment

Question 1: Fill the blanks

9- How many bits are required for a 46-level quantizer? _____________.

10- Increasing the number of bits of a uniform quantizer results in _____________ the resolution of the quantizer. (Increasing or decreasing or not affecting).

11- In non-uniform companding quantizer, the product of the compressed values with the expanded values is _______________.

12- To improve the quantization process (reduce the quantization error), we can increase the _______________.

13- In non-uniform companding quantizer, to study the characteristic of the expander, the compressor characteristic is chosen to be ______________.

14- We need 5 bits to make a quantizer with 35 quantization levels. True or false?

Question 2: A DC message signal with amplitude varies from -2V to 2V is quantized by a 3-level uniform quantizer. Draw the output of the approximate quantization process

Experiment #8:

Pulse Code Modulation (Part 2)

Objectives

This experiment studies a full digital multiplexing system consisting from PAM and PCM. Moreover, it studies the Quantization Noise for triangle and sinusoidal signals. Finally, it introduces enhanced PCM modulation technique called Difference Pulse Code Modulation (DPCM)

Pre-Lab Work

Theoretical Prelab:

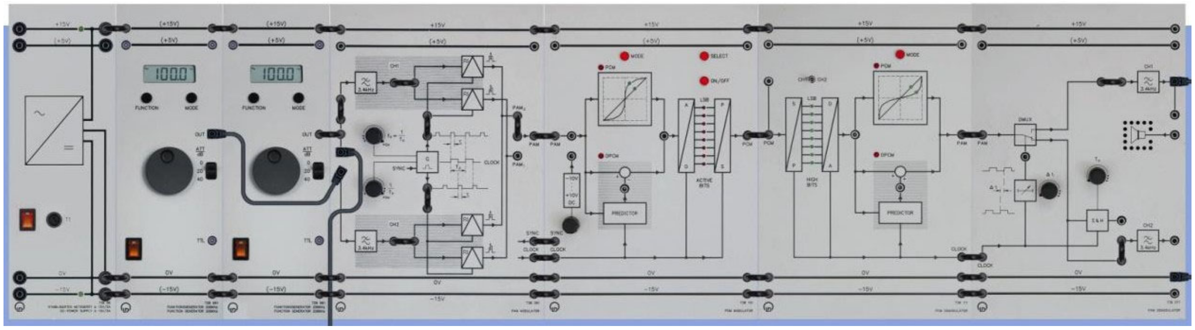
Review the PAM (Sampling) and the PCM from the past two experiments. Also, review the Difference Pulse Code modulation.

Procedure

Part One: PCM Transmission with TDM

In this part of the experiment, you will be required to transmit **sampled, quantized, and binary encoded data** of two analog signals over one communication channel using the concept of time division multiplexing.

To carry out this experiment, assemble the components as shown below.



1. Connect CASSY UA1 to Input PAM **Modulator** CH1.
2. Connect CASSY UB1 to Output PAM **Demodulator** CH1.
3. set the PCM modulator and demodulator panels to **linear** quantization.
4. Activate all the coded bits.

For the **PAM Modulator**:

5. Set the duty cycle of the clock generator (Sampler) to the max.
6. Set the sampling frequency of the clock generator to the min.
7. Set Function generator 1: Sine, f_{m1} = 300 Hz, V_{SS} = 10 V.
8. Set Function generator 2: Triangle, f_{m2} = 200 Hz, V_{SS} = 5 V.

For the **PAM Demodulator**:

9. Set the time shift knob Δt to the Min (Anticlockwise).
10. Start the measurement by pressing F9.

Take a picture for 5 cycles.

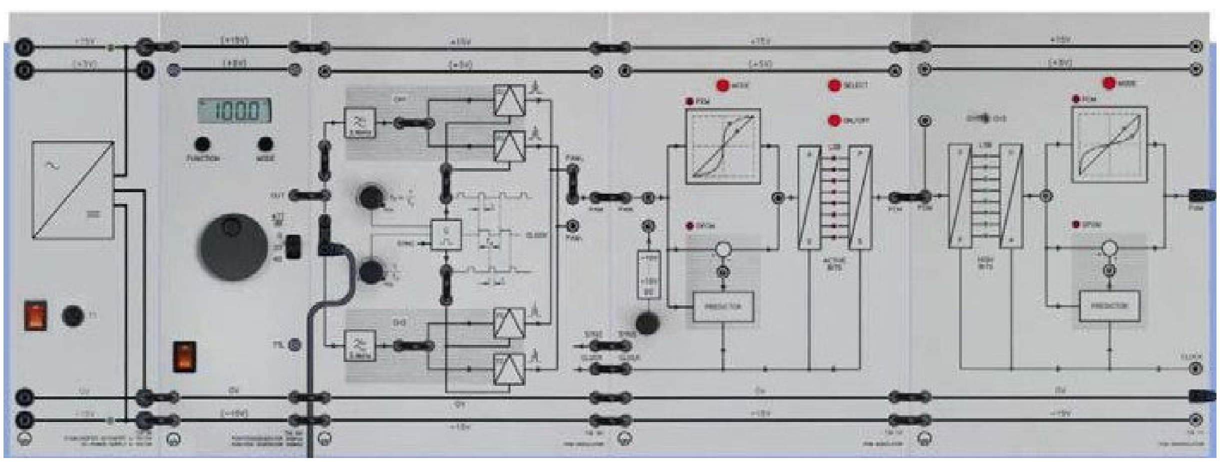
11. Connect the CASSY UA1 to Input PAM Modulator CH2.
12. Connect the CASSY UB1 to Output PAM Demodulator CH2.
13. Start the measurement by pressing F9.

Discuss whether the quantization process and digital data transmission still provided proper communication schemes to recover both the message signals over TDM.

Part Two: Quantization Noise

Section 2.1: Triangle Signal

To carry out this experiment, assemble the components as shown below.



1. Connect **both** channels (CH1 and CH2) of the PAM Modulator with one function generator.

   Function generator: **Triangle**, f_m = 30 Hz, V_{SS} = 12 V.

2. This is done to avoid the time gaps at the output of the PCM demodulator. **This can be seen by disconnecting one of the inputs of the PAM modulator and see the result.**
3. Set the PCM modulator and demodulator to linear quantization.
4. Activate all bits.

5. Connect the CASSY UA1 to the Input PAM Modulator CH2.
6. Connect the CASSY UB1 to the Output PCM Demodulator CH2.
7. Load the CASSY Lab 2 example QNoise.labx.
8. Start the measurement by pressing F9.
9. Sketch the measurement and give an interpretation. (Notice there are three plots whereas only two inputs where measured)
10. Repeat the measurement for a resolution of 5 bits. (**Deactivate the least significant 3 bits**)
11. Repeat the measurement for a resolution of 5 bits for:

Triangle, f_m = 300 Hz, V_{SS} = 12 V.

Discuss the effect of changing both the resolution and the message frequency over the quantization process and the quality of the demodulated signal.

Section 2.2 Sinusoidal Signal

Repeat the same procedure of Part II but use a sinusoidal modulating signal. This results in a more complicated structure of the quantization noise. Procedure of Part II using non-linear quantization.

1. Connect **both** channels (CH1 and CH2) of the PAM Modulator with one function generator.

Function generator: **Sine**: f_m = 30 Hz, V_{SS} = 12 V.

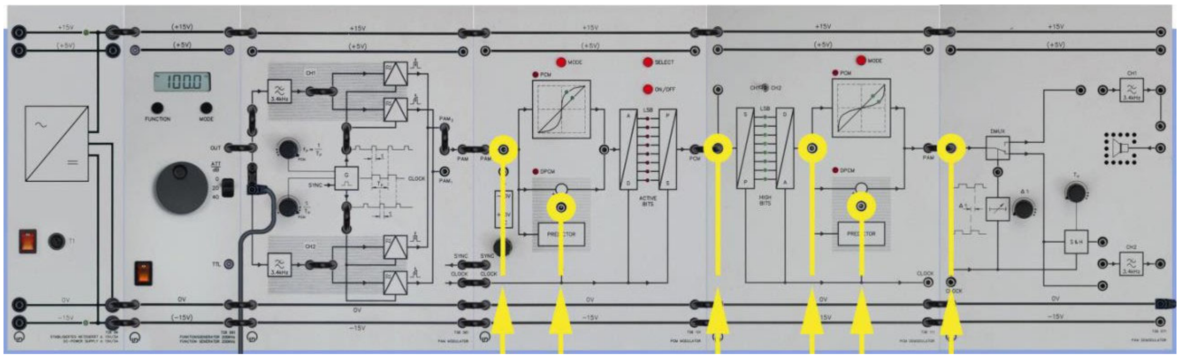
2. Set the PCM modulator and demodulator to Non-linear quantization.
3. Activate all bits.
4. Connect the CASSY UA1 to the Input PAM Modulator CH2.
5. Connect the CASSY UB1 to the Output PCM Demodulator CH2.
6. Load the CASSY Lab 2 example QNoise.labx.
7. Start the measurement by pressing F9.
8. Sketch the measurement and give an interpretation. (Notice there are three plots whereas only two inputs where measured)
9. Repeat the measurement for a resolution of 5 bits. (**Deactivate the least significant 3 bits**)
10. Repeat the measurement for a resolution of 5 bits for:

Sine: f_m = 300 Hz, V_{SS} = 12 V.

Discuss the effect of changing both the resolution and the message frequency over the quantization process and the quality of the demodulated signal.

Part Three: Difference Pulse Code Modulation (DPCM)

DPCM: is a redundancy reducing method. Here, the difference between the signal and a predicted value of the signal (provided by the predictor element) is transmitted by the system. At the start of the transmission, it is important that the predictors in the PCM modulator and in the PCM demodulator start from the same prediction value.



To carry out this experiment, assemble the components as shown above. Since the two systems cannot be switched on simultaneously, the following **switch-on sequence** has to be adhered to:

1. Connect the PAM input of the PCM modulator to 0 V.
2. Switch the PCM modulator to DPCM mode.
3. Switch the PCM demodulator to the DPCM mode.**(Should be carried out at the same instant)**
4. Drop the amplitude of the modulation signal to 0 V (on the function generator).
5. Disconnect the PAM input of the PCM modulator from 0 V, then Feed the sampled signal into the PCM modulator and reset to the desired amplitude. **(Increase the Vss gradually 0~12 V)**
6. Connect the channel UA1 of the CASSY with the input signal of the PAM modulator
7. Connect the channel UB1 of the CASSY to take:
    1. Predictor of the DPCM modulator
    2. Output of the DPCM modulator
    3. Input of the DPCM demodulator
    4. Predictor of the DPCM demodulator
    5. PAM output of the DPCM demodulator
8. Repeat all measurement for a following resolution below 4 bits); by deactivating the indicated bits “--”

LSB							MSB
ON	ON	ON	--	--	--	--	ON

9. Note: The switch-on sequence has to be performed every time before selecting the ACTIVE BITS. Afterwards the signal amplitude can be enhanced again.
10. Discuss the effect of reducing the number of bits used on the detection resolu

Post Lab Assignment:

Question 1: In a 2-user TDM communication system, two messages are required to be transmitted in the same channel.

$$m_1(t) = 20\,\text{tri}(2000\pi t) \qquad\qquad m_2(t) = 10\,\text{tri}(1000\pi t)$$

A clock generator with duty cycle = 50% was used.

f- Draw the block diagram of the full TDM system showing all the required components.

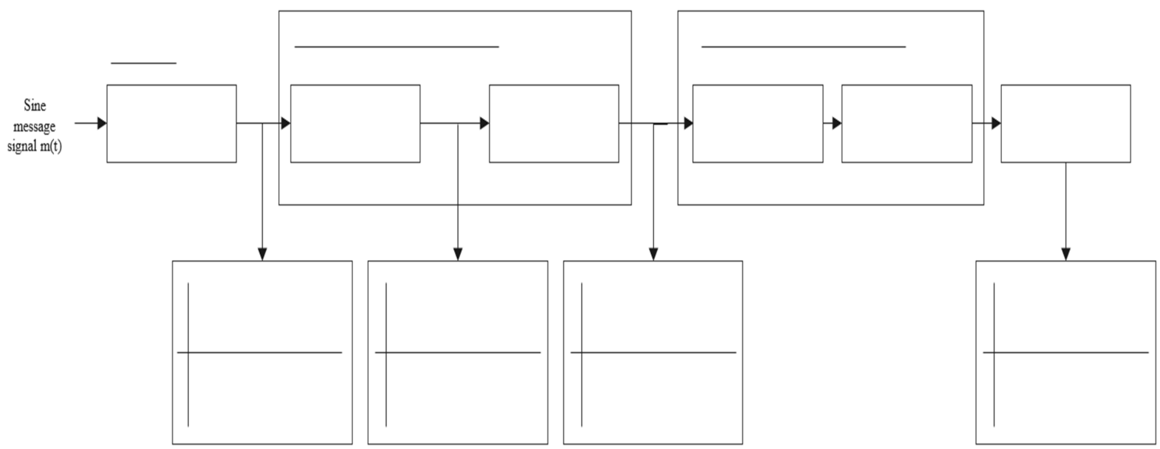
g- Draw the time domain representation of the PAM signal in the channel.

h- Draw the reconstructed message signals from user No.1 and user No.2.

i- Design the gain of the filter so that the reconstructed message signals will be the same as the original ones.

Question 2: Fill the spaces in the figures below

Digital Communication System:



Experiment #9:

Delta Modulation (Linear & DCDM)

Objectives

To study two types of Delta-Modulational and demodulation and compare them to sow the power points of each one.

Pre-Lab Work

Theoretical Prelab:

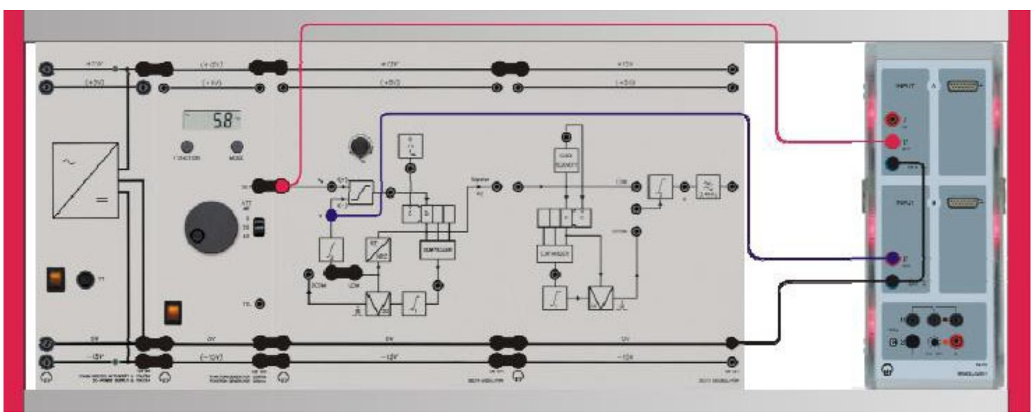
Review the theoretical background of the Delta Modulation and Demodulation in addition to the coding techniques

Procedure

Part 1: Prediction signals in Linear delta modulation (LDM)

The objective of this part is to compare the original message signal with the predicted signal for the Linear Delta Modulation.

Assemble the components as shown below.



1. Set the Clock frequency f_{Clock} = 100 kHz (max)
2. Set the function generator to: Sine, f_m = 100 Hz, V_{SS} = 1 V.
3. Set the bridging plug to LDM (at the input of $\int_2$) [Use wire instead of the plug]
4. Connect the CASSY Sensor UA1 to the modulating signal $S_m(t)$
5. Connect the CASSY Sensor UB1 to the prediction signal X(t) (at the output of $\int_2$)
6. Start the measurement by pressing F9.
7. Reduce the clock frequency gradually to Clock frequency f_{Clock} = 10 kHz (min)
8. Repeat the measurement.

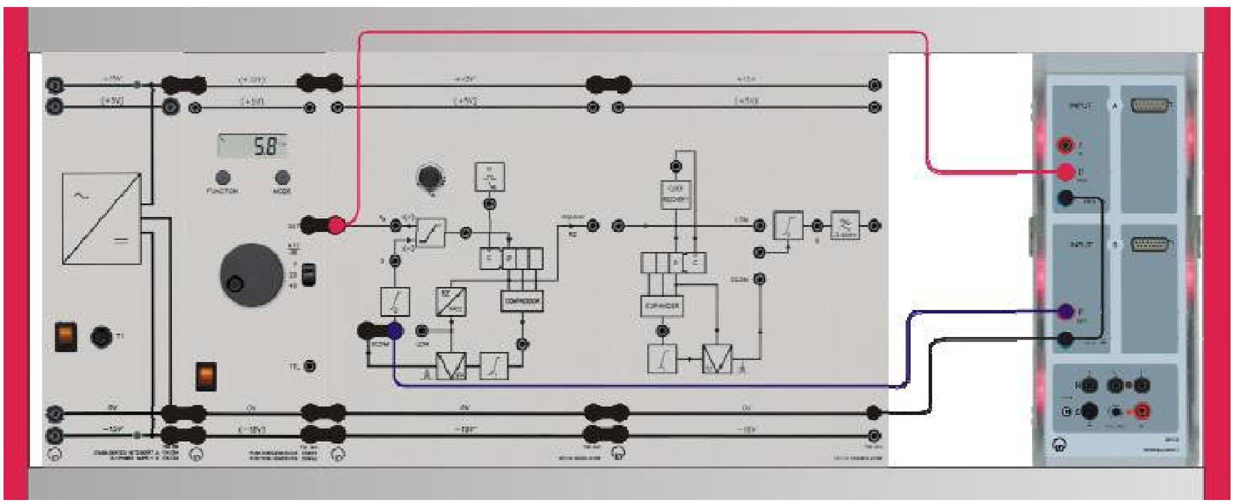
Part 2: Prediction signals in Digital Controlled Delta Modulation (DCDM)

The objective of this part is to compare the original message signal with the predicted signal for the Digital Controlled Delta Modulator.

1. Use the same setup from part one
2. Set the bridging plug to DCDM (at the input of $\int_2$)
3. Repeat the same measurements as in part 1.

Part 3: Pulse height in LDM

To carry out this experiment, assemble the components as shown below.



1. Set the Clock frequency f_{Clock} = 50 kHz (Approx. slightly to the right of the midpoint)
2. Set the function generator to Sine, f_m = 100 Hz, V_{SS} = 1 V.
3. Set the bridging plug to LDM (at the input of $\int 2$)

   Note: To obtain a proper measurement of the delta (increment/ decrement) contributing in X(t), during each clock period; the input of the accumulating integrator must be measured (at the input of $\int_2$). [Notice the pulse amplitude]

4. Connect the CASSY Sensor UA1 to the modulating signal $S_m(t)$
5. Connect the CASSY Sensor UB1 to the LDM signal (at the input of $\int_2$)
6. Start the measurement by pressing F9.
7. Change gradually V_{SS} in step of 1V to 7V.

What is the consequence of increasing V_{SS} over the output of the LDM (the input of $\int_2$)?

8. Connect the CASSY Sensor UB1 to the prediction signal *X(t)* (at the output of the $\int_2$)
9. Repeat step 7.

What is the consequence of increasing V_{SS} over the predicted signal X(t) (the output of $\int_2$)?

10. Append to the previous measurement.

Part 4: Pulse height in DCDM

1. Use the same setup from part three
2. Set the bridging plug to DCDM (at the input of $\int_2$)
3. Repeat the same measurements as in part 3.

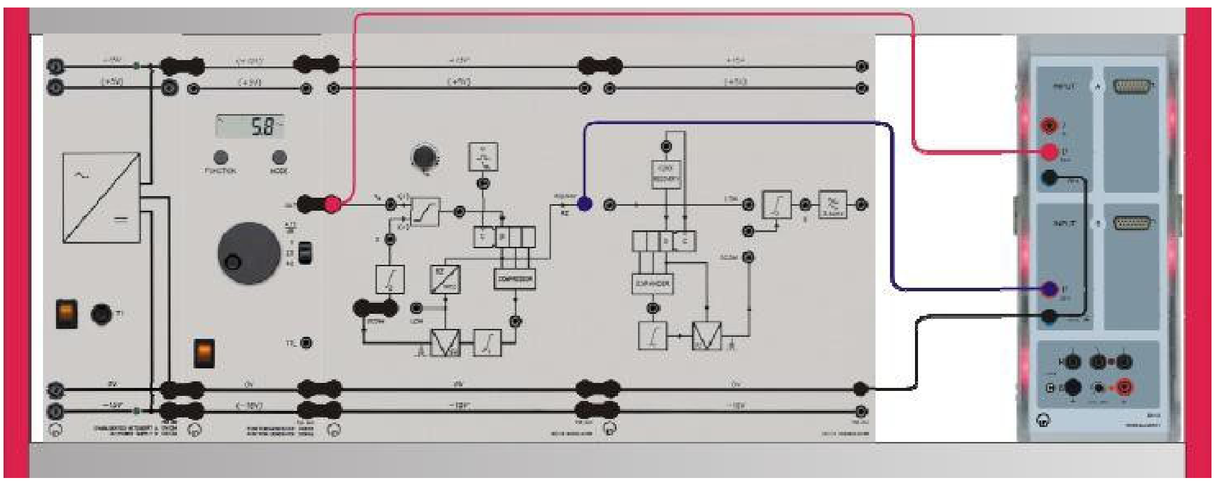
Is the pulse height dependent/independent on $S_m(t)$?

What is the relation between the pulse height of the DCDM output (the input of $\int_2$) with the amplitude of $S_m(t)$?

Part 5: Output signals of the LDM modulator (RZ/NRZ)

The objective of this part is to find the type of signals used to represent the modulated delta signal and the signal used in the feedback path to generate the prediction.

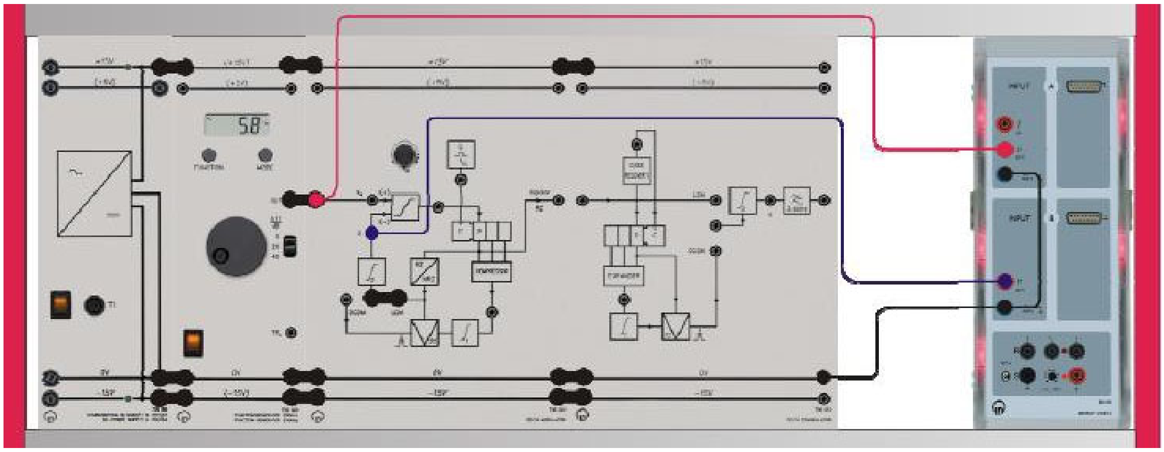
To carry out this experiment, assemble the components as shown below.



1. Set the Clock frequency f_{Clock} = 10 kHz (min)
2. Set the function generator to Sine, f_m = 100 Hz, V_{SS} = 1 V.
3. Set the bridging plug to LDM (at the input of $\int_2$)
4. Connect the CASSY Sensor UA1 to the LDM signal (at the input of $\int_2$)
5. Connect the CASSY Sensor UB1 to the DM signal at the output of DM modulator (bipolar, RZ)
6. Start the measurement by pressing F9.

Part 6: Granular noise in LDM

To carry out this experiment, assemble the components as shown below.



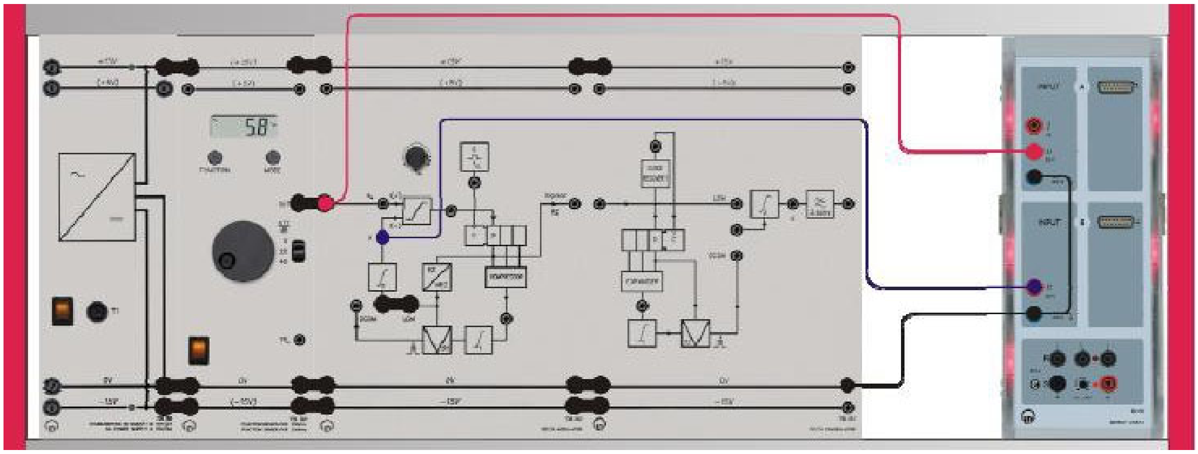
1. Set the Clock frequency f_{Clock} = 10 kHz (min)
2. Set the function generator to Pulse train, fM = 200 Hz, V_{SS} = 2 V, d% = 50
3. Set the bridging plug to LDM (at the input of $\int_2$)
4. Connect the CASSY Sensor UA1 to the modulating signal $S_m(t)$
5. Connect the CASSY Sensor UB1 to the prediction signal X(t) (at the output of $\int_2$)
6. Start the measurement by pressing F9.
7. Repeat the experiment for f_{Clock} = 100 kHz (max).
8. Remove the bridging plug between the function generator and the input ofthe delta modulator.
9. Connect the input of the delta modulator to ground.
10. Repeat the measurements for f_{Clock} = 10 kHz (min) and f_{Clock} = 100 kHz (max).

Part 7: Granular noise in DCDM

1. Use the same setup from part nine
2. Set the Clock frequency f_{Clock} = 10 kHz (min)
3. Set the function generator to Pulse train, fM = 200 Hz, V_{SS} = 2 V, d% = 50
4. Set the bridging plug to DCDM (at the input of $\int$2)
5. Repeat all the measurements as in part nine.

Part 8: Slope-overload in LDM

To carry out this experiment, assemble the components as shown below.



1. Set the Clock frequency f_{Clock} = 100 kHz (Max)
2. Set the function generator to Sine, f_m = 100 Hz, V_{SS} = 4 V.
3. Set the bridging plug to LDM (at the input of ∫2)
4. Connect the CASSY Sensor UA1 to the modulating signal $S_m(t)$
5. Connect the CASSY Sensor UB1 to the prediction signal X(t) (at the output of ∫2)
6. Start the measurement by pressing F9.
7. Set the function generator to Pulse train, f_m = 100 Hz, V_{SS} = 4 V, d% = 50
8. Repeat the measurement
9. Set the function generator to Pulse train, f_m = 300 Hz, V_{SS} = 4 V, d% = 50
10. Repeat the measurement

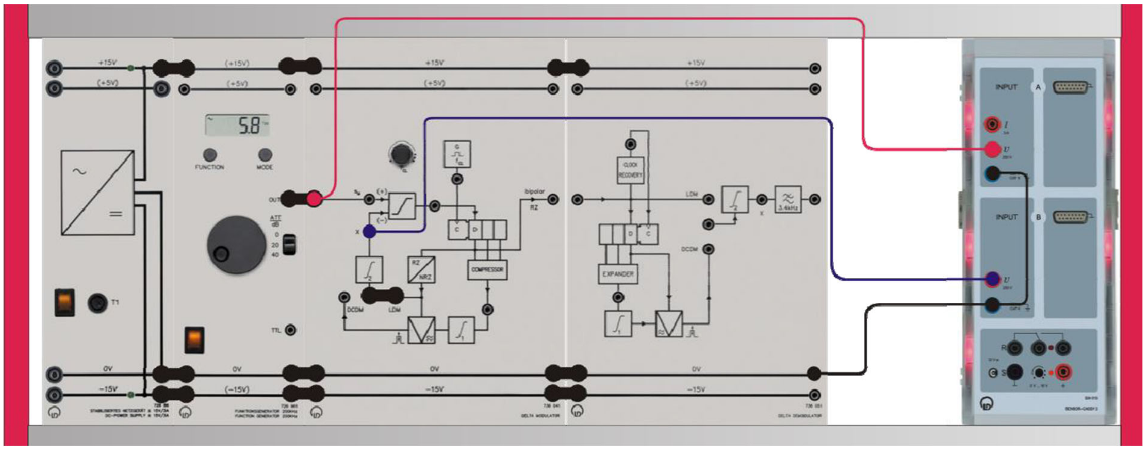
Part 9: Slope overload in DCDM

1. Use the same setup from part eleven but increase Vss to 9V.
2. Set the bridging plug to DCDM (at the input of ∫2)
3. Repeat all the measurements as in part eleven.

Part 10: Dynamic of LDM and DCDM

In this part, you will be required to determine the maximum value of the input voltage (for a given frequency) below which slope overload can be avoided for the LDM.

To carry out this experiment, assemble the components as shown below.



1. Set the Clock frequency f_{Clock} = 100 kHz (max)
2. Set the function generator to: Sine, f_m = 100 Hz, V_{SS} = 1 V.
3. Set the bridging plug to LDM (at the input of $\int_2$)
4. Connect the CASSY Sensor UA1 to the modulating signal $S_m(t)$
5. Connect the CASSY Sensor UB1 to the prediction signal X(t) (at the output of $\int_2$)
6. Start the measurement by pressing F9.
7. Change V_{SS} until the prediction signal *X(t)* shows the beginning of the slope overload. This value is denoted as $\boldsymbol{A_{max}}$ (Record it in Table 1).
8. Repeat the measurements for the frequency of $S_m(t)$ signal of 200, 300, 400, 500, 1000, 1500, 2000 Hz.

Frequency (Hz)	100	200	300	400	500	1000	1500	2000
A_{max} for LDM								

Calculate the dynamic D.

$$D = 20 \log\left(\frac{A_{max}}{A_{min}}\right) dB$$

Note: For $\boldsymbol{A_{Mmin}}$ use the value for granular noise (Assume constant = 20m Vpp).

9. Change the bridging plug to DCDM (at the input of ∫2).
10. Reduce Vss to 1V.
11. Change Vss until the prediction signal *X(t)* shows the beginning of the slope overload. This value is denoted as $\boldsymbol{A_{max}}$ (Record it in Table 2).
12. Repeat the measurements for the frequency of $S_m(t)$ signal of 200, 300, 400, 500, 1000, 2000, 3000 Hz.

Frequency (Hz)	100	200	300	400	500	1000	1500	2000
A_{max} for DCDM								

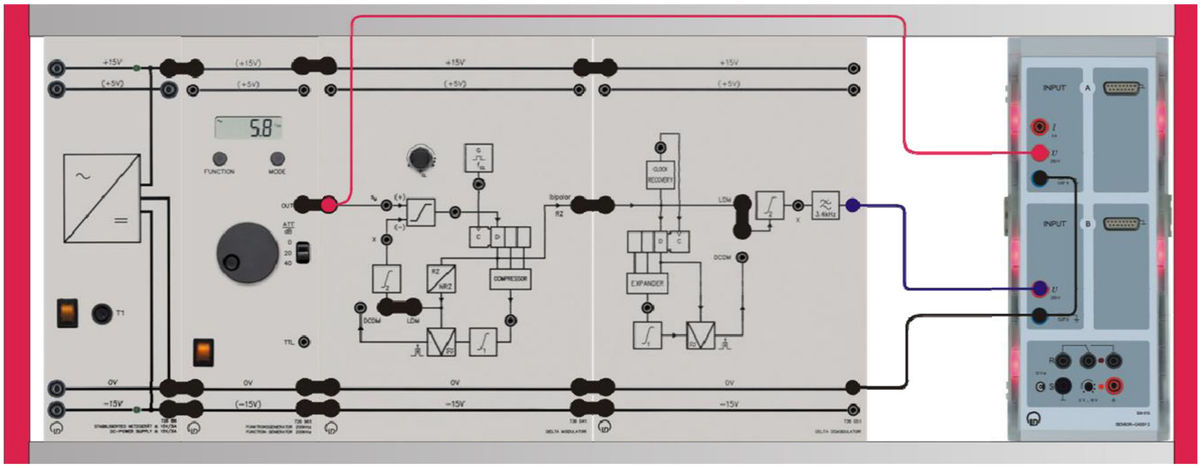
Calculate the dynamic D.

What conclusions can you make with regard to the performance and dynamic response of both types of delta modulation.

Plot: D Vs. fm for LDM & DCDM

Part 11: Demodulation (LDM/DCDM)

To carry out this experiment, assemble the components as shown below.



LDM:

1. Set the Clock frequency f_{Clock} = 100 kHz (max)
2. Set the function generator to: Sine, f_m = 100 Hz, V_{SS} = 4 V.
3. Set the bridging plug to LDM (at the input of $\int_2$) in the modulator and the demodulator.
4. Connect the CASSY Sensor UA1 to the modulating signal $S_m(t)$ at the input of the DM modulator
5. Connect the CASSY Sensor UB1 to the demodulated signal $S_D(t)$ at the output of the DM demodulator
6. Start the measurement by pressing F9.
7. Set the function generator to: Pulse train, f_m=100Hz, V_{SS}=4 d=50%.
8. Start the measurement by pressing F9.
9. Change the frequency to 300Hz and repeat.

Note: Demodulation distortion can be displayed better with this signal.

DCDM:

10. Repeat the same steps as in LDM but this time set the bridging plug to DCDM (at the input of $\int_2$) in the modulator and the demodulator.
11. Start the measurement by pressing F9.

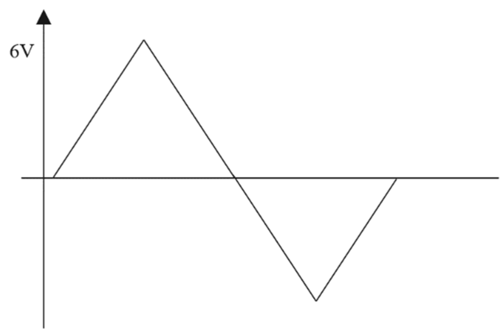
Post Lab Assignment:

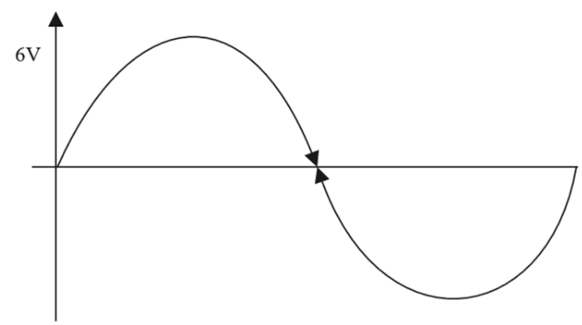
Q1: Fill the blanks:

What are the two types of distortion occurred in Delta Modulation? ______________________ and __________________________.

Q2: Find a formula that relates the maximum step size of the delta modulation with the amplitude of a sinusoidal signal message signal.

Draw the output of a DCDM compressor if the dynamic range of the DCDM.





Digital Communication

Experiment #10:

Amplitude Shift Keying (ASK)

Objectives

The objective of this experiment is to introduce the Amplitude shift keying. Two keying methods will be presented the Hard and the Soft keying. Moreover, the modulation index effect will be shown and interpreted in this experiment. The study will be for both domains the time and the frequency.

Pre-Lab Work

Theoretical Prelab:

Review the theoretical background of the Amplitude shift keying. Moreover, try to investigate the difference between the hard and soft keying.

Software Prelab:

Build a full system that describes all the parts of this experiment using Matlab Simulink. Starting from generating the square wave and modulate it in hard keying method, plot the results (message, carrier and modulated signal) in both time and frequency domains. Until building the coherent demodulation of the ASK, also, plot the results of the demodulated signal in both the time and the frequency domains. ***Write your observation and conclusions in all results.***

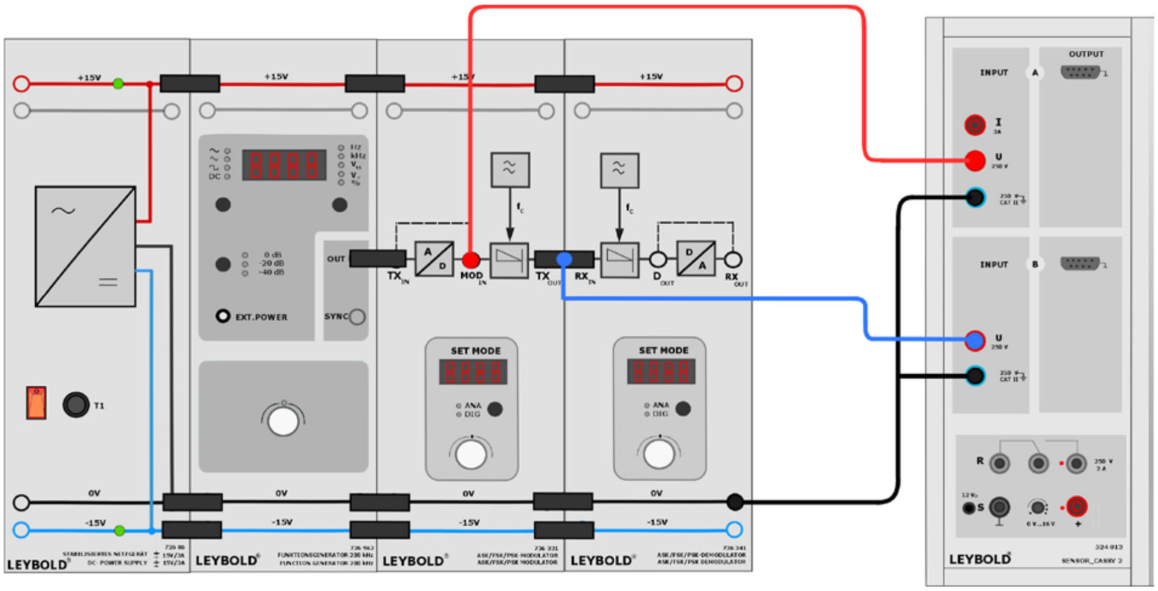
Use sinusoidal signal: $\boldsymbol{c(t) = Cos(2\pi(20k)t)}$

Procedure

Part 1: Amplitude shift keying Modulation (Time domain)

Hard keying:

Assemble the components as shown in the figure below:



1. Set the function generator to:

   Square wave, Freq = 1000 Hz, Vss = 10V, duty-cycle = 50%

2. Set the modulator mode to Digital (DIG).
3. Select Amplitude shift keying – Hard keying with modulation index m = 100% (A_11).
4. Connect the Cassy sensor UA1 to the modulating signal.
5. Connect the Cassy sensor UB1 to the Unipolar square-wave signal at socket MOD_{IN}.
6. Start the measurement. **(Show 5 cycles and take a picture of the output).**
7. Connect the Cassy sensor UA1 to the Unipolar square-wave signal at socket MOD_{IN}.
8. Connect the Cassy sensor UB1 to the ASK signal at the output TX_{OUT} of the modulator.
9. Start the measurement. **(Show 5 cycles and take a picture of the output).**

Write your observations:

____

____

10. Repeat the previous part but this time select the Amplitude shift keying - Hard keying with modulation index m = 50% (A_21).
11. Start the measurement. **(Show 5 cycles and take a picture of the output).**

Write your observations:

What is the coding method that is used in the experiment system? circle the correct answer.

- Unipolar NRZ
- Unipolar RZ
- Manchester Code
- Bipolar NRZ
- Bipolar RZ

Soft keying:

Keep the connection as it was assembled for the hard keying part.

1. Repeat the same procedures but this time select the Amplitude shift keying - Soft keying with modulation index m = 100% (A_12).
2. Start the measurement. **(Show 5 cycles and take a picture of the output).**

Write your observations:

____

____

3. Finally, select the Amplitude shift keying - Soft keying with modulation index m = 50% (A_22) and repeat the same procedure.
4. Start the measurement. **(Show 5 cycles and take a picture of the output).**

Write your observations:

____

Is there any similarities between the amplitude modulation and the amplitude shift keying?

____

____

What do you expect the differences between the hard and soft keying techniques can be?

Feature	Hard	Soft
Bandwidth		

Detecting the comparator threshold:

In this part we are going to find the two thresholds (Upper and lower) that switch the ASK signal from the first amplitude (High) to the other (low).

1. Keep the same connection as it was used for the previous parts.
2. Set the function generator to:

   DC signal, $V_{=}$ = 0V

3. Select Amplitude shift keying – Hard keying with modulation index m = 100% (A_11).
4. Start the measurement and slowly increase the DC value until the high level of the ASK signal appears. **(Take a picture of the output).**

DC upper threshold value: ______________

5. Now reduce the value from 2.5V until the low level (zero volt) appears on the ASK output signal. **(Take a picture of the output).**

DC lower threshold value: ______________

Write your observations:

____

____

____

Part 2: Amplitude shift keying Modulation (Frequency domain)

This part studies the modulation of the ASK signal from the spectrum point of view.

In this section set the Cassy Lab in FFT mode. To do this go to:

Settings > Calculator > FFT > choose input channel (FFT of)

1. Keep the same connection as it was used for the previous parts.
2. Connect the Cassy sensor UA1 to the ASK signal at the output TX_{OUT} of the modulator.
3. Set the function generator to:

   Square wave, Freq = 1000 Hz, Vss = 10V, duty-cycle = 50%

Hard keying:

4. Select Amplitude shift keying – Hard keying with modulation index m = 100% (A_11).
5. Plot the ASK signal spectrum using the Cassy Lab then **take a picture** of the impulses. (Adjust the x-axis range to be suitable for the plot).

Write your observations about the carrier and the behavior and separation of the spectrum impulses:

____

____

____

6. Repeat the previous part but this time select the Amplitude shift keying - Hard keying with modulation index m = 50% (A_21).
7. Plot the ASK signal spectrum using the Cassy Lab then **take a picture** of the impulses. (Adjust the x-axis range to be suitable for the plot).

Write your observations about the carrier and the behavior of the spectrum impulses:

____

How is the amplitude of the side impulses affected by changing the modulation index value? Is there a relation between them?

____

____

____

Soft keying:

Keep the connection as it was assembled for the hard keying part.

1. Repeat the same procedures but this time select the Amplitude shift keying - Soft keying with modulation index m = 100% (A_12).
2. Plot the ASK signal spectrum using the Cassy Lab then **take a picture** of the impulses. (Adjust the x-axis range to be suitable for the plot).

Write your observations about the carrier and the behavior of the spectrum impulses:

____

3. Finally, select the Amplitude shift keying - soft keying with modulation index m = 50% (A_22) and repeat the same procedure.
4. Plot the ASK signal spectrum using the Cassy Lab then **take a picture** of the impulses. (Adjust the x-axis range to be suitable for the plot).

Write your observations about the carrier and the behavior of the spectrum impulses:

____

Compare between the Ask hard and soft keying modulation spectrum from the bandwidth view. Interpret the results scientifically.

____

____

____

____

Studying the effect of changing the message signal amplitude (Time and frequency domains):

1. Keep the same connection as the previous parts.
2. Reduce the message signal amplitude to 1.5V (Vss = 3V).
3. Plot the ASK signal spectrum using the Cassy Lab then **take a picture** of the impulses. (Adjust the x-axis range to be suitable for the plot).

Write your observations about how the message amplitude affects the ASK spectrum.

____

____

Studying the effect of changing the message signal frequency on (Time and frequency domains):

1. Keep the same connection as the previous parts.
2. Set the function generator to:

   Square wave, Freq = 500 Hz, Vss = 10V, duty-cycle = 50%
3. Connect the Cassy sensor UA1 to the Unipolar square-wave signal at socket MOD_{IN}.
4. Connect the Cassy sensor UB1 to the ASK signal at the output TX_{OUT} of the modulator.
5. Plot the ASK signal spectrum using the Cassy Lab then **take a picture** of the impulses. (Adjust the x-axis range to be suitable for the plot).

Write your observations about how the message frequency affects the ASK spectrum.

____

____

Studying the effect of changing the message signal duty cycle (Time and frequency domains):

1. Keep the same connection as the previous part.
2. Set the function generator to:

   Square wave, Freq = 1000 Hz, Vss = 10V, duty-cycle = 10%
3. Increase the duty-cycle and observe its effect on the ASK spectrum.
4. Plot the ASK signal spectrum using the Cassy Lab then **take a picture** of the impulses. (Adjust the x-axis range to be suitable for the plot).

Write your observations about how the message duty cycle affects the ASK spectrum.

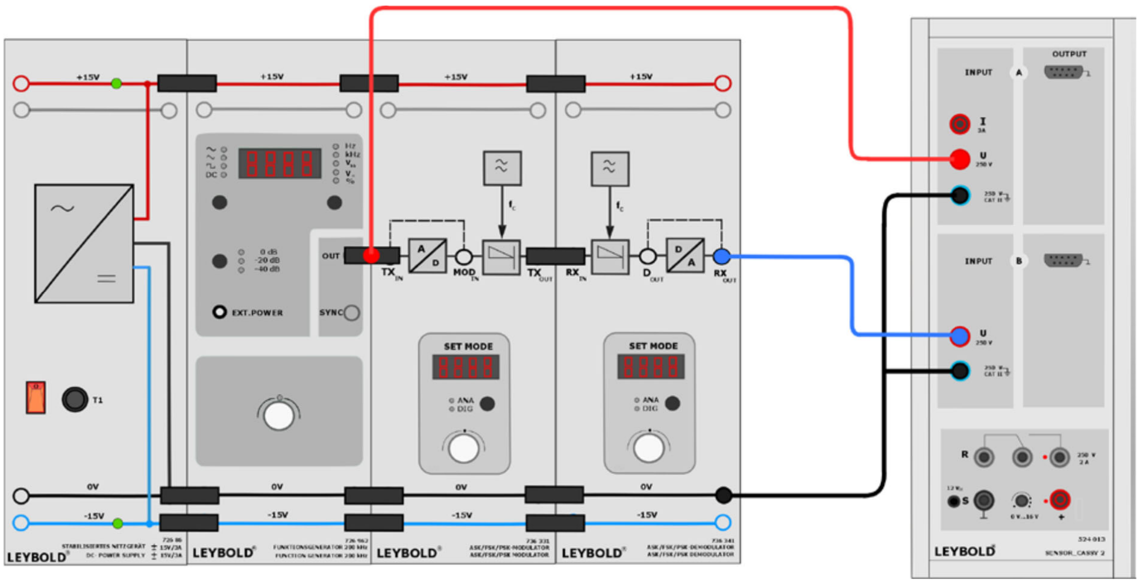
____

____

____

Part 3: Amplitude shift keying Demodulation (Time and frequency domains)

Assemble the components as shown in the figure below:



1. Set the function generator to:

   Square wave, Freq = 1000 Hz, Vss = 10V, duty-cycle = 50%

2. Set the demodulator mode to Digital (DIG).
3. Select the demodulation type (A).
4. Connect the Cassy sensor UA1 to the bipolar message square-wave signal at MOD_{IN}.
5. Connect the Cassy sensor UB1 to the demodulated signal at the output RX_{OUT}.

Hard Keying:

6. Set the modulator mode to Digital (DIG).
7. Select Amplitude shift keying – Hard keying with modulation index m = 100% (A_11).
8. Start the measurement. **(Show 5 cycles and take a picture of the output).**

Does the demodulation of the ASK 100% hard keying process success?

____

____

9. Repeat the previous part but this time select the Amplitude shift keying - Hard keying with modulation index m = 50% (A_21).
10. Start the measurement. **(Show 5 cycles and take a picture of the output).**

Does the demodulation of the ASK 50% hard keying process success?

____

____

____

Soft Keying:

Keep the connection as it was assembled for the hard keying part.

1. Repeat the same procedures but this time select the Amplitude shift keying - Soft keying with modulation index m = 100% (A_12).
2. Start the measurement. **(Show 5 cycles and take a picture of the output).**

Does the demodulation of the ASK 100% soft keying process success?

---

3. Finally, select the Amplitude shift keying - Soft keying with modulation index m = 50% (A_22) and repeat the same procedure.
4. Start the measurement. **(Show 5 cycles and take a picture of the output).**

Does the demodulation of the ASK 50% soft keying process success?

Questions:

What is the main difference between the message signal and the demodulated signal?

What causes this difference? And does it consider as a disadvantage?

Is there a time delay between the message and the demodulated signal? If so, what do you expect the reason behind it?

Is the time delay for the soft keying greater or smaller than that of the hard keying? Interpret your answer?

Does the modulation index affect the time delay between the message and the demodulated signal?

Studying the effect of changing the message signal frequency on the demodulation:

1. Keep the same connection as the previous parts.
2. Set the function generator to:

   Square wave, Freq = 500 Hz, Vss = 10V, duty-cycle = 50%

3. Connect the Cassy sensor UA1 to the bipolar message square-wave signal at TX_{IN}

4. Connect the Cassy sensor UB1 to the demodulated signal at the output RX_{OUT}.
5. Start the measurement. **(Show 5 cycles and take a picture of the output).**

Write your observations:

____

____

Studying the effect of changing the message signal duty cycle on the demodulation:

1. Keep the same connection as the previous part.
2. Set the function generator to:

   Square wave, Freq = 1000 Hz, Vss = 10V, duty-cycle = 10%

3. Increase the duty-cycle and observe its effect on the ASK demodulation.
4. Start the measurement. **(Show 5 cycles and take a picture of the output).**

Write your observation:

____

____

What duty-cycle value can be considered as the best one? Why?

____

____

Is there a difference between the smaller and greater duty-cycle values? Will they affect the low or high state of the Ask signal?

____

Experiment #11:

Frequency and Phase Shift Keying

Objectives

The objective of this experiment is to introduce the Frequency and Phase shift keying. Two keying methods will be presented the Hard and the Soft keying. The study will be for both domains the time and the frequency.

Pre-Lab Work

Theoretical Prelab:

Review the theoretical background of the Frequency and Phase shift keying.

Software Prelab:

1- Frequency shift keying:

Build a full system that describes all the parts of this experiment using Matlab Simulink. Starting from generating the square wave and modulate it in hard keying method, plot the results (message, carrier and modulated signal) in both time and frequency domains. Until building the coherent demodulation of the FSK, also, plot the results of the demodulated signal in both the time and the frequency domains. ***Write your observation and conclusions in all results.***

Use two sinusoidal signals: $\boldsymbol{c_1(t) = Cos(2\pi(15k)t)}$
$\boldsymbol{c_2(t) = Cos(2\pi(25k)t)}$

2- Phase shift keying:

Build a full system that describes all the parts of this experiment using Matlab Simulink. Starting from generating the square wave and modulate it in hard keying method, plot the results (message, carrier and modulated signal) in both time and frequency domains. Until building the coherent demodulation of the PSK, also, plot the results of the demodulated signal in both the time and the frequency domains. ***Write your observation and conclusions in all results.***

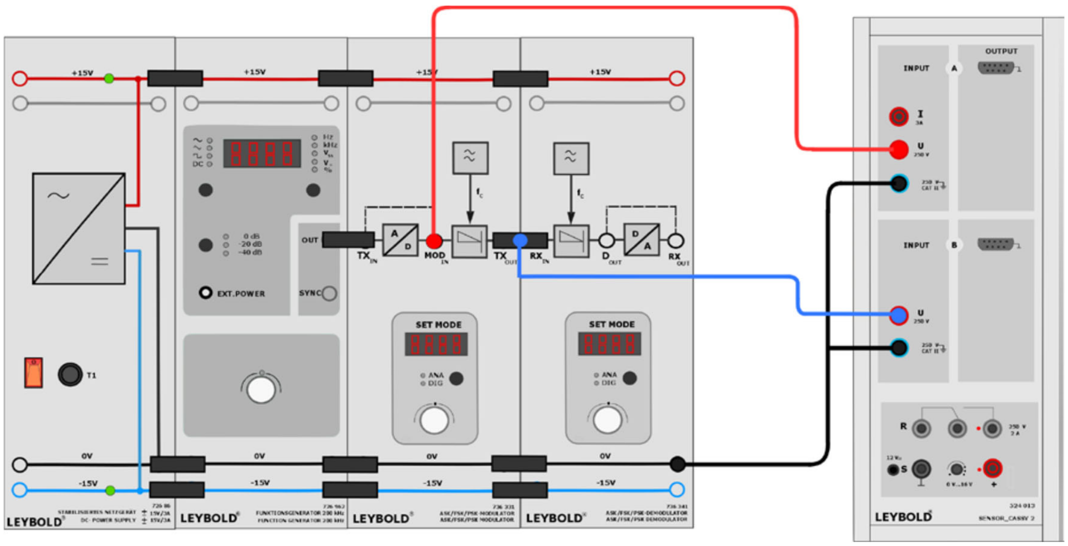
Use sinusoidal signal: $\boldsymbol{c(t) = Cos(2\pi(20k)t)}$

Procedure

Part 1: Frequency shift keying Modulation (Time domain)

Hard keying:

Assemble the components as shown in the figure below:



1. Set the function generator to:

   Square wave, Freq = 1000 Hz, Vss = 10V, duty-cycle = 50%

2. Set the modulator mode to Digital (DIG).
3. Select Frequency shift keying – Hard keying (F_1).
4. Connect the Cassy sensor UA1 to the modulating signal.
5. Connect the Cassy sensor UB1 to the Unipolar square-wave signal at socket MOD_{IN}.
6. Start the measurement. **(Show 5 cycles and take a picture of the output).**
7. Connect the Cassy sensor UA1 to the Unipolar square-wave signal at socket MOD_{IN}.
8. Connect the Cassy sensor UB1 to the FSK signal at the output TX_{OUT} of the modulator.
9. Start the measurement. **(Show 5 cycles and take a picture of the output).**

Write your observations:

____

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____

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Soft keying:

Keep the connection as it was assembled for the hard keying part.

10. Repeat the same procedures but this time select the Frequency shift keying - Soft keying (F_2).
11. Start the measurement. **(Show 5 cycles and take a picture of the output).**

Write your observations:

____

____

Is there any similarity in the behavior of the ASK hard and soft keying with the FSK hard and soft keying?

____

____

____

____

Part 2: Frequency shift keying Modulation (Frequency domain)

This part studies the modulation of the FSK signal from the spectrum point of view.

In this section set the Cassy Lab in FFT mode. To do this go to:

Settings > Calculator > FFT > choose input channel (FFT of)

1. Keep the same connection as it was used for the previous parts.
2. Connect the Cassy sensor UA1 to the FSK signal at the output TX_{OUT} of the modulator.
3. Set the function generator to:

Square wave, Freq = 1000 Hz, Vss = 10V, duty-cycle = 50%

Hard keying:

1. Select Frequency shift keying – Hard keying (F_1).
2. Plot the FSK signal spectrum using the Cassy Lab then **take a picture** of the impulses. (Adjust the x-axis range to be suitable for the plot).

Write your observations:

____

____

____

Soft keying:

Keep the connection as it was assembled for the hard keying part.

1. Repeat the same procedures but this time select the Frequency shift keying - Soft keying (F_2).
2. Plot the FSK signal spectrum using the Cassy Lab then **take a picture** of the impulses. (Adjust the x-axis range to be suitable for the plot).

Write your observations:

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Compare between the FSK hard and soft keying modulation spectrum from the bandwidth view. Interpret the results scientifically.

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Studying the effect of changing the message signal amplitude (Time and frequency domains):

1. Keep the same connection as the previous parts.
2. Reduce the message signal amplitude to 2V (Vss = 4V).
3. Plot the FSK signal spectrum using the Cassy Lab then **take a picture**. (Adjust the x-axis range to be suitable for the plot).

Write your observations about how the message amplitude affects the FSK spectrum.

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Studying the effect of changing the message signal frequency on (Time and frequency domains):

1. Keep the same connection as the previous parts.
2. Set the function generator to:
    3. Square wave, Freq = 500 Hz, Vss = 10V, duty-cycle = 50%
4. Connect the Cassy sensor UA1 to the Unipolar square-wave signal at socket MOD_{IN}.
5. Connect the Cassy sensor UB1 to the FSK signal at the output TX_{OUT} of the modulator.
6. Plot the FSK signal spectrum using the Cassy Lab then **take a picture**. (Adjust the x-axis range to be suitable for the plot).

Studying the effect of changing the message signal duty cycle (Time and frequency domains):

1. Keep the same connection as the previous part.
2. Set the function generator to:

   Square wave, Freq = 1000 Hz, Vss = 10V, duty-cycle = 10%
3. Increase the duty-cycle and observe its effect on the FSK spectrum.
4. Plot the FSK signal spectrum using the Cassy Lab then **take a picture**. (Adjust the x-axis range to be suitable for the plot).

Write your observations about how the message duty cycle affects the PSK spectrum.

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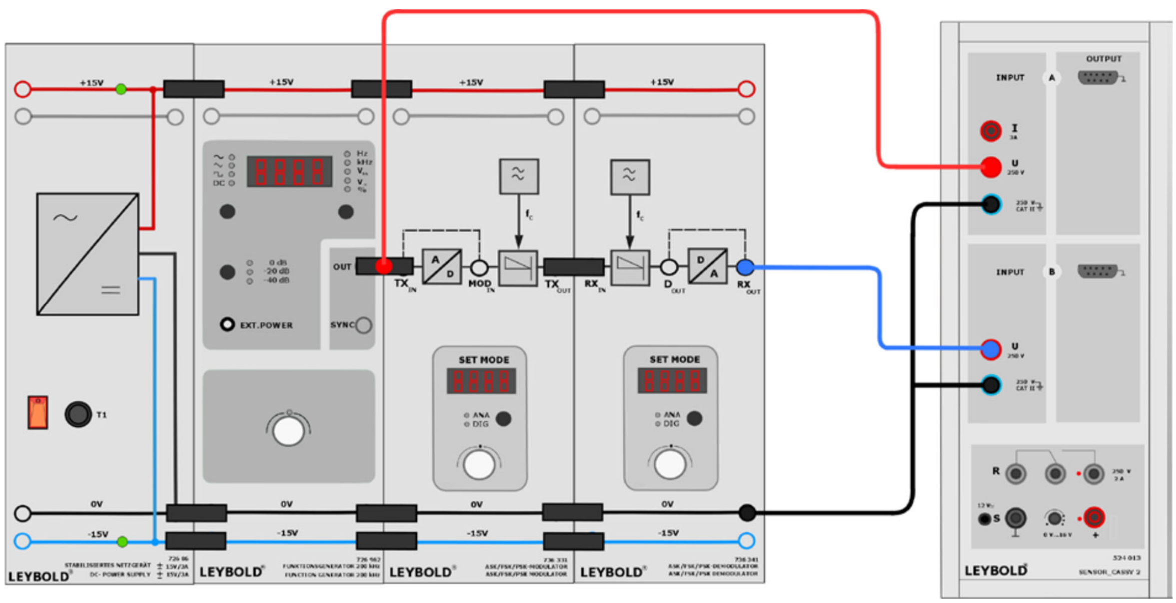
Part 3: Frequency shift keying Demodulation (Time domain)

Assemble the components as shown in the figure below:



1. Set the function generator to:

   Square wave, Freq = 1000 Hz, Vss = 10V, duty-cycle = 50%
2. Set the demodulator mode to Digital (DIG).
3. Select the demodulation type (F).
4. Connect the Cassy sensor UA1 to the bipolar message square-wave signal at TX_{IN}
5. Connect the Cassy sensor UB1 to the demodulated signal at the output RX_{OUT}.

Hard Keying:

1. Set the modulator mode to Digital (DIG).
2. Select Frequency shift keying – Hard keying (F_1).
3. Start the measurement. **(Show 5 cycles and take a picture of the output).**

Does the demodulation of the FSK hard keying process success?

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Soft Keying:

Keep the connection as it was assembled for the hard keying part.

1. Repeat the same procedures but this time select the Frequency shift keying - Soft keying (F_2).
2. Start the measurement. **(Show 5 cycles and take a picture of the output).**

Does the demodulation of the FSK soft keying process success?

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Studying the effect of changing the message signal frequency on the demodulation:

1- Keep the same connection as the previous parts.

2- Set the function generator to:

Square wave, Freq = 500 Hz, Vss = 10V, duty-cycle = 50%

3- Connect the Cassy sensor UA1 to the bipolar message square-wave signal at TX_{IN}

4- Connect the Cassy sensor UB1 to the demodulated signal at the output RX_{OUT}.

5- Start the measurement. **(Show 5 cycles and take a picture of the output).**

Write your observations:

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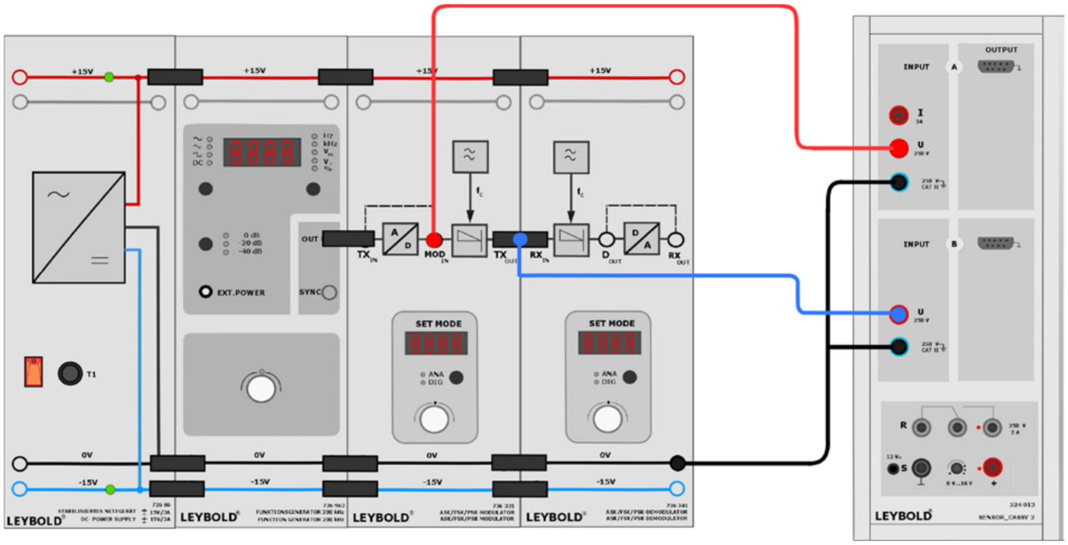
Part 4: Phase shift keying Modulation (Time domain)

Hard keying:

Assemble the components as shown in the figure below:



1. Set the function generator to:

   Square wave, Freq = 1000 Hz, Vss = 10V, duty-cycle = 50%
2. Set the modulator mode to Digital (DIG).
3. Select Phase shift keying – Hard keying (P_1).
4. Connect the Cassy sensor UA1 to the Unipolar square-wave signal at socket MOD_{IN}.
5. Connect the Cassy sensor UB1 to the PSK signal at the output TX_{OUT} of the modulator.
6. Start the measurement. **(Show 5 cycles and take a picture of the output).**

Write your observations:

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Soft keying:

Keep the connection as it was assembled for the hard keying part.

1. Repeat the same procedures but this time select the Phase shift keying - Soft keying (P_2).
2. Start the measurement. **(Show 5 cycles and take a picture of the output).**

Write your observations:

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Is there any similarity in the behavior of the ASK and FSK hard and soft keying with the PSK hard and soft keying?

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Part 5: Phase shift keying Modulation (Frequency domain)

This part studies the modulation of the PSK signal from the spectrum point of view.

In this section set the Cassy Lab in FFT mode. To do this go to:

Settings > Calculator > FFT > choose input channel (FFT of)

1. Keep the same connection as it was used for the previous parts.
2. Connect the Cassy sensor UA1 to the PSK signal at the output TX_{OUT} of the modulator.
3. Set the function generator to:

   Square wave, Freq = 1000 Hz, Vss = 10V, duty-cycle = 50%

Hard keying:

4. Select Phase shift keying – Hard keying (P_1).
5. Plot the PSK signal spectrum using the Cassy Lab then **take a picture** of the impulses. (Adjust the x-axis range to be suitable for the plot).

Write your observations:

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6. Plot the PSK signal spectrum using the Cassy Lab then **take a picture** of the impulses. (Adjust the x-axis range to be suitable for the plot).

Write your observations:

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Soft keying:

Keep the connection as it was assembled for the hard keying part.

7. Repeat the same procedures but this time select the Phase shift keying - Soft keying (P_2).
8. Plot the PSK signal spectrum using the Cassy Lab then **take a picture** of the impulses. (Adjust the x-axis range to be suitable for the plot).

Write your observations:

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Compare between the PSK hard and soft keying modulation spectrum from the bandwidth, carrier observation and the spectrum structure views. Interpret the results scientifically.

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Studying the effect of changing the message signal amplitude (Time and frequency domains):

1. Keep the same connection as the previous parts.
2. Reduce the message signal amplitude to 2V (Vss = 4V).
3. Plot the PSK signal spectrum using the Cassy Lab then **take a picture**. (Adjust the x-axis range to be suitable for the plot).

Write your observations about how the message amplitude affects the PSK spectrum.

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Studying the effect of changing the message signal frequency on (Time and frequency domains):

1. Keep the same connection as the previous parts.
2. Set the function generator to:

   Square wave, Freq = 500 Hz, Vss = 10V, duty-cycle = 50%
3. Connect the Cassy sensor UA1 to the Unipolar square-wave signal at socket MOD_{IN}.
4. Connect the Cassy sensor UB1 to the PSK signal at the output TX_{OUT} of the modulator.
5. Plot the PSK signal spectrum using the Cassy Lab then **take a picture**. (Adjust the x-axis range to be suitable for the plot).

Studying the effect of changing the message signal duty cycle (Time and frequency domains):

1- Keep the same connection as the previous part.
2- Set the function generator to:

Square wave, Freq = 1000 Hz, Vss = 10V, duty-cycle = 10%

3- Increase the duty-cycle and observe its effect on the PSK spectrum.
4- Plot the PSK signal spectrum using the Cassy Lab then **take a picture**. (Adjust the x-axis range to be suitable for the plot).

Write your observations about how the message duty cycle affects the PSK spectrum.

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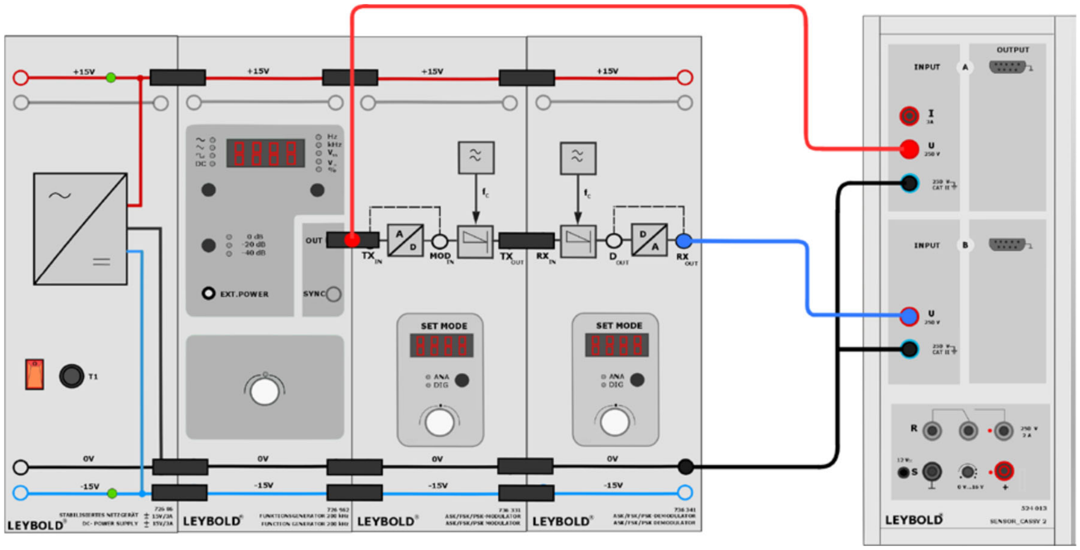
Part 6: Phase shift keying Demodulation (Time domain)

Assemble the components as shown in the figure below:



1. Set the function generator to:
   2. Square wave, Freq = 1000 Hz, Vss = 10V, duty-cycle = 50%
3. Connect the Cassy sensor UA1 to the bipolar message square-wave signal at TX_{IN}
4. Connect the Cassy sensor UB1 to the demodulated signal at the output RX_{OUT}.

Hard Keying:

5. Set the demodulator mode to Digital (DIG).
6. Select the demodulation type (P_1).
7. Set the modulator mode to Digital (DIG).
8. Select Phase shift keying – Hard keying (P_1).
9. Start the measurement. **(Show 5 cycles and take a picture of the output).**

Does the demodulation of the FSK hard keying process success?

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Soft Keying:

Keep the connection as it was assembled for the hard keying part.

10. Repeat the same procedures but this time select the modulator and the demodulator Phase shift keying - Soft keying (P_2).
11. Start the measurement. **(Show 5 cycles and take a picture of the output).**

Does the demodulation of the PSK soft keying process success?

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Do the message and the demodulated signal have the same phase shift?

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Interpret the results.

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Studying the effect of changing the message signal frequency on the demodulation:

1. Keep the same connection as the previous parts.
2. Set the function generator to:

   Square wave, Freq = 500 Hz, Vss = 10V, duty-cycle = 50%

3. Connect the Cassy sensor UA1 to the bipolar message square-wave signal at TX_{IN}
4. Connect the Cassy sensor UB1 to the demodulated signal at the output RX_{OUT}.
5. Start the measurement. **(Show 5 cycles and take a picture of the output).**

Write your observations:

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