Stellenbosch University

Department of Electrical and Electronic Engineering

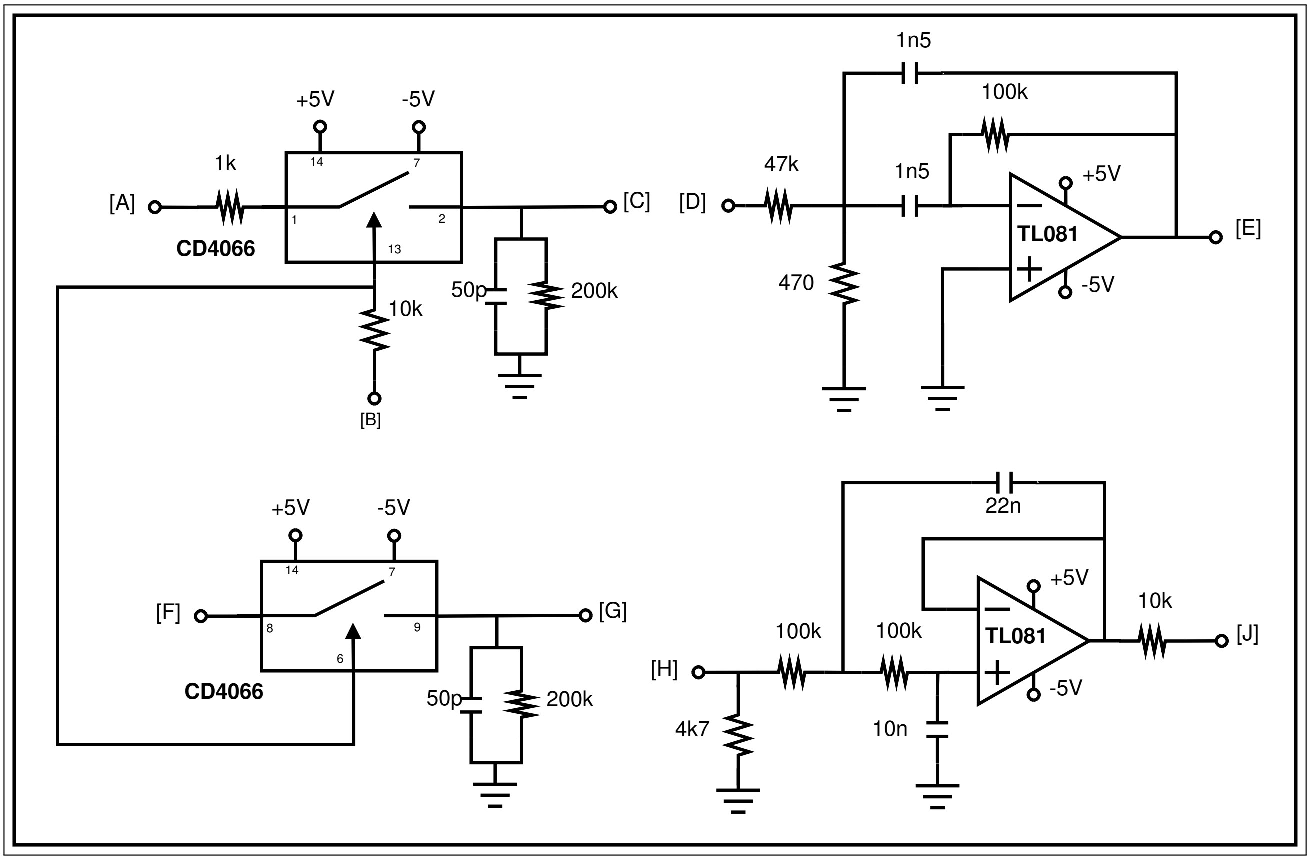
Systems and Signals 315

11 May 2020

Practical 3: Amplitude Demodulation

Aim

Practical 3 examines DSB-SC and AM (DSB-LC) demodulation using the circuits shown below. In this practical you will demodulate both a DSB-SC and AM signal by using sinchronous demodulation. Thereafter you will demodulate an AM signal by respectively using a rectifier detector and an envelope detector.



The left-hand circuit is a so-called *chopper modulator* based on the CD4066 analog CMOS switch. The logical control signal applied at [B] switches the connection between points [A] and [C] on and off. By also connecting pin 6 of the CD4066 to [B] the connection between points [F] and [G] is switched at the same frequency (synchronised with the switching that occurs between [A] and [C]). The logical control signal is a 10 $V_{\text{p-p}}$ square wave with frequency f_c and 50% duty cycle. The circuit at the top right is a second-order bandpass filter while the circuit at the bottom right is a second-order lowpass filter.

The aim of the practical to build and simulate the circuit using the LTSpice simulation software and confirm that demodulated signals agrees with the theory, both in the time-domain and in the frequency domain.

Instructions

- The practical will be performed synchronously using a live Microsoft Teams contact session during the scheduled practical time slot on Monday 14:00-17:00.
- Since we do not have physical access to the laboratories yet, the practical will involve building simulation models of electronic circuits and executing the models to obtain simulated results.

- The free LTSpice electronic simulation software will be used.
- Students who do not have access to a personal computer, or cannot install and run the LTspice software, must please notify the lecturers by completing the online form on SUNLearn.
- The lecturers will upload the practical instructions to SUNLearn in advance, and students are expected to attempt the practical before the scheduled practical session.

Live Microsoft Teams contact session

- Students must join the Systems and Signals 315 Microsoft Teams site and go to the "Practical 3 Chat (Praktika 3 Klets)" chat channel during the scheduled practical time slot on Monday 14:00-17:00.
- Students can ask for help on the "Practical 3 Chat (Praktika 3 Klets)" chat channel, and the lecturers and demies will then assist by starting temporary MS Teams meetings directly with individual students or groups of students.

Practical report

- Each student must complete their own practical report and submit an electronic pdf copy on SUNLearn. The practical report will be marked and will form part of your semester mark.
- The deadline for the report submission is Sunday 17 May at 23:59. Late submissions will receive a mark of zero. Failure to submit a practical report will result in an INCOMPLETE for the module.

Download and install LTspice electronic circuit simulator

Download and install the LTspice simulation software from SUNLearn for one of the following operating systems:

- Windows 7, 8, and 10 (LTspiceXVII.exe)
- Mac 10.9+ (LTspice.dmg)
- Windows XP (LTspiceIV.exe)

Join Microsoft Teams

- Join the Systems and Signals 315 Microsoft Teams site.
- A short guide is also provided on how to use Microsoft Teams.

Task 1: Theoretical Preparation

The following preparation must be done before the practical.

1. Determine the theoretical transfer function of the second-order lowpass filter by using circuit analysis. Also determine the 3-dB cutoff frequency of the lowpass filter.
2. **Synchronous/coherent demodulation:** A synchronous demodulator can be built by connecting [C] to [D], [E] to [F], and [G] to [H].
   a) Assume a 100 Hz, 5 $V_{\text{p-p}}$ sine wave is applied at [A] (message signal) and a 10 $V_{\text{p-p}}$ square wave with frequency f_0 [1] is applied at [B]. Give a mathematical representation (both in the time and frequency domain) of the synchronous demodulation process by plotting the signals at [E], [G] and [J].
   b) Assume a 100 Hz, 5 $V_{\text{p-p}}$ sine wave is applied at [A] (message signal) and a 10 $V_{\text{p-p}}$ square wave with frequency $f_0/3$ is applied at [B]. Give a mathematical representation (both in the time and frequency domain) of the synchronous demodulation process by plotting the signals at [E], [G] and [J].
3. **Non-coherent demodulation:** Assume an AM (DSB-LC) message signal with modulation index of $\mu = 1$ is applied at [A] by adding a DC offset to the message signal.
   a) **Rectifier detection:** A rectifier detector can be built by connecting [C] to [D], and connecting a diode (1N4148)between [E] and [H]. Give a mathematical representation (both in the time and frequency domain) of the process that occurs in the rectifier detector by plotting the signals at [E], [H] and [J].

[1] f_0 is the measured center frequency of the bandpass filter between [D] and [E].

b) **Envelope Detection:** Draw the circuit required for envelope detection. Choose and motivate appropriate values for the resistor and capacitor to obtain acceptable distortion in the demodulated message signal.

Construct the circuits above in LTSpice (you should have previously constructed the chopper circuit and bandpass filter). LTSpice libraries have been provided for the TL081 op-amp and the CD4066 analog CMOS switch.

Task 2: Measure the transfer function of the lowpass filter

Measure the transfer function $H(f)$ (amplitude and phase) of the lowpass filter between [H] and [J] at a few frequency points, and plot it. Pay special attention to what happens at 100 Hz, and determine the 3-dB bandwidth of the filter. The transfer function can be determined by performing a Small Signal AC Analysis in LTSpice. Attach a 1V AC voltage source to the input [H] of the filter (and also ground the AC voltage source). Run the following LTSpice directive to perform an AC analysis: `.ac <oct, dec, lin> <NumberOfSteps> <StartFrequency> <EndFreque` For example `.ac dec 1000 10k 20k` will perform 100 steps per decade starting at 10kHz and ending at 20kHz.

Task 3: Synchronous/coherent demodulation

Connect [C] to [D], [E] to [F], and [G] to [H].

1. Apply a 100 Hz, 5 $V_{\text{p-p}}$ sine wave at [A] (message signal) and a 10 $V_{\text{p-p}}$ square wave with frequency f_0 at [B] (carrier wave). Plot the signals at [E], [G] and [J]. What happens if the frequency of the message signal is increased or decreased? EXPLAIN the process using spectra.

2. Repeat Task 3.1, but with a carrier wave of frequency $f_0/3$. Again plot the waveforms, and EXPLAIN any discrepancies.

3. Repeat Task 3.1, but change the modulated signal into an AM (DSB-LC) signal by adding a DC offset to the message signal. Is the signal at [J] still a faithful representation of the message signal?

Task 4: Non-coherent demodulation

1. **Rectifier detection:** Connect [C] to [D] and the diode between [E] and [H]. Attempt to demodulate the AM signalof the previous question without synchronisation. Also try to transmit other message signals (such as square waves and triangular waves), and explain any distortion that occurs. SKETCH what you observe.

2. **Envelope detection:** Connect [C] to [D] and use a diode, a resistor and a capacitor to build an envelope detector (use the capacitor and resistor values previously calculated). Connect the envelope detector to the output of [E]. Do not use the low-pass filter, it is only used for rectifier detection and synchronous detection. Attempt to demodulate the AM signal of the previous question without synchronisation. SKETCH what you observe.

Task 5: Write and submit a report

Compare the measured transfer function of the lowpass filter with the theoretical prediction. Draw time and frequency domain graphs that to explain the synchronous demodulation. Your report should at least cover the following items:

- Introduction and description of the experimental setup.
- Theoretical predition.
- Measure results.
- Comparison of measured result with the theoretical predictions.
- Conclusion.