**Stellenbosch University**

**Department of Electrical and Electronic Engineering**

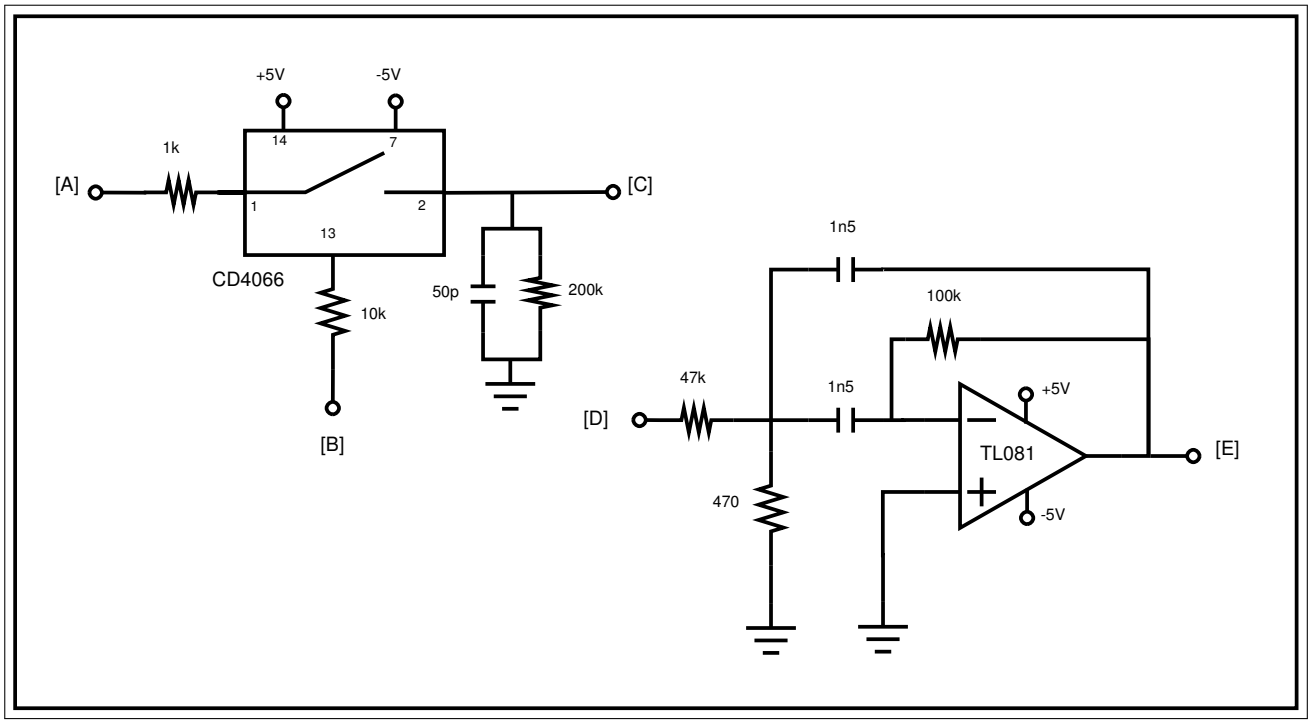
**Systems and Signals 315**

**4 May 2020**

# Practical 2: Amplitude Modulation

## Aim

Practical 2 examines amplitude modulation using the circuits below. 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. A square wave with frequency $f_c$ and 50% duty cycle is applied at [B] and serves as the carrier signal. The message signal is a sine wave given by $m(t) = A_m \cos(2\pi f_m t)$, which is applied at [A]. The right-hand circuit is a second-order bandpass filter.




The aim of the practical to build and simulate the circuit using the LTSpice simulation software and confirm that modulated DSB signal 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 2 Chat (Praktika 2 Klets)" chat channel during the scheduled practical time slot on Monday 14:00-17:00.
- Students can ask for help on the "Practical 2 Chat (Praktika 2 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 10 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.

### Kyk na die volgende instruksie videos op SUNLearn

- How to build a simulation model in LTspice
- How to run a simulation in LTspice and plot the simulation results
- How to use the cursors to perform measurements
- How to determine the amplitude and phase angle of the simulated sinusoidal signals in LTspice

### Task 1: Theoretical Preparation

The following preparation must be done before the practical.

1. Give a mathematical representation (or model) of the process that occurs in the chopper circuit.
2. Determine the spectrum of the chopped signal at [C]. Pay special attention to the magnitudes of any harmonics/impulses in the spectrum.
3. Determine the theoretical transfer function of the second-order bandpass filter by using circuit analysis. [D] is the input of the filter and [E] is the output of the filter. Determine the theoretical center frequency $f_0$ and the bandwidth of the bandpass filter. Use the values on the transfer function where the input voltage is attenuated with 3dB to determine the bandwidth of the bandpass filter.
4. Determine the spectrum of the output signal at [D] if [C] and [D] are connected. Use the transfer function of the second-order bandpass filter to determine the effect on the input signal.

Construct the circuits above in LTSpice. LTSpice libraries have been provided for the TL081 op-amp and the CD4066 analog CMOS switch.

### Task 2: Measure the transfer function of the bandpass filter

Measure the transfer function (both amplitude and phase) of the filter and compare it to the predicted theoretical transfer function. Also measure the center frequency $f_0$ and the bandwidth of the filter. Specifically measure the value of the transfer function at $f_0$ Hz, $f_0 + 100$ Hz and $f_0 - 100$ Hz. The transfer function can be determined by performing a Small Signal AC Analysis in LTSpice. Attach a 1V AC voltage source to the input [D] 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> <EndFrequency>`. For example `.ac dec 1000 10k 20k` will perform 100 steps per decade starting at 10kHz and ending at 20kHz.

### Task 3: Investigate the effect of the filter of a square wave

Investigate the effect of the filter on a $5V_{p-p}$ ($V_{p-p}$ means peak-to-peak) square wave, applied as input signal at [D], in both the time- and frequency domain. Investigate the output signal at [E] for the following fundamental frequencies of the square wave: i) $f_0$ and ii) $f_0/3$. Use your MEASURED value of $f_0$.

### Task 4: DSB modulation using a sinusoidal message signal

Investigate DSB-SC modulation of a sinusoidal message signal using a chopper modulator, in both the time and frequency domain. This can be done by applying a 100 Hz $5V_{p-p}$ sine wave at [A] (as the modulating/message signal), a $10V_{p-p}$ square wave with frequency $f_0$ at [B] (the carrier wave) and also connecting [C] and [D]. The chopped message signal can be measured at [C] and the modulated output signal can be measured at [E]. Also investigate changing the carrier frequency to $f_0/3$ Hz.

### Task 5: DSB modulation using non-sinusoidal message signals

Investigate the DSB-SC modulation of other message signals (triangular and square waves) at [A] and explain any distortion that occurs.

### Task 6: Write and submit a report

Compare the measured transfer function and signals with the theoretical versions. Draw time and frequency domain graphs to explain what you saw. Your report should at least cover the following items:

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