ENGD2001 APPLIED ELECTRONICS
PROJECT
2018-2019

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Title:* *Laboratory Notes, Weeks 10-11

PLEASE READ THIS CAREFULLY

The coursework for this module is a continuously assessed individual project. There are NO formal reports required. However, you will keep and maintain an online journal (a.k.a. a logbook) on the Blackboard shell to which you will be expected to make regular updates, and when you have completed your hardware, this will be assessed in a simple quick demonstration.

1 Aims and objectives

This document provides an outline for the ENG2001 Laboratory Sessions for Weeks 10 – 11.

It is recommended that you have completed the 0-2V and 0-20V DC ranges of your multimeter, before embarking on the tasks in this laboratory sheet.

Some candidates might complete the task for the week before the end of their allotted laboratory session. If that is the case please feel free to move onto the next task.

Candidates who don't complete the task by the end of their laboratory session are strongly encouraged to come back to the laboratory in their own time (assuming no other scheduled session is running). Please remember that there is no written examination for this module, so any time that would have been used to read around the subject can now be spent in the lab!

Please remember to keep your on-line journal up-to-date, and remember to post updates on a regular basis to the Blackboard shell. Your designs should be logged. Your rationale for choosing a particular approach should be logged. Test results should be logged. If something works as expected, make a note of it. If something doesn't work as expected then this should also be logged, along with explanations of why it doesn't work and how the problem is rectified.

Each laboratory session is timetabled for one hour. Therefore you are strongly recommended to familiarize yourself with the task before the session begins.

2 A.C. Voltage Sensing

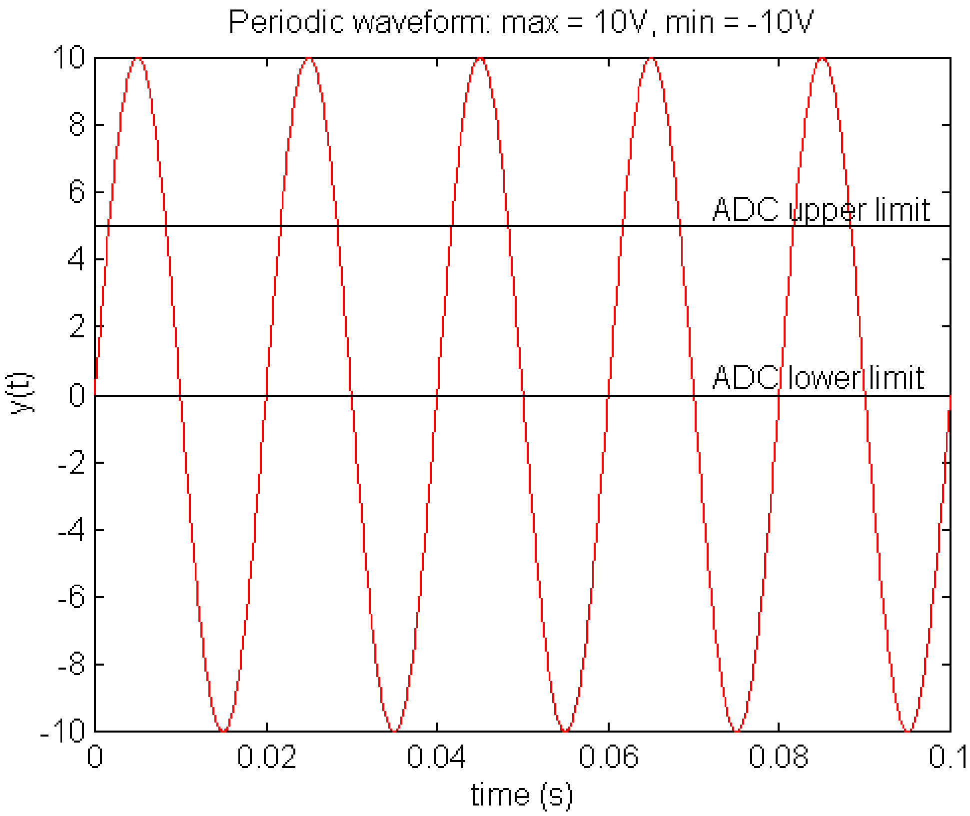
The specification originally called for A.C. Voltage sensing circuitry with an upper limit of 20Vrms. This will now be changed to 20V peak-to-peak owing to the limitation of laboratory signal generators

For the A.C. Voltage sensing part of the circuitry, the circuit needs to be able to cope with signals as high as +10V and as low as -10V. In other words, 20 Volts peak-to-peak.

Consider the following waveform:-

$$y(t) = 10 \sin(\omega t)$$

where ω is the angular frequency. This waveform varies periodically between +10V and -10V (i.e. this would be representative of the worst-case situation for the specification).



Now the ADC can sample signals ranging from 0V to 5V. This presents us with two problems:-

- the ADC cannot sample voltages above the top of its range (i.e. above 5V).
- the ADC cannot sample negative voltages.

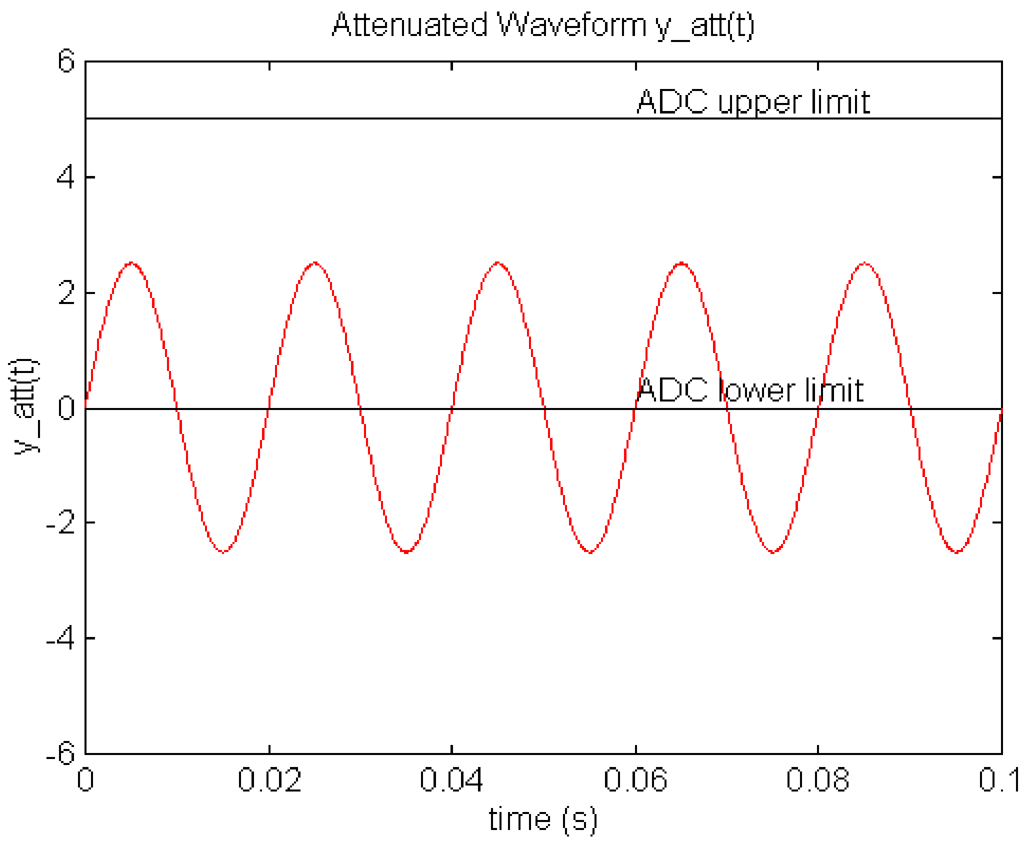
How can a waveform such as y(t) be sampled by the ADC?

Firstly, the waveform y(t) has an overall voltage swing of 20V. The ADC has a sampling range of 5V. Therefore a good place to start would be to divide (attenuate) the input voltage by (at least) a factor of 4. This yields an attenuated waveform, $y_{att}(t)$:-

$$y_{att}(t) = y(t) / 4 = (10 / 4) \sin(\omega t), \text{ i.e.}$$

$$y_{att}(t) = 2.5 \sin(\omega t)$$

This results in a waveform that varies periodically between +2.5V and -2.5V (see overleaf).



This is certainly an improvement as the positive-going cycle of the waveform can now by sampled in its entirety by the ADC. However, the ADC will still not be able to sample the negative-going cycle of the waveform.

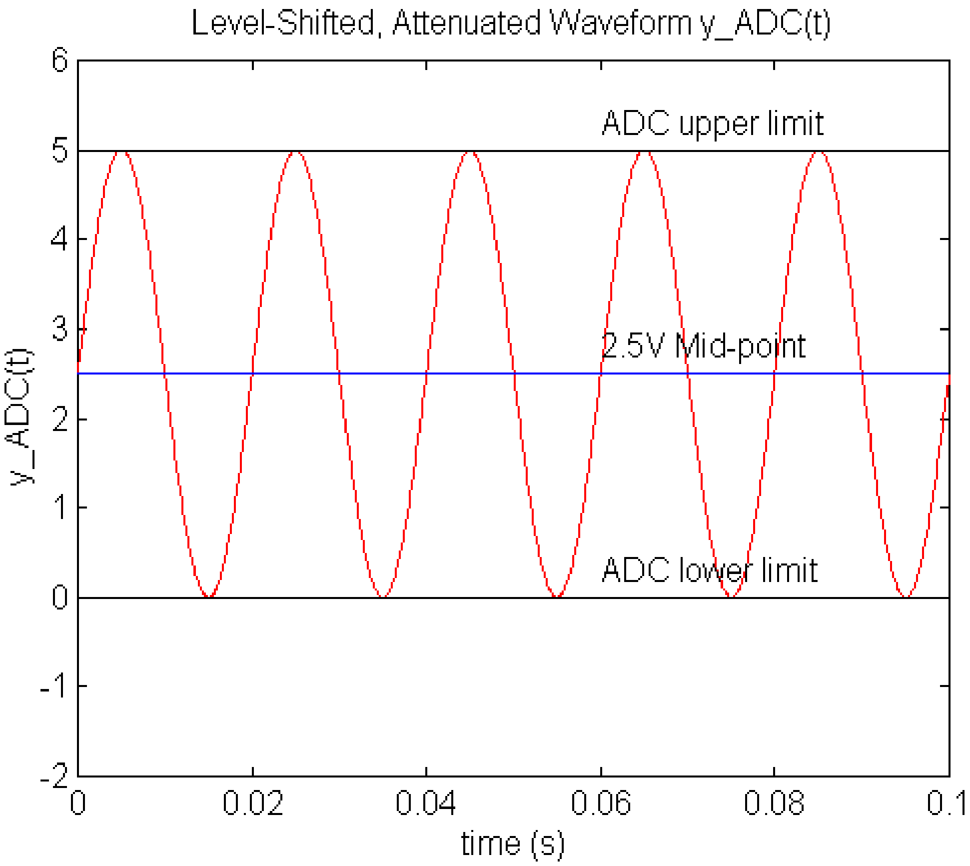
Suppose a d.c. offset equating to half of the ADC range could be added to $y_{att}(t)$. This gives a shifted waveform to be presented to the ADC: $y_{ADC}(t)$.

- If the ADC measures a value equating to half the ADC range, then it can be considered to be 0V by the firmware.
- If the ADC measures a value greater than half the ADC range, then it can be considered positive by the firmware.
- If the ADC measures a value less than half the ADC range, then it can be considered negative by the firmware.

In this case the ADC range is 5V, half the ADC range is 2.5V and therefore:-

$y_{ADC}(t) = y_{att}(t) + 2.5$, i.e.

$y_{ADC}(t) = 2.5 \sin(\omega t) + 2.5$



The aim of the task is to design and implement the circuitry that effectively performs the mathematical operation:-

$$y_{ADC}(t) = A\, y(t) + k$$

where, in this case:

$A \leq 0.25$, and $k = 2.5$

This exercise is essentially a basic introduction to the world of analogue computing!

This task involves the design of circuitry to attenuate the input signal.

3 Part 1: Attenuating The Input Signal

As mentioned earlier the aim of this particular task is to design an attenuator to reduce the input signal to no more than 1/4 (0.25) of its original value.

The non-inverting amplifier introduced in the DC measurement can immediately be ruled out as an option as its gain is greater or equal to 1.

There are (at least) two methods of tackling this problem.

- Use a potential divider and a high-impedance unity-gain buffer.
- Use an inverting amplifier (as the name implies the polarity of the output signal is inverted with respect to the input signal).

At this stage is recommended to start driving the op-amps from split power supplies. In other words two power supplies are needed; one to produce a positive supply and one to produce a negative supply.

Once you have designed and constructed your circuitry on breadboard, the circuit can be tested. Supply the input with a 50Hz sinewave of amplitude 20V peak-to-peak from a signal generator, and use an oscilloscope to verify the performance. Connect Channel 1 of the oscilloscope to the input signal, and Channel 2 to the output of the attenuator circuitry. Measure the amplitude of both signals and determine whether your circuitry delivers the required amount of attenuation.

4 Part 2 - Deriving an Offset Voltage

This task involves the design of circuitry to provide a 2.5V offset voltage.

As a start point, the you have access to a somewhat crude 5V supply. This could potentially be attenuated to give the required 2.5V offset.

Again, the non-inverting amplifier introduced in Week 4 can immediately be ruled out as an option as its gain is greater or equal to 1.

This again leaves at least two methods of tackling this problem.

- Use a potential divider and a high-impedance unity-gain buffer.
- Use an inverting amplifier (as the name implies the polarity of the output signal is inverted with respect to the input signal).

By now, you should be driving the op-amps from split power supplies.

Once you have designed and constructed your circuitry on breadboard, measure the input voltage (approx 5V) and output voltage to see if the 2.5V is correctly generated.

5 Part 3 - Combining the two signals

This task involves the design of circuitry to combine the 2.5V offset voltage to the attenuated input signal.

By this stage you will have completed the circuitry for attenuating the input signal and generating the 2.5V offset.

The summing junction, is the logical approach for combining the two signals. Note that the polarity of the output signal is inverted with respect to the components of its input signals. As mentioned before, you should be driving the op-amps from split power supplies.

Once you have designed and constructed your circuitry on breadboard, the circuit can be tested. Supply the input with a 50Hz sinewave of amplitude 20V peak-to-peak from a signal generator, and use an oscilloscope to validate the performance. Connect Channel 1 of the oscilloscope to the input signal, and Channel 2 to the output of your circuitry. Analyze the output waveform; it should be sinusoidal and constrained within the range 0V to 5V. If this works, it can be connected to Analog pin ADC1 on your ATMEGA328P.

6 Part 4 - Recommended Work

This section provides some ideas for additional things that can be tried-out.

1. The circuit currently uses a rather crude 5V supply for generating the 2.5V reference voltage. This 5V supply may be prone to noise from the microcontroller. Using the components that you were issued with during Week 1, can you think of a better technique for generating the 2.5V reference?

2. Looking at the schematic for your a.c. section of the project, can you simplify this? Depending on your particular implementation, this may or may not be possible.

3. You are currently driving your circuit from two power supplies, which can be a little inconvenient, if not cumbersome. The TL7660 integrated circuit is a switched-capacitor voltage converter that performs supply-voltage conversions from positive to negative. Try appending this to your circuit. Check the output voltage. It should be equal in magnitude to the supply voltage, but negative. Once this works, this can be used in place of the negative power supply.