PROBLEM 1 (20 points)

1a (10 points) Sketch a block diagram of the main components of the **successive approximation** analog to digital converter.

1b (10 points) Describe in words or a list of steps the operation of the **successive approximation** analog to digital converter.
PROBLEM 2 (20 points)

2a (10 points) Sketch a block diagram of the main components of the flash analog to digital converter.

2b (10 points) Describe in words or a list of steps the operation of the flash analog to digital converter.
Problem 3 (20 points) The integral Fourier transform of a single square pulse of width $T_0$ is $H(f) = \frac{\sin(\pi T_0 f)}{\pi T_0 f}$. (See equation sheet for a table of values.)

3a (10 points) Using the Fourier convolution theorem, write the equation for the integral Fourier transform of an infinite periodic series of square pulses of width $T_0$ and period $T_r$.

3a (10 points) Sketch the integral Fourier transform $H(f)$ of an infinite series of square waves of 1 µs width and 1 ms period from $f = 0$ Hz to 1 MHz.
Problem 4 (total 40 points) You have been assigned the task of determining the gain $|V_{out}/V_{in}|$ of a “black box” circuit from 0 Hz to 100 kHz in 100 Hz steps with 1% accuracy. The circuit has an input $V_{in}$ and an output $V_{out}$ but you do not know what is in the black box.

- Rather than measuring the response of the black box at 1000 separate frequencies, you decide to input a periodic series of 1 µs pulses. As seen in problem 3, this allows you to input all frequencies of interest simultaneously.
- You then sample the output and perform the FFT to determine the frequency content of the output.
- Since the periodic pulses also contain frequencies well above the frequencies of interest, you decide to use an 8-pole Butterworth filter with gain $>0.999$ for frequencies below 100 kHz and gain $<0.01$ for frequencies that could alias below 100 kHz. (Hint: use the equation sheet filter gain table with $n = 8$)
- Assume that you have a circuit that can produce 1 µs-wide pulses with a period $T_r$ of your choosing.
- Assume that you have a computer with a data acquisition circuit that can take $M$ samples of a waveform at a sampling frequency $f_s$ of your choosing.

4a. (10 points) Draw a block diagram of your system, showing all essential elements.

4b. (10 points) Determine (1) the corner frequency $f_c$ of the Butterworth filter and (2) the sampling frequency $f_s$ of the data acquisition circuit that meet the anti-aliasing requirements.
4c. (10 points) If you minimize the number of samples $M$ (where $M$ is power of 2), what is your sampling frequency $f_s$, pulse repetition rate $T_r$ and the value of $M$?

4d. (10 points) To what frequency $f_n$ does the Fourier coefficient $H_n$ correspond, and how would you compute the black box circuit gain $|V_{out}/V_{in}|$ at that frequency?