Switched Capacitor Circuits

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This lab consists of four modules:

- RC Integrator
- Switch Capacitor Integrator
- A Fourth Order Butterworth RC Filter
- A Fourth Order Butterworth Switched Capacitor Filter

The first two modules shows a comparison between an RC-integrator circuit and a switched capacitor integrator showing the nuances of implementing a resistor without using a resistor. The latter two modules are essentially the application perspective of the switched capacitors and how similar (or different) it is compared to a regular RC topology that we traditionally opt for.

Connect the circuit as shown in the fig.(1):

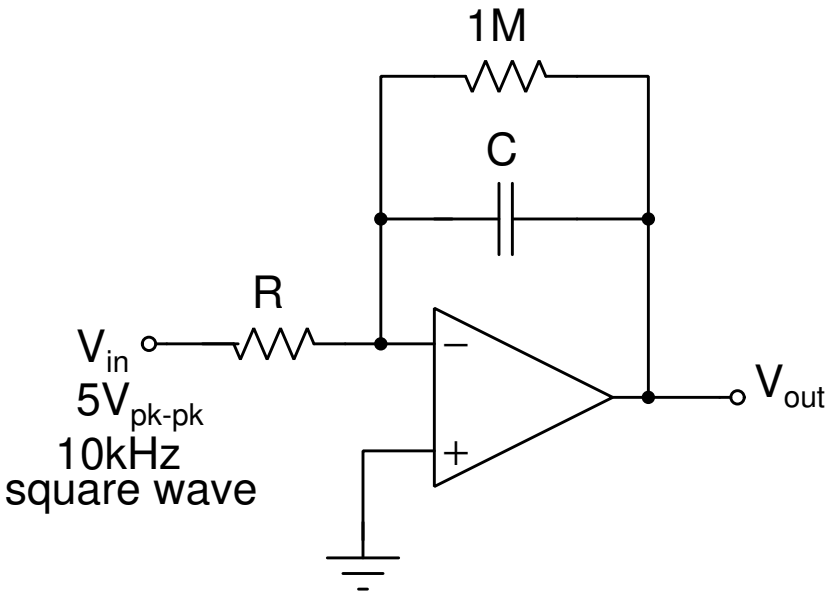


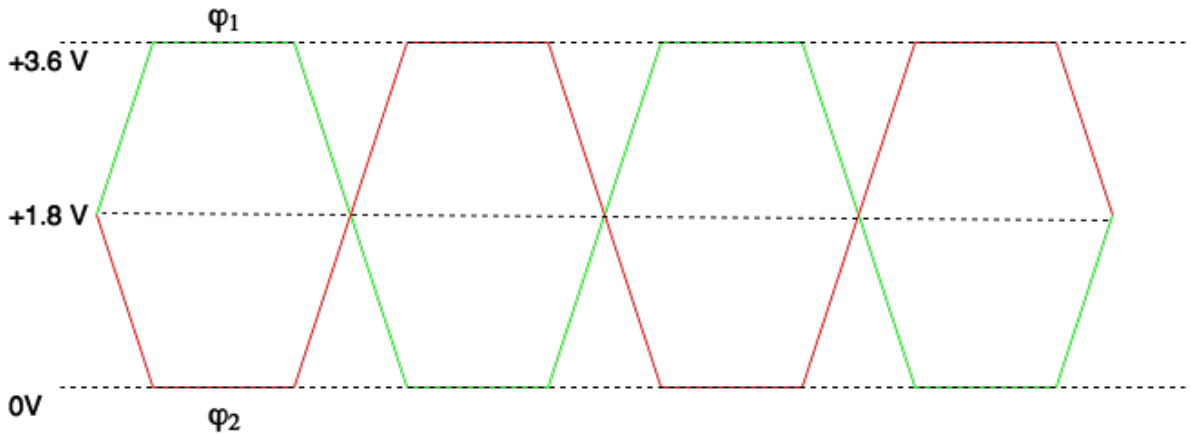
Figure 1: An RC Integrator

Connect a discrete resistor R and capacitor C obtained in Q5 and Q6 of Design Exercise.

- Observe the output of TTL source of AFG. Is it unipolar or bipolar? What are the minimum and maximum magnitude?
- Observe the relationship between the amplitude, frequency and phase settings of Channel-1 Output and TTL Output. Discuss your observation with your TA.
- The switches S_1 and S_2 are connected to the two control signals obtained from Channel-1 and TTL output of the AFG.
- In switch capacitor circuits there should be no overlapping of the two phase clocks (Fig.(2)). This can simply be obtained by exploiting AFG's Channel-1 and TTL relationship, rather than designing a different circuitry altogether.
- Generate two non-overlapping signals at a frequency of $10kHz$ with a voltage of 0 to 3.6V as shown below and show it to your TA

Question: Can we use a simple inverter to obtain non-overlapping clocks? What might be the problems one could face while using an inverter?

Question: Suggest an alternative method to obtain non-overlapping clock using Op-Amps.



Connect the circuit as shown in the fig.(3), use switch from IC CD4066 (operating at supply voltage of $V_{DD} = +5V$ and $V_{SS} = 0V$) :

- Use the values of C_1 and C_2 as calculated in design exercise.
- Apply a 0 to 5V square wave signal at 10 Hz at the input.
- Vary the frequency from 10 Hz to 2 kHz and note the change in the output waveform.
- How can you explain the discrepancy between the obtained wave and RC integrator output?
- What change would you need to make to this circuit to obtain an output similar to the discrete RC integrator?

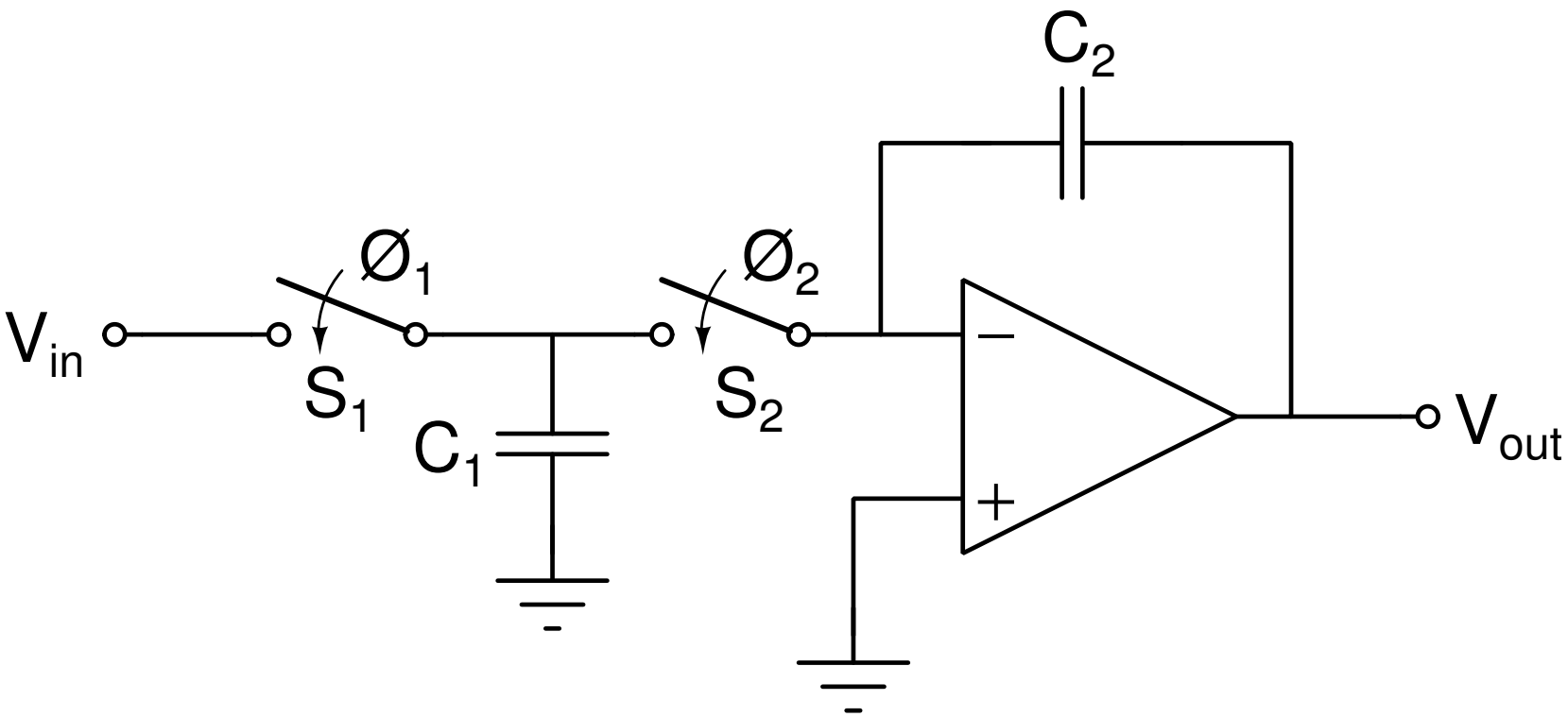


Figure 3: Switched Capacitor Based Integrator

Connect the circuit as shown Fig.(4) with the values of resistors $R_{1A,B}$,$R_{2A,B}$,$R_{3A,B}$ and $R_{4A,B}$ as calculated in design exercise and answer the following:

- Vary the input signal frequency from 1Hz to 10 kHz and note the Magnitude and Phase of the output.
- What is the measured DC gain of the circuit?
- How much is the measured 3-dB frequency of the filter?
- Refer to the block diagram of the IC in the datasheet, and comment on the functionality of the circuit.
- Draw the simplified circuit for the low pass configuration? How can you explain that the circuit is a 4^{th} order circuit?
- Refer to the datasheet and answer what all types of filters can be implemented using IC LMF100CCN?

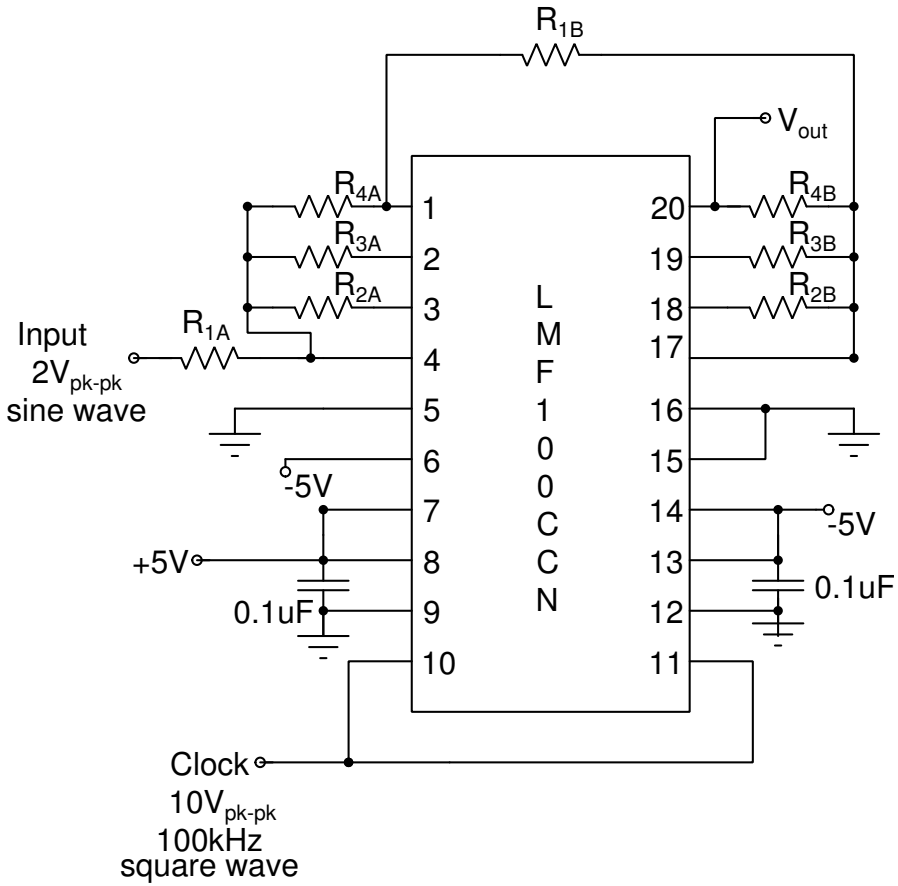


Figure 4: 4^{th} order Butterworth switched capacitor Low pass filter

Connect the circuit as shown Fig.(5) and answer the following:

- Vary the input signal frequency from 1Hz to 10 kHz and note the Magnitude and Phase of the output.
- What is the measured DC gain of the circuit?
- How much is the measured 3-dB frequency of the filter?
- Based on the circuit diagram explain how does the circuit implement a 4^{th} order filter?
- Plot the magnitude of the RC filter and the Switched-Capacitor filter overlaid in the same plot.
- Plot the phase of the RC filter and the Switched-Capacitor filter overlaid in the same plot.
- What are the roll-off (in dB/dec) and phase after the filter corner frequency? Explain your observation.

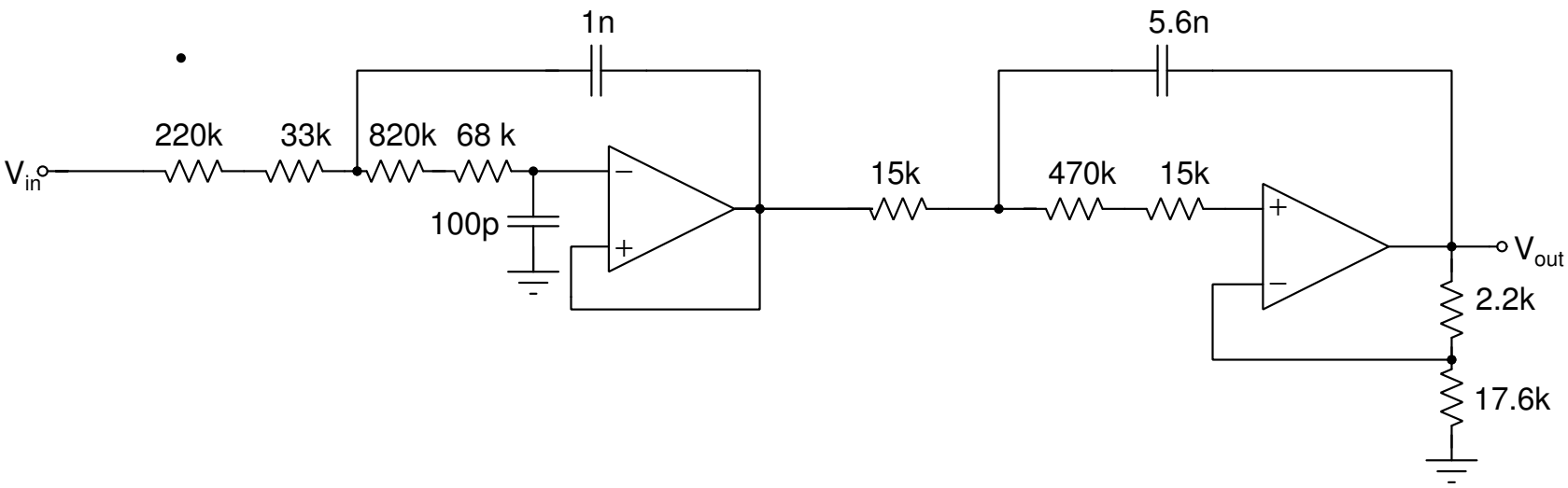


Figure 5: 4^{th} order Butterworth RC low pass filter