EE230: Experiment 7
Switched Capacitor Circuits

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1 Overview of the experiment

1.1 Aim of the experiment

To compare RC-integrator circuit and a switched capacitor integrator.
To study butterworth switched cap low pass filter and butterworth RC low pass filter

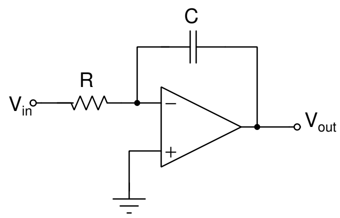
1.2 Methods

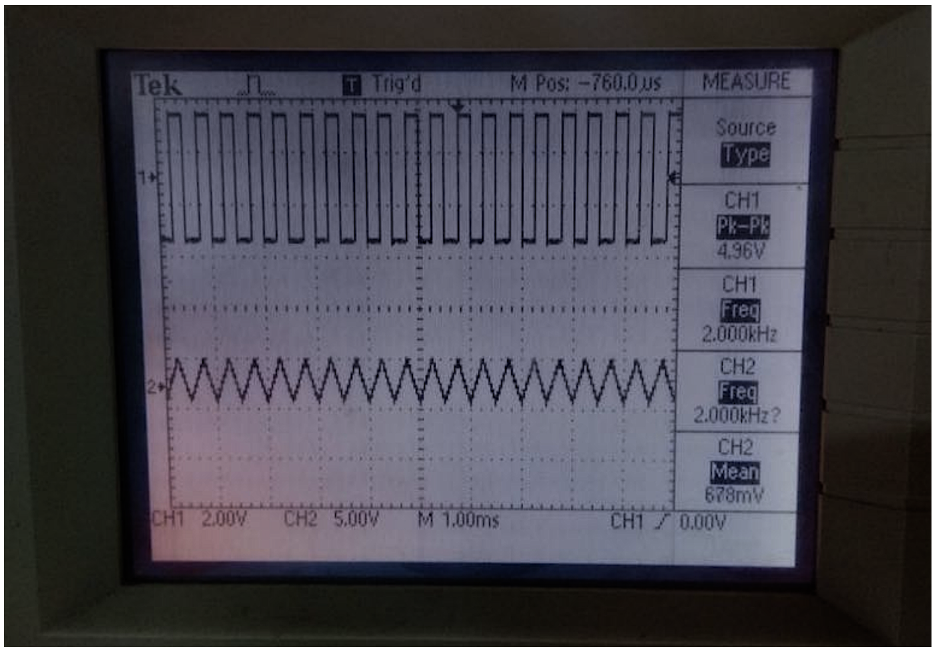
The normal Rc integrator has only 20Db roll-off which is very low. In practice we need more than 20 Db roll off so we construct a butterworth filter which has much more roll off, hence a better low pass filter.

2 Experimental results

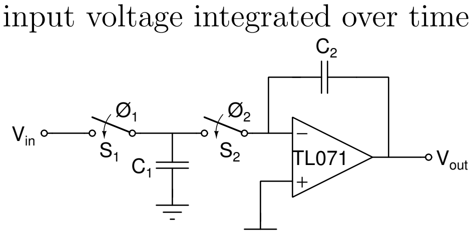
2.1 Comparison of discrete RC integrator and switched-capacitor integrator

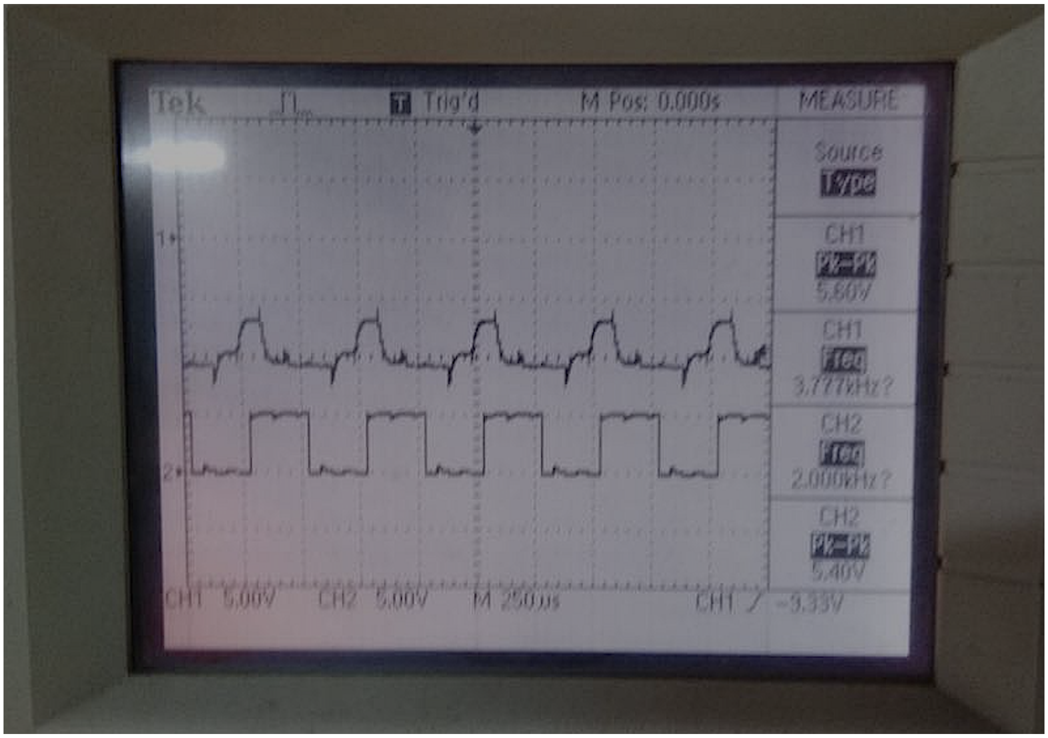
Include the circuit diagrams for the two circuits.





When the input is square wave the Rc integrator performs the mathematical operation of integration.The output voltage is equal to the input voltage integrated over time.





pic credit : Adil Gupta

QCan we use a simple inverter to obtain non-overlapping clocks? What might be the problems one could face while using an inverter?
No, the problem can not be solved using an inverter as in the inverter their are delays.due to this delay there is a chance that the booth switches might be on simultaneously. The switches can not be on simultaneously.

QSuggest an alternative method to obtain non-overlapping clock using Op-Amps.
Ans To obtain non overlaping we can use an inverting opamp with gain -1 .By doing this we will have two oscillating signals with 180 phase difference.

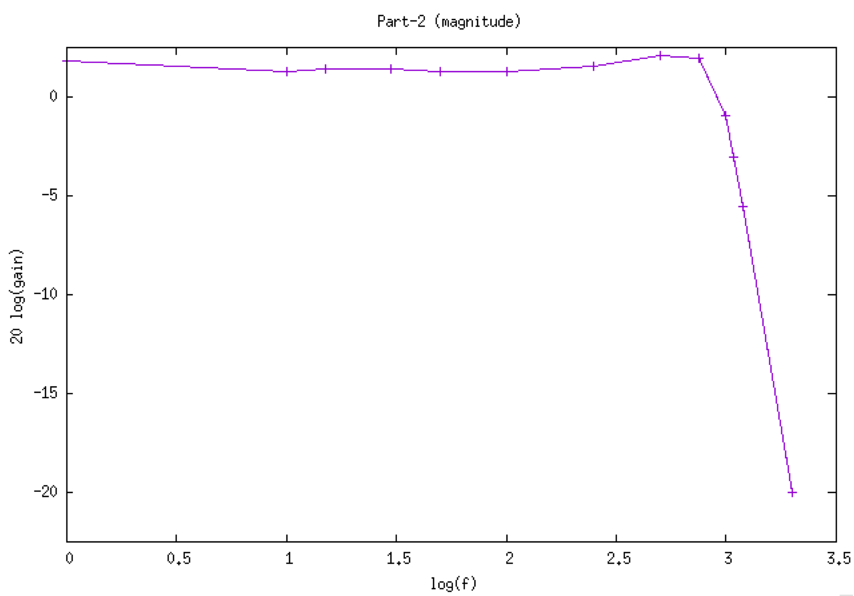
Q How can you explain the discrepancy between the obtained wave and RC integrator output?
The discrepancy arises the operating frequency is low. At low frequency the capacitor gets fully charged and voltage waveform is not linear but rather saturated.

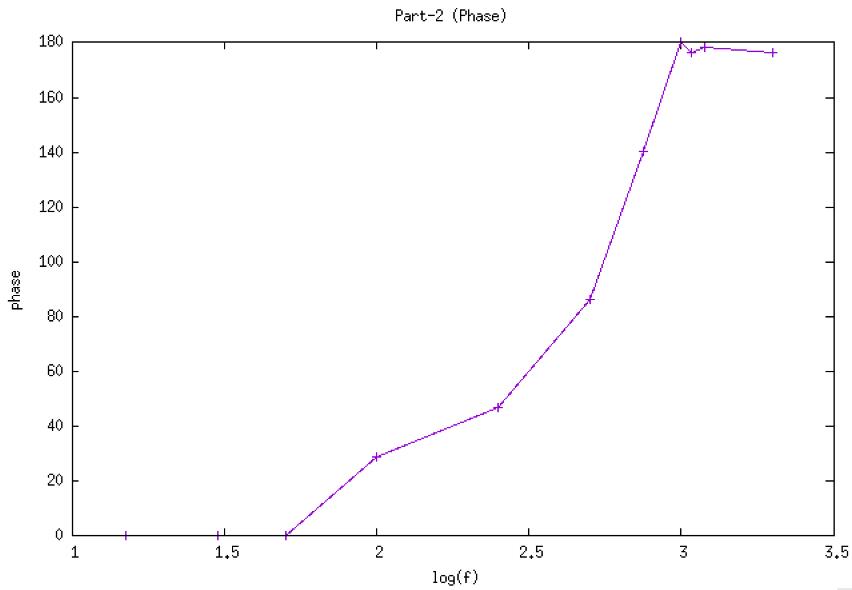
Q What change would you need to make to this circuit to obtain an output similar to the discrete RC integrator?
To obtain the output similar to RC integrator, we can increase the switching frequency, so that the equivalent R increases.

2.2 Fourth order switched-capacitor Butterworth filter

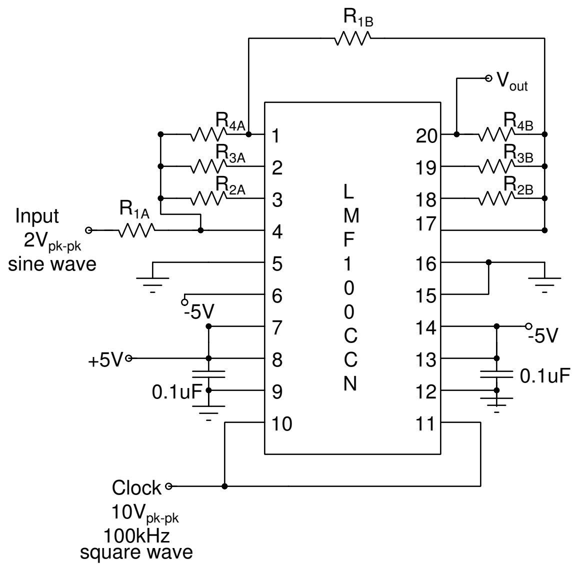
$C_1 = 0.068uF$, $R_{1B} = 18K$
$C_2 = 0.1uF$, $R_{2B} = 18K$
$R_{1A} = 18K$, $R_{3B} = 22K$
$R_{2A} = 20.2K$, $R_{4B} = 22K$
$R_{3A} = 11K$
$R_{4A} = 20.2K$

Tabulate your frequency response data and include your amplitude and phase response Bode plots (log-log). Answer questions asked on slide 8.





f(hz)	gain
1	1.24
10	1.16
15	1.18
30	1.18
50	1.16
100	1.16
250	1.2
500	1.28
750	1.26
1000	0.9
1084	0.705
1200	0.53
2000	0.1



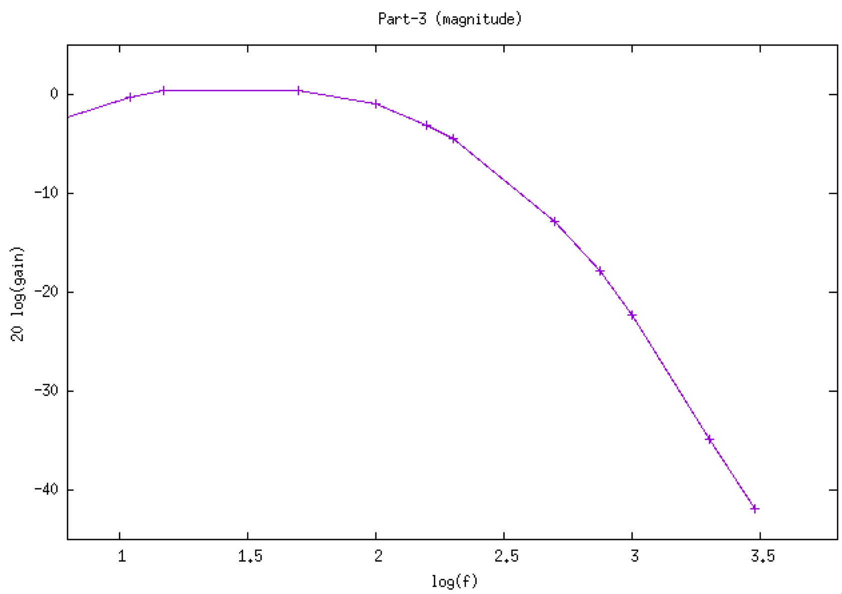
QWhat is the measured DC gain of the circuit
1.31

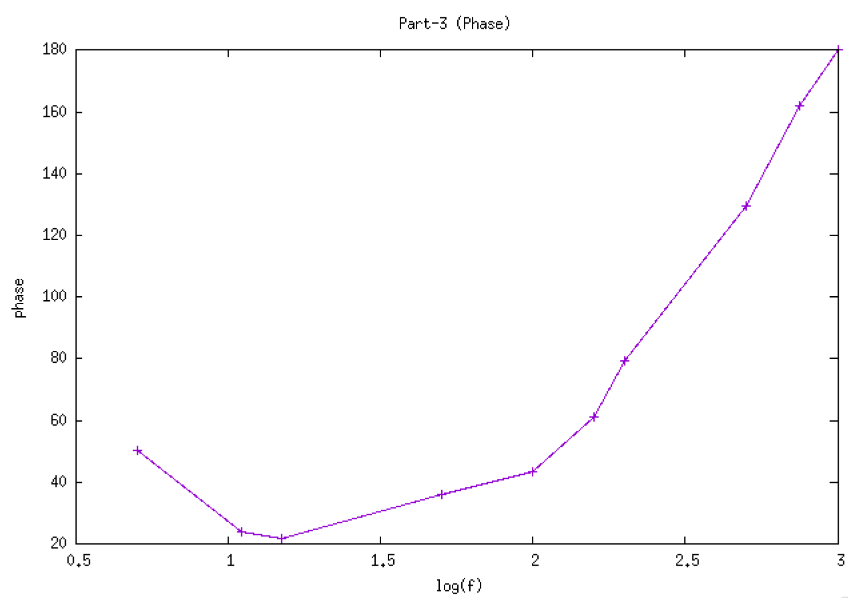
QHow much is the measured 3-dB frequency of the filter
Ans 1084 hz

Calculation of different components from the data sheet was tricky and perhaps new thing.The circuit connections were easy.

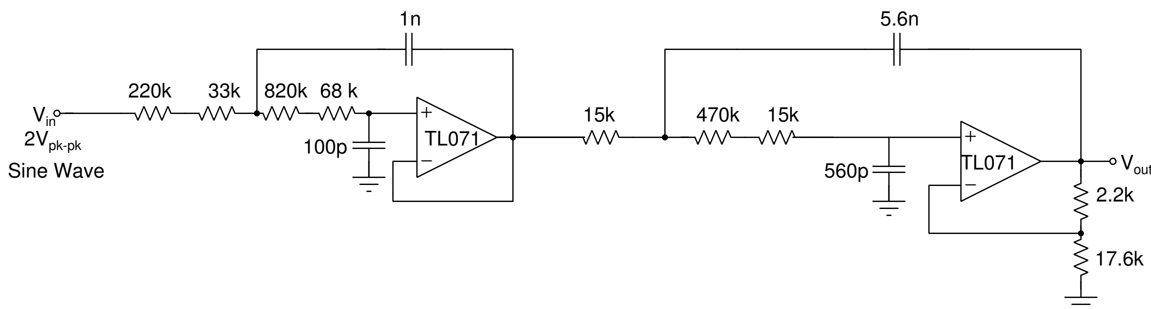
2.3 Fourth order discrete RC Butterworth filter

Include the circuit diagram. Tabulate your frequency response data. Overlay the Bode plots for the discrete RC and switched-capacitor 4^{th} order Butterworth filter on the same plot (separate plots for amplitude and phase) and include in this section. Compare the two different implementations and answer questions asked on slide 10.


Part-3 (magnitude)
20 log(gain)
0
-10
-20
-30
-40
1
1.5
2
2.5
3
3.5
log(f)


Part-3 (Phase)
phase
180
160
140
120
100
80
60
40
20
0.5
1
1.5
2
2.5
3
log(f)

f(hz)	gain
1	0.168
5	0.69
11	0.98
15	1.06
50	1.06
100	0.9
158	0.705
200	0.6
500	0.228
750	0.128
1000	0.077
2000	0.018
3000	0.008
5000	0.008

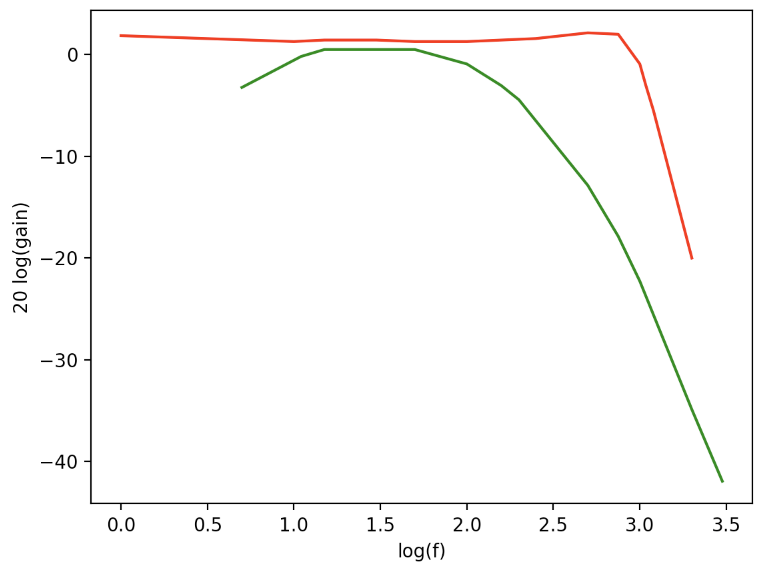


QWhat is the measured DC gain of the circuit?
1.27

Q How much is the measured 3-dB frequency of the filter?
158 hz

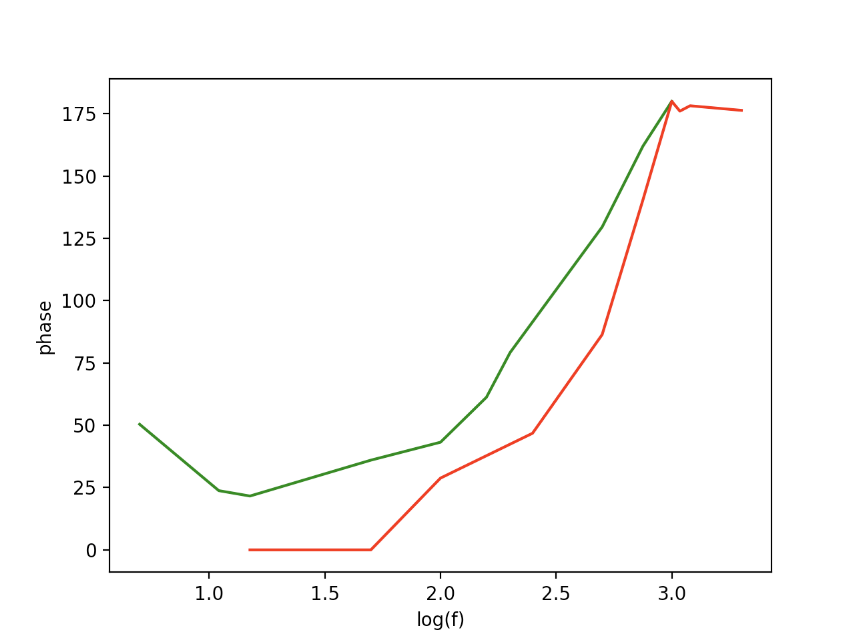
Q Based on the circuit diagram explain how does the circuit implement a 4th order filter?
The given circuit has four capacitor, so it has four poles.thus it will have -4*20 slope. So, it is 4th order.

Q Plot the magnitude of the RC filter and the Switched-Capacitor filter overlaid in the same plot.



Green:RC filter Red: switched-capacitor

Q Plot the phase of the RC filter and the Switched-Capacitor filter overlaid in the same plot.



Green:RC filter Red: switched-capacitor

QWhat are the roll-off (in dB/dec) and phase after the filter corner frequency? Explain your observation.
-30.18007545
What challenges did you face in performing this part of the experiment?
There was noise in the system .

3 Questions for reflection

1. In switched capacitor circuits, both the time-stamp as well as amplitude of the signal are discretized (i.e. not continuous). Would this create problem if it were used in an audio amplifier? Or could you choose the sampling frequency wisely to avoid problems? Answer the question, as an electrical engineer would.
Ans. Yes it will create a problem but we know that any wave can be generated by sampling theorem(approximately).

2. Read this article to gain some good insights into filter design. Why is a Butterworth filter a good choice for an anti-aliasing filter? (hint: think of pass-band ripple)

Ans. The Butterworth filter has the flattest region before cutoff frequency, meaning it has the least attenuation over the desired frequency range.So less ripple will be formed

3. An often overlooked aspect of filter design is group delay. Read this link to see how the group delay for a Butterworth filter would look like (and some matlab resources to simulate any such filter). Clearly, the group delay is not flat for all frequencies in the pass-band. What problems may this cause? (hint: think of dispersion). The best filter design from group delay flatness perspective is a Bessel-Thomson filter.
Ans. When the group delay is constant for every frequency in the pass band then some frequencies might get delayed by to and others by 2to. Due to this delay the whole frequency spectrum gets spectrum distorted.

Useful link: http://www.analog.com/designtools/en/filterwizard/ (to quickly design an analog filter)