Wadhwani Electronics Lab

Dept. of Electrical Engineering

Analog Circuits Lab (Code: EE-230)

Design Exercise

Name:

Roll No.:

Suggested Time: 30 min.

——————– Part-1: Integrator Design Exercise ——————–

1 Basic Switch Capacitor Circuit

1. The transfer function ($\frac{V_{out}}{V_{in}}$) of the circuit shown in Fig.(1) is ....
2. The cut-off frequency (ω_{3-dB}) of the transfer function derived in Q1 is ....
3. If circuit shown in Fig.(2) is to function same as that of an RC integrator (Fig.(1)) and switching period is given by T. Then the its transfer function and cut-off frequency ω_{3-dB} will be .... and ....
4. For the circuit in Fig.(2) if sampling frequency is 10 kHz, then the ratio $\frac{C_1}{C_2}$ for 1 kHz cut-off frequency ($f_c = 1kHz$) is ....
5. Choosing C_2 to be 0.1 μF, the value of C_1 based on the answer of Q4 will be ....
6. Based on the answers of Q1-5 the value of discrete resistor R will be ....

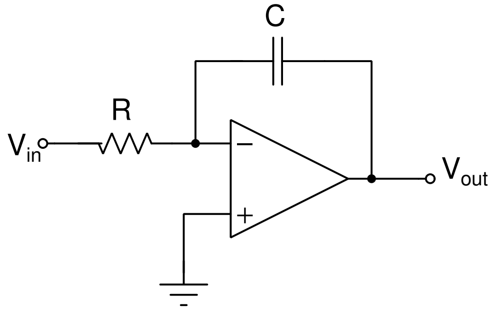

Figure 1: RC Integrator

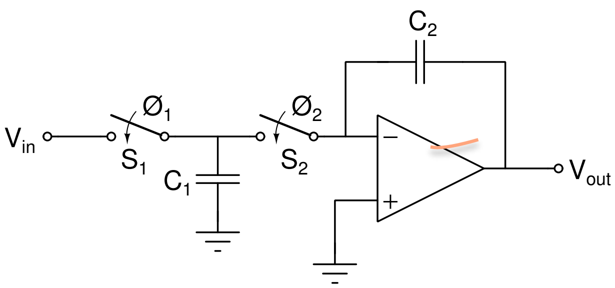

Figure 2: Switch Cap Integrator

———————-Part-2: Filter Design Exercise ——————

2 Design Specifications

- Filter Type: Butterworth Low Pass Filter
- Center Frequency (3-dB Frequency for LPF): $f_0 = 1\ kHz$
- Stop Band Frequency: $f_s = 3.5\ kHz$
- Pass Band Gain: $H_0 = 1$ dB
- Maximum Allowable Pass Band Rillple: $A_{max} = 1$ dB
- Stop Band Attenuation: $A_{min} = 40$ dB
- Clock Frequency: $f_{clk} = 100\ kHz$
- Mode of Operation for LMF100CCN = 3

3 Questions

Refer to the datasheet of the IC LMF100CCN (click on the IC name) used in Mode-3 of Low Pass Filter configuration.

7. Using the method explained in Section: 3, filter order for the specifications given in Section: 2 is ....

8. Assuming that the desired dc-gain is to be obtained from the first stage only, answer the following:

   - Q for the two stages (Stage-A and Stage-B) are: Q_A = ... and Q_B = ...
   - Center frequencies for the two stages (Stage-A and Stage-B) are f_{0_A} = ... and f_{0_B} = ...
   - Normalized DC Gain value of the two stages (Stage-A and Stage-B) are H_{0_A} = ... and H_{0_B} = ...

9. The DC Gain (H_{0_A}) of stage -A (or B) in terms of resistances R_{1_A} and R_{4_A} is .... (*Hint*: Refer to the datasheet)

   If we choose R_1 for both the stages to be 18 kΩ. Then :

   - R_{2_A} = ... and R_{2_B} = ...
   - R_{3_A} = ... and R_{3_B} = ...
   - R_{4_A} = ... and R_{4_B} = ...

4 Using Nomographs and Tables

The nomographs and tables are the most helpful tools that can be used for the hand design of filters. Nomographs are used to find the order of the filter based on desired specifications and the table is used to find the necessary parameters such as center frequencies and Quality Factor(Q) of a low-pass equivalent. The nomographs and tables are given in Fig.(4) and Fig.(5)

To use a nomograph A_{max}, A_{min} and the ratio f_s/f_c for low-pass must defined by the designer. We can calculate the filter order required by drawing a straight line(1) joining the desired value of A_{max} and A_{min} to the y-axis of the nomograph. Then draw a line vertical (2) from the desired f_s/f_c, cutting the order curves at point A and B. Finally, draw a horizontal line (3) from the intersection of line-1 and y-axis points. The intersection of line(1) and line(3) on the curves will give the filter order based on the desired specifications. This process is elaborated in Fig.(3) where the order of the filter turns out to be n_2.

The table is given in Fig.(5) is specified for a normalized frequency of $1Hz$. To obtain the necessary desired filter cut-off, simply multiply all of center frequency values given in the table by the desired f_c.

Note: This is a simple filter design table and hence the table is simple one as the scaling factor. Table in Fig.() gives a design of Chebyshev filter design where cut-off frequency will not a multiplication factor of 1 (You need not to use it in this experiment it is just for your reference).

Remark: To read nomographs either you can use adobe reader or bring a printout of it, no printout of the nomographs will be provided during the lab.

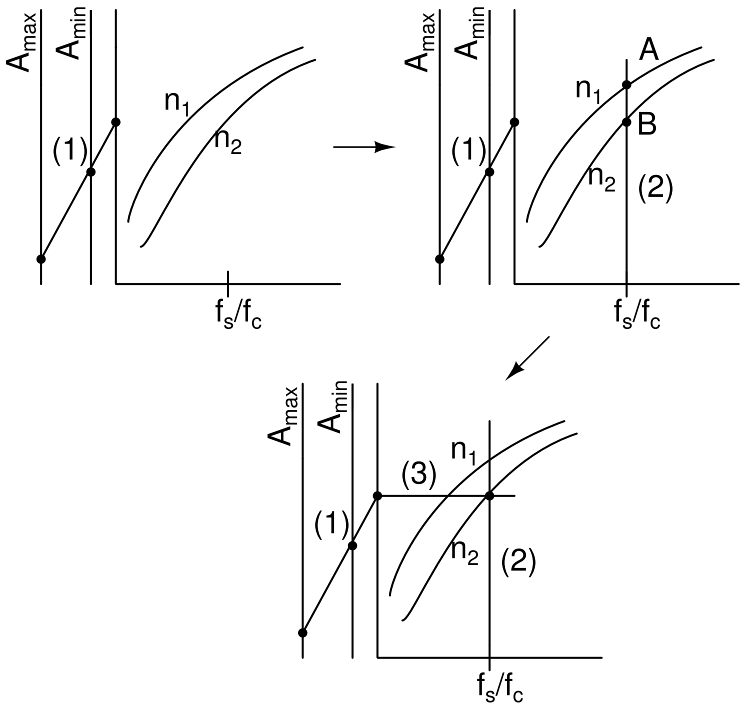

Figure 3: Example of Nomograph Use

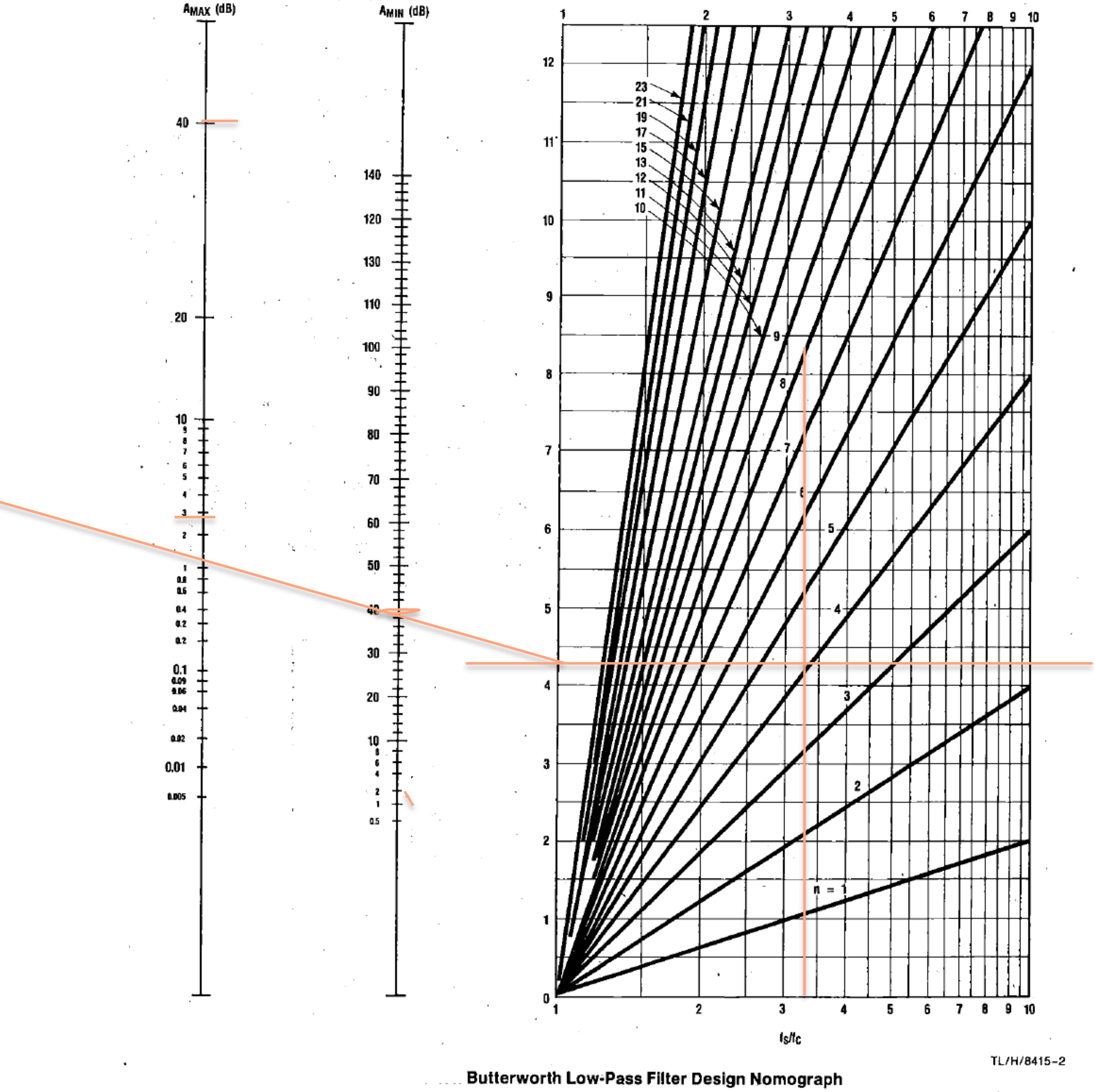

Figure 4: Butterworth Low Pass Nomograph

Butterworth Design Table for 1 Hz −3 dB Frequency

Order	$f_{-3\,dB} = 1$ Hz										Att (dB)
N	F1	Q1	F2	Q2	F3	Q3	F4	Q4	F5	Q5	2Fc
1	1										9
2	1	0.707									15
3	1	1.000	1								21
4	1	0.541	1	1.306							27
5	1	0.618	1	1.620	1						33
6	1	0.518	1	0.707	1	1.932					39
7	1	0.555	1	0.802	1	2.247	1				45
8	1	0.510	1	0.601	1	0.900	1	2.563			51
9	1	0.532	1	0.653	1	1.000	1	2.879	1		57
10	1	0.506	1	0.561	1	0.707	1	1.101	1	3.196	63

Figure 5: Normalised Butterworth Low Pass Design Table

Order	F	Q1	F2	Q2	F3	Q3	F4	Q4	F5	Q5	Att at 2 fc
2	3.229	0.725									0.46
3	1.810	1.139	1.589								4.08
4	1.416	1.724	1.140	0.575							13.56
5	1.254	2.483	1.007	0.761	0.817						24.82
6	1.171	3.416	0.969	1.034	0.711	0.556					36.24
7	1.124	4.521	0.961	1.380	0.707	0.703	0.558				47.68
8	1.093	5.798	0.962	1.791	0.736	0.916	0.521	0.550			59.12
9	1.073	7.247	0.965	2.264	0.771	1.181	0.547	0.682	0.426		70.56
10	1.059	8.866	0.969	2.797	0.804	1.489	0.593	0.872	0.413	0.547	82.00

Figure 6: Chebyshev Low Pass filter with pass band ripple of 0.01dB