Sample Final Exam

**Question 1 (Switched-Capacitors)** Below is the functional equivalent circuit for a SC IC. (The numbers indicate the IC pin numbers).

(a) Show, by drawing in components, how you can use the IC to invert a positive supply voltage
(b) Indicate input- and output voltages and their polarities
(c) Indicate typical values of components you would expect to use
(d) Indicate a typical switching frequency

![Switched-Capacitors IC Circuit](image)

**Question 2** Show an analog circuit that will produce the square root($\sqrt{v_1}$) of an input voltage. The circuit should implement this functionality using some resistors, one or more analog multiplier(s), and op-amp(s). For simplicity, you do not have to show power supplies, and assume that the multiplier’s scaling factor is 1. However, you have to derive a relationship between the input and output voltages.

**Question 3** The LPF shown has a 3-dB frequency of $xx$ rad/s. Using an RC $\rightarrow$ CR transformation, and frequency- and impedance scaling, convert the filter to an HPF with 3-dB frequency of $yyy$ kHz. The smallest resistance value in the HPF must be $zzz$ kHz. Draw a schematic for the HPF.

**Question 4** Consider the switched capacitor circuit below where $C_A = xx$ pF, and the switch is the ‘1’ position. Further, $C_B = yy$ pF and it is initially charged to $zzz$. Also, $V_I = x V$ and the switching frequency is $xxx$ kHz. Determine the output voltage $V_O$ after 3 cycles.
Question 5  The op-amp in the circuit below is non-ideal and has the following parameters: blah, blah, blah, …

Using two-port theory, determine the gain $A_f = v_o / v_i$, and the input- and output resistances $R_{if}$ and $R_{of}$ of the feedback amplifier. You may assume no feed forward for the feedback network.

Note on this exam you will not be asked to calculate $h$-parameters. Make sure you can apply the turn-off the feedback method though.

Question 6  A filter has the following transfer function below. Determine the output $y(t)$ if the input is $x(t) = 2 \cos(2\pi 25t)$.

$$H(s) = \frac{1,000s}{s^2 + 20s + 1,000}$$

Question 7  Using the attached filter design table, design a xx-th order, yy-dB ripple, Chebyshev LPF with cutoff frequency $f_c = xx$ kHz. Draw a block diagram with the second-order sections’ Qs and center frequencies indicated. Make sure the sections are properly ordered.
**Question 8** The sub-circuits below are integrated into an IC. Draw external components, to show how to configure the IC as a buck (or boost) regulator. You can ignore $A_2$ and $I_{LM}$. Specify the component values to set the output voltage to $V_{out}$. Estimate minimum attainable output ripple voltage if the hysteresis for $A_1$ is $330$ mV.

![IC Diagram](image)

**Question 9** Below is a sub circuit for carrier extraction of NRZ data. Also shown is a sample of random NRZ data. Assume the bit duration is $T_B = 10 \mu s$. Next to the NRZ data stream, neatly sketch the signal’s spectrum. Below the NRZ data stream, neatly sketch the signal at $B$, clearly showing the time-relationship between the two signals. Assume that the $RC$ network delays signals by $5 \mu s$. Also sketch the spectrum of the signal at $B$. Be sure to label with numerical values important spectral components, nulls, etc., on the both the spectra.

![Carrier Extraction Diagram](image)

This was very poorly answered on the quiz.
Lab questions. We spent quite a bit of time on the labs and there will be questions on the FM link labs. On the transmitter lab you have to design the differentiation that glues VCO together the 555 timer. You also had to design the driver for the IR transmitter diodes. Go over your notes and design and make sure you understand how it works.

On the receiver lab you had to design the coupling capacitors so that the help filter. What is the purpose of the inductor? Why is it important that you have large GBP op-amp? Why is it important to carefully decouple your circuit? Explain how is it possible to get a reliable link going when the poor IR transmitter has to compete with the sunlight and the incandescent and fluorescent lamps.

Oscillator Questions

Be sure you can figure out the oscillation frequency of a circuit such as this assuming you have the relevant information (trip voltages, C, R_F, ...)

Be sure you can figure out how to determine the amplitude at which a Wien bridge oscillator stabilizes.

Be sure you can determine the oscillation frequency and starting conditions if the loop transfer function is given. For example:

$$T(s) = \frac{A}{s^2LC + 2s + 1}$$

Phase Locked Loop

You will have all the relevant equations. However, you need to be able to apply these. We did several examples and HW problems. Take a look at those. Be sure you can determine the phase detector constant for XOR, AND phase detector. Don’t forget the analog multiplier as a phase detector.

Schmitt Trigger (probably the worst-answered this semester). Make sure you can determine the trigger thresholds for circuits such as this assuming you are given the required information. The general strategy is to recognize that $V_{out}$ has two state – high and low. Pick one, remove the op-amps and solve for the voltage at $V_+$. Repeat for the other state.