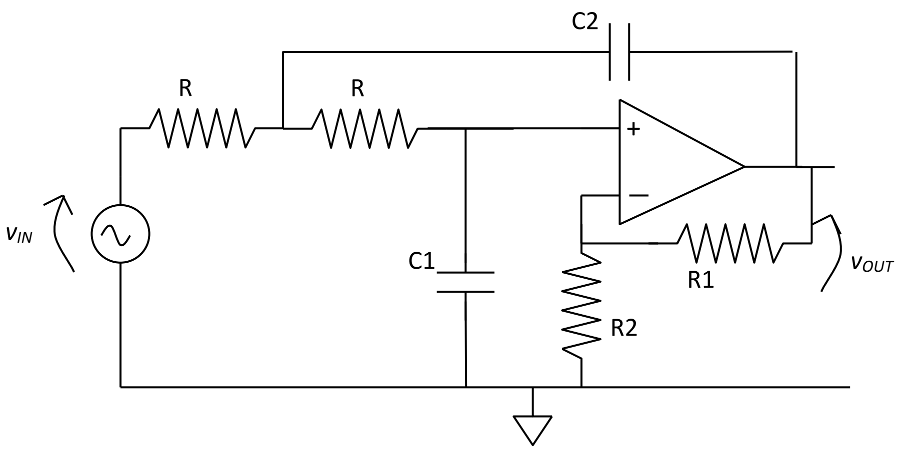
Engineering 1620 – Spring 2016

Practice Problems for Exam

1. The Sallen and Key positive gain low pass filter was long a popular way to make continuous time active filters. One can show that the dependence of the filter's transfer function on component tolerance is reduced if the gain of the filter is about 1.4X. Here is the basic circuit:



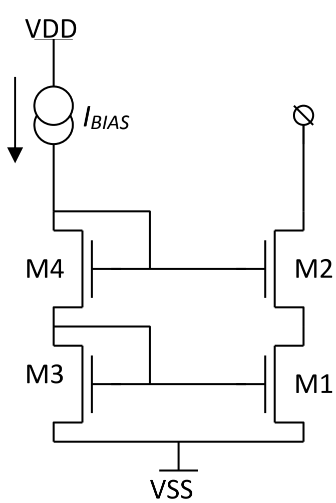
1.1) Derive the transfer function of this circuit. You may leave the opamp closed-loop gain as a single constant but also write that constant in terms of the component values.

1.2) Suppose that you really do want a a 1 rad/second, second-order Butterworth low pass filter with gain at DC of 1.4. Select component values to do this. Make R = 1 megohm to make capacitors reasonable values. Choose R1 and R2 on any reasonable basis.

1.3) You change your mind and want a 3.1 KHz filter of the same type. What are the capacitor values in this case if at the same time you lower R to 100 K.

2.) We have spent most of the last month on small signal analysis and the basic properties of both BJT and MOSFET standard circuits for use in analog integrated circuits.

2.1) What is this circuit? What is the purpose of M3 and M1? What do M2 and M4 do?

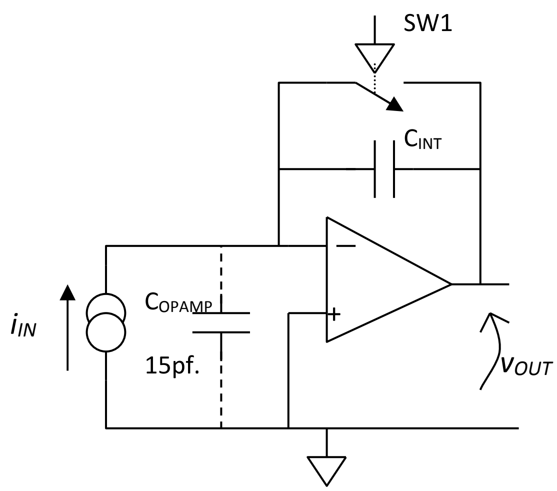


2.2) Derive the output impedance of this circuit, that is, the impedance at the drain of M2 relative to VSS in terms of the device small signal parameters of M1 and M2 as needed.

2.3) Suppose I_{BIAS} = 20 uamp. The circuit has all identical transistors and the overvoltage on M4 is 0.33 volts. The manufacturing process leads to $\lambda = 0.025$ for these devices. What is the numerical value of the output impedance?

3.) We also spent some time looking semi-quantitatively at opamps in use. Here is a current integrator circuit. When the digitally-operated switch is closed, then the capacitor is discharged and the circuit is insensitive to the incoming current signal. When it is open, the output voltage follows the integrated input current. Resettable integrators are used in optical systems, smoke detectors, radiation counters and quite a number of other places. This problem looks at the performance of the circuit while the switch is open.

The operational amplifier has a gain-bandwidth product of 24 MHz. The capacitor C_{OPAMP} in the figure represents the input impedance of the amplifier which is simply a capacitance of 15 pf. The DC gain is 112 DB ($4 \cdot 10^5$ X). Assume that C_{INT} does not change the amplifier gain appreciably.



3.1) Let C_{INT} = 150 pfd and assume the switch is open for the rest of the problem. Neglecting the 15 pf. of the amplifier input, find an expression for the impedance seen by the current source, that is, the input impedance of the integrator circuit? This is the Miller effect in its simplest form. Include the actual frequency dependent gain of the amplifier which will make Miller's theorem exact.

3.2) At 1 Hz, what is the numeric value of the impedance from part 3.1? What is the phase angle of the impedance? What single passive component has impedance closest to this value?

3.3) At 1 KHz, what is the numeric value? What is the phase angle of the impedance? What single passive component has impedance closest to this value?

3.4) What is the impedance of the amplifier input capacitance at 1 KHz? Is it significant compared to the Miller impedance?

3.5) Repeat parts 3.3 and 3.4 for 1 MHz. The impedance probably does not change very much in this range of frequency – why?