Problem #10:

Fig. (P10a) depicts a simple single pole RC filter driven by a transconductance amplifier. The circuit at hand is subsequently modified to realize improved circuit bandwidth by inserting an inductance, $L$, in series with resistance $R$, as depicted in Fig. (10b).

(a). Show that the model in Fig. (10a) delivers a maximally flat magnitude (MFM) voltage gain response, $A_v(s) = V_o/V_i$.

(b). Derive, in terms of resistance $R$ and capacitance $C$, an expression for inductance $L$, such that the circuit in Fig. (10b) also delivers an MFM voltage gain response.

(c). For the condition in Part (b), what is the factor by which the incorporated inductance improves the bandwidth of the original circuit in Fig. (10a)?

(d). Derive, in terms of resistance $R$ and capacitance $C$, an expression for inductance $L$, such that the circuit in Fig. (10b) delivers a maximally flat delay (MFD) voltage gain response.

(e). Determine the zero frequency envelope delays of the filters considered in Parts (a), (b), and (d).

(f). Derive expressions for the step responses of the filters corresponding to Parts (a), (b), and (d).

Problem #11:

With reference to Fig. (P10), assume the availability of transconductors having transconductance ($g_m$) values in the range of 10 mmho -to- 50 mmho.

(a). Design the filter of Fig. (P10a) for a zero frequency gain of 0 dB and a 3-dB bandwidth of 400 MHz. Use SPICE to simulate the resultant voltage gain magnitude response, the voltage gain phase response, the voltage gain delay response, and the transient step response to a 10 mV input step excitation. Examine the resultant SPICE responses in light of the cal-
calculations in Parts (e) and (f) of the preceding problem and the stipulated steady state design criteria.
(b). Repeat (a) for the filter corresponding to Part (b) of the preceding problem.
(c). Repeat (a) for the filter corresponding to Part (d) of the preceding problem.

**Problem #12:**
A lowpass, biquadratic, Butterworth filter is to be designed to deliver a zero frequency gain of 0 dB and a 3-dB bandwidth of 100 MHz. The filter is to be capable of driving a 300 Ω load and is to provide at least 30-dB of attenuation at 250 MHz. Assume the availability of transconductors having transconductance ($g_m$) values in the range of 10 mmho to 50 mmho. Show the schematic diagram for the completed design and use SPICE to simulate its steady stage magnitude response.

**Problem #13:**
Repeat Problem #12, subject to the following provisos.
i. The filter is to be a Chebyshev network having at most 0.25 dB of ripple throughout its passband.
ii. The ripple bandwidth, not the 3-dB bandwidth, is to be 100 MHz.

**Problem #14:**
The “selectivity ratio,” $SR$, of a lowpass filter is defined to be the ratio of the frequency passband over which the transfer function magnitude is 60-dB below the zero frequency value of transfer function -to- the frequency passband at which the response magnitude is 6-dB below the zero frequency transmittance.
(a). Derive an expression for the $SR$ of an $nth$ order Butterworth filter.
(b). Derive an expression for the $SR$ of an $nth$ order Chebyshev filter having a ripple of $e$.
(c). Derive an expression for the $SR$ of a lowpass filter characterized by an $nth$ order, real, left half plane pole.
Problem #10: