As mentioned in lecture, three basic single-transistor amplifier “atoms” are used to build essentially all other amplifiers. Once you have gained an understanding of the characteristics of these fundamental building blocks, you will have gone a long way towards understanding amplifiers of almost arbitrary complexity.

You will not need to run HSPICE for this problem set. But in anticipation of having do so in the near future, we will soon distribute a handout on how to do this (and, as always, periodically check the website for hints and late-breaking news, and for the scheduling of a SPICE tutorial session for those who desire it).

**Problem 1:** We’ve mentioned that feedback can modify impedances, perhaps to values far from expectations. As a result, component impedances may differ dramatically from port impedances. It is extremely important to keep in mind that the presence of dependent generators often enables these dramatic changes in impedance. To underscore this idea, as well as to develop other important insights, consider the following abstraction presented in lecture:

**FIGURE 1. Generalized impedance converter**

When originally introduced in lecture, the triangle was an ideal voltage amplifier with a purely scalar gain factor, $A$, which could take on any value. The amplifier had the usual unattainable characteristics (e.g., infinite input and zero output impedances, zero power consumption, etc.). Here we consider what happens if the gain factor is no longer purely scalar. That is, now allow $A$ to be a complex quantity in general. To improve the uniformity of your answers, specifically let the amplifier gain be

$$A = T + jU,$$  (EQ 1)

where $T$ and $U$ are real, and which may be functions of frequency in general.
a) Derive a general expression for the input impedance, $Z_{in}$, as a function of the feedback impedance and complex amplifier gain.

b) Consider the specific case where the gain magnitude is precisely unity. In the purely scalar case, this “bootstrapping” causes the input impedance to be infinite. Is this still true with a complex gain? Explain.

c) For the configuration in b), let the feedback element be a pure capacitance, $C$. Is it possible to produce an input impedance that is nonetheless resistive? Inductive? Over what, if any, range of phase values will those behaviors occur? [Define the resistive range as where the phase angle between voltage and current is under $45^\circ$ in magnitude, the capacitive range as where the voltage lags the current by $45^\circ$ to $135^\circ$, and the inductive regime as one where the voltage leads the current by $45^\circ$ to $135^\circ$.]

**Problem 2**: Razavi, P3.1.

**Problem 3**: Razavi, P3.2.

**Problem 4**: Razavi, P3.13.

**Problem 5**: Razavi, P3.21. (Again, this may appear to be tedious, but in reality, it is.)