High-Frequency Amplifiers (Prelab 1 & “Warm-ups” for Ch.4 Krauss)

There are two gain blocks that will limit performance of your walkie-talkies: the front-end amp (hopefully a Low Noise Amp or LNA) and the power amp (PA). Chapter 4 considers aspects of the front-end and Chapters 12-14 address the power amp.

Chapter 4, Fig. 4-1 shows a basic CE (common emitter) tuned amplifier. Due to its simplicity and the fact that in relates directly to EE113 background, let’s use it and consider alternatives later in the quarter as part of the project phase. This circuit has tuned load (LC) and related issues of stability as discussed below. For simplicity (including the fact that half of the class doesn’t have the text (!)…let’s consider the simplified CE stage in Figure 2 of Prelab 1 and as shown on the next foil.

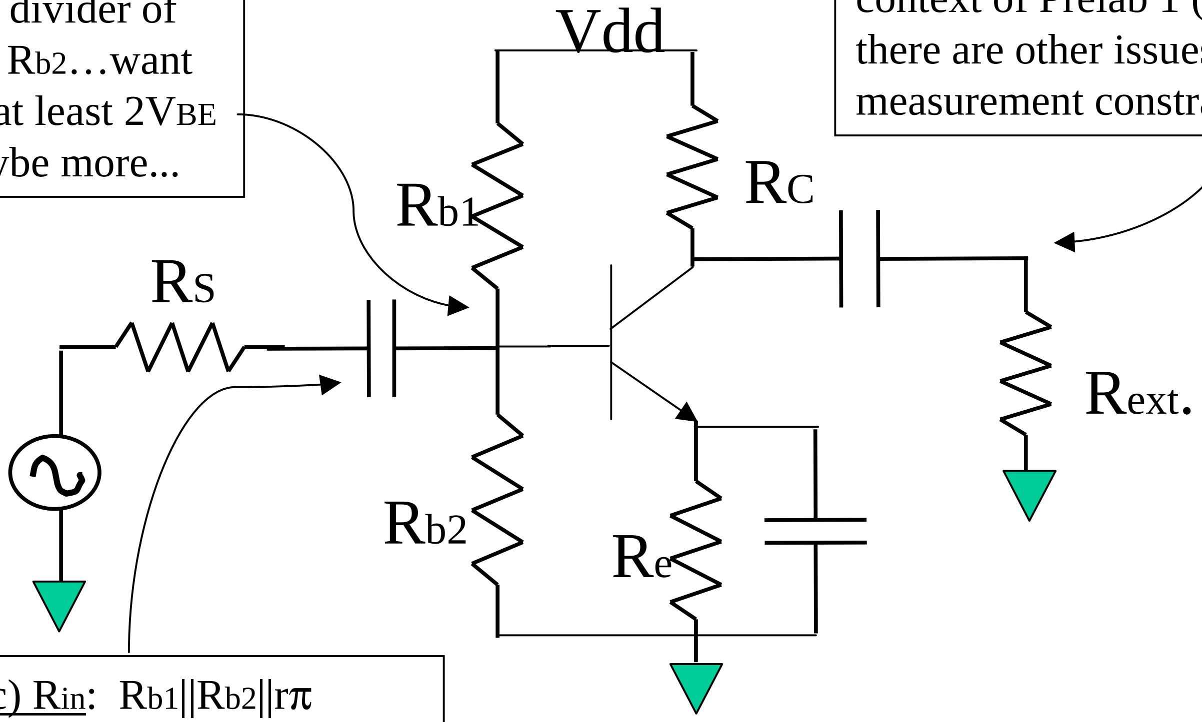
Key design points to be considered include:

- Base bias ($V_B = I_C R_e + V_{BE}$) set by voltage divider of resistors
- Collector voltage at bias is $V_{dd} - I_C R_C$ (with inductor--Krauss Fig. 4-1--collector is at V_{dd} but and the ac value can swing to both positive and negative values about that bias point)
- To first order, small signal voltage gain is $-g_m R_L$ (where R_L is either: a) $R_C \| R_{ext}$. or b) the “parallel tank” resistor $R_t \| R_{ext}$.)

Biasing and Mid-Band (ac) Impedances

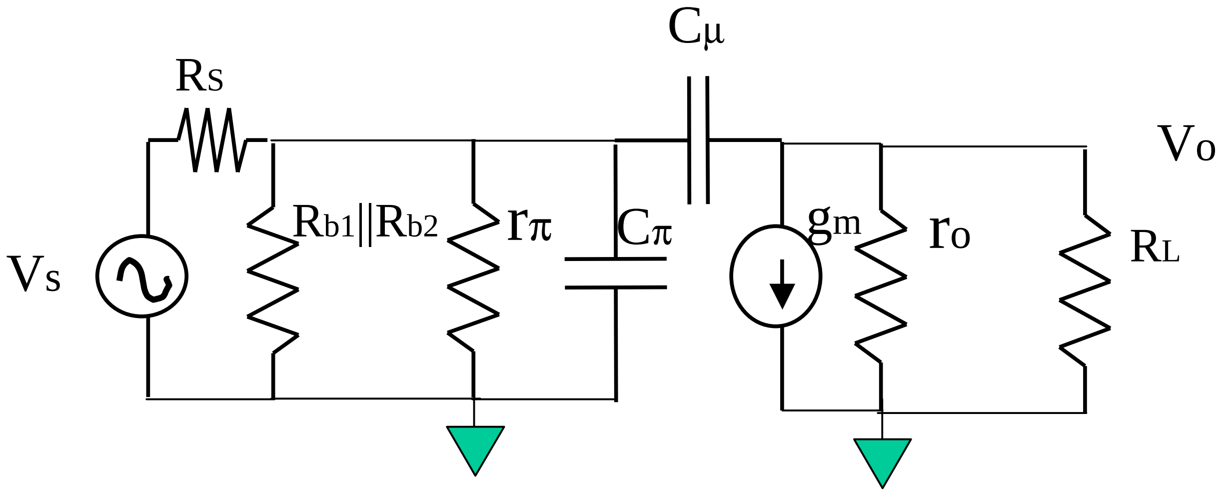
<u>Small Signal (ac) R_{out}</u>: $R_c||r_o||R_{ext}$ (assuming that R_e has bypass Cap). Design objective--long term--is to get good “match” between internal RC||ro and next sage Rext. In context of Prelab 1 (and Lab 1) there are other issues related to measurement constraints

<u>Bias Point:</u>
Voltage divider of R_{b1} and R_{b2}…want it to be at least $2V_{BE}$ and maybe more...



<u>Small Signal (ac) R_{in}</u>: $R_{b1}||R_{b2}||r\pi$ (assuming that R_e has bypass Cap). Design objective is to keep Rin small but practical limits for this circuit--bias point (voltage) and low power (I.e. don’t want I_{BIAS} to be large compared to I_C

Small Signal Freq. Analysis



- Coupling Caps, Bypass Caps and V_{dd} (as an ac ground) reduce previous circuit to the one shown above
- The Hybrid-π model has been inserted for transistor…r_π, C_π, C_μ, g_m and r_o (neglect other C's for the moment)
- Use Miller Approximation to break the C_μ feedback path…**$C_M=C_\mu(1+g_mR_L||r_o)$** and $C_o \sim C_\mu$
- The result is a two time-constant circuit and ESTIMATE of the dominant pole comes from **~1/(sum of TCs)**
- All of the above is quick-and-dirty…get a "handle" on the problem. In reality, SPICE will do a bunch of things for you:
    - Computes dc bias point
    - Computes ac small sigmal parameters (which you often want to list and check with what YOU computed)
    - Uses ac small signal values (including possible additional parasitic caps) to do ac frequency response (I.e. the "**Bode Plot**"). COMMENT: This will have at least TWO poles. The DOMINANT pole should have a pretty good correlation with ESTIMATE per above sum-of-TCs method

Other Comments about CE and EE113 Revisited

- For those NON EE folks (and/or EE grad. Students) without specific background in CE circuit and design, we’ll get you access to few lecture notes ala Mar Hershenson (Pres. & Founder of Barcelona Design)
- We’re NOT (!) trying to fully revisit the gore of hand calculations…merely trying to make sure you keep the right “rules of thumb” (guidelines) in mind as you use SPICE as “interactive learning tool” and design aid
- Single transistor circuit is VERY useful as: a) basic amplifier (pre-amp and/or low-noise versions), b) power amplifier (“PA” ala Ch. 12-14) and also inter-stage “buffer”
- We will re-visit the pre-amp/LNA later in the quarter and that will in fact use much more of Ch 4 (Krauss)…the following few foils point out one key issue about DISTORTION

A Brief Word about Linearity (and Distortion)

Above analysis assumes that small signal (ac) model is correct…that things are PURELY LINEAR.

In reality as you will see from Krauss (Equations 4-2 to 4-4), the bipolar device is an EXPONENTIAL device I_C vs V_{BE}. Strictly speaking, V_{BE} needs to be a fraction (I.e. 1/2 or smaller) of kT/q…25.9mV at 300K.

Figure 4-2 (Krauss…printed below) shows important points about:
- Linearity (I.e. for values of x less than 0.5)
- Harmonic distortion (and our first look at Bessel functions)

For pre-amplifiers (pre-amp) these issues are not critical “show stoppers” since we will be in small signal regime as far as signals we are trying to receive. When we get to the power-amp (PA), effects of linearity and distortion are indeed important.