FREQUENTLY ASKED QUESTIONS

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Content Questions

Why can we short the supply in the AC equivalent diagram?

The reason this works is that AC circuit analysis doesn't care about DC offsets— all that matters is the *change* in the signal as a function of time. So we set the voltage supply to ground. Warning: don't actually do this in meat (or silicon) space or Bad Things will happen! "Shorting the supply" is an abstract operation to help us understand AC circuit behavior.

Is the AC equivalent diagram imaginary?

The AC equivalent diagram describes the circuit behavior when you have varying (usually sinusoidal) signals, for which DC offsets don't matter—only the variation in time matters. This kind of abstract diagram can be useful in any context involving AC signals, not just amplifiers.

If you remove the base biasing resistor from a transistor, how does it change its functionality?

If there's no biasing resistor, the transistor might not work at all during at least some of the input voltage sinusoidal swing, i.e., the transistor might not even be in its operational regime (and the Transistor Man equation would not apply). This might result in a seriously distorted or even non-existent output. You want to choose the base-biasing resistor(s) so that the base voltage is at least V_{pn} above the emitter voltage, and you typically also want the collector voltage to be a few volts above the emitter voltage (and less than V_{CC}). There may be other requirements on output currents or voltages that you select the base resistor in order to meet.

How do you go from steps 1 and 2 from the handout to step 3?

Steps 1 and 2 are straightforward (short the capacitor, i.e., replace it with a wire, and connect the supply to ground). For step 3, you *replace* the transistor with the idealized model transistor in the step 3 diagram. Snip out the transistor (in your mind) and connect up the spots labeled B, C, E with the base, collector and emitter, respectively.

How is the behavior of an amplifier dependent on V_{CC}?

So long as the transistor is properly DC-biased, the AC behavior of an amplifier like the ones we considered today does not depend on the *specific* value of V_{CC}. When we make the AC equivalent, V_{CC} is treated as if it is at ground, so the value doesn't matter.

However, note that the value of V_{CC} *does* matter for proper DC-biasing of the transistor. It must have a value such that the voltage through the base resistor voltage divider at the transistor base is large enough to keep the transistor "on" (i.e., in the linear active regime) throughout the entire input voltage swing.

What difference does size of input and output impedance make for different amplifiers?

The input and output impedances matter for the properties of the two-terminal network when connected to other circuits at the input and the output (which is usually what you are doing!). Whether you want small or large, or some particular value, depends entirely on what you are doing with the amplifier. For example, if you connect a load to the output, you want to make sure the amplifier can provide enough current— that will determine requirements on output impedance. Or you might not want to draw too much current from a supply, so you'd want a high-enough input impedance. Sometimes you want to match input and output impedance to maximize power transfer. Or you might just want to match the impedance of the circuit, or cable, you are connecting up to, in order to avoid reflections.

When we talked about impedance matching, we talked about input and output impedance as the impedance viewed from different parts of the circuit. Can you explain that again?

The input and output impedances we are discussing in the context of transistor amplifiers are in fact exactly the same as what we were discussing before. The input impedance is the impedance "seen" from the input. Imagine the circuit as a black box with the input terminals poking out from it, put a voltage $V_{\rm in}$ across the terminals, and measure the current $I_{\rm in}$. You would infer that the black box has an impedance $V_{\text{in}}/I_{\text{in}}$: that's Z_{in}, the input impedance. Similarly, imagine "looking" at the black box from the two output terminals: the "Thevenin equivalent" impedance is the open-terminal voltage over the short-circuit-terminal current, i.e., $Z_{\text{out}} = \frac{V_{\text{out}}(R_L=\infty)}{I_{\text{out}}(R_L=0)}$.

Now for impedance *matching*: that's the idea that when you have power supply impedance and load impedance the same, you get maximum power transfer (worked out in Eggleston 2.9 in the context of transformers). In this context, the power supply Thevenin equivalent resistance is the output impedance of the supply, and the load resistance is the input impedance of the circuit you attach to the supply. The concept actually holds generally for input and output impedances of four-terminal networks you attach to each other– when the input impedance of the second is matched to the output impedance of the first, power transfer is maximum. This is a reason you often want to know input and output impedances. (Also, matched impedances suppress signal reflections, although we haven't really talked much about that.)

...So for the RLC circuit is $Z_{\text{in}} = Z_{\text{out}}$?

Well, if you work out input and output impedance for a passive RLC network, you will find that in general $Z_{in} \neq Z_{\text{out}}$. Z_{in} will be $R + \frac{1}{j\omega C} + j\omega L$ and Z_{out} will depend on where you are taking the output.

But indeed, for the RLC circuit also, power transfer from the supply *is* maximum when the input impedance of the RLC circuit (which depends on ω) is matched to the output impedance of the power supply at the input of the RLC circuit.

Why do we get a resistance $R_B(\beta+1)$ for so many of these examples?

Well, the exact situation is different for each, but in many there is a voltage drop $i_{\text{tot}}R$ across some resistor R, where i_{tot} is the sum of i_b and βi_b. This then gives a voltage drop $i_b(\beta + 1)R$, which is where the $\beta + 1$ factor comes from.

Do these amps produce an AC circuit with + and − in phase with their outputs or is their gain like a shift?

I'm not sure I read or understood your question correctly... but the amps can indeed result in phase shifts, i.e., a difference in phase between the input and output sinusoids. The phase shift can be intrinsic to the amplifier operation.

For example, for the CE amp, the output is inverted with respect to the input, which represents a half-cycle or 180° phase shift. There can in addition be phase shifts associated with "roll-off", if the frequency is such that there is capacitive-filter attenuation.

How does parasitic capacitance come about?

Everything has capacitance, since every piece of material can hold at least some charge.

What is stray capacitance approximately equal to in Farads?

It depends on the circuit... A typical value for a transistor base-to-collector capacitance would be ∼5 pF ("puffs").

How do you find the corner frequency of a transistor circuit?

You find the corner frequency in a similar way as you did for the filter circuits we saw: find the (complex) gain as a function of frequency, $\mathbf{A}(\omega)$. Then find the values of ω that connect the different regimes.