FREQUENTLY ASKED QUESTIONS

May 1, 2003

Administrative Questions

What's going to be on the quiz?

I don't know exactly, but Prof. Roland will let you know the specifics, probably on Monday. My best guess is that it will be everything up to what will be covered in class on Monday, which will include electromagnetic waves. I don't think experiment MW will be covered (although I'm guessing that some of the concepts involved in that experiment, *i.e.* electromagnetic waves, will be covered).

What sort of AMP questions would be on Quiz 4? Would they be this mathy?

Practice Quiz 4 has an example of an AMP question. Basically you are responsible for the general ideas (op-amp operation, gain, negative feedback, the calibration) but I doubt you will have to do extensive calculations.
P.S. I like the word "mathy".

Will we have to know section 32-5?

This will be covered tomorrow or Monday, so yes, but I think in terms of ideas rather than extensive calculations. The most important point to understand is that solutions to Maxwell's equations in vacuum give a *wave equation* with a specified speed.

Content Questions

How do you know whether to use a sine or a cosine function for current or voltage when dealing with an AC circuit?

Either will work. In general, current as a function of time is $I_0 \sin(\omega t + \phi)$, where ϕ is the phase shift. Because $\sin(\omega t)$ is the same as $\cos(\omega t - \pi/2)$, the difference is just a different chosen phase shift.

What is the meaning of "solid state components"?

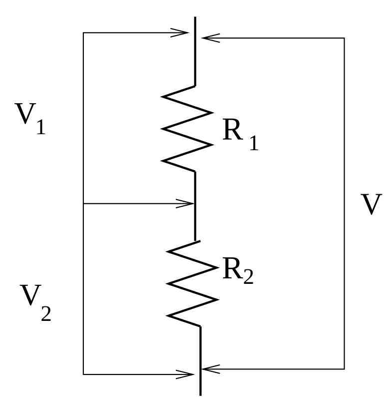
"Solid state components" are components like transistors, diodes, etc. which contain semiconductors (which are solids). You might ask: "well, aren't *all* the components in an electronic device also solid state? It's not like we have liquid radios." Well, yes. I think this nomenclature was introduced in the 1950's or 60's, when most electronic devices were based on vacuum tube components... "solid state" really means "as opposed to vacuum tubes".

What exactly is negative feedback? How is it relevant?

We've seen negative feedback in the specific example of your experiment AMP. The idea is to "feed back part of the output to the input". In our specific case, this consisted of applying a fixed fraction of the output voltage (via a voltage divider) to the inverting input of the op-amp. As we saw in the calculation, this led to a lower gain (~ 100 as opposed to $\sim 10^5$), but a gain which was *more stable*. The amplification A of the op-amp is highly subject to temperature variations, noise etc. However the negative feedback gain, G, is nearly independent of A, and depends only on the resistor values.

What exactly does a voltage divider do? How does it work?

A voltage divider is a configuration that divides a voltage using resistors. Because of Ohm's Law, resistors which have the same current through them have voltages across them which are proportional to their resistance. Here's the generic example of a voltage divider:



Since the current is the same through R_1 and R_2, and Ohm's Law holds for each resistor, and also for the equivalent resistor $R_1 + R_2$, we can write

$I_1 = I_2 = I$, so

$\frac{V_1}{R_1} = \frac{V_2}{R_2} = \frac{V}{R_1+R_2}$.

Solving for V_2 in terms of V and the resistances, we get

$\boxed{V_2 = V\frac{R_2}{R_1+R_2}}$, which is the voltage divider equation.

So V_2 is a fraction of V. Another way of saying it: the voltage V is divided into two parts.

The negative feedback part of your amplifier is a voltage divider. So are parts of the amplifier calibration circuit.

In the AMP writeup, what approximations are we supposed to make?

You can assume that A is very large. The experiment writeup actually specifies the approximations on p. 4.

Can EMF be a source of energy?

An "EMF" can be thought of as a power supply, which adds energy to a circuit. Of course, globally, energy must be conserved in the universe, so the energy added to the circuit must come from somewhere. For instance, a battery EMF gets energy from chemical energy stored in molecules. The energy for an induced EMF comes from energy stored in a magnetic field.

A long time after a switch is closed, will there still be energy in an inductor?

That depends on the situation. If the switch closing causes current to go to zero, there will be no energy stored. If the switch closing leads to a steady state current: yes, there will be energy stored in an inductor. This stored energy is $LI^2/2$.

What are I_{rms} and V_{rms}?

The abbreviation "rms" stands for "root mean square". V_{rms} is related to the peak voltage V_0 simply by $V_{\text{rms}} = V_0/\sqrt{2}$. Similarly, the rms current is $I_{\rm rms} = I_0/\sqrt{2}$. Generally, if you are told that a power supply is a "60 V power supply", 60 V refers to the rms voltage.

So where does that $\sqrt{2}$ factor come from? It comes from the evaluation of power dissipated in an AC circuit. Power at any time t is $P = I^2(t)R$, and since current varies with time, power does too. What we really care about is the *average* power. For $I = I_0 \sin \omega t$, the average power is $\overline{P} = \overline{I_0^2 R \sin^2 \omega t}$. The ave rage over time of a sine wave comes out to 1/2, so $\overline{P} = \frac{1}{2} I_0^2 R$ (see Fig 25-20 in your text). So $\overline{P} = I_{\rm rms}^2 R$. So the reason we use rms is that rms quantities are the ones that follow the "$P = I^2R$ rule" for average power in AC circuits.

In the CyberTutor problem it said that τ changes and is affected by the size of L and R. It says that if L is large and R is small, this is different than when L is small and R is large. Why and how?

The time constant τ of an RL circuit is L/R. This comes from solving the DE for the Kirchoff's Loop around the circuit. So τ will be large if L is large and R is small. It will be small if L is small and R is large. Qualitatively: the time constant will be big (slow response to change) for a big inductance (big resistance to change in current).

***Why* aren't sound waves electromagnetic waves?**

We know sound waves aren't electromagnetic waves because they have different properties than electromagnetic waves must have (for instance, Maxwell's equations specify what speed em waves must travel with, and we observe that sound waves travel much more slowly than that speed.) *Why* aren't they em waves? Well, that's sort of like asking why water waves aren't em waves. They are just a different type of phenomenon. They are waves of expansion and compression in the air.

What are "plane waves"?

They are waves described by $y(x,t) = A\sin(kx - \omega t)$: this describes a wave wiggling along y and traveling in the x direction with frequency ω and amplitude A. We'll see more about this in a bit.

Could we have some hints for the problem set?

- Problem 2: You can think in terms of inductance or energy. Before the current is interrupted, is there any stored energy? What property does any circuit have which leads to stored energy?
- Problem 3: There are lots of correct answers to this one. Probably the best answer involves wave speed.
- Problem 4: What is the phase shift for an LC circuit? What phase shift do you expect for RC or RL? Once you've decided what the components are, use the AC equations in the AC summary. You are given I_{rms}, V_{rms} and the frequency.
- Problem 5: Start from the definition of the displacement current ($I_D = \epsilon_0 d\Phi/dt$) and use what you know about parallel plate capacitors.

Tidbits

"Negative feedback" is actually a very general concept useful in engineering, and actually in lots of other complex systems, too, such as biological and climate systems. Generally, "part of the output" goes back to the input for stabilization purposes. For example, imagine that you have a process which depends on atmospheric carbon dioxide that warms the oceans (carbon dioxide is the "input", warming is the "output"). If the ocean warming results in less carbon dioxide somehow (the warming output feeds back negatively to the input, reducing carbon dioxide), then the temperature will tend to be stable: any increase in warming will be moderated.

"Positive feedback", on the other hand, usually applies to a case where output going back to the input actually amplifies the outcome, leading to a runaway situation. Suppose now that warming the oceans led to *more* carbon dioxide in the atmosphere. Then increase in carbon dioxide would warm the oceans, which would increase carbon dioxide more, warming the oceans more, and so on...

Another example: temperature control in your body. When you get hot, you sweat. This sweat makes you cooler (feeds back negatively to your body temperature). This tends to stabilize your temperature. Suppose sweat interacted with the atmosphere to make you hotter: you would sweat more, and get yet hotter, and eventually you would burn up! It's a good thing your body doesn't have positive feedback in this case...

However in this class we're considering only the specific case of the amplifier.