Electrical Engineering

Quals Questions

1998

To: John Gill <gill@ISL.Stanford.EDU>
Subject: exam questions and answers
Date: Tue, 13 Jan 1998 18:22:47 -0800
From: "Mary G. Baker" <mgbaker@gunpowder.Stanford.EDU>

CS

If I remember correctly from last year, you'll also want the exam questions and answers. They are below.

Thanks,
Mary
Scores depended not so much on how much students already knew about the topic but rather on how well they were able to reason about it. Students I had to "lead" the whole way or who couldn't pick up quickly on hints I gave them didn't do as well as other students.

The main question:

Note: if the student didn't know the difference between a hardware-level network address and an IP address, I explained it to them. That was the only previous knowledge needed.

Assume there is a bunch of portable radios attached to laptops. Each radio has a range of 1/4 mile. Radios send out beacons advertizing their hardware addresses. This means hosts within range will find out the hardware addresses of their neighbors.

So that we can ignore coverage issues, assume there are also a bunch of radios that are not moving and are spread around the planet. Each is within a quarter mile of some neighbors, and packets can be forwarded among radios, so every radio is connected to the network.

Assume also that the network takes care of routing. All you need is the hardware address to put on a packet header, toss the packet into the air, and a low-level network protocol will make sure the packet reaches its destination reliably.

You need to know your destination's hardware address to send a packet to it.

Each host knows its radio's hardware address and its IP address.

Now assume you're a higher level piece of software that knows only the IP addresses of your destinations. What are two scenarios for finding the mapping to hardware addresses for those IP addresses, and what are good and bad points about them?

The answer:

There are lots of variations, but in general I looked for a distributed and a centralized answer. I gave hints to get people going in those directions. For the most decentralized, radios find out their neighbors hardware addresses (and can then ask them for their IP addresses). They could then ask these neighbors to send them info about their neighbors in turn, and gradually build up IP->hardware mappings for the whole network. Some people chose to do this. Others chose to do this per request by sending their neighbors a request for the hardware address for a particular IP address. If the neighbors didn't know the answer, they'd in turn send it on to their neighbors. Good points are that there's no configuration information needed to start with, and with suitable changes to make sure the algorithm terminates, it's fairly robust. However, it requires a lot of messages and the delay for a specific request can be tremendous. Variations on this had the non-mobile radios collect data, different sorts of caching, or using exchange of different sorts of route tables.

The centralized version picks a designated radio or set of radios to store the mappings. Some folks went with one server, some used a server per some size of region, etc. Radios can then send the server(s) their IP/hardware address pairs. To find the hardware address of a host, send the server a query with the IP address of the host. Good things are that this can be simple, and individual queries may be answered quickly. However, the radios need to know the hardware address of the server(s) to get started, or else there has to be some slow algorithm to pick a server. It can take a while for the server to develop its table of mappings, and the load on it for receiving IP/hardware pairs or for handling queries can be large. It may take a lot of storage as well. Delay for answering queries depends on how far away the server is from the requester. Bandwidth requirements near the server may be large as requests are passed in towards it. But there's less flooding of the network with messages. There are fault tolerant issues, especially if the student chose not to replicate the service. This solution can be considered simpler in many ways, unless the replication scheme gets complex.

Another question:

> Note: Only one student got this question, because he wanted a "harder question." Unfortunately, he didn't do that well on either question.

At what level or levels of the TCP/IP stack should encryption be performed?

Answer:

There are various answers here, depending upon what you're trying to make secure (avoid traffic analysis? protect data from eavesdroppers? protect just one physical link?) However, bad answers are to say "at each level" or at "every level except the application level." This would seem to show a lack of understanding of the end-to-end argument.

Signals

1998 QUALS – J. CIOFFI

The linear system

$$x_k \longrightarrow \boxed{\;H\;} \longrightarrow y_k$$ (k = discrete-time index)

is described by the equation:

$$y_k = \alpha y_{k-1} + x_k \qquad 0<\alpha<1 \quad \alpha \text{ is real}$$

a). Find the Z-transform $H(z)$ of the systems. (1 pt)

b). Describe what kind of Filter is H? (1 pt)

x_k is a random process with mean μ_x and variance σ_x^2.
x_k is stationary and white (uncorrelated at different time pts).

c). What is the autocorrelation function of x_k, $r_{x,k} = E[x_n x_{n-k}] =$ (1

d). Find $S_x(f)$, the power spectral density of x_k? (1 pt)

e). Find $S_y(f)$? (2 pts)

f). What is the variance of y? (1 pt)

let $\bar{y}_k = W \cdot y_k$ where w is a constant

g). Find w so that $E[\bar{y}_k] = \mu_x$. (2 pts)

h). How would you choose α to make $\bar{y}_k \cong \mu_x$ (1 pt.)

OFFICE MEMORANDUM ◇ STAR LABORATORY

February 7, 1998

To: Diane Shankle

From: Tony Fraser-Smith   *Electromagnetics*

Subject: Ph.D. Quals Question, 1998

Question: When we look at our AM/FM radio dials we find that the frequency range for the various AM stations is 500–1600 kHz. In addition, typical frequencies in the shortwave range, where radio signals from most of the countries in the world can be picked up, are 3 – 30 MHz. Despite the great numbers of stations operating in these frequency bands, the US operates a radio station that transmits at a center frequency of 76 Hz and Russia operates a similar station at 82 Hz. These are the only two such radio stations in the world. At these low frequencies it is very expensive to build and to operate transmitters, so why would the US and Russia bother?

Answer: There are many different ways to answer this question. An ideal answer would include most or all of the following: (1) Recognition that the US and Russia must use their low-frequency radio stations to communicate with their submarines (they have to use low frequencies for the signals to penetrate deeply enough into the sea water to reach the subs). (2) A brief discussion of how sea water is a good conductor, and that a measure of the ability of an electromagnetic wave to penetrate a good conductor is given by the skin depth δ, where $\delta = [2/(\omega\mu\sigma)]^{1/2}$, where where ω is the angular frequency, μ is the permeability, and where σ is the electrical conductivity. (3) The student should demonstrate some knowledge of how the wave is exponentially attenuated (with attenuation constant $\alpha = 1/\delta$).

At or around this stage the instructor gives the student the representative skin depth of 250 m for a 1 Hz electromagnetic wave penetrating sea water, and asks what the skin depth is for the US and Russian low-frequency radio signals.

Using the above information, the ideal answer would then include the following: (4) assuming a typical frequency of around 80 Hz, the skin depth is found to be $250/\sqrt{80} \approx 28$ m. This is probably not a very great depth for a submarine, so the 76 Hz and 82 Hz radio signals must be attenuated quite strongly as they penetrate the sea water down to the submarines. (5) Further, attenuation in the water is not the only loss mechanism – there will be substantial energy loss simply getting the signals into the sea water, due to reflection from the surface. (6) Another disadvantage would be the inability to send much information over a 76/82 Hz data link. In particular, it would not be possible to send a voice signal (in real time). The final conclusion is that the 76 and 82 Hz transmissions must work, or the US and Russia would not use them, but they must be difficult to detect at submarine depths and their ability to transfer information must be extremely limited.

Skin depth $\delta = \left(\frac{2}{\omega\mu\sigma}\right)^{1/2}$

Good Conductor approximation $\frac{\sigma}{\omega\epsilon} >70$

Will it improve transmit range if transmitter tower is put under water?

X-Authentication-Warning: ISL.Stanford.EDU: gill owned process doing -bs
To: shankle@ee.Stanford.EDU
Subject: Maker's quals questions
Reply-to: gill@ISL.Stanford.EDU
Mime-Version: 1.0
Date: Thu, 15 Jan 1998 14:28:20 -0800
From: John Gill <gill@ISL.Stanford.EDU>
Status:

LS

I will print this. But in case I forget, here is Mary Baker's question.

------- Forwarded Message

To: John Gill <gill@ISL.Stanford.EDU>
Subject: exam questions and answers
Reply-To: mgbaker@cs.stanford.edu
Date: Tue, 13 Jan 1998 18:22:47 -0800
From: "Mary G. Baker" <mgbaker@gunpowder.Stanford.EDU>

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3 Assume $x(t)$ as before but now set $H(s) = 1/s^2$. Describe the tracking error in the steady state.

Now $E(s) = 1/(1 + s^2)$ from (1), which has inverse transform $\sin t$, an oscillation which also does not converge to zero.

Comment: Here the final value theorem clearly breaks down.

4 Suppose that $x(t)$ is as before and $H(s) = A(s)/s^2$. Find $A(s)$ so that $\epsilon(t) \to 0$ for large t and sketch $\epsilon(t)$, $x(t)$, and $y(t)$ on a common graph.

Again from (1) $E(s) = 1/(s^2 + A(s))$. The trick is to avoid the problems of the previous two parts. The key point is that you need to have all the poles in the left half plane. This can be done by a little guess work, e.g., two popular solutions were $A(s) = 2s + 1$ which puts a double pole at -1 and hence $\epsilon(t) = te^{-t}u(t)$, and $A(s) = 3s + 2$ which puts poles at -1 and -2 and hence produces a sum of e^{-t} and e^{-2t}. An alternative is to simply say $\epsilon(t) = e^{-t}u(t)$ so that $E(s) = 1/(1 + s)$ and then solve for $A(s) = s + 1 - s^2$.

For the pictures, students were expected to draw whatever $\epsilon(t)$ they got and the ramp, and then realize that $y(t)$ was just the difference of the two.

Devices

1998 PhD Quals Question

James Harris

1. Draw an energy band diagram for a p/n junction. What does the vertical axes represent? (Total E, KE or PE?)

A. The vertical axis is Total Energy. $\mathbf{E}_c$ and $\mathbf{E}_v$ are lines of PE and zero KE for electrons and holes, respectively. KE is the energy above $\mathbf{E}_c$ for electrons and below $\mathbf{E}_v$ for holes.

2. Draw the I-V characteristic for the p/n junction and explain what physically happens in terms of the band diagram above when you apply a bias to the junction. What is the "turn-on voltage"?

A. At zero bias, there is an electrostatic barrier (built-in voltage) that provides a balance between drift and diffusion of carriers in the junction. Under forward bias, the barrier is reduced, thus favoring carrier diffusion over drift. The carriers have a Boltzmann distribution in energy, thus the number of carriers which exceed the remaining barrier (and are injected as minority carriers into the opposite conductivity region) is proportional to $\exp(V_{appl} - V_{bi})/kT$, providing an exponential dependence of current on voltage. Under reverse bias, the barrier is increased, reducing the injection of carriers and favoring drift. However, the concentration of minority carriers can only go to zero and the number which reach the p/n junction is limited by diffusion from the bulk, which remains essentially constant with bias, producing a saturation current independent of bias. The threshold voltage, V_{th}, is just the extrapolation from the high forward current region to zero current and is usually about 2/3 $\mathbf{E}_g/q$ (at ROOM TEMPERATURE).

what is this?

?

3. What happens to the injected carriers? What energy do the photons have if the recombination is radiative?

A. The injected carriers are minority carriers (i.e. electrons in p-region and holes in n-region) which are at a higher concentration than their thermal equilibrium concentrations and they are surrounded by a far larger number of majority carriers, thus they recombine (either radiatively or non-radiatively) to move toward their equilibrium value. If the recombination is radiative, then the photon energy, $h\upsilon$, is equal to the bandgap energy, $\mathbf{E}_g$.

4. How is it possible to get $h\upsilon = \mathbf{E}_g$ photons emitted when we've only had to apply V_{th}~2/3 $\mathbf{E}_g/q$ volts bias to get forward current to flow? Isn't this a violation of Conservation of Energy and the Laws of Thermodynamics?

A. The minority carriers only require about 2/3 E_g/q to be injected because these are the carriers farthest up (highest kinetic energy) in the Boltzmann distribution, so the "added" energy is kinetic (thermal) energy from the lattice.

5. What would happen if the diode was placed in thermal isolation and forward biased but with a window where the photons could escape? Could I make a refrigerator with such a diode?

A. If the diode were placed in a thermally isolated environment and forward biased with only radiative recombination occurring, the diode initially loses energy, thus it's temperature drops and it serves as a refrigerator.

but later on external source will provide energy to it.

6. What would the ideal "asymptotic" I-V characteristic look like and what would be the values of V_{th} and T?

A. In the ideal, the asymptotic I-V characteristic would have zero current until reaching $V_{appl}=E_g/q$ whereupon the current increases extremely rapidly, since I is proportional to $\exp(V_{appl} - V_{bi})/kT$ and in the limit, T is going to 0°K.

exponentially

7. Do you think the same thing will happen with a Schottky barrier (metal-semiconductor) diode? Why or why not?

majority carrier devices

A. No. Because forward current is a result of majority carriers from the semiconductor being injected as hot ($KE = \Phi_b$) into the metal, which has no bandgap, thus all of the KE is dissipated by scattering and thermal energy deposited into the metal. , can not use as refrigerator

X-Sender: horowitz@vlsi.stanford.edu
Mime-Version: 1.0
Date: Wed, 21 Jan 1998 13:08:24 -0800
To: shankle@ee.stanford.edu
From: Mark Horowitz <horowitz@ee.stanford.edu>
Subject: Quals questions
Status:

Computer Architecture

We would like to build a logic block that detects when the 32 or 64 bit operand is equal to zero.

1. What logic function is this?
   NOR

2. How would you implement this using static logic gates
   Looking for NOR-NAND tree. pseudo nMOS was an interesting answer too, but then asked about using std cells to get tree solution

Show the students a simple datapath diagram for a simple processor. Zero detect is placed after a 3-1 mux for bypass (inputs from Regfile, ALU out, and cache memory). The mux has a flop in it. Say that the delay of the zero detect unit is too slow, and that you need the output right after the clock edge.

3. How can you get the output earlier
   Triplicate the unit and move it to the inputs of the mux

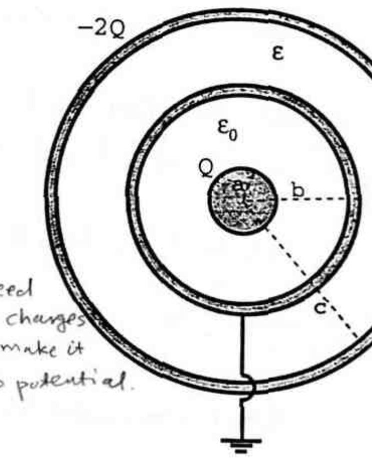
4. What assumptions are you making by moving the unit
   There is excess time in the regfile, alu and memory paths

5. You ask the Regfile designer whether there is spare time, and he say no. Can you get the same effect a different way?
   Store a 33 or 65 bit that indicating whether the value is zero, since you must have computed it already on the path that created the value.

Inan / January 1998 / PhD Quals / Problem 1:

Electromagnetics

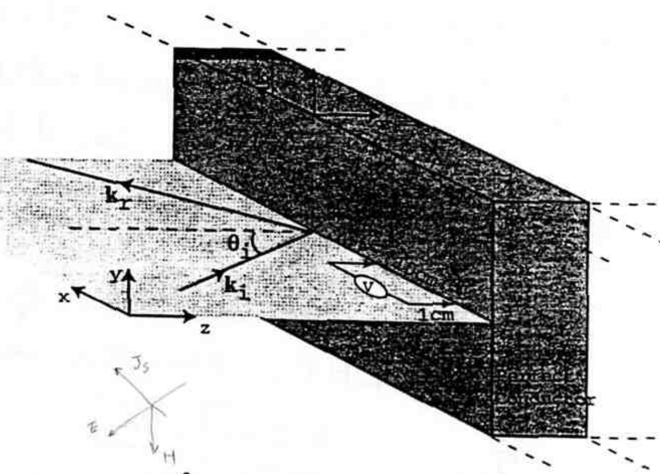
Problem Statemement: This problem involves concentric spherical conductors as shown. The students were told that the conductors were perfect, that the middle shell was grounded (as shown), that the outer shell had a charge of -2Q placed on it, and the middle sphere had a charge of +Q placed on it. The students were asked to plot the radial variation of either the electric field or the electrostatic potential, starting at $r = 0$ and going out to $r > c$.



Answer: The important point to realize here was that the ground is essentially an infinite reservoir of charge and that the inner and outer surfaces of the grounded shell would have charge induced as required respectively by the +Q charge on the inner sphere and the -2Q charge on the outer sphere. Thus, charges of -Q and +2Q are respectively induced on the inner and outer surfaces of the grounded spherical shell. The electric field can then be directly found from Gauss' Law.

It need those charges to make it zero potential.

The system basically works as if there are two capacitors sharing a common ground.



Time variant current

$$\mathbf{J_s}(x,t) = \mathbf{a}_x \cos(6\pi\, 10^8 t - \pi x) + \mathbf{a}_y \cos(6\pi\, 10^8 t - \pi x) \quad \text{mA/m}$$

Inan / January 1998 / PhD Quals / Problem 2:

Problem Statemement: The students were told that half-space is occupied by a perfect conductor, with a uniform plane wave incident on at an angle θ_i as shown. Given that the surface current on the conductor is as shown, the students were asked to determine the voltage that an ideal (infinite impedance) voltmeter, connected with perfectly conducting leads as shown, would read.

Answer: The wrong answer, of course, was that the Voltmeter would read zero, because it is 'shorted-out' by the perfect conductor. There are a number of ways to solve this problem: (i) determine the magnetic field from $\hat{\mathbf{n}} \times \mathbf{H} = \mathbf{J}_s$ and integrate over the 1 cm $\times$ 10 cm loop to find the induced emf via Faraday's Law (i.e., $\int \mathbf{B} \cdot d\mathbf{s}$), (ii) After finding $\mathbf{H}$, find the corresponding $\mathbf{E}$, which is necessarily normal to the conductor surface and evaluate the emf using $\oint \mathbf{E} \cdot d\mathbf{l}$, noting that the non-zero contributions will come from the 1-cm long leads, since $\mathbf{E}$ varies with x, (iii) Use the continuity equation to find the surface charge density ρ_s directly from $\mathbf{J}_s$ and then use the boundary condition $\hat{\mathbf{n}} \cdot \mathbf{D} = \rho_s$ to find $\mathbf{E}$.

time variant current related to time vari ent magnetic field

Systems PH.D. QUALS, JAN. 1998 . T. KAILATH

- Consider a causal linear time-invariant system described by

$$a\ddot{y}(t) + b\dot{y}(t) + c\,y(t) = u(t)$$

- $\{a, b, c\}$ are real-valued, i.i.d. random variables uniformly distrib. over $[-1,1]$.

a) Find the conditions on $\{a,b,c\}$ to ensure that the system is stable.

b) Calculate the probability that the system is stable and has two complex poles.

Solution: a) The transfer function is $\dfrac{1}{as^2+bs+c}$.

For stability, the two roots of $as^2+bs+c=0$ should be in the LHP. Now the roots are

$$s_{1,2} = \frac{-b \pm \sqrt{b^2-4ac}}{2a}.$$

We have 2 cases: i) two real roots ; ii) 2 complex roots.

For (i): $\frac{b}{2a} > 0 \Rightarrow \{a,b\}$ have the same sign.

We also need $0 < b^2-4ac < b^2$. Therefore $\{a,c\}$ must have the same sign.

$\therefore$ the conditions for (i) are $b^2 > 4ac$ or $\{a,b,c\}$ all positive or all negative

For ii) : We must have

$$\frac{b}{2a} > 0 \text{ and } b^2 - 4ac < 0 .$$

So again $\{a, b, c\}$ must be all > 0 or all < 0 and $|b| < 2\sqrt{ac}$.

b) To compute the probability, we can by symmetry consider just the case $\{a, b, c\}$ all > 0 and double the answer. So we have to evaluate

$$\int_0^1 \int_0^1 \int_0^{2\sqrt{ac}} \frac{1}{2} \cdot \frac{1}{2} \cdot \frac{1}{2} \, db\, dc\, da$$

$$= \frac{1}{8} \int_0^1 \int_0^1 2\sqrt{ac} \, da\, dc = \frac{2}{8} \int_0^1 \sqrt{a}\, da \int_0^1 \sqrt{c}\, dc$$

$$= \frac{1}{4} \cdot \left[\frac{a^{3/2}}{3/2} \right]_0^1 \cdot \left[\frac{c^{3/2}}{3/2} \right]_0^1 = \frac{1}{4} \cdot \frac{2}{3} \cdot \frac{2}{3} = \frac{1}{9}.$$

So the final answer is twice this : $2/9$.

Note: Similarly one can compute the probability of both roots being real + negative (which I asked sometimes). The answer is

$$2 \int_0^1 \int_0^1 \int_{2\sqrt{ac}}^1 \frac{1}{2} \cdot \frac{1}{2} \cdot \frac{1}{2} \, db\, dc\, da = \frac{1}{36} .$$

1998 Qualifying Exam Questions

Richard Kiehl

The students were shown a schematic of a semiconductor heterostructure containing an n-type widegap surface layer, an undoped narrowgap layer, and another n-type widegap layer which was grown on an undoped narrowgap substrate. Two ohmic contacts, which allowed electrical contact to free carriers in all the underlaying layers, and a Schottky barrier contact where shown on the surface, providing source, drain and gate contacts in a field-effect transistor-like geometry.

Part I.
The students were asked to draw the energy band diagram under the gate. If they encountered difficulty, appropriate hints were given, such as to consider the possibility of charge transfer between layers or to consider the detailed shapes dictated by Poisson's equation. Points were awarded according to the number of detailed features of the diagram that were correct, with some deduction for hints.

Part II.
The students were then shown the correct energy band diagram for the structure as the starting point for Part II. They were asked to explain some of the details of the device, such as the distribution of free carriers in the structure. They were asked to explain the implications of modifying the structure by making the narrowgap layer much thinner and by changing lattice constant of this layer. They were asked to indicate how the drain current versus gate-voltage of the structure might deviate from that of a conventional FET and to discuss possible advantages or disadvantages of this FET in terms of maximum current, transconductance, subthreshold characteristics, etc.

Part III.
In the third part, the students were shown a modified version of the structure in which the substrate was removed and replaced with a gate, so that the electron channel forned in the narrow gap layer was now gated on both the top and bottom. They were also shown energy band diagrams under the gate for two different gate bias conditions: one where free electrons were present only at the top interface of the channel and one where free electrons were present only at the bottom interface. The total free electron density under the gate was the same for both biases, the only difference being the interface where the electrons formed. The students were asked to propose ways to modify the structure so that an on/off switching action (high and low current states) might be obtained for the two bias conditions, despite the fact that the electron density was unchanged. Students answers included reducing the electron mobility for one bias by introducing scattering centers at one interface and by increasing the source resistance for one bias by modifying the contacting at the two interfaces. Finally, they were asked to suggest any possibile advantages or applications such a device might have.

New information was provided at the beginning of each part so errors in earlier parts were not cumulative. I was more interested in a persons ability to reason through things well than in "textbook" answers, which by themselves did not yield full credit. So students were often asked to more fully explain their answers and to suggest other possibilities. People gained points by supporting their answers with good arguments or by making clever suggestions (worth bonus points), even if these were unlikely or not very practical.

Subject: Re: Quals Meeting Reminder
Date: Fri, 23 Jan 98 20:48:46 -0800
From: Gregory Kovacs <kovacs@cis.Stanford.EDU>
To: "Diane Shankle" <shankle@ee.Stanford.EDU>
Mime-Version: 1.0
Status:

Circuits

Diane,
Sorry that I couldn't attend. Here is my question.

Thanks,
Greg

G. Kovacs Quals Question 1997/98

Question: The student was given four cylindrical plastic containers filled with four different substances. They were asked to provide as much information as possible about their contents without opening them.

Answer: There was no correct or incorrect answer. The evaluation was based on the methods used, clarity of thinking and approach of the student.

>Qual's Meeting
>Friday, January 23, 1998
>3:30 P.M.
>Durand 450
>
>Please bring a copy of your Qual's question and answer to the meeting.
>
>Thanks!
>Diane
>
>
>

Date: Tue, 17 Feb 1998 15:55:17 -0800 (PST)
From: David Luckham <dcl@poset.Stanford.EDU>
To: shankle@ee.Stanford.EDU
Status:

retire. founder of rational software

From: David Luckham <dcl@architecture.Stanford.EDU>
To: shanlee@ee.Stanford.EDU
CC: suvan
Subject: Quals question

Last year's exam description is still valid.
That's what I asked this year too.
If you read it, you will see that it is NOT a
question, but a set of examples of "typical questions".
The actual questions vary, depending upon what programming
languages the candidate is familiar with.
If he/she knows pascal, then I'll ask about strong typing in Pascal;
if he doesnt know Pascal, but knows C++, then I'll ask about strong
typing in C++.

The only wording I might change this year is:

"well-known programming languages of their choice such as
Pascal, C++ and Ada ..."

to:

"well-known programming languages of their choice such as
Pascal, C++, Java, VHDL and Ada ..."

- David Luckham

Electromagnetics

Professor Bruce Lusignan: Quals Question

We transmit from a cell phone to a satellite 1000 miles high. The power required is 10 watts. The Analog FM uses 20 kHz and 10 dB C/N Both satellite and cell phone use directional antennas. 10 watts is enough.

a. The satellite moves to 2000 miles. How much power?
b. The satellite changes its antenna beam from a 40° circle to a 20° circle beam. How much power?
c. Change from a 800 MHz frequency to a 400 MHz frequency. How much power?
d. Change from analog 20 kHz 10 dB C/N to digital. 10 kb/sec and 7 dB Eb/No How much power? BPSK QPSK

(a.) $\propto \frac{1}{R^2}$

(b) $G \approx \left(\frac{139}{\alpha}\right)^2$

(c) $P_R \propto \frac{1}{\lambda^2}$

(d) $B \cdot \frac{C}{N} \Leftrightarrow R \cdot \frac{E_b}{N_0}$

20 KHz + 10 dB $\Leftrightarrow$ 10 Kb/sec + 7 dB

change to dB   change to dB

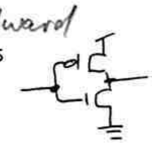
analog require 5 dB more

1998 Quals

Computer Architecture

E J McCluskey
Edward

<u>Question 1.</u> Draw a static CMOS Inverter Ans



<u>Question 2</u> Given the table for two functions f & g design good gate circuits

wx	fg
00	01
01	00
10	01
11	11

<u>ANS</u> $f = wx$, $g = w + x'$

<u>Question 3</u> Modify the above table (if necessary) by reordering the f g rows to obtain better circuits. <u>ANS</u> $f = w'x'$, $g = w' + x'$

<u>Question 4</u> Modify the above table (if necessary) by reordering the f rows and the g rows independently to obtain better circuits. <u>ANS</u> $f = w'x'$, $g = f'$

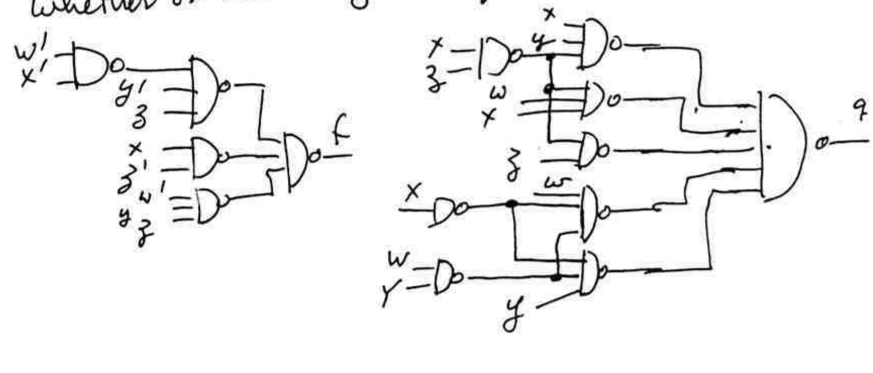
<u>Question 5</u> Use additional combinational circuitry to convert a D flip flop into an SR flip flop.

$D = S + R'Q \leftarrow$ <u>ANS</u>

<u>Question 6</u> Repeat Question 5 but obtain an SR flipflop the holds the current state when the inputs are $S = R = 1$

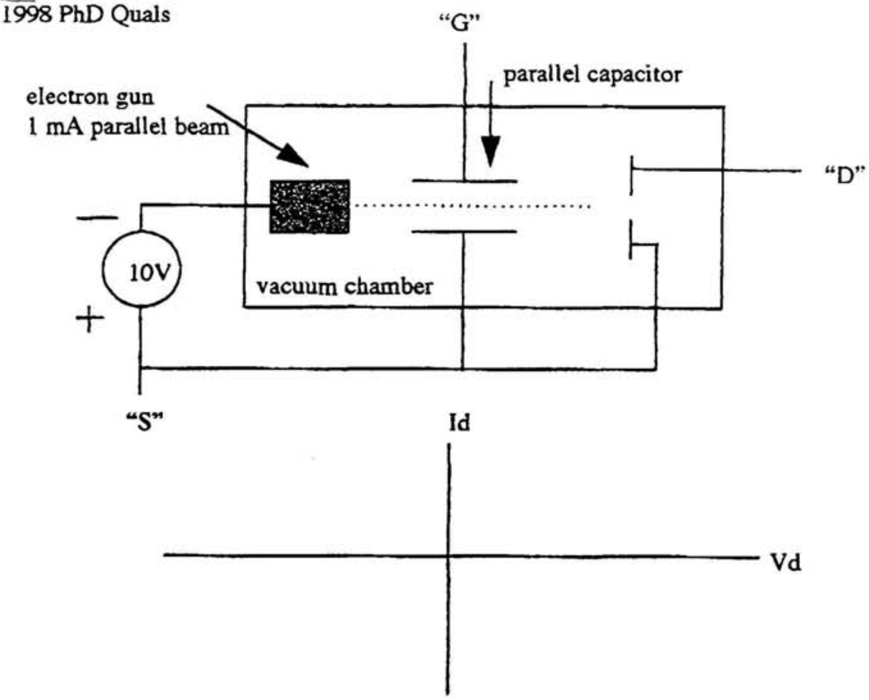
$D = SR' + Q(S + R') \leftarrow$ <u>ANS</u>

<u>Question 7</u> For the two circuits below, how could you tell whether or not they realize the same output function ($g = f$?)



? leave

Mark McCord
1998 PhD Quals



Sketch Id vs Vd for various representative Vg for the device shown above

Compare/contrast the operation of this device to a silicon mosfet. Are there analogous parameters and regions of operation? (linear, saturation, Vt ...)

Could this device be used as an amplifier? What type is it intrinsically (voltage, current, transcond., transimp.) ? What physical parameters affect the transconductance?

comments on solution:
At first glance this device has a behavior similar to a mosfet. With more careful consideration, a number of "troubling" differences may be noted. In order to properly compare to a mosfet, the student must understand the basic operation and definitions; memorized equations are of little help. No students were able to complete the comparison accurately within the alloted time.

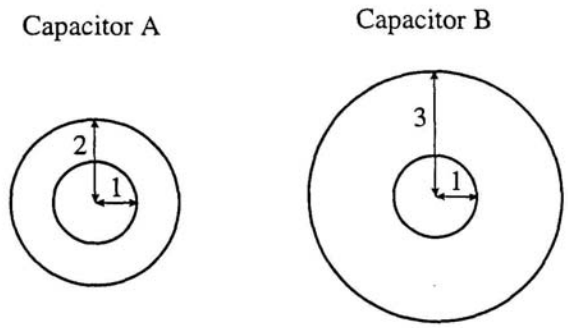
Devices

EE Ph. D Qualifying Exam Question 1998

D. A. B. Miller

David

Consider capacitors made from two concentric, conducting, thin spherical shells. These spherical shells are therefore the "plates" of the capacitor. I have two such capacitors, shown in cross section below. In both capacitors, the radius of the inner spherical shell is 1 unit. In capacitor A, the radius of the outer shell is 2 units. In capacitor B, the radius of the outer shell is 3 units. What is the ratio of the capacitances of these two capacitors, A and B?



(cross-sectional view)

Supplementary Question (for those who basically completed the first part above):

Suppose now I have, instead of two concentric spheres, two separate spherical balls as the plates of the capacitor. What happens to the capacitance of this new capacitor as the balls are moved very far away from one another? I.e., does the capacitance become zero, a constant, or infinite?

Little tricky

Solution

There are several ways of solving this problem, all of which are valid. Nearly all the students did this problem by drawing a Gauss surface round the inner sphere to deduce the field from a charge Q on the inner sphere, then integrated to get the voltage between the two plates, then deduced the capacitance. Here I give a different solution derived as much as possible from physical principles, without relying on intermediate formulae.

For capacitance C

$$C = \frac{Q}{V}$$

where Q is the charge on the plates, and V is the voltage between the plates.

We know that the potential at a distance r from a point charge is

$$V(r) \propto \frac{Q}{r}$$

Therefore, the difference in potential between two radii r_1 and r_2 is therefore

$$V \propto Q\left(\frac{1}{r_1} - \frac{1}{r_2}\right) = Q\frac{r_2 - r_1}{r_1 r_2}$$

The next important step in this solution is to realize that this is also the voltage between the "plates" of a capacitor with concentric spherical shell "plates" of radii r_1 and r_2 and with charge Q on the inner spherical shell. The spheres are placed at equipotential surfaces of the point source problem, so, without charge on them, they make no difference to the field from the charge. It is a relatively standard result from electrostatics (or gravity) that, as far as fields outside a sphere are concerned, we can replace a charge at the center of a sphere with the same total charge distributed over the surface of the sphere, hence we can replace the point charge with our inner sphere with charge Q on its surface. It is similarly a standard result that there is no field inside a sphere from a uniform charge on the sphere's surface, so putting the charge $-Q$ on the outside sphere does not affect the calculated potential.

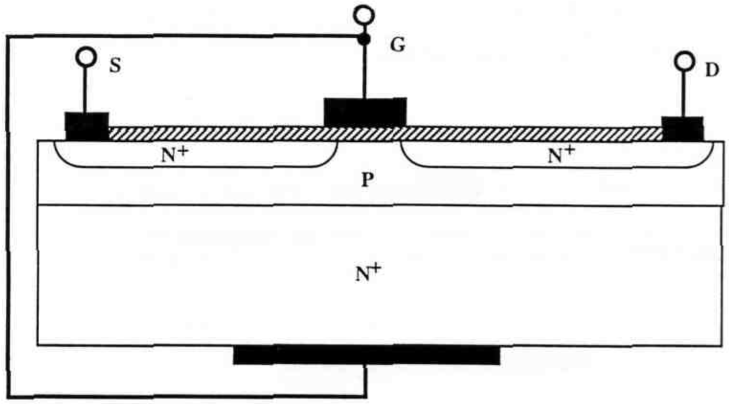
Now we can calculate the ratio of the capacitances, C_A and C_B, of capacitors A and B. We have, using an obvious notation for the radii,

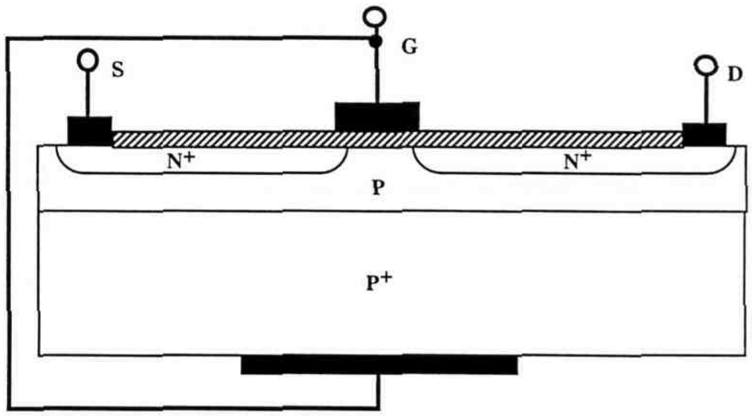
$$\begin{aligned}\frac{C_A}{C_B} &= \frac{V_B}{V_A} = \frac{r_{1A}r_{2A}}{r_{2A} - r_{1A}} \times \frac{r_{2B} - r_{1B}}{r_{1B}r_{2B}} \\ &= \frac{2}{1} \times \frac{2}{3} \\ &= \frac{4}{3}\end{aligned}$$

In assessing the student's performance on this question, I am at least as interested in seeing how the student approaches it as I am in getting the question answered completely and exactly. The scoring is not "all or nothing", but is instead layered, and someone who knew little about the background would still be able to get a reasonable score if they were able to think on their feet. I was also prepared to give hints if someone is stuck. Common sense estimates and approximate answers also have value. Even knowing which of the structures has larger capacitance is worth something!

The second part of the question can be approached by considering the voltage as a function of distance from just one of the charged balls. The important point to realize is that there is only a finite amount of energy required to pull a test charge an infinite distance away from a charged sphere. This is reminiscent of the fact that there is a finite "escape velocity" to send a body an infinite distance away in the earth's gravitational field. Hence the voltage between these two balls with opposite charges is going to tend to a finite value as the balls are pulled very far apart. As a result, the capacitance also tends to a finite value, even for infinite distance, because we have finite voltage with finite charge, even for infinite separation distance. The first part of the problem is a hint, because as we make the radius of the outer sphere go to infinity, the capacitance in the concentric spherical problem goes to a constant determined only by the radius of the inner sphere.

1997-98 Ph.D. Quals
J. D. Plummer ?





I asked two questions corresponding to the structures above. In each case the question was to figure out how the device worked and what the I-V characteristics might look like. The top structure is a standard MOSFET except that the gate is tied to the substrate, which is N type. Positive gate voltages reverse bias the N^+P substrate. Effects on the otherwise normal MOSFET I-V characteristics include D-Sub punchthrough, large S/D parasitic resistances, and open base BJT effects. I was mainly looking for how the student reasoned through some or all of these possible effects.

In the bottom case, the substrate is P type and the dominant effect is that the gate voltage now turns on a parallel BJT device.

Alvin

X-Sender: quate@EE.stanford.EDU
Date: Sat, 07 Feb 1998 08:38:10 -0800
To: Diane Shankle <shankle@ee.Stanford.EDU>
From: cal quate <quate@stanford.EDU>
Subject: Re: Copy of Your 1998 Quals Questions
Mime-Version: 1.0
Status:

Electromagnetics

Diane;

I asked about simple definitions of Inductance and asked them to calculate the inductance for simple geometries. We went from there to discuss the concept magnetic energy and the differences between ferromagnetic and paramagnetic materials. I, also, asking about the origins of the magnetic moments in ferromagnetic materials.

If that went well, I moved on to electrostatics, asking about meaning of capacitance and the evaluation of the capacitance of a sphere in free space. I asked about the dielectric constant of water.

Is this what you need??
cal quate

========
At 09:44 AM 2/4/1998 -0800, you wrote:
>
>Reminder:
>
>Please turn in your Quals Question by Friday, February 13th.
>

Date: Wed, 4 Feb 1998 09:39:34 -0800 (PST)
From: Krishna Saraswat <saraswat@cis.Stanford.EDU>
X-Sender: saraswat@cis
To: Diane Shankle <shankle@ee.Stanford.EDU>
Subject: Re: Copy of Your 1998 Quals Questions
MIME-Version: 1.0
Status:

devices

PhD Quals question 1998

Q.1 In an MOS capacitor the gate electrode is made of Si identical to the substrate and both are lightly doped. What will be the C-V characteristics?

A. At zero bias the MOS capacitor will be in the flatband condition with gate oxide capacitance, Cox as the total capacitance. As the potential across the device is changed the gate electrode will also be subjected to band bending similar to the substrate. When substrate is depleted the gate will be in accumulation and vice versa. The total capacitance will be the gate oxide capacitance, Cox in series with the Si depletion capacitance. As a result the C-V characteristics for positive bias will be a mirror image of the characteristics for negative bias and will look like a bell shaped curve for a high frequency measurement.

Q.2 If the gate electrode is made of a metal and the substrate of Si with equal density of donors and acceptors, what will be the C-V characteristics? (Assume metal to semiconductor workfunction = 0)

A. Again at zero bias the MOS capacitor will be in the flatband condition with gate oxide capacitance, Cox as the total capacitance and Si will be intrinsic with Ef at mid gap. As the bias is made -ve or +ve the Fermi level at the surface will shift towards the conduction or valance band, respectively. In each case the surface will be accumulated with electrons or holes. Carrying this argument further the C-V characteristics will look similar to the case of Q1.

Prof. Krishna Saraswat
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X-Sender: len@nova.stanford.edu
Mime-Version: 1.0
Date: Mon, 26 Jan 1998 19:10:15 -0700
To: Diane Shankle <shankle@ee.Stanford.EDU>
From: len tyler <len.tyler@stanford.edu>
Subject: Quals question
Status:

Electromagnetics

Quals question: Winter 1998, Len Tyler

The Republic of Panama is thinking very seriously about upgrading the Panama Canal. At present boats are moved through the locks and channels of the system by a pair of locomotives, one on each side of the waterway, to pull the ships along and control the position of the ships in the canal structure by means of attached cables. Panama would like to replace the current system with an electromagnetic drive. In such a scheme there would be no mechanical connections to the ships, and the ships would not be modified in any way.

The system is to use electric and/or magnetic forces only, with no moving parts. For the purposes of the problem, consider the canal about 10 m deep by 30--40 m wide. Ships have very little lateral clearance, of order of only a meter on each side. Consider that a typical ship using the canal might have a mass of 10,000 to 40,000 tons (metric).

What are your thoughts as to how an electromagnetic drive might be implemented?

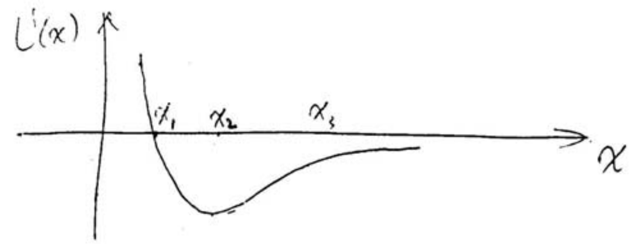
(This is in fact a real problem. I have been told that Panama is seeking a consulting firm to help with the redesign.)

G. Leonard Tyler (415) 723-3535
Department of Electrical Engineering (415) 723-9251 FAX
Durand Building 227
Stanford University, California 94305-9515

Shan Wa
SSPL

EE Qualifying Exam 1998 physics

1. Interatomic potential energy $U(x)$ is a function of interatomic distance x:



What is the average interatomic distance $\langle x \rangle$ at $T = 0\,K$?

2. What happens to $\langle x \rangle$ when $T \gg 0\,K$?

3. Why?

Howard

Quals question/answer
H. Zebker, 1998 Signals

Q: The student is presented a set of points comprising a sampled function, and asked to interpolate the data according to some rule. The discussion turns to linear interpolation, with the following questions

1) What is the impulse response of the linear interpolator?

2) What is its transfer function?

3) Given an input signal spectrum, what is the spectrum of the interpolated signal? Describe any artifacts or distortion present.

4) What is a superior algorithm?

5) Are there any limitations to this algorithm?

A:

1) Triangle function
2) $\mathrm{Sinc}^2(\,)$
3) The signal is low-pass filtered plus out-of-band artifacts are introduced
4) A rectangular transfer function corresponding to sinc interpolation is better.
5) Sinc is not limited in time, thus impossible to implement exactly for general data.

To: Diane Shankle <shankle@ee.Stanford.EDU>
Subject: Re: Quals Meeting Reminder
Date: Wed, 21 Jan 1998 13:43:57 -0800
From: Jennifer Widom <widom@DB.Stanford.EDU>
Status:

CS

I'm afraid I cannot attend the meeting. My Q&A are below.

Jennifer

Question 1

Suppose you have a dictionary stored as a sorted list of valid words in pages on disk, and the dictionary is much larger than the available memory. Now suppose you have a document stored in memory and you want to check if each word in the document is valid. It suffices to output a list of invalid words appearing in the document. Suggest an efficient algorithm.

One answer: Sort the words in the document, then traverse the document and the dictionary in order (bringing pages of the dictionary into memory one at a time), checking that each word in the sorted document appears in the dictionary. A disadvantage is that many unneeded pages in the dictionary may be scanned; can solve by integrating binary search into the process.

Question 2

Given a singly linked list, goal is to print the list backwards. Suggest two different algorithms. Briefly discuss their relative space efficiency, time efficiency, and implementation effort.

Some answers:

(1) Reverse the links, print the list, then reverse the links back. Constant extra space, traverses list twice, medium implementation effort compared to others.

(2) Recursive procedure. Implicitly uses stack -> linear space. Traverses the list once then 'unwinds' the stack. Very easy to implement.

(3) Traverse the list building a backwards copy. Then print and delete the new one. Lots of dynamic memory allocation, traverses list twice, hardest to implement.

(4) Combination of (2) and (3): use an explicit stack. Similar properties, harder to implement than (2) but easier than (3).

Answer:

1. $\langle x \rangle = x_2$ at $T = 0\,K$.

No kinetic energy at ~~0~~ Kelvin, so the potential energy must be at the minimum.

2. $\langle x \rangle$ increases with T for most solids, which accounts for thermal expansion.

3. As temperature rises, the atomic distance starts to vibrate. The average interatomic distance $\langle x \rangle$ will not change due to pure vibration. However, the asymmetry of the potential well will lead $\langle x \rangle$ to increase.

Analytically, the Boltzman distribution $\propto e^{-\frac{U(x)}{k_B T}}$

Therefore,

$$\langle x \rangle = \frac{\int_0^\infty x e^{-U(x)/k_B T}\,dx}{\int_0^\infty e^{-U(x)/k_B T}\,dx} \propto T.$$

EE Ph.D. Qualifying Examination

Examiner: Y. Yamamoto

January 12-16, 1998

physics

Suppose we initially have a constant number of events (particles, pulses, etc.) and delete each event with an average rate of $q = 1-p$ independently from the other events. The probability of finding K events out of the initial (constant) N events for such statistically independent random deletion is given by the "bionomial distribution":

$$W_N(K) = \frac{N!}{K!(N-K)!}\, p^K q^{N-K}$$

$$(q = 1-p)$$

Discuss under what conditions the binomial distribution is reduced to the "Poisson distribution":

$$W^p(K) = \frac{\overline{K}^K}{K!}\, e^{-\overline{K}}$$

$\overline{K}$: average number of events

and the "Gaussian distribution":

$$W^G(K) = \frac{1}{\sqrt{2\pi\overline{\Delta K^2}}} \exp\left[-\frac{(K-\overline{K})^2}{2\overline{\Delta K^2}}\right]$$

$\overline{\Delta K^2} = \overline{K^2} - \overline{K}^2$: variance of events

Mime-Version: 1.0
Date: Thu, 5 Feb 1998 12:18:37 -0800
To: Diane Shankle <shankle@ee.Stanford.EDU>
From: Simon Wong <swong@snf.stanford.edu>
Subject: Re: Copy of Your 1998 Quals Questions
Status:

circuits

1998 Qualifying Exam Questions
Simon Wong

What mechanisms are responsible for the breakdown of a MOSFET at large drain-to-source bias?
Answers. punch-through, bipolar-induced avalanche breakdown

Given a MOSFET with a breakdown voltage of 10 volts, describe the various device modifications or circuit configurations that will allow the MOSFET to operate under a supply voltage of 15 volts.

Answer:

1. $\langle x \rangle = x_2$ at $T = 0\,K$.

No kinetic energy at ~~0~~ Kelvin, so the potential energy must be at the minimum.

2. $\langle x \rangle$ increases with T which accounts for thermal expansion for most solids.

3. As temperature rises, the atomic distance starts to vibrate. The average interatomic distance $\langle x \rangle$ will not change due to pure vibration. However, The asymmetry of the potential well will lead $\langle x \rangle$ to increase.

Analytically, the Boltzman distribution $\propto e^{-\frac{U(x)}{k_B T}}$

Therefore,

$$\langle x \rangle = \frac{\int_0^{\infty} x e^{-U(x)/k_B T}\,dx}{\int_0^{\infty} e^{-U(x)/k_B T}\,dx} \propto T.$$

Quals Solution

a). $H(z) = \frac{1}{1-\alpha z^{-1}} \quad |z| > \alpha$

b). Low pass

c). $r_{x,k} = \mu_x^2 + \sigma_x^2 \delta_k$

d). $S_x(F) = \mu_x^2 \delta(F) + \sigma_x^2$ (periodic)

e). $S_y(F) = \left| \frac{1}{1-\alpha e^{-j2\pi F}} \right|^2 \sigma_x^2 + \frac{\mu_x^2}{(1-\alpha)^2} \delta(F)$

F). $\sigma_y^2 = \alpha^2 \sigma_y^2 + \sigma_x^2$

$\therefore \sigma_y^2 = \frac{\sigma_x^2}{1-\alpha^2} \qquad E(y^2) = \frac{\sigma_x^2}{1-\alpha^2} + \left(\frac{\mu_x}{1-\alpha}\right)^2$

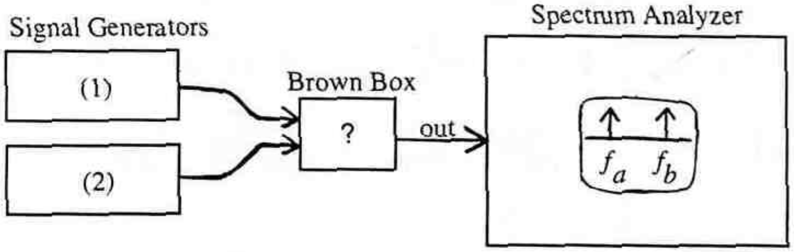
g). $w = (1-\alpha)$

h). $\alpha \lesssim 1$

Signals

1998 Ph.D. Qualification Exam Question
Donald C. Cox
January 1998

In the room were 2 signal generators, (1) and (2), an RF spectrum analyzer, and a brown cardboard box. These were connected with coaxial cables as indicated below.



The sketch above was also on the whiteboard. The spectrum analyzer was displaying two equal height "impulses". The spectrum analyzer controls were masked with paper. The signal generator controls were also masked, except for the frequency and amplitude adjustments which were open and available to be adjusted.

1. As an introduction, I described the setup and the spectrum analyzer and noted a) it was a sweeping filter, b) the frequency and amplitude axis, and c) that zero frequency was off scale to the left. I also noted that there was something in the box that affected the signals from the signal generators in some way, that is, that the box output was some function of the inputs, or that some processing of the signals was done in the box.

2. After noting that there were many possibilities and that it wasn't possible to tell which possibility was in the box without more information, the student was asked to tell one or two things that could be in the box, that is, to describe what functions of the input the box could be producing. [Some students noted they would assume the signal generators were each producing a single frequency sine wave output, or would ask if that were the case. Most students suggested the output could be a) a linear sum of two input frequencies, b) modulation products, or c) the multiplication of two input frequencies (a form of AM)].

3. The student was then told he/she could adjust the exposed controls on the signal generators (frequency and amplitude, increase or decrease) if he/she thought they would help to decide what was in the box. [Most students immediately increased and then decreased the frequency of first one signal generator, and then the other one. The observation on the spectrum analyzer

was as follows: a) increasing the frequency of signal generator 1 caused the two impulses to move apart and away from their center by equal amounts and decreasing it caused them to move together, b) increasing the frequency of signal generator 2 caused the two impulses to move to the right keeping their separation constant while decreasing it caused motion to the left. There was no amplitude change of the impulses as the frequencies changed. Some students changed the amplitude of the generator outputs. Amplitude changes caused the amplitudes of both impulses to change by the same amount, and the amplitudes of the two "impulses" remained equal.] [In observing this, many students immediately said it was modulation, or it was double sideband modulation with no carrier, or it was multiplication of the outputs of the signal generators, and then proceeded to explain why from the observations.]

4. Whether or not they had concluded modulation or multiplication, the students were asked to write an expression that described what they observed. Those who had not concluded the answer were given the suggestion that writing the expressions might help them, and it did help many. [Some students wrote multiplication of two cosines of two frequencies and the expansion into sum and difference frequencies, some wrote the equivalent expressions as complex exponentials, some did delta functions and convolutions in the frequency domain. Any correct expression of the product and sum and difference frequencies was acceptable.] [A few students did not manage to solve the problem, even after several hints.] [The box did contain a multiplier, i.e. a DSBSC modulator, that amplitude modulated the output of signal generator one onto the carrier produced by signal generator two.]

5. The students were then asked to consider what would be seen on an oscilloscope time trace if an oscilloscope were connected in place of the spectrum analyzer. They were asked to sketch the waveform and to make and state assumptions as needed to sketch the waveform. [Most were able to sketch a DSBSC envelope for a sinusoidal modulated carrier and most noted a relationship between carrier and modulation frequencies needed to be able to see both. Some students noted the π phase shift at the envelope zeros. A few students sketched an AM with carrier envelope. Some corrected it with hints, some could not.

6. Those students who did not note the π phase shift at the envelope zeros were asked if there would be any differences between the different segments of the waveform that they sketched. [Some noted the π phase shift, but a few did not, even after being asked if their sketch was consistent with their equation.]

Qualifying Examination 1998

Computer Architecture

Logic Design

Giovanni De Micheli

January 1998

Let us consider Boolean functions of two arguments. How many of such functions

There are 16 functions.

Can you implement all Boolean functions of two arguments with:

- ANDs and ORs ? *No*
- ANDs and INVs ? *Yes*
- ORs and INVs ? *Yes*
- XORs and ANDs ? *Yes*

Consider 2-input multiplexers. Can you derive all functions of two arguments from 2-input multiplexers?

Yes. You need only one multiplexer if inputs are available in both polarity.

Give examples of how to implement:

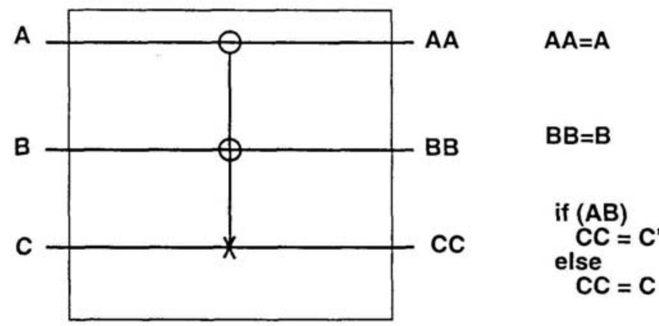
- INVs
- ORs
- ANDs

Let the multiplexer be $sx + \bar{s}y$*. Then:*

- $INV(a) \quad s = a; x = 0; y = 1.$
- $OR(a, b) \quad s = a; x = 1; y = b$
- $AND(a, b) \quad s = a; x = b; y = 0$

Can you recover the input values always from the inputs of:

- MUXes *No*
- ANDs *No*
- ORs *No*
- INVs *No*



Consider the controlled controlled inverter (CCN) gate. Can you derive a complete set of Boolean functions? Can you recover the input values always from the inputs of a CN from its outputs? How?

CCN is complete (realizes $INV(C)$ by setting $A = B = 1$ and AND(A,B) by setting $C = 0$.) and reversible $A = A'; B = B'; C = AB\overline{C'} + (\overline{A'} + \overline{B'})C$

What are the advantages of reversible computation?

Reversible computation may be more energy-efficient from a theoretical standpoint. As a consequence of the second law of thermodynamics, all reversible engines can be at least as efficient as irreversible ones. In other words, reversible gates (e.g., CCN) do not have the loss of information (increase in entropy) of the irreversible gates, which must be then compensated by providing energy to the circuit.

To: Diane Shankle <shankle@ee.stanford.edu>, group@glowworm.Stanford.EDU
Subject: Re: Copy of Your 1998 Quals Questions
Date: Thu, 05 Feb 1998 15:37:22 -0800
From: "Robert W. Dutton" <dutton@glowworm.Stanford.EDU>
Status:

Circuits

Hi Diane:

As has been my custom (past, present and future)
I do not provide "the answers".

What is an "ideal" Amplitude Modulated (AM) signal...describe
it both in frequency and time.

What are the limitations imposed by a real power
amplifier on the ideal signal...how is the signal changed
due to these real effects.

(Here the discussion varies a bit depending on response
from candidate but the directions of the question move in
the following way...)

Give details of impact of the passive network (i.e. only finite
gain is possible and what happens if you exceed the limits)
How does it look in frequency and time

Give details of how a single transistor amplifier affects
the results (i.e. for either MOS or BJT what happens when the
signals get too large)
How does it look in frequency and time

OK...that's enough to let the next generation think about
my question.

Cheers,
Bob

To: Diane Shankle <shankle@ee.Stanford.EDU>
Subject: Re: Copy of Your 1998 Quals Questions
Reply-to: abbas@isl.Stanford.EDU
Mime-Version: 1.0
Date: Wed, 04 Feb 1998 16:20:43 -0800
From: Abbas El Gamal <abbas@silt.stanford.edu>
Status:

Here it is:

Consider the following simple coin flipping game. Two players A and B alternately flip a fair coin. The player that gets heads first wins the game and the game ends.

A and B play N rounds of this game. In the first round player A starts first. In each subsequent round the player that won the previous round plays first. Find the expected number of times that player A wins.

$N\tilde{\sim}$?

The answer:
- ----------

There are lots of variations, but in general I looked for a distributed and a centralized answer. I gave hints to get people going in those directions. For the most decentralized, radios find out their neighbors hardware addresses (and can then ask them for their IP addresses). They could then ask these neighbors to send them info about their neighbors in turn, and gradually build up IP->hardware mappings for the whole network. Some people chose to do this. Others chose to do this per request by sending their neighbors a request for the hardware address for a particular IP address. If the neighbors didn't know the answer, they'd in turn send it on to their neighbors. Good points are that there's no configuration information needed to start with, and with suitable changes to make sure the algorithm terminates, it's fairly robust. However, it requires a lot of messages and the delay for a specific request can be tremendous. Variations on this had the non-mobile radios collect data, different sorts of caching, or using exchange of different sorts of route tables.

The centralized version picks a designated radio or set of radios to store the mappings. Some folks went with one server, some used a server per some size of region, etc. Radios can then send the server(s) their IP/hardware address pairs. To find the hardware address of a host, send the server a query with the IP address of the host. Good things are that this can be simple, and individual queries may be answered quickly. However, the radios need to know the hardware address of the server(s) to get started, or else there has to be some slow algorithm to pick a server. It can take a while for the server to develop its table of mappings, and the load on it for receiving IP/hardware pairs or for handling queries can be large. It may take a lot of storage as well. Delay for answering queries depends on how far away the server is from the requester. Bandwidth requirements near the server may be large as requests are passed in towards it. But there's less flooding of the network with messages. There are fault tolerant issues, especially if the student chose not to replicate the service. This solution can be considered simpler in many ways, unless the replication scheme gets complex.

Another question:
- ---------------

Note: Only one student got this question, because he wanted a "harder question." Unfortunately, he didn't do that well on either question.

At what level or levels of the TCP/IP stack should encryption be performed?

Answer:
- ------

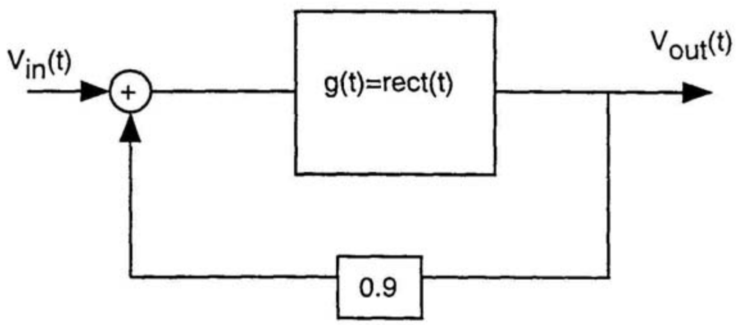
There are various answers here, depending upon what you're trying to make secure (avoid traffic analysis? protect data from eavesdroppers? protect just one physical link?) However, bad answers are to say "at each level" or at "every level except the application level." This would seem to show a lack of understanding of the end-to-end argument.

------- End of Forwarded Message

Qualifying Exam Questions
J.W. Goodman

Joseph January 24, 1998

Question: In the system shown below, the box contains a linear invariant *non-causal* system with impulse response $g(t) = \text{rect}\, t$. Nine tenths of the output is fed back to the input using positive feedback. Is this system stable?



Solution: If this system were causal, the solution would be straightforward. However, it is not causal, and therefore extra thought is needed. The most straightforward solution is one in which the non-causal impulse response is regarded to be the sum of causal and an anti-causal components,

$$g(t) = g_c(t) + g_a(t) = \text{rect}\left[2\left(t - \frac{1}{2}\right)\right] + \text{rect}\left[2\left(t + \frac{1}{2}\right)\right].$$

The causal part of the impulse response of the overall system will then have a Laplace transform

$$H_c(s) = \frac{G_c(s)}{1 - 0.9G_c(s)}$$

while the anti-causal part of the overall impulse response will have a Laplace transform

$$H_a(s) = \frac{G_a(s)}{1 - 0.9G_a(s)}$$

Note that $s = \sigma + j\omega$ and that the Laplace transforms used in the causal and anti-causal cases above are

$$G_c(s) = \int_0^{\infty} g_c(t) \exp(-st)\, dt = \int_0^{1/2} \exp(-st)\, dt = \frac{1}{s}\left(1 - e^{-s/2}\right)$$

and

$$G_a(t) = \int_{-\infty}^{0} g_a(t)\exp(-st)\,dt \int_{-1/2}^{0} \exp(-st)\,dt = -\frac{1}{s}\left(1 - e^{s/2}\right).$$

It follows that the transfer functions of the causal and anti-causal parts of the overall system transfer function are

$$H_c(s) = \frac{\left(1 - e^{-s/2}\right)}{s - 0.9\left(1 - e^{-s/2}\right)}$$

and

$$H_a(s) = -\frac{\left(1 - e^{s/2}\right)}{s + 0.9\left(1 - e^{s/2}\right)}.$$

The locations of the poles of these two transfer functions are determined by the zeros of the denominators of the two transfer functions. The poles at $s = 0$ are canceled by zeros at that location.

Setting the denominators of the two expressions to zero, it is rather straightforward to show that there are no poles on the $j\omega$ axis. At this point I suggested exploring the real axis. With $\sigma = \mathrm{Re}\{s\}$, we want to determine whether equality can be achieved in each of the following equations, in the first case for $\sigma > 0$ and in the second case for $\sigma < 0$:

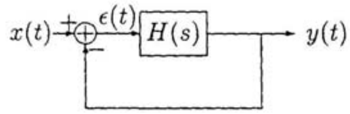
$$\sigma = 0.9\left(1 - e^{-\sigma/2}\right),$$
$$\sigma = -0.9\left(1 - e^{\sigma/2}\right).$$

For the first equation, the left hand side rises linearly for $\sigma > 0$, while the right hand side rises more slowly than linear, so there is no positive σ for which equality is achieved. That is, there are no poles on the right-hand real axis. For the second equation, the same conclusion can be reached for the left-hand plane. Thus unless there is a pole somewhere we have no explored (there isn't), the causal and anti-causal parts of the transfer function are stable, so the system is stable.

system

R.M. Gray 1998 Quals Question

The following simple linear feedback system can be used as a tracking system, where ideally $\epsilon(t) \to 0$ as t grows.



Capital letters denote unilateral Laplace transforms, e.g., $X(s) = \int_0^\infty x(t)e^{-st}\,dt$. Suppose that $x(t)$ is the unit ramp function,

$$x(t) = \begin{cases} t & t \geq 0 \\ 0 & t < 0 \end{cases}$$

---

1 What is the transfer function $Y(s)/X(s)$?

From the picture, $Y = HE = H(X - Y)$ hence $Y[1 + H] = XH$ hence

$$\frac{Y(s)}{X(s)} = \frac{H(s)}{1 + H(s)}$$

Point: students should either recall the formula for simple feedback or be able to derive it quickly as above. This was to get people started.

2 Suppose that $H(s) = 1/s$. Find the steady state form of $\epsilon(t)$. Is the tracking error zero in the steady state?

From the picture again, $E = X - Y = X - HE$ so that

$$E(s) = \frac{X(s)}{1 + H(s)} \tag{1}$$

Have $H(s)$, need $X(s)$. Here expected either

- students knows the transform of a ramp, or
- student knows (or was given a hint) the transform of a step and can infer that of a ramp from it (either using the integral property or the multiply by t property of Laplace transforms).

Regardless, $X(s) = 1/s^2$ so $E(s) = 1/s(s + 1)$. Using partial fraction expansion

$$E(s) = \frac{1}{s} - \frac{1}{s+1}$$

so that $\epsilon(t) = 1 - e^{-t}$ for $t \geq 0$, which does not converge to zero.

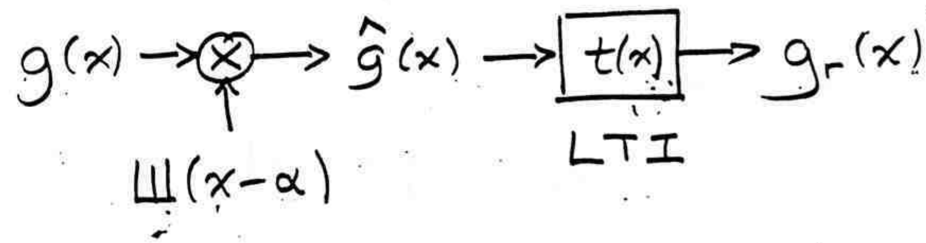
Comment: You cannot count on the final value theorem here because of the pole on the imaginary access, you need no poles on or to the right of the imaginary access to invoke the final value theorem. (Mechanically it gives the right answer, but the conditions needed to use it do not hold.)

NISHIMURA

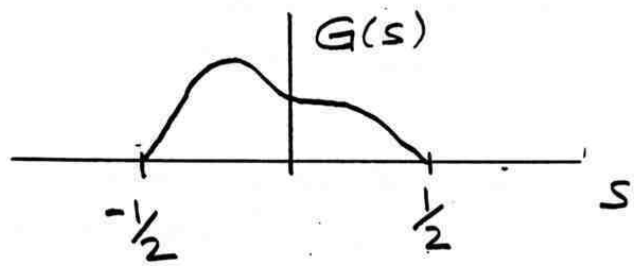
system

The Effect of Shifting the Sampling Function

- $g(x)$ is sampled to produce $\hat{g}(x)$.
- The LTI system has impulse response $t(x) = \mathrm{sinc}(x)$ (unless noted) and produces the recovered signal $g_r(x)$.
- The sampling function is shifted by α.



For problem 1, let $\mathcal{F}\{g(x)\} = G(s)$ as shown below.



1. Let the measure of error between $g_r(x)$ and $g(x)$ be

$$\epsilon = \int_{x=-\infty}^{\infty} |g_r(x) - g(x)|^2 \, dx .$$

   (a) Will this error depend on the shift α?

   (b) Repeat part (a) but let $t(x) = \wedge(x)$.

2. For the previous question, will $g_r(x)$ depend on α?

3. Now consider $g(x)$ that is not bandlimited.
Will the error ϵ depend on α?

ANSWERS

1a) No, $g_r(x) = g(x)$, independent of α

1b) No, $g_r(x)$ depends on α but ϵ will not

2) No for $t(x) = \text{sinc}\, x$
Yes for $t(x) = \Lambda(x)$

3) Yes. Both frequency-domain and time-domain explanations can be given.

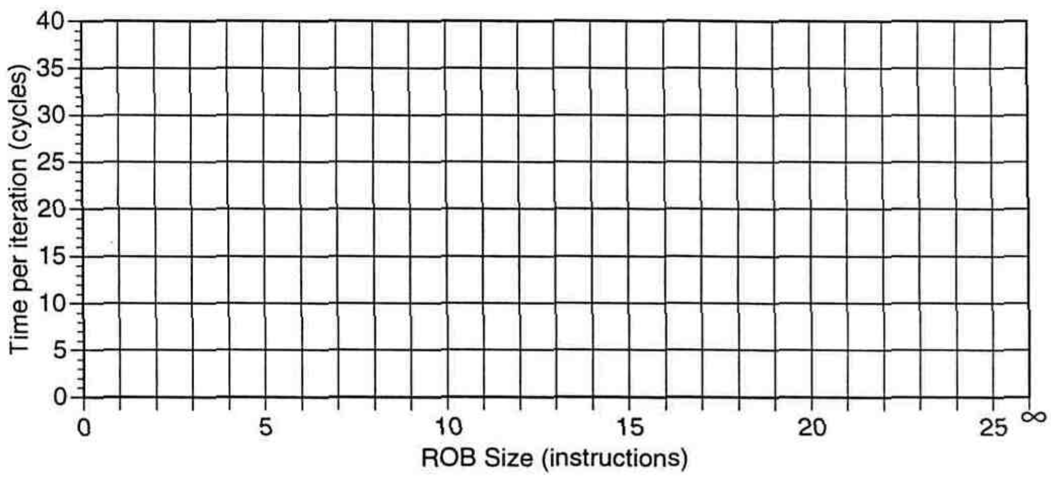
computer Architecture

K. Olukotun

1. What's a non-blocking cache (NBC)?
2. How does it improve AMAT?
3. What do you need in processor and memory system to make a NBC most effective?
4. Fill in the graph below? (assume a pipelined memory system)

```
for (i = 0; i < 1000; i +=2)
      B[i] = B[i] + C[i] + B[i+1] + C[i+1]; /* all arrays are 4-byte
                                             integers */

        top:  LD   R1, B[i]
              LD   R2, C[i]
              ADD R3, R1, R2
              LD   R4, B[i+1]
              ADD  R5, R3, R4
              LD   R6, C[i+1]
              ADD R7, R5, R6
              ST   R7, B[i]
              3 instrs to update i, B[i], C[i]
              BLT R8, #1000, top
```



Assumptions

1. fully associative non-blocking data cache, initially empty
2. 8 byte cache line size
3. write back, write allocate
4. 10 cycle miss penalty
5. single issue fully pipelined processor
6. perfect branch prediction

Brad Osgood System

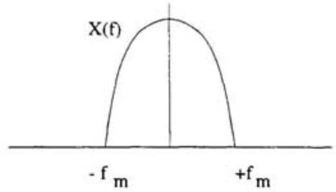
There are competing populations of robins and worms on an island. The presence of worms is good for the robins. The absence of robins is good for the worms. Interactions beween robins and worms are good for the robins and bad for the worms. Write a system of differentila equations that describes how the populations of robins and worms evolve over time.

?

Paulraj: Quals Questions 1998

arogyaswami

Let $x(t)$ be a zero mean, low pass stationary process with PSD $X(f) = 0,\ |f| \gtreqless f_m$. $T_{samp} = 1/f_{samp}$



Questions: Set I

- Draw the PSD of ideally sampled $x(t)$ when $f_{samp} = 2.5 f_m$ and $f_{samp} = 1.5 f_m$.
- If the sampling is non-ideal because it uses a finite sampling window T_{win} over which it averages the signal during sampling, what will be the PSD of the output be when $f_{samp} = 2.5 f_m$.
- How can you reconstruct the ideally sampled signal from sampled sequence. Explain both freq. and time domain views.

- If the sampling uses a finite window T_{win}. How will you correct for this.
- If the waveform reconstruction uses a zero order hold, what is the distortion in the frequency domain.
- What is the dynamic range of an ideal 8 bit ADC.
- If we only have 4 bit ADC/DAC, but we really need 6 bit performance. How can one achieve this.
- If the input signal has a Gaussian PDF with STD$= \sigma$, what should be the optimum step size of a linear 6 bit ADC.
- How can I use non-linear transformations to improve dynamic range performance of the ADC.

Questions: Set II

Let $x(n)$ be a long random signal sequence. We need to convolve $x(n)$ with a FIR filter sequence $y(n),\ 0 \leq n \leq M$. How can you efficiently use FFT to implement this convolution.