Electrical Engineering

Quals Questions

1993

Date: February 1, 1993

To: File
From: G. FRANKLIN
Subject: 1993 Quals

Question: The ME Department of NASA has sent over the Bode plot or Frequency response shown. You are to provide a feedback control design for it.

I. Excellent Answers [8-10]
Stu: The phase clearly does not match the minimum phase for the magnitude shown. I conclude that there must be either a pole or a zero in the right half plane. The magnitude shape suggests a pole. Is this system open-loop stable?

Prof: No, there is one pole in the right half plane.

Comment: It's all downhill from here to a double-lead compensation.

II. Standard Answer: [4-7]

Stu: We must look at the gain and phase margins. The phase at crossover is $\sim 127^0$ thus I conclude the system is [stable or unstable].

Prof: What is the theory behind that conclusion?

Stu: Nyquist's stability theory.

Prof: Draw the corresponding Nyquist Plot.

Stu: Does so, in 3-10 minutes. Usually needing several hints and suggestions.

Prof: Is it stable with only <u>gain</u> feedback?

Stu: $N = CW$ or $CCW = \pm Z \pm P$

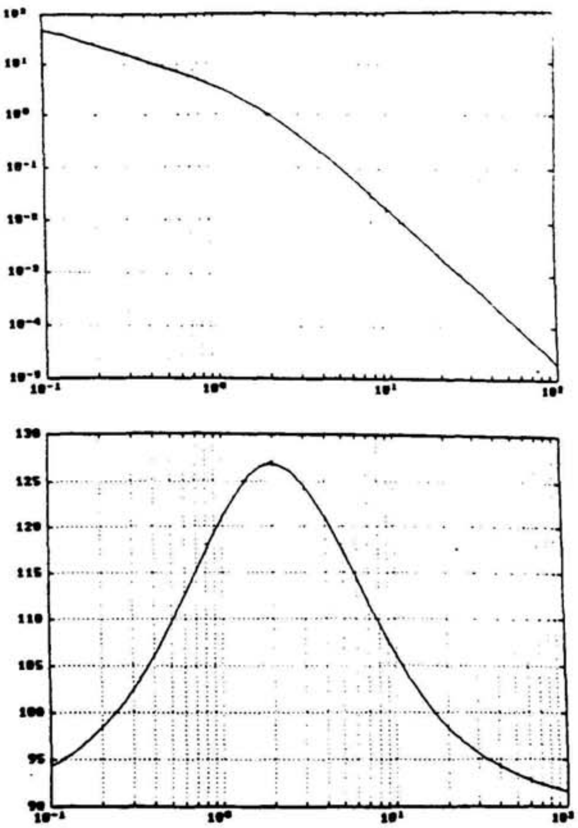
[After hints, $N_{CW} = Z - P$].

What is P?

Prof: $P = 1$

Stu: Unstable.

Prof: We're out of time.


10^2
10^1
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10^-1
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130
125
120
115
110
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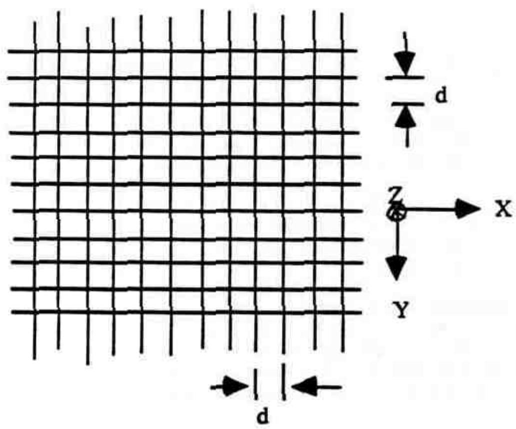
100
95
90
10^-1
10^0
10^1
10^2

\eave

Prof. C. Chang-Hasnain
Electrical Engineering
Qualifying Exam 1993

Question:
An uniform metal grid/mesh (see Figure), on x-y plane at z=0, extends to infinity in both x and y directions. Assume the mesh is made of perfect conducting wires. The periods of the grids are d in both x and y directions. The metal may have some thickness, but it does not matter. A plane wave propagating in the +z direction with wavelength λ is incident onto the mesh in the direction normal to the x-y plane.
1. How does one design d to optimize the reflection in the direction normal to the x-y plane?
2. Assume 1 is achieved. If a detector is placed on the other side of the mesh (z>0), how does the power detected behave with distance z?
3. To the first order, how does one estimate the decay constant?



Answer:
1. This problem can be simplified into a 1D problem, simply solving the reflection pattern of the 1D array. The reflection pattern have multiple peaks (Fourier transform) at angles off-normal due to constructive and destructive interferences. The peaks are located at

$k\, d \sin\theta = (2\pi/\lambda)\, d \sin\theta = 2\, m\, \pi$ where $m = 0, 1, 2, \ldots$ and $|\theta| \leq \pi/2$

Hence, to optimize reflection requires $d < \lambda$.

2. The power should exponentially decay as a function of z away from the mesh.

3. The decay constant will be proportional to d.

Message 45 (4900 chars)
Return-Path: <cover@isl.stanford.edu>
Received: from ISL.Stanford.EDU by Sierra.Stanford.EDU (4.1/25-eef) id AA23036; Fri, 19 Feb 93 14:02:25 PST
Received: by ISL.Stanford.EDU (4.1/25-eef) id AA14704; Fri, 19 Feb 93 14:02:22 PST
Message-Id: <9302192202.AA14704@ISL.Stanford.EDU>
To: shankle@Sierra.Stanford.EDU, franklin@isl.stanford.edu
Cc: cover@isl.stanford.edu
Subject: Quals question by Tom Cover
Date: Fri, 19 Feb 1993 14:02:22 -0800
From: Thomas Cover <cover@isl.stanford.edu>

1993 QUALS QUESTIONS

by Tom Cover Signal

Subject: Elementary problems in mathematics, statistics, physics, and signal processing.

I ask two questions, one on the meaning of duality, and the second on the meaning of the expected value of e^iXt. My idea is that people who have thought about problems in mathematics, physics and engineering would have also puzzled over the meaning of duality. Inquiring minds should be able to come up with many examples of duality and to find a curious fact about these examples, which I will mention shortly.

The question on the meaning of the expected value of e^itx was meant simply to see if they knew the definition of expected value and recognized that this was simply the characteristic function (Fourier transform) of the underlying density.

Both questions are at the foundational level and do not test particular knowledge of electrical engineering. I am persuaded that the other nine exams would reveal these particulars and that a balanced ten-exam program should have a question like mine in order to reveal the intellectual curiosity and creativity of the examinee.

First question:

The first question began, "You may have encountered duality in your studies. It is seldom defined. I wish to elicit a definition of duality, but before that, can you give me examples of duality in electrical engineering, physics, mathematics, art, music and literature? Later we will consider these examples and try to arrive at a definition."

Answer:

Good examples of duality are circuit dualities like RLC vs. RCL,

parallel vs. series, Thevenin vs. Norton, and current and voltage (with perhaps the correspondences of the dual quantities in these relationships). Further dualities are RLC vs. mass spring dashpot, graph-theoretic duality for planar graphs, electric and magnetic fields, good and evil (the dictionary example), hot and cold, black and white, yin and yang, point and counterpoint, wave and particle, Fourier transform pairs, Boolean duality, DeMorgan's laws, controllability and observability, dual spaces, duality in linear programming, and so on.

I tended to consider even weak examples of duality, like short and long, to be better than no example. Also, I feel that it is easy to take language barriers into account on this question because the essential ideas for the examples come through even without a facility with language.

I then asked for definitions of duality which one could extract from these examples. It is clear that there are two kinds of duality -- isomorphism, as in the correspondence of a mechanical systems and an electrical system through the same set of linear differential equations, and complementarity, as in good and evil or Boolean functions.

Some clever examinees noticed that these two definitions -- similarity and complementarity -- were themselves dual.

Second question:

The question on expected value of e^iXt was phrased as follows. "A random variable X has a probability density function f(x). Do you know what this means? Now I form a new random variable. I multiply X by the real number t and then by the square root of -1, exponentiate the whole thing and take the expected value. Let's call that r(t). What is r(0)? Is r(t) bounded? And finally, given the value of r(t) for all values of t, what can you say about the underlying density function f(x)?"

Answer to second question:

The answers are: r(0)=1, r(t) is bounded in the unit circle in the complex plane, and, finally, r(t) is simply the Fourier transform of f(x), so one can recover the density from it by taking the inverse Fourier transform.

The punchline is that r(t) is the dual of f(x) since they form a Fourier transform pair.

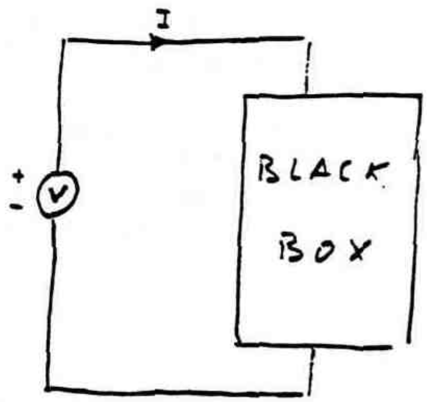
Final comment:

I found that the duality question gave me confidence in the complexity and clarity of thought of the examinee and whether that person would be likely to do research which would interest other people. The weaknesses of the question are obvious. It provides little information on whether the examinee knows any of the substantial areas of electrical engineering, and I don't know whether the person has strong mathematical power or physical intuition. Presumably, the other nine examiners will discover the rest of the answer.

DE MICHELI

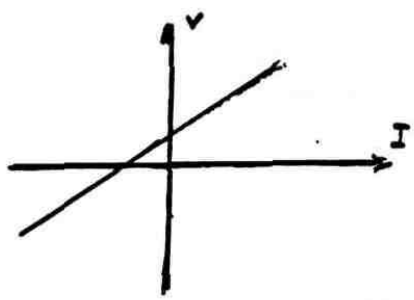
Quals 93
Linear and Non-linear circuits

An engineer is interested in characterizing a two-terminal black-box by means of current/voltage measurements.



1. Is it linear?
2. Is it active or passive?
3. Model the black-box by two-terminal elements.

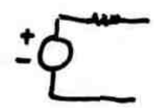
A



ANSWERS:

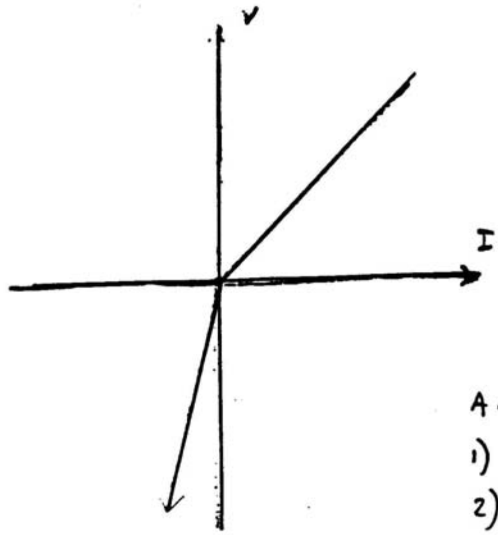
1) LINEAR RESISTIVE CIRC.

2) ACTIVE

3) 

1. Is it linear?
2. Is it active or passive?
3. Model the black-box by two-terminal elements.

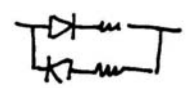
B



ANSWERS:

1) NON-LINEAR

2) PASSIVE

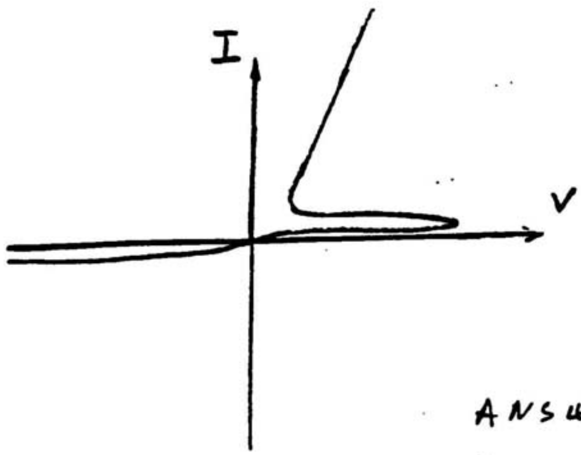
3) 

1. Is it linear?

2. Is it active or passive?

3. What off-the shelf component it represents? (NOT BLOCKING QUESTION)

C



ANSWERS

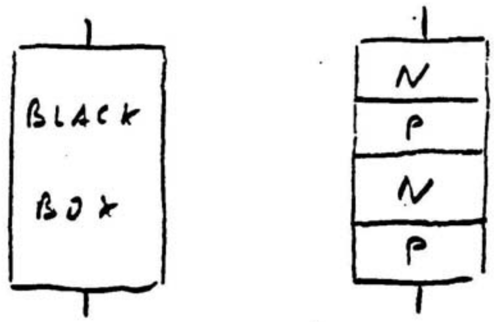
1) NON-LINEAR

2) PASSIVE

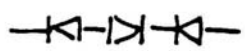
3) SCR

8

Assume a SCR can be modeled as drawn below.
Sketch how you would find the current/voltage behavior of the two-terminal element.



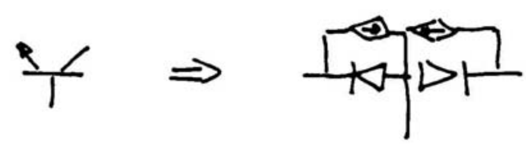
ANSWER

STEP 1 : 

Justify open circuit behavior

STEP 2 : 

STEP 3 : EBERS-MOLL MODEL



QUALITATIVE ANSWER SUFFICIENT

9

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3 PST

rom: "Robert W. Dutton" <dutton@gloworm.stanford.edu>

Robert dutton

essage-Id: <9302110227.AA06491@gloworm.Stanford.EDU>

o: "Diane J. Shankle" <shankle@sierra.stanford.edu>

ubject: Re: Quals Questions

n-Reply-To: Your message of "Wed, 10 Feb 93 11:34:04 PST."
<CMM.0.90.0.729372844.shankle@Sierra.Stanford.EDU>

ate: Wed, 10 Feb 93 18:27:13 -0800

What is the Miller Capacitance

Explain how a shunt-shunt feedback resistor
anges the input and output impedance of a
ngle-stage transistor amplifier

Do you see contradictions between the results
1 and 2? Expalin.

10

Date: Wed, 24 Feb 93 16:13:47 -0800
From: flynn@mimd.stanford.edu (Michael Flynn)
Message-Id: <9302250013.AA24623@mimd.Stanford.EDU>
To: shankle@sierra.stanford.edu
Subject: Re: Quals Questions

1. Given two decks of cards. A draw is made from each deck. What's the probability that at least one of the two cards is the Ace of Hearts.

2. Note that 16/64=1/4 and 19/95=1/5. In both cases the result can be determined by cancelling out the 6's and the 9's. For two digit numbers (numerator starting with 1) what property must be satisfied for cancellation to be possible resulting in a unit fraction of the same value as the original two digit pair. Find another pair that satisfies the property.

3. What's clock skew? How does it effect cycle time.

4. What is the purpose of rounding modes in floating point arithmetic. Specifically, what's the value of "round to + infinity".

Mike Flynn

R

OFFICE MEMORANDUM ◇ STANFORD UNIVERSITY
SPACE, TELECOMMUNICATIONS AND RADIOSCIENCE LABORATORY

February 15, 1993

To: Gene Franklin/Diane Shankle

From: Tony Fraser-Smith   Electromagnetics

Subject: Ph.D. Quals Question, 1993

Question: What do you know about the propagation of electromagnetic waves in electrically conducting media? In particular, what can you tell me about their velocity of propagation, and about the possibility that you could ever swim faster that their speed of propagation in sea water?

Answer: Maxwell's Equations are

$$\nabla \cdot \mathbf{B} = 0; \quad \nabla \cdot \mathbf{D} = \rho; \quad \nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}; \quad \nabla \times \mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t}$$

where the last is the most important, since it involves $\mathbf{J} = \sigma\mathbf{E}$ (Ohm's law) and σ is the electrical conductivity of the medium. Using $\mathbf{D} = \epsilon\mathbf{E}$, and assuming a time variation of the form $\exp(j\omega t)$, we obtain $\nabla \times \mathbf{H} = (\sigma + j\omega\epsilon)\mathbf{E}$ and the two wave equations

$$\nabla^2\mathbf{E} - \gamma^2\mathbf{E} = 0; \quad \nabla^2\mathbf{H} - \gamma^2\mathbf{H} = 0$$

where the *propagation constant* γ is given by $\gamma^2 = j\omega\mu(\sigma + j\omega\epsilon)$. For $\gamma = \alpha + j\beta$, we obtain

$$\mathbf{E} = \mathbf{E}_0 e^{-\alpha\xi} e^{j(\omega t - \beta\xi)}; \quad \mathbf{H} = \mathbf{H}_0 e^{-\alpha\xi} e^{j(\omega t - \beta\xi)}$$

$\frac{2\pi}{\lambda} = \frac{1}{\delta}$

where ξ is distance. For a good conductor, given by $\sigma/\omega\epsilon \gg 1$ (note the frequency dependence!!), we have $\alpha = \beta = 1/\delta$, where $\delta = \boxed{2/(\omega\mu\sigma)}^{1/2}$ is the *skin depth.* Thus the wave propagates with phase velocity $v = \omega/\beta = \omega\delta$, it has a wavelength $\boxed{\lambda = 2\pi\delta,}$ and it is exponentially attenuated with attenuation constant $\alpha = 1/\delta$. The phase velocity has a $\omega^{1/2}$ frequency dependence (*dispersion*!); it gets slower as the frequency gets smaller.

For sea water, the instructor gives $\sigma = 4$ S/m, $\sigma/\omega\epsilon = 1$ at 899 MHz, and $\delta = 251$m at 1 Hz. The student should then point out that the good conductor criterion applies at frequencies less than 100 MHz, say. The phase velocity is $2\pi \times 251$m/s, or about 1580 m/s at 1 Hz. Given the $\omega^{1/2}$ frequency dependence, the phase velocity will be 158 m/s at 10^{-2} Hz; 15.8 m/s at 10^{-4} Hz; and 1.6 m/s at 10^{-6} Hz. Clearly any swimmer can swim faster than the speed of propagation of electromagnetic waves in sea water *at some low frequency.*

Qualifying Exam Questions and Answers
J.W. Goodman
January 1993

Consider the following Fourier Transform pair:

$$c(t) = \exp\left(-j\pi t^2\right) \supset \exp\left(-j\frac{\pi}{4}\right)\exp\left(j\pi f^2\right) = C(f)$$

Question 1: What is the autocorrelation function of the chirp function c(t) above?

Answer: By the autocorrelation theorem, the Fourier transform of the autocorrelation function is $|C(f)|^2 = 1$. Therefore the autocorrelation function of the chirp function is a delta function, $\delta(t)$.

Observation: This function of infinite extent is seen to have an autocorrelation function of infinitesimal width!

Question 2: We often define the delta function through a limit of a sequence of ordinary functions. Can you specify an appropriate sequence of chirp functions that will do the job?

Answer: It is easiest to answer in the frequency domain. We require a sequence of Fourier transforms, each of which has value unity at the origin (area property), and which in the limit approach unity everywhere on the frequency axis. A suitable sequence is

$$C_N(f) = \exp\left[j\pi\left(\frac{f}{N}\right)^2\right]$$

which has as its inverse Fourier transform (from original Fourier transform pair and the similarity theorem)

$$c_N(t) = \exp\left(j\frac{\pi}{4}\right)\cdot N\exp\left[-j\pi(Nt)^2\right]$$

and from the frequency domain result, we known that

$$\lim_{N\to\infty} c_N(t) = \delta(t)$$

where the left and the right sides are taken to be equal under integration.

Question 3: How can it be that we were able to define the delta function, which is infinitesimally narrow, by means of a sequence of functions whose magnitude is always unity everywhere? Give as physical as possible an answer.

Answer: The chirp functions in the sequence oscillate more and more rapidly everywhere except at the origin as the index N increases. As a consequence the integral of the product of the chirp function with any other continuous function will in the limit yield zero everywhere but at the origin, due to the cancellation of positive and negative lobes of the product. A sketch of the real or imaginary parts of the function $c_N(t)$ helps a great deal here.

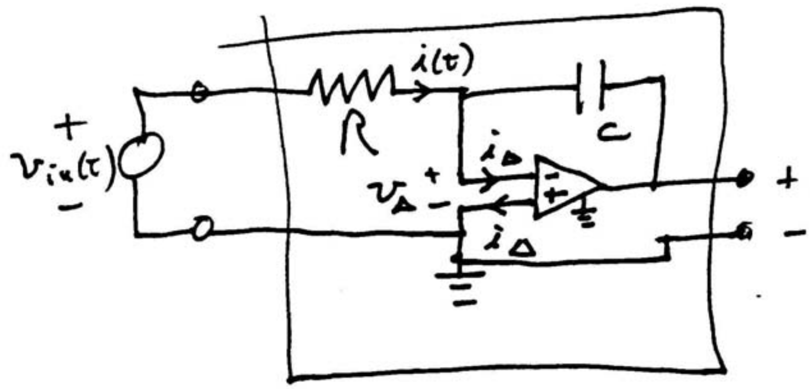
Gray

February 1993 Quals Question

(Note: I made minor variations in different exams)

Part I:

Consider the following Circuit



Ideal Op Amps $i_\Delta = 0$, $v_\Delta = 0$

(a) If $v_{in}(t) = e^{j\omega_0 t}$, all t, what is $v_{out}(t)$?

Answer: Many ways to do this, fastest is: $e^{j\omega_0 t}$ an eigenfunction $\Rightarrow v_{out}(t) = H(j\omega_0)e^{j\omega_0 t}$

$$\Rightarrow H(s) = \frac{V_{out}(s)}{V_{in}(s)} = \frac{-I(s)\,1/sC}{V_{in}(s)} = -\frac{V_{in}(s)/R}{V_{in}(s)\,sC} = -\frac{1}{RsC}$$

$\Rightarrow v_{out}(t) = -\frac{1}{j\omega_0 RC} e^{j\omega_0 t}$ //

Also doable by differential equations or Laplace Xforms (unilateral or bilateral)

(b) What is impulse response?

Ans: Inverse Laplace Xform of $-\frac{1}{RCs} \Rightarrow$

$-\frac{1}{RC} \underbrace{u(t)}$ unit step (an integrator)

(c) Is system Stable? No, put constant in, output blows up (not BIBO, it is an integrator)

Part II: $x_n \rightarrow \boxed{} \rightarrow y_n$ $\quad y_0 = 0$, $y_n = y_{n-1} + x_n$, $n \geq 1$

(a) If $x_n = ar^n$, $n = 1, 2, \ldots$ $x_n = 0$, $n \leq 0$, what is y_n?

Ans: $y_n = y_{n-1} + x_n = y_{n-2} + x_{n-1} + x_n \ldots$

$= \sum_{k=1}^{n} x_k$ (discrete time integrator)

$= \sum_{k=1}^{n} ar^k = \frac{r(1-r^n)}{1-r}$ (or, with much more effort, by z transforms)

(b) Stable? Ans. No 15

(c) (A few got this far) if x_n iid Gaussian, mean m, variance σ^2, find mean + variance of $\frac{y_n}{n}$

3

Ans

$$\frac{1}{n}\sum_{i=1}^{n} x_i$$

$$E(y_n) = \frac{1}{n}\sum_{i=1}^{n} E(x_i) = \frac{\cancel{n}\, m}{\cancel{n}} = m$$

$$\sigma^2_{y_n/n} = \frac{\sigma^2_{y_n}}{n^2} = \frac{\sum_{i=1}^{n} \sigma^2}{n^2} = \frac{\sigma^2}{n}$$

since iid

Jim Harris

Devices

In device courses, you have focused on device trade-offs based upon the properties of a single semiconductor like Si or GaAs. I claim I can make you a semiconductor with whatever properties you would like. What would the properties of your "ideal" semiconductor be and why?

1. Bandgap - 1.2-1.5 eV - Bandbap too small; large n_i, inability to control n and p, poor operating temperature range, large leakage currents, low FET and bipolar transistor breakdown voltages. Bandgap too large: unable to ionize impurities and obtain free carriers (insulator), poor ohmic contacts, high power dissipation and high V_{TH} for FET and bipolar transistors diodes and lasers. Bandgap too high; desirable to have direct bandgap for optical devices.

2. Would like to have a good, naturally forming oxide which is an insulator which has no interface states, passivates the surface, is thermally stable, a good high temperature diffusion and ion implantation barrier, is easily etched, and has good etch selectivity to semiconductor.

urface state

3. Material which can be easily grown and prepared as large area wafers which are physically robust, thermally and chemically stable, compatible with both metals and insulators, able to be controllably doped n or p over a broad range and particularly to high densities, able to be semi-insulating and have a lower dielectric constant. < 2

4. High mobility for both e^- and h^+ (equal for complementary circuits) and low resistivity for diodes, lasers, BJT, etc., and high saturated drift velocity which is reached at low electric fields for high speed and low power dissipation.

5. High thermal conductivity and small thermal expansion coefficient and one that matches to its oxide and metals.

6. Heterojunction possibilities to be able to fabricate much higher performance lasers, HBTs, MODFETs, OEICs, QW devices).

7. Properties that are independent of temperature.

8. High Breakdown field for high power devices.

9. Small and equal effective mass - better tunneling for low resistance ohmic contacts, lower I_{th} for lasers and higher currents in tunneling devices.

? 10. Lifetime - generally short for high speed devices, long for CCDs, solar cells and high power devices.

11. Widely abundant, low cost, non-toxic material.

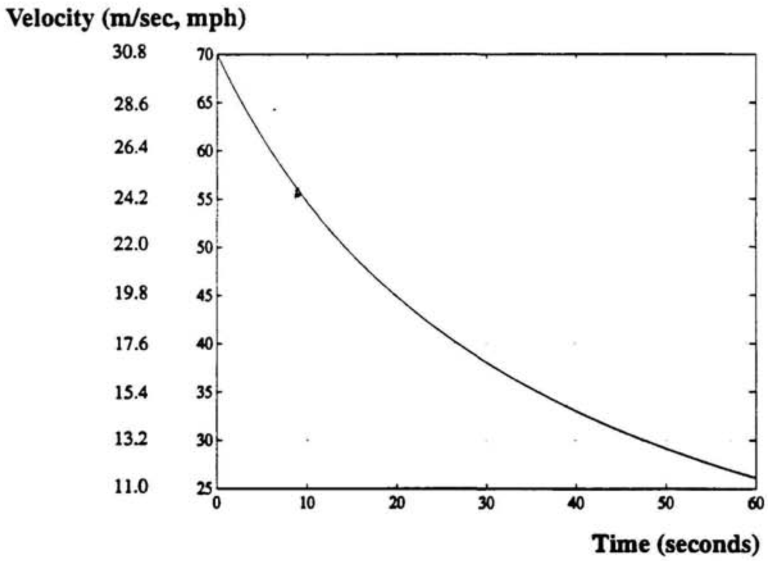
If you could choose one property that was temperature independent, which would you choose?

Bandgap - temperature variation in bandgap causes threshold variation in FETs and HBTs wavelength of lasers and leakage currents in all devices. A high temperature independent mobility for both electrons and holes makes complementary high speed circuits much easier to design mobility-circuit speeds.

martin (Emeritus)

Prof. Hellman's 1993 Quals Question

Question 1: A 1 ton car is accelerated to 70 mph, put in neutral, and then allowed to coast, yielding the graph of velocity vs. time shown below. How would you find the power required to propel the car at 55 mph? (Don't actually do the computation. Explain how you would and why.)



Question 2: To a first approximation, the required power P is due to air resistance and increases as the velocity cubed. Devise a model that explains this behavior on the basis of simple freshman physics.

Optimal Answer 1: I don't know how to find power, but I could find F if I knew the mass of the car: $F=ma$ and $a = dv/dt$ which is the slope (tangent) at 55 mph, but of course use the mks units to simplify life (1 ton≈1 tonne=1,000 kg). Work (W) is F times distance (L) and $P = dW/dt$, so at constant speed $P = FdL/dt = Fv$. Ah, now I remember that formula! [You also could approach this form $P = dE/dt$, the rate of loss of kinetic energy of the car when no power is applied (as in the above graph). Then from $E = mv^2/2$ you find $P = mv\,dv/dt$.

Optimal Answer 2: Since $P = Fv$ we have to show F is proportional to v^2. I'll assume the molecules of air are at rest and compute the force they exert on the car. Now $F=dp/dt\approx\Delta(mv)/\Delta t$ where $p = mv$ is momentum. Δv (of the molecules) should be proportional to v, and dm/dt (the rate of hitting air mass) is also proportional to v. Voila! If time: go over elastic ($\Delta v=2v$) *vs*. inelastic collisions ($\Delta v=v$); add in air is only at rest on average, but that doesn't change average $\Delta(mv)/\Delta t$.

Received: by vsop.Stanford.EDU (5.57/Ultrix3.0-C)
id AA27883; Tue, 2 Mar 93 16:38:11 -0800
Message-Id: <9303030038.AA27883@vsop.Stanford.EDU>
To: "Diane J. Shankle" <shankle@sierra.stanford.edu>
Subject: Re: Last Chance
In-Reply-To: Your message of "Tue, 02 Mar 93 13:32:53 PST."
<CMM.0.90.0.731107973.shankle@Sierra.Stanford.EDU>
Date: Tue, 02 Mar 93 16:38:10 -0800
From: jlh@vsop.stanford.edu
X-Mts: smtp

Q: Consider a simple peiplined machine with different instruction latencies. What are the best and worst case CPIs? Show code sequences that exhibit these.

A: Best case CPI = 1. Worst case = the instruction latency adjusted by the instruction mix frequency. Best case code sequence: all instructions independent. Worst case: all instructions dependent.

R>

8; Wed, 3 Mar 93 08:35:48 PST
Received: by chroma.Stanford.EDU (5.57/Ultrix3.0-C)
id AA22838; Wed, 3 Mar 93 08:35:47 -0800
Message-Id: <9303031635.AA22838@chroma.Stanford.EDU>
To: "Diane J. Shankle" <shankle@sierra.stanford.edu>
Cc: horowitz@chroma.stanford.edu
Subject: Re: Last Chance
In-Reply-To: Your message of Tue, 02 Mar 93 13:32:53 -0800.
<CMM.0.90.0.731107973.shankle@Sierra.Stanford.EDU>
Date: Wed, 03 Mar 93 08:35:47 PST
From: Mark Horowitz <horowitz@chroma.stanford.edu>

Architecture

Quals Question:

1. You are designing a computer and need to build a function unit that checks to see if the value on the source bus is zero. How would you build the function unit in CMOS?

Answer:
There are two ways of solving this problem. No matter which you choose I would ask for the other answer as well.

The circuit that is needed is a 32 input NOR gate, since its output will be 1 only if all the inputs are zero. This can be built by using a precharged gate will 32 parallel transistors, a precharge pullup, and a single pulldown device. For this gate to work, the inputs must be stable when the evaluate transistor turns on. A pseudo nMOS gate, with a single pMOS static load and 32 pulldown nMOS devices would be ok for this part of the problem as well.

The other solution is to use static CMOS gates. Since there is a series stack of transistors that is proportional to the number of inputs, each gate must have a limited fanin. Let's set the fanin to be 2. One can use a tree to build a 32 input out of 2 input gates. The first layer is 16 2input NOR gates. Since the outputs are inverted, the next stage must be NOR with inverted inputs, which are NAND gates. There are 8 or these gates. The next level in the tree is then 4 NOR gates, and this is followed by 2 NAND gates, and the final NOR gate. The key was to realize that you need to flip from NORs to NANDs to handle the inversions.

2. How does the delay of these structures scale with the number of inputs.

For the precharge gate, the resistance of the worst-case pulldown is constant. The cap of the output node will increases linearly with the number of inputs, since each additional input adds some diffusion cap to the output node.

In the tree, the critical path is the depth of the tree. This is log2 of the number of inputs. Thus, since the delay of all the 2input gates should be similar, the delay is proportional to the log2 of the number of inputs.

3. Which of the two structures is faster? Does the answer depend on the number of inputs?

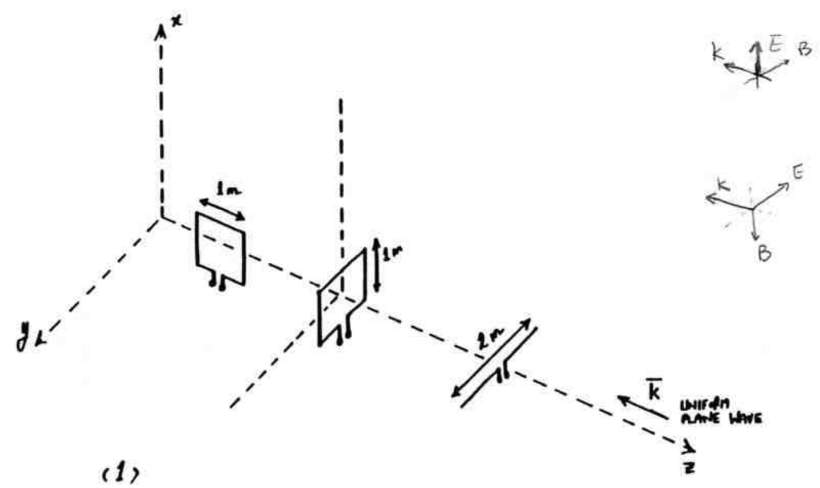
ince the precharge gate's delay increases linearly with n, and the ree is log(n), the tree must be faster for large n. The key question s which is faster for small n. I was interested in how students ttacked this problem. The precharge gate will be faster, since it has ewer transistors, and that means less input and output capacitance. o the right anwer is the precharge gate is faster at small n and the ree is faster for large n.

. Does the answer to question 3 give you an idea of how to build a aster 32 input NOR?

ure, replace the NOR gates in the tree with precharge gates. This ould allow you to increase the fanin of these gates, and shorten the epth of the tree while maintaining the same gate delay. The NAND ates in the tree invert the output of the precharge gates, so the nputs to the NAND gates are monotonically rising signals.

1993 PhD Quals Questions for Professor Inan

Electromagnetics



(1)

22

Question 2:

Given a transmission line of length L and characteristic impedance Ro and with the switch being closed at t=0, please plot the voltage across the capacitor as a function of time.

Ans: The voltage starts to vary only after a propagation time of c/L. The capacitor voltage should not change suddenly and in this case $\boxed{\text{does not reach a steady state}}$ value due to the fact that there is no source impedance and reflections also occur at the source end. The system behaves more like an oscillator.

Comment: All except one student missed the fact that the voltage does not settle down. I gave nearly full credit to those who properly dealt with the first reflection at the load end.

Question 1:

a) Assuming a linearly polarized uniform plane wave with E-field in the x-direction, please discuss the relative magnitudes of the voltage induced at the terminals of each sensor.

Ans: zero voltage on the electric dipole
zero voltage on the x-y plane loop
finite voltage on the x-z plane loop

b) How would your results change if the wave is circularly polarized?

In x Y plane or in what plane

Ans: finite voltage on electric dipole
zero voltage on the x-y plane loop
finite voltage on the x-z plane loop

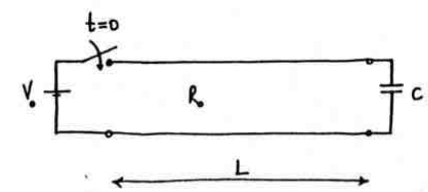
c) For the case of a linearly polarized wave (Case (a)), plot the magnitude of the voltage induced at the terminals of the first loop (one in x-z plane) as a function of frequency.

Let $B = e^{i\omega t}$

Ans: Sinusoidal dependence on frequency with zeros at points where wavelength=1 m.

$\mathcal{E} = \frac{d}{dt}\int B \cdot ds$
$= i\omega e^{i\omega t}$

Comment: Most students observed that the dependence would be linear (which it roughly is at low frequencies) but were then puzzled by the implication that the voltage would appear to indefinitely increase with increasing frequency!



(2)

Return-Path: shankle@Sierra.Stanford.EDU
Return-Path: <shankle@Sierra.Stanford.EDU>
Received: from Sierra.Stanford.EDU by rascals.stanford.edu (5.65/inc-1.0)
id AA18146; Wed, 10 Feb 93 11:35:18 -0800
Received: by Sierra.Stanford.EDU (4.1/25-eef) id AA14572; Wed, 10 Feb 93 11:34:04 PST
Date: Wed, 10 Feb 93 11:34:04 PST
From: "Diane J. Shankle" <shankle@sierra.stanford.edu>
To: EE-faculty@Sierra.Stanford.EDU
Cc: Shankle@Sierra.Stanford.EDU
Subject: Quals Questions
Message-Id: <CMM.0.90.0.729372844.shankle@Sierra.Stanford.EDU>

1. Define a Poisson random process
2. Compute its covariance function.
3. How would you "estimate" its mean value from a single record?
4. ~~How~~ What guidance can you give on how long a record length to choose?

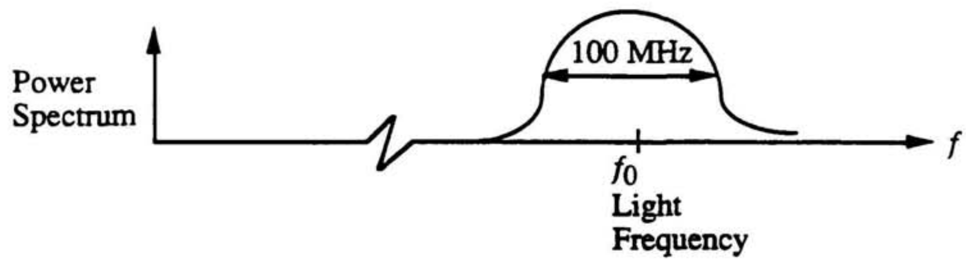
Ans: 1. Need an expression for the variance
2. Can use Chebyshev's inequality.

T. Kailath

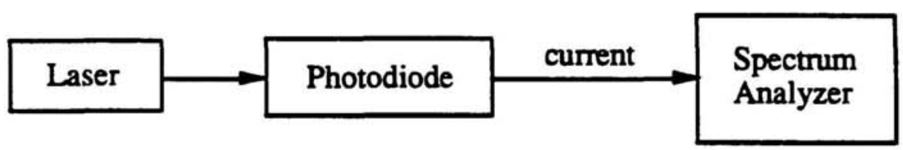
Prof. Leonid Kazovsky

Ph.D. Quals. January 1993

You are given two single-frequency lasers, Laser A and Laser B. Laser A exhibits phase noise only and no intensity noise; Laser B exhibits intensity noise only and no phase noise. You measure the output power spectrum of the two lasers and discover that they are identical and look as follows:



You send the light of each laser to a photodiode and measure the power spectrum of the photocurrent:



Sketch the photocurrent spectrum (i.e., spectrum analyzer display) for each laser.

rom: "Butrus T. Khuri-Yakub" <khuri-ya@sierra.stanford.edu>
o: snankle@Sierra.Stanford.EDU
ubject: Quals question of Prof. B. T. Khuri-Yakub

physics

ou are given two wires of radii r1 and r2 which are placed in parallel, eparated by a distance D. Calculate the capacitance per unit length of the wo wires, and find the force of attraction between the wires if a constant voltage V s placed across them.

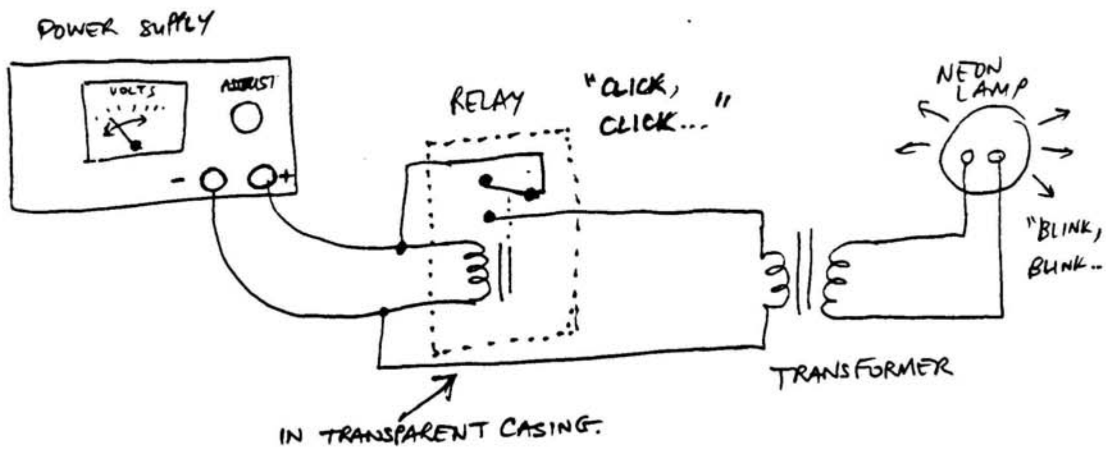
cceptable answer: You can used the method of image charges to calculate the apacitance, or, you can assume that the distance between the wires is large ompa ed to the radii and use Gauss' s law to find the voltage between the wires ue to the charges on both. The force is calculated using the principle of irtual ork.

uri-Yakub

1993 Qualifying Exam Question - G. Kovacs

The philosophy of my question this year circuits was to test the abilities of the student to understand and describe the operation of an extremely simple circuit consisting of three circuit elements known at the turn of the century and a regular, bench-top adjustable D.C. power supply. The point was to see if the student could think on his or her feet, so to speak.

The circuit is shown in schematic form below:



When the power was turned on, the circuit oscillated, producing audible "clicks" of the relay and visible flashes of the neon lamp. The analog voltmeter on the power supply could also be seen to be oscillating between its "unloaded" voltage and a lower voltage.

The relay used was encased in transparent plastic, the wiring was simple (only 5 wires) and the entire setup was in plain view.

The operation of the circuit is best described as:

1) The relay, connected across the outputs of the power supply is energized and closes.
2) The transformer is then placed in parallel with the coil of the relay.
3) This current pulse on the primary of the transformer creates a higher voltage pulse on the secondary which lights the neon lamp transiently.
4) The additional load of the transformer on the power supply causes the voltage to drop, forcing the relay to open.
5) The cycle repeats.

The student did not need to discuss the secondary circuit (e.g. neon lamp) in any way, and was told that it did not affect the oscillations of the circuit.

3/1/93

electromagnetics

QUALS ORALS

Prof. Bruce Lusignan
Communications Satellite Planning Center

QUESTION:

An astronaut is receiving a voice transmission from 1000 km away. The spacecraft uses a 10 watts radio transmitter into a 10 foot diameter parabolic antenna. The power is just enough to receive an adequate signal.

We will change the above data and want to know how the range, the 1000 km, can change.

(a) Transmit power increases from 10 watts to 20? $\sqrt{2} \cdot 1000$

(b) Antenna diameter increases from 10ff to 20? $2 \cdot 1000$

(c) Data rate changes from 64kb/sec to 32? $\sqrt{2}\ 1000$

? (d) Radio frequency changes from 10MHg to 1000?

(e) We introduce a Foreword Error Correcting code (FEC). Qualitatively what pro's and con's can come from FEC?

ANSWER:

The first three issues deal with the physical interpretation of the link equation. The fourth (d) includes the Gain-Area relationship of an antenna as well. The fifth deals with coding theory. The student's explanation formed part of the score.

(a) New range is 1000 x $\sqrt{2}$ km

(b) New range is 2000 km

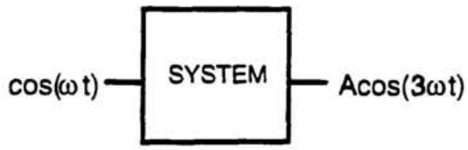
(c) New range is 1000 x $\sqrt{2}$ km

only when both ides are directional. $P_R \propto \frac{1}{\lambda^2}$

(d) New Range is unchanged when the astronaut antenna is ommidirectional (the examinee must ask for this information) and the parabola is still 10ft.

(e) The FEC code can allow more range by reducing the C/N required for the required error rate. The FEC can decrease range by increasing the required data rate.

A. Macovski Quals 1993



CAN THIS BE A LINEAR TIME-INVARIANT SYSTEM ?

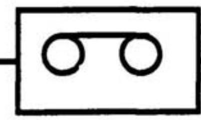
No; An LTI system cannot create new frequencies

HOW MIGHT THIS BE IMPLEMENTED IN A NON-LINEAR SYSTEM ?

Apply to any non-linear device having a cubic term, followed by a band-pass filter around 3ω.

HOW MIGHT THIS BE IMPLEMENTED IN A LINEAR SYSTEM ?

Multiply by $\cos 2\omega t$ or $\cos 4\omega t$ followed by the same band-pass filter



A tape recorder plays back the input signal T seconds after the recording is begun.

Find the inpulse response h(t,τ) if the recorder plays back the signal at twice the recording speed.

$h(t,\tau) = \delta(t - T - \tau/2)$

Find the response to an input cos(ωt).

$w(t) = \int \cos\omega\tau \, \delta(t - T - \tau/2) \, d\tau = 2\cos[2\omega(t-T)]$

February 10, 1993

TO: Gene Franklin

FR: Larry Manning

FEB 17 REC'D

RE: Quals questions

My primary questions were as follows:

First I drew the circuit diagram for an iron core transformer with a center-tapped secondary, and asked what it represented. [Answer: transformer]

Then I said suppose I gave you the actual transformer, and there were two leads coming out one side, and three identical leads from another side. It was designed for 120 volts rms across the primary, and 220 across the secondary. How could you tell which lead was the center tap?

Whenever they gave an answer, such as [use a voltmeter, and if it measured 220, the C.T. was the other lead], I said good. Now suppose you didn't have a voltmeter. I gave them infinite resources, but took them away as soon as they used them.

There was an unending series of possible solutions, including [use an ammeter and a resistor (making a voltmeter], [place resistors across the leads and see where they got hottest], [use a light bulb] I then said good, but suppose you only have one light bulb and don't want to burn it out? [put the 120 volts across the secondary, and the light bulb across the primary]. [Put other devices across the secondary, such as a motor]. [Use an ohm-meter] [Use an inductance bridge] [feed dc and break the circuit, examine the size of spark] [take it apart] [put a lower voltage on the primary, use the light bulb, or take a shock]. etc.

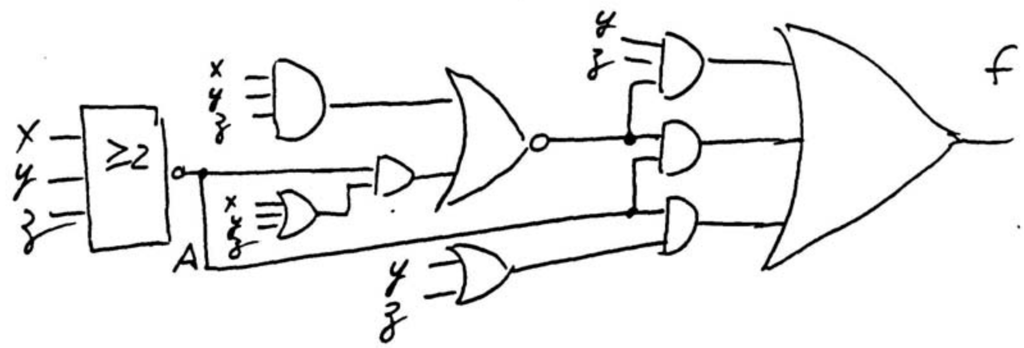
In some cases I then tried one of two other questions. One was, "how much voltage do cars place across the spark plugs?", followed by the question, "why don't auto mechanics get electrocuted right and left?" [perhaps 20 kV, but small current].

In a few cases I also asked, how would you design an electric blanket to minimize human exposure to magnetic fields? [use twisted pair, opposing currents adjacent, or even send warmed liquids through tubes in the blanket]

Quals Jan 1993

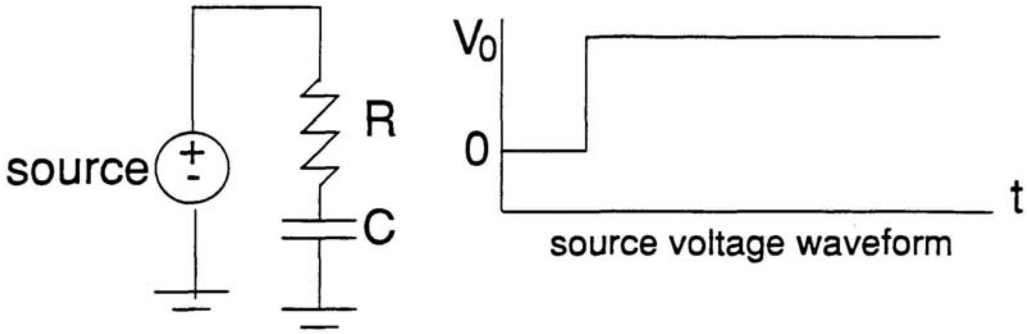
E J McCluskey
Computer Architecture

1. Draw transistor circuit for NAND (or NOR) gate
   (Warm up on familiar material)
2. Draw transistor circuit for XOR gate
   (see how slightly less familiar circuit is approached)
3. Gate Array library – How many elements needed to include all 2-variable (non degenerate) gates.
   (see approach to unfamiliar problem)
4. Same as 3 except now inversion is free
   (less straight forward situation)
5. analyze circuit and determine f



(Test ability to work way through an apparently complex problem by thinking to novel approach)

T. Meng



(a) Derive the instantaneous **power** consumption of this RC circuit as a function of time.

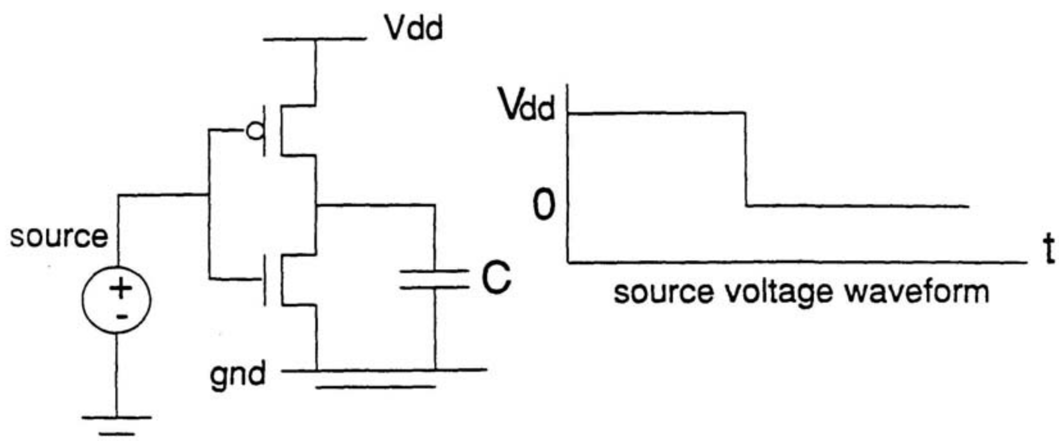
(Give the current as a function of time, then derive the power.)

(b) What is the total energy needed to charge the capacitor from 0 to Vo?

(Either through integration of part (a) or using the total stored energy of a capacitor.)

(c) An intuitive explanation on why the instantaneous power is a function of R, while the energy to charge the capacitor isn't.

(Bring the concept of delay *into the explanation.)*



(a) If Vdd were reduced by a factor of two, how would the energy required to charge the capacitor change accordingly?

(One quarter of the original amount.)

(b) How would the time needed to charge the capacitor be affected?

(Need to show that the driving capability of the transistor is reduced by approx. a factor of four and that the total charge required is only halved, not one-fourth.)

(Linear Algebra Problem)
Is it true that all linear functions can be represented by a matrix operation? If yes, give your reason. If no, think of a counter example.

(Several ways to show that the statement is true. I prefer the one by Taylor series expansion.)

Satisfactory Responses

Question 1

To determine sampling frequency, should have looked for the input frequency where aliasing begins or where the sound goes away.

Question 2

Should have drawn a sketch in the time or frequency domain to determine the dominant frequency component. Dominant tone is at the sampling frequency.

Question 3

Should know how the zero-order hold affects the shape of the frequency spectrum. Spectrum is multiplied, not convolved, with a sinc.

Question 4

The wavering nature of the output is due to beating of two frequencies. Frequency-domain sketch clearly shows why the two frequency components exist. Time-domain explanation is possible too.

Nishimura

Set-Up

This Wavetek function generator produces a signal that is sampled by the box behind it. The sampling box performs a simple sample-and-hold and its output is fed directly to a loudspeaker.

Question 1

Determine the sampling frequency of the sampling box by experimenting with the frequency and/or waveform of the function generator. Explain as you proceed.

Question 2

Set the function generator to a sinusoid at 10 Hz. What is causing the dominant tone that you hear and at what frequency is it?

Question 3

Sketch the magnitude of the frequency spectrum coming out of the loudspeaker.

Question 4

Set the function generator to about half the sampling frequency. Explain why you hear an oscillation in the loudness. What is the frequency of this oscillation? (Show me in the frequency domain what is going on).

35

Quals Question
Prof. Olukotun

Computer Architecture

Q: What are precise exceptions?

A: All instructions before exception PC have been execute d and have modified machine state

All instructions following exception PC are unexecuted

The instructions following the exception PC are restartable

Q: Give an example instruction that must be handled precisely

A: Page fault

Q: How do you implement precise interrupts in a simple instruction pipeline that has in-order instruction completion?

A: Post exception in a status register that can be checked at a common commit point. At the commit point in the execution pipeline all interrupts must have occurred but the state to the machine must not have been modified. In a DLX style pipeline this point is just before the write-back stage.

Q: How do you implement precise interrupts in a machine that has out-of-order instruction completion?

A: A possible answer is use a reorder buffer.

Q: How does the reorder buffer work?

The reorder buffer is FIFO queue that is placed between the output of the functional units and the write-back port of the register file. It keeps the register file in a precise state. The entries of the reorder buffer are en queued when instructions are issued. Each entry contains the following fields: destination register, result value, PC, interrupt status, valid. Instructions are removed from the head of the queue when they have valid result values after they have written back their results. Exceptions are checked for an instruction when the instruction reaches the head of the queue. If an instruction causes an exception all entries behind it in the reorder buffer are discarded and do not write back their results. Bypassing of result values from the reorder buffer is required for maximum performance.

Full-Name: Richard H. Pantell
Date: Mon, 1 Mar 93 13:28:10 PST
From: "Richard H. Pantell" <pantell@sierra.stanford.edu>
To: shankle
Subject: Quals Questions
Message-Id: <CMM.0.90.0.731021290.pantell@Sierra.Stanford.EDU>

1.When there is energy transfer from one particle to another, what are the principles that govern this exchange?

2. Astronomers can determine the speed of stars. How do they do this? Derive the nonrelativistic Dopples formula.

3. What is the spectrum of sunlight reaching the earth, and why is this the spectrum? What is the spectrum of the earth's light seen from the moon. Why? What is the greenhouse effect?

4. What is radiation pressure? How would you calculate radiation pressure?

A "satisfactory" answer is one that shows a creative thinking process. A "correct" answer is not required. Novel proposals are a plus.

Dick Pantell

$= 10^{-17}$ columb

$\frac{\Delta I}{I} = \frac{1 \text{ electron}}{100 \text{ electrons}} = 1\%$

physics

PEASE'S 1993 QUALS QUESTION

1. Define the Ampere.

2. How do you measure current (absolutely)?

10^4 Hz $= 10^{-4}$ s $= 10^2$ µs

3. Given that charge is quantized (in integral multiples of q) should not a low current have appreciable fluctuations? How big would these fluctuations be if we measured a current of 0.1pA (1 electron /µs) with a bandwidth of 10 KHz (i.e. integration times of about 100µs)?

4. If we measured current by observing (say, with a scanning tunneling microscope) the deposition of silver atoms at the cathode in an electrolytic cell would we see fluctuations corresponding to the $\boxed{\text{Poisson distribution}}$: i.e. a mean deposition rate of 100 electrons/100µs (corresponding to the 10 KHz bandwidth) and a standard deviation of √100 or 10% of the mean? Do not understand. for Poisson $E[X] = Var[X]$?

e^{-100}

5. If we measured current by measuring the force between two wires carrying the current (fig. 1) would the force fluctuations be averaged out over the huge number of electrons in the wires (note the small dimensions to allow a bandwidth of 10KHz)? How many electrons are there?

6. If we introduced a pn junction diode into the circuit (fig. 2) would this change the fluctuations observed? Give reasons.

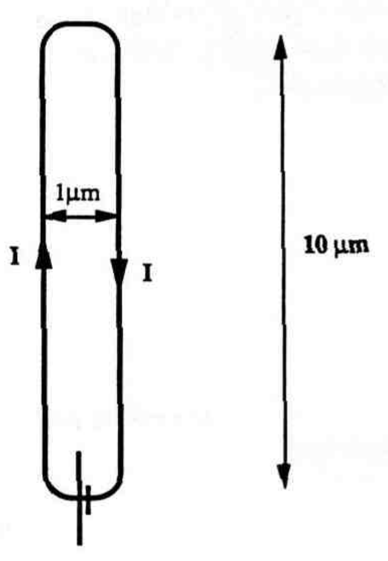


fig. 1

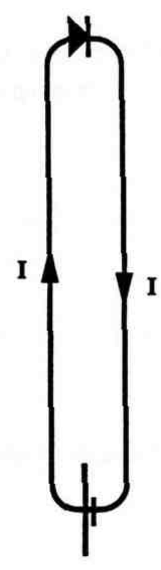


fig. 2

In each case the wire diamter is 0.1µm and the current is measured by measuring the force between the long arms of the wire with a very sensitive sensor (e.g. AFM).

Piero Pianetta

EE Qualifying Exam Question, January 1993. Devices

Question:

I tell the students I have two pieces of n-type GaAs which are identical except that one has an additional band of donors that are located 0.25 eV below the conduction band minimum. The concentration of the additional band of donors is the same as the original n-type doping. To make the situation more concrete, I show the students the 1 dimensional band diagrams of the two semiconductors and I draw in the extra band of donors.

I ask the students to describe how they might tell the two samples apart using simple electrical measurements in an effort to get them to describe how the additional band of n-type donors would affect the electrical properties of the semiconductor. After they get through the first part of the question, I ask them to consider how a Schottky barrier formed on the two semiconductors would differ.

need to understand answer

Answers:

1. The minimum answer I expected was that at room temperature, the additional band of donors is about 10kT from the conduction band minimum so that the band would not be ionized and thus not contribute significantly to the conductivity.
2. In response to the Schottky barrier part of the question, I expected the students to draw the 1-D band diagram for a Schottky barrier on the simple n-type semiconductor followed by that for the semiconductor with the additional donors. This second diagram would have the additional donors rising above the Fermi level in the depletion region and thus become depleted and contribute to the fixed charge. This would have the affect of decreasing the width of the depletion region and thus make the second semiconductor appear to have a higher doping density than would be apparent from a simple room temperature resistivity measurement. The narrower depletion region could be detected by several methods depending on the actualy doping density. For low to moderate doping, a CV measurement would directly measure the depletion width. For high doping densities, the contact would be ohmic and a narrower depletion width would result in a higher tunneling probability which in turn would cause the barrier to conduct a higher current at a given voltage. Although this level of effect can probably be only been seen in a contact resistance measurement, I did not require the student to go to that level of detail.

1993 QUALS QUESTION: A. E. SIEGMAN

Stated subject for questioning was "Resonance, modes, normal modes, eigenmodes, orthogonality, hermiticity, and their application to the real world".

I started by asking in general terms, "What is a 'mode' of a system? What does orthogonality mean? What are 'normal modes'?" -- mostly to get some idea of the level of background and sophistication of the student in this area.

[For computer students, I sometimes asked about "orthogonal coding" or "orthogonal codes" -- but I never got any very good answers.]

I then set up on the chalk rail of my blackboard a pre-prepared sketch showing three coupled pendula -- three identical pendulums hanging from a rail, weakly coupled by weak springs connecting the first to the second and the second to the third pendulum -- and started asking:

* "Will this system have modes? What will some of the individual modes look like? What will be their resonance frequencies (compared to any one individual isolated pendulum)?"

[Desired answers: Should be a symmetric mode with all three pendula swinging in synchronism; an antisymmetric mode with the center pendulum stationary and the outer pendulums swinging out of phase (and resonance frequency shifted upward); and probably a third mode.] why?

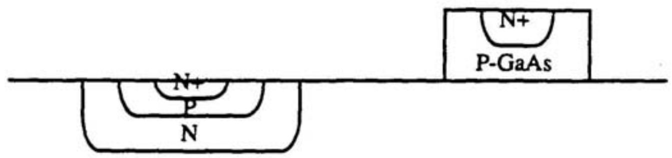
* "Are these modes orthogonal? In what sense? Can you describe a state space for this system?"

[Desired answers: Could lead better students into setting up a column vector (x1(t), x2(t), x3(t)) for the motions of the three pendula, with eigenvector (1,1,1) for the symmetric mode, (1,0,-1) for the antisymmetric mode, and (a,b,c) for the unknown third mode, and then noting that the first two vectors were indeed orthogonal in the dot product sense. Best students could then use mutual orthogonality to the other two modes to discover that the third mode must have form (1,-2,1), and could deduce the physical motions corresponding to this third mode.]

AES

93 Qualifying Exam Question

S. Simon Wong



Monolithic Integration of GaAs LED and Si NPN BJT

1. How does an LED work ?
Under forward bias, the recombination of minority carriers injected across the junction will emit light.

2. Would the electrons injected from the N^+-GaAs affect the operation of the BJT ? If so, in what manner ?
The electrons could be collected by the collector and result in an increase in the collector current.

3. How do you prevent this (part 2) ?
Many possible answers : thicker GaAs, decrease lifetime of P-Si, surround the LED with an N^+ guard ring, ...

4. How would light emitted from the LED affect the operation of the BJT ?
Depends on where the light hits : e.g., if it hits the collector-substrate junction, the leakage current of the collector-substrate junction will increase; if it hits the bas-collector junction, ...(Students only have to describe one or two scenarios.)

5. How do you prevent this (part 4) ?
Many possible creative answers !