EE 391 (All Sections)

Midterm Examination

Tuesday, November 2, 2004

7:00 PM

Time Allowed: 2 Hours

Materials allowed: Laboratory Notebooks, Calculators

Instructions:

- **Answer all questions in the space provided (use page backs for rough work if necessary)**
- **State your assumptions; show all relevant work. Box, circle or otherwise highlight your answers where appropriate. For multiple choice, circle the correct answer.**
- ***Put your <u>name</u> and <u>student number</u> on each page; (we may separate them for marking purposes)***
- **Refer to the last page for relevant product data when required**
- **Weighting for each question is indicated in the left margin (Total marks: 120)**

(Marker's use only.)

S. L.	BJT	2nd Ord	Fourier	Op A	FET	Total
/20	/15	/20	/20	/20	/15	71 /~~110~~

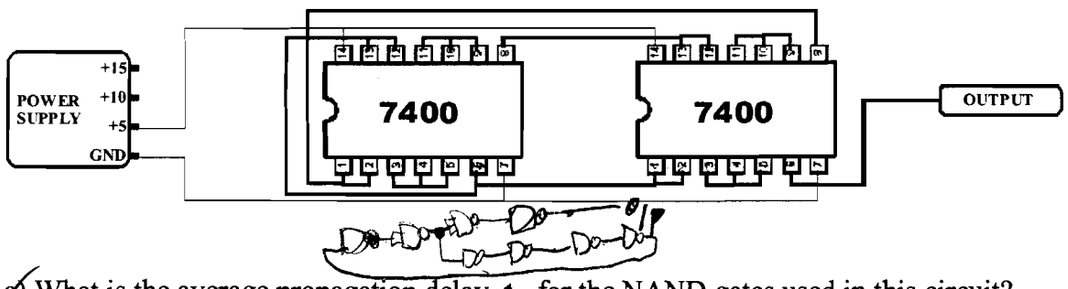
Name: Kyle Ness

Student Number: 961016

Timing in Sequential Logic

12

Q1.1) Analyze the following circuit made from two 7400 TTL logic chips (Note: some potentially useful information in the Appendices).

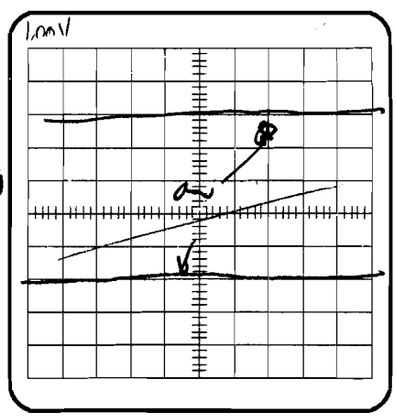


a) What is the average propagation delay, t_P, for the NAND gates used in this circuit?

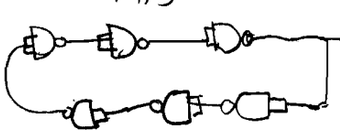
[1] ~7.25ns

1

b) Sketch the approximate waveform at the output on the "scope screen at right. Be sure to label the axes and their scales. Show any supporting calculations you may need to make.



This is how the chip is set up to operate according to Diagram above



[6]

This should not give you an o/p since the circuit will not operate when set up using an even # of NAND gates

6

Q1.2) Design a simple astable oscillator using a single 4069 CMOS Hex-inverter chip so that it could be used as a clock source for a counter circuit. Show the necessary wiring connections on the drawing below. Design for a clock frequency of 5MHz (Assuming "typical" operation).

$\frac{1}{5MHz} = 0.2\mu s = 200ns$

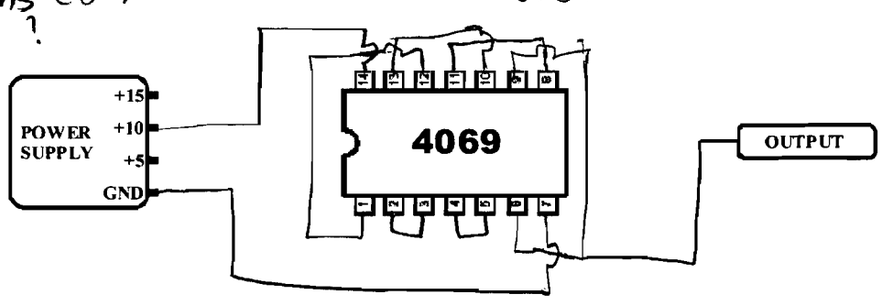
$\frac{200}{6} =$

at $V_{DD}=10V$ we get b/w 20-40ns delay So ~30?

~30ns per inverter

We have 6 so use all of them.

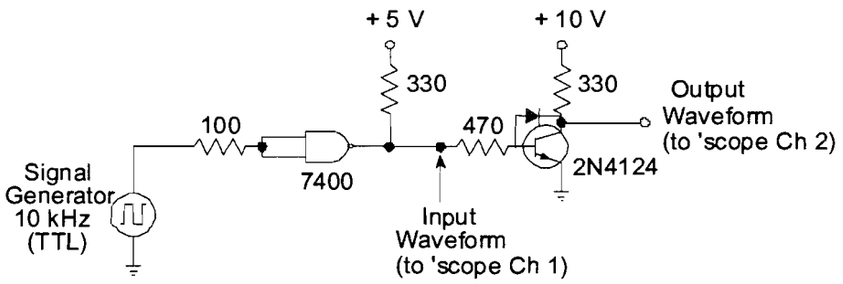
will oscillate!



[6]

1

Q1.3) Consider the basic inverter circuit shown below driven by a 10kHz TTL square wave from the signal generator.



a) The oscilloscope trace of the input and output waveforms are shown at right. Determine the values of the following parameters if shown, and label them on the 'scope figure.

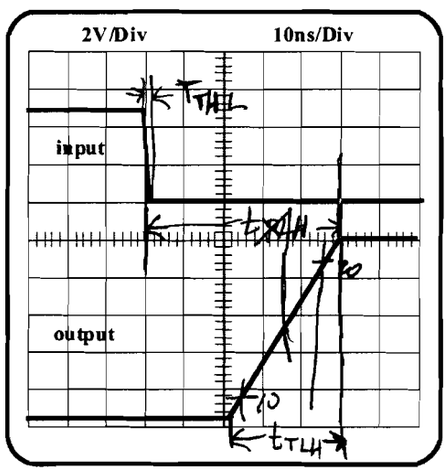
[5]

i) t_{PHL} not shown

ii) t_{PLH} 56ns ✓

iii) t_{THL} ~29ns ✓

iv) t_{TLH} ~29ns ✓✓



2

Q1.4) A piece of electronic Laboratory equipment is labeled "74C7". Describe *briefly*, but *specifically*, where this piece of equipment should be stored.

[2] You should store it in Room 2C74 the 74 tells you this It should then be Placed in the Shelf e in spot 7. The C7 tells you wherein the room it should go.

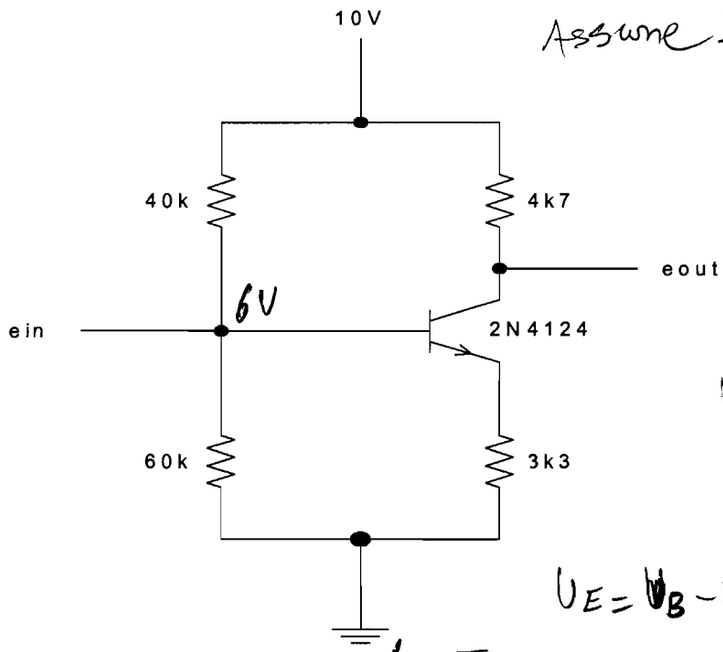
2

Q2.1) a) Determine whether the following circuit is biased properly for use as an amplifier. State any assumptions that you make.

[4]

Assume $V_{BE} = 0.7V$

Assume $I_C = I_E$



$V_B = \frac{60k}{60k+40k} 10V$

$= 6V$

$V_E = V_B - V_{BE} = 6V - 0.7V = 5.3V$

$I_E = \frac{V_E}{R_E} = \frac{5.3V}{3k3\Omega} = 1.6mA$

$\therefore V_{CE} = 10V - I_C(4k7 + 3k3) = 10V - (1.6mA)(8k)$

$V_{CE} = -2.8V$

Since V_{CE} is -ve we drop too much voltage across R_C and R_E that are transistor will not be biased properly.

b) Is the transistor operating in: [*cutoff*, *active region*, *saturation*]? (circle one)

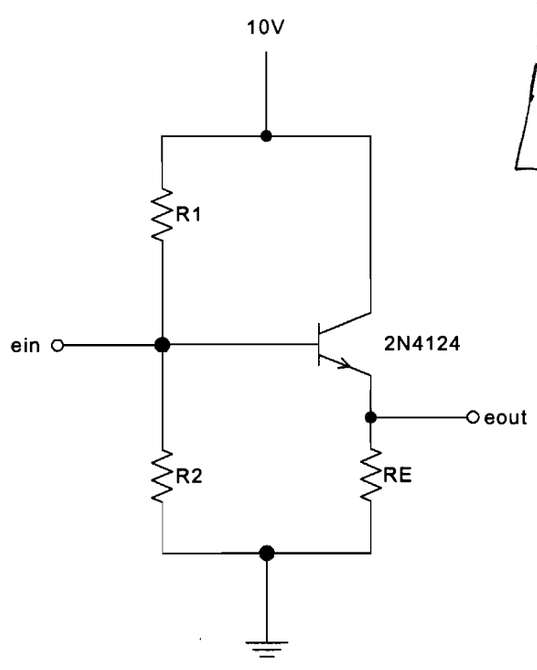
Q2.2) What is the general expression for the output resistance of the following circuit?

[4]

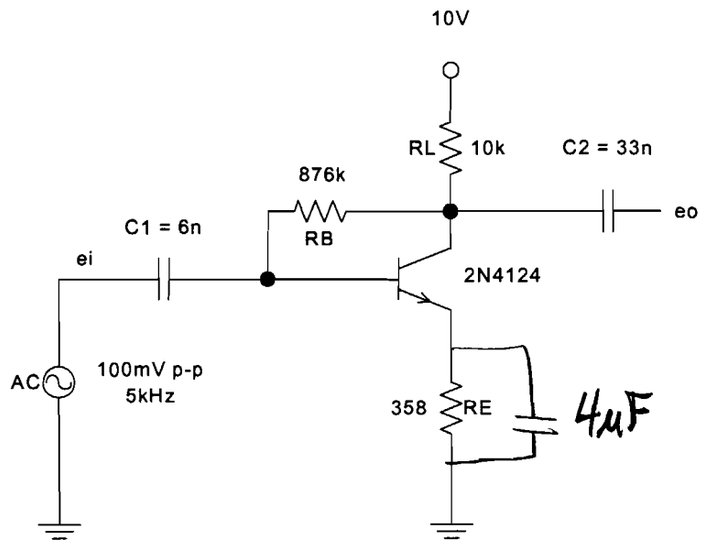
$R_{OUT} = R_E // h_{ie}$

$R_{OUT} = R_E // \beta r_e$

0



Q2.3) The following circuit was designed for use in the EE 391 BJT laboratory. The nominal operating characteristics of the circuit were $B \approx 150$, $A_V = -25$, $Z_{OUT} = 10k\Omega$, $V_{CE} = 4V$, and f = 5kHz. The values shown are approximate.



A 4uF capacitor was then placed across the $R_E = 358\Omega$ resistor. What changes, if any, must be made to the circuit in order to measure the voltage gain, A_V, of the circuit at f = 5kHz?

[7]

we now need to look at blocking capacitors and see in they are rated high enough removing R_E will only affect o/p blocking cap since it is determined by being >10 R_{out} and I/p blocking cap worries about I/p impedance.

$R_B // r'_e + R_E = 10K\Omega$

$\therefore R_B // r'_e = 10K\Omega - 358 = 9.642K\Omega$

$C7 \geq \frac{1}{2\pi (5KHz)(9642\Omega)}$

C7 33.01μF So capacitor should be made bigger.

Also the 100mV p-p should be turned down since the gain will now shoot up to about $\frac{R_L}{r_e}$ or by ~ 8 times and we are limited by 10V o/p so we want to decrease I/p voltage so we don't get cut off on our o/p.

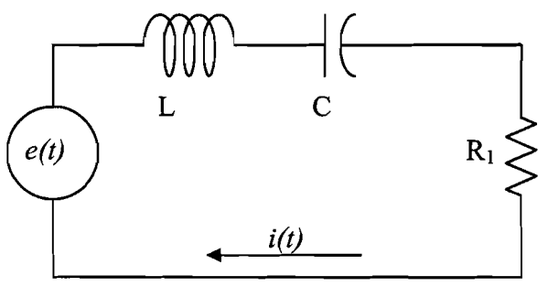
4

Second Order Systems

Q3.1) a) For the circuit shown in the figure, derive the transfer function $H(S)=\frac{I(S)}{E(S)}$

(Assume: Internal resistance of the source is R_S and that of the inductor is R_L)

[4]



$$E(S) = I(S)\left[LS+\frac{1}{CS}+R_1+R_L+R_S\right]$$

$$\frac{I(S)}{E(S)} = \frac{1}{LS+\frac{1}{CS}+(R_1+R_L+R_S)}$$

$$\frac{I(S)}{E(S)} = \frac{CS}{LCS^2+R_TCS+1} = \boxed{\frac{S/LC}{S^2+\frac{R}{L}S+\frac{1}{LC}}}$$

call $R_1+R_L+R_S = R_T$

2 ✓ 9

b) Write the Characteristic equation for the circuit in terms of R, L and C (where R is the *total* resistance of the system).

[2]

$$\boxed{S^2+\frac{R}{L}S+\frac{1}{LC}}$$

$\omega_n = \sqrt{\frac{1}{LC}}$ $\quad 2\zeta\omega_n = \frac{R}{L}$

$\zeta = \frac{R}{L}\cdot\frac{\sqrt{LC}}{2} = \frac{R}{2}\sqrt{\frac{C}{L}}$

2 ✓

c) Derive the equations for:

i) Undamped natural frequency
ii) Damping factor and
iii) Damped natural frequency

[4.5]

i) $\zeta = 1$ undamped

$2\zeta\omega_n = \frac{R}{L}$

$\boxed{\omega_n = \frac{R}{2L}}$ ✓

ii) Damping factor $= \zeta$

$\omega_n = \sqrt{\frac{1}{LC}} \Rightarrow 2\zeta\omega_n = \frac{R}{L}$

$\zeta = \frac{R}{L}\frac{\sqrt{LC}}{2}$

$\boxed{\zeta = \frac{R}{2}\sqrt{\frac{C}{L}}}$ ✓

2

iii) ω_d Damped $\zeta \neq 1$

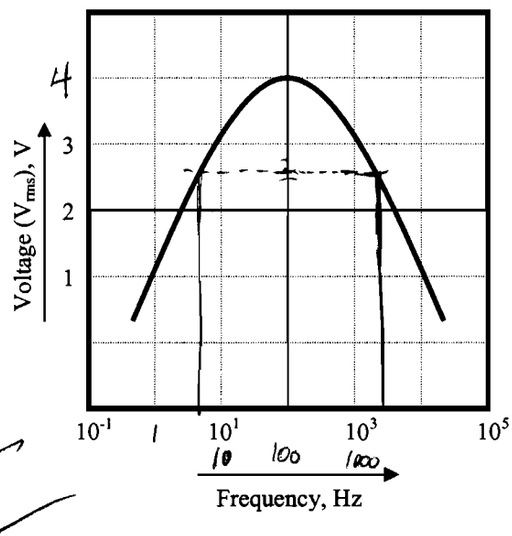
$\omega_n^2 = \frac{1}{LC}$

$\boxed{\omega_n = \sqrt{\frac{1}{LC}}}$ ✓

Q3.2) The following diagram shows a frequency response curve for a second order system.

a) Determine the followings from the diagram:
i) Lower and upper cut-off *angular* frequencies (ω_1 & ω_2)
ii) Bandwidth of the system *in Hz*

[2]



$dB = 20\log_{10}(x)$

$\left(\frac{3}{20}\right) = 1.41 \text{ V} = \sqrt{2}$

$\sqrt{2}$ V from top will gives f_1 & f_2

$4 - 1.41 = 2.586\text{V} \sim 2.6\text{V}$

i) $\omega_1 \approx 2\pi(6\text{Hz}) = 12\pi$

$\omega_2 \approx 2\pi(1200\text{Hz}) = 2400\pi$

ii) BW in Hz

$BW = 1200 - 6 \approx 1194\text{Hz}$

b) If the circuit has a capacitance of 100μF, what are the values of the other passive elements?

[3]

Resonant frequency when $f = 100\text{Hz}$

$\therefore 2\pi fL = \frac{1}{2\pi fC}$ when $f = 100\text{Hz}$

$2\pi(100)L = \frac{1}{2\pi(100)(100\times10^{-6}\text{ F})}$

$L = 25.3\text{m H}$

$2\zeta\omega_n = \frac{R}{2}\sqrt{\frac{C}{L}}$

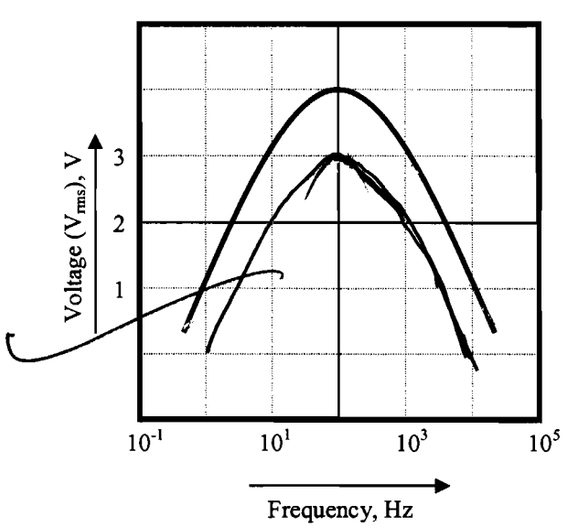
$\zeta = \frac{R}{4\omega_n}\sqrt{\frac{C}{L}} = \frac{R}{4(100)}\sqrt{\frac{100\times10^{-6}\text{F}}{25.3\times10^{-3}\text{H}}} = 1.57\times10^{-4}R$

Assume $\zeta = 0.7$ $\Rightarrow$ $R = 4.454\text{K}\Omega$

$\zeta = 1 \Rightarrow R = 6.37\text{K}\Omega$

c) What should the response look like if the resistance of the system is lowered?
[Draw it on the same diagram]

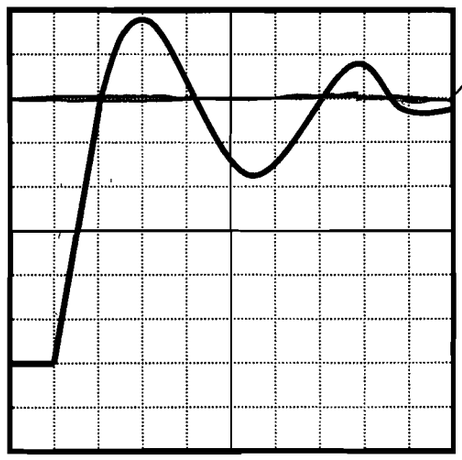
[1]



Q3.3) a) Find out the followings from the given diagram:
i) Percentage overshoot
ii) Damping factor

[2]

[Oscilloscope setting for this diagram is
Horizontal setting : 0.1 ms/div
Vertical setting : 1 V/div]



Assume graph settles to this point eventually.

i) $P.O. = \frac{1.8V}{6V} \times 100 = 30\%$

ii) This is underdamped with a damping factor of:

$\zeta \sim 0.7$

b) What should the value of the resistance be if the values of capacitance and inductance of the system are 100nF and 100mH respectively?

[1.5]

use $\zeta = 0.7$ for underdamped

$\zeta = \frac{R}{2}\sqrt{\frac{C}{L}}$

$R = 2\zeta\sqrt{\frac{L}{C}} = (0.7)(2)\sqrt{\frac{100 \times 10^{-3} H}{100 \times 10^{-9} F}}$

$R = 1400\,\Omega$

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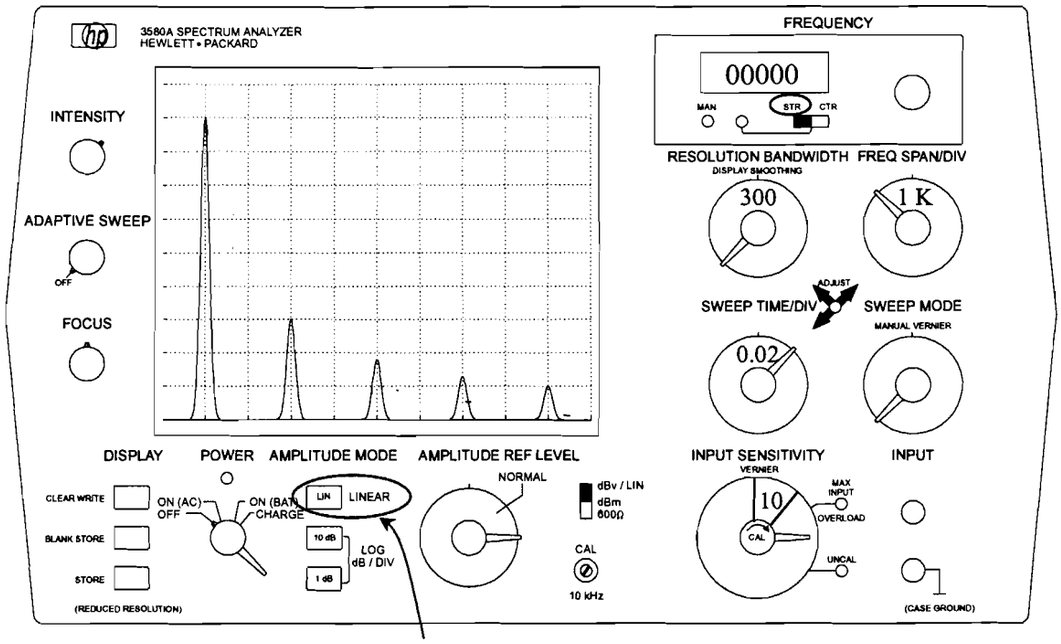
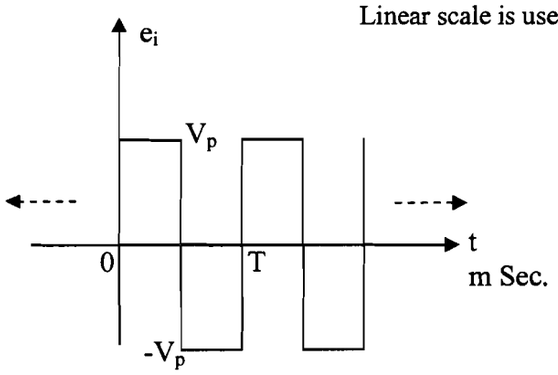
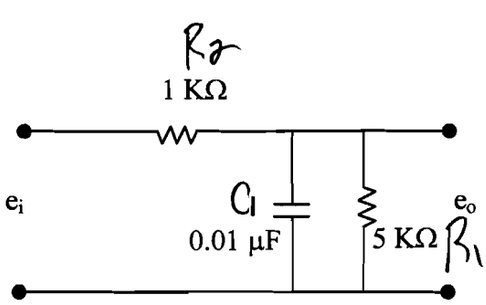
Fourier Analysis

Q4.1)



Linear scale is used





$\frac{1}{f}$ C=0

Consider the input waveform and circuit shown above (the input waveform is connected to the Spectrum analyzer which is set as shown):

a) What is the value of V_p?

[4] From spectrum analyzer peak is at 9th division or 1 from top so top is at 10 so 9 dB

$10^{\left(\frac{9}{20}\right)} = 2.82 V_{rms}$

$(2.82V)\sqrt{2} = V_{p-p} = 4V$

So $\boxed{V_p = 2V}$

b) What is the periodic time of the input waveform?

[2] $T = \frac{1}{f} = \frac{1}{1K} = \boxed{1mS}$

c) Drive the transfer function $E_o(s)/E_i(s)$ for the circuit shown above.

[6]

$$\frac{E_o}{E_i} = \frac{R_1 \| \frac{1}{C_1 s}}{R_1 \| \frac{1}{C_1 s} + R_2} = \frac{\frac{R_1 \frac{1}{C_1 s}}{R_1 + \frac{1}{C_1 s}}}{\frac{R_1 \frac{1}{C_1 s}}{R_1 + \frac{1}{C_1 s}} + R_2} = \frac{\frac{R_1}{R_1 C_1 s + 1}}{\frac{R_1}{R_1 C_1 s + 1} + R_2}$$

$$\frac{E_o}{E_i} = \frac{R_1}{R_1 + R_2 R_1 C_1 s + R_2} = \frac{R_1}{R_1 + R_2 R_1 C_1 s + R_2}$$

$$\frac{E_o}{E_i} = \frac{R_1}{R_1 R_2 C_1 s + (R_1 + R_2)} = \frac{5K}{0.005s + 6K}$$

(6)

$$\frac{E_o - E_i}{R_2} = \frac{E_o}{R_1 \| \frac{1}{C_1 s}}$$

$$\frac{E_o - E_i}{R_2} = \frac{E_o}{\frac{R_1 \frac{1}{C_1 s}}{R_1 + \frac{1}{C_1 s}}}$$

$$\frac{E_o - E_i}{R_2} = E_o \frac{R_1 C_1 s + 1}{R_1}$$

$$1 - \frac{E_i}{E_o} = \frac{R_2 R_1 C_1 s + R_2}{R_1}$$

$$\frac{E_i}{E_o} = \frac{R_1 - R_2 R_1 C_1 s + R_2}{R_1}$$

$$\frac{E_o}{E_i} = \frac{R_1}{R_1 - R_2 R_1 C_1 s + R_2}$$

d) What type of filter is this circuit?

[2]

This a low pass filter (LPF) since high frequencies will cause C to look like a short and so no voltage will show up at the o/p. (2)

e) Using the transfer function, predict the 9th harmonic component of the output waveform in rms [NOTE: DON'T USE V_P VALUE OBTAINED IN PART (a)]

[6]

$$\frac{E_o}{E_i} = \frac{(5K)^2}{\sqrt{(0.005\, 2\pi\, 9f)^2 + (6K)^2}} = \frac{\sqrt{(5K)^2}}{\sqrt{(0.005\, 2\pi\, (9)(1K))^2 + (6K)^2}}$$

$$\frac{E_o}{E_i} = 0.7538 \text{ gain} \quad (2) \quad \text{in dB} \quad dB = 20 \log_{10} 0.7538$$

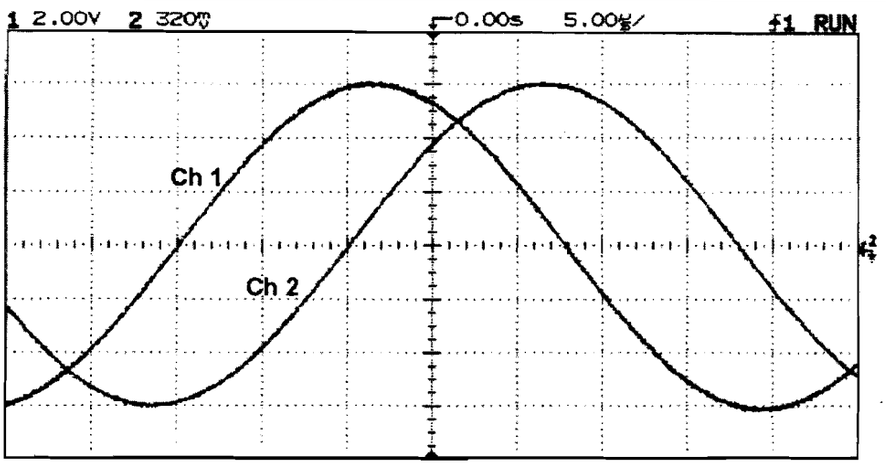
$$dB = -2.45\, dB$$

9th component = $(-2.45\, dB) + 1\, dB = -1.45\, dB$

from spectrum analyzer

Operational Amplifiers

16



Q5.1) Refer to the oscilloscope trace shown above. Channel 1 is the input waveform; Channel 2 is the output.

a) What is the frequency of the signals? $\frac{1}{9\text{div}\cdot\frac{5\times10^{-6}\text{s}}{\text{div}}} = 22.2\text{kHz}$

[1] 1

b) What is the gain of the system in db_v? $-15.9\,db_v$

[3] $12\,V_{p\text{-}p}$ I/p

$6(320\times10^{-3})\,V_{p\text{-}p}$ o/p $= \frac{6(320\times10^{-3})}{12} = 0.16$

Gain dB $= 20\log_{10}(0.16$

3

c) What is the phase shift (in degrees) of the Channel 2 signal with respect to the Channel 1 signal?

[3] Assuming non inverting op amp? who cares?

~2 divisions $\frac{10\text{ns}}{\text{div}} \sim 20\text{ns}$

$360^\circ\left(\frac{20\text{ns}}{\frac{1}{22.2\text{kHz}}}\right) = 160^\circ$

$\frac{1}{22.2\text{kHz}}$ is full cycle so 360°

2

Q5.2) Assume you are designing an op-amp circuit that requires a sinusoidal output signal of $20V_{P\text{-}P}$ at a maximum frequency of 300kHz. What is the minimum slew rate specification for the op amp? (*Note: there may be some useful information in the Appendix.*)

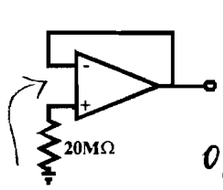
[8] Slew rate is max $\frac{V}{\mu s}$ it can change so if we want 40V change every cycle we need a slew rate spec of at least.

$\text{Slew rate} = \frac{\Delta V}{\Delta t} = \frac{40V}{\frac{1}{300\text{kHz}}} = 12\times10^6\,\frac{V}{s}\left(\frac{1s}{1\times10^6\mu s}\right) = \boxed{12\,\frac{V}{\mu s}}$

5

Q5.3) The op amp shown in the figure has a Unity Gain bandwidth of 3MHz and a negligible offset voltage. If an output of +0.63V is observed, what is the magnitude and direction of the input bias current?

[5] O/p = 0.63V



We have I/p bias current flowing into the op amp.

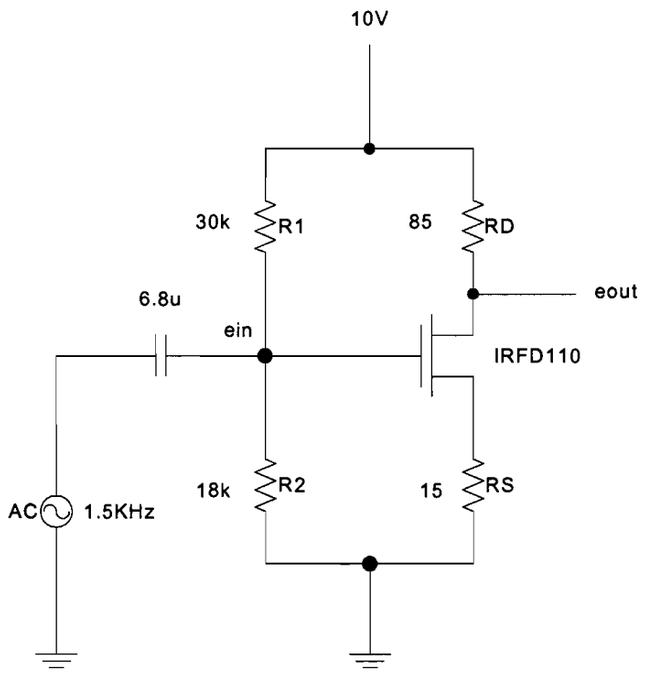
$I_{bias} = \frac{0.63V}{20M\Omega} = \boxed{31.5\text{pA}}$

5

FET Amplifiers

11

Q6.1) The following circuit was used in your FET lab. The nominal operating characteristics of the circuit were gm ≈ 0.2S, I_D = 50mA, and Rin > 10k. The values shown are appropriate.



a) What is the unloaded gain of the circuit from gate to drain?

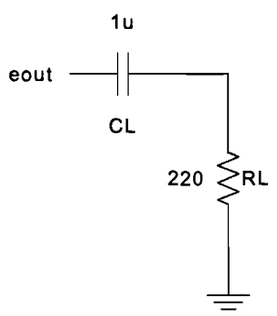
[2]

$$A_V = \frac{-R_D}{\frac{1}{g_m} + R_S} = \frac{-85}{\frac{1}{0.2} + 15} = \boxed{-4.25}$$

✓

b) The 1.5kHz input voltage source is adjusted to give 1V p-p at *e*out. The following circuit was then connected to *e*out. What is the p-p voltage across R_L?

[5]



1Vp-p

at freq 1.5KHz

$C7 \frac{1}{2\pi f 8.8}$

$C7 \frac{1}{2\pi(1.5\times10^3)(22\Omega)}$

C7 4.82μF

C will take some of the voltage since it isn't big enough

$Z_C = \frac{1}{2\pi f C} = \frac{1}{2\pi(1.5\times10^3)(1\times10^{-6}F)} = 106$

$V_R = \frac{1V}{\sqrt{2}}\angle 0^\circ \frac{R_L}{R_L + Z_C} = \boxed{0.574\ V}$

Low

3

c) The 1.5kHz input voltage source was replaced by a properly calibrated and buffered spectrum analyzer (as done in the EE 391 laboratory) in order to measure the frequency response from 10Hz – 10kHz (the C_L-R_L load on eout is still connected). Is the value of the input capacitor appropriate for this measurement? DO NOT CALCULATE THE VALUE. CONSULT YOUR EE 391 LABORATORY LOG BOOK FOR THE CORRECT VALUE. Circle one answer below and supply the correct value.

[2]

Yes (No (too small)) No (too big)

Need about 3uF or more so not big enough

2

d) Assuming a correct value of C1 is used and with reference to spectrum analyzer front panel below, what are the settings for the following controls if the frequency response from 10Hz – 10kHz is to be measured and the screen display is to be appropriate.

[6

FREQUENCY (INCLUDING STR-CTR SWITCH): STR 0 ✓

FREQ. SPAN/DIV: 10Hz ✗

INPUT SENSISTIVITY: 0 ✓ 4

INPUT SENSISTIVITY VERNIER: clockwise all the way ✓

AMPLITUDE REF. LEVEL: 0dB ✗

AMPLITUDE MODE: 10dB ✓

Nothing happens past about 30Hz so you need to zoom in around 0-100Hz