University of Toronto

Term Test 1

Date - Oct 14, 2009

Duration: 1.5 hrs

ECE512 — Analog Signal Processing
Lecturer - D. Johns

ANSWER QUESTIONS ON THESE SHEETS **USING BACKS IF NECESSARY**

1. Both programmable and non-programmable calculators allowed.

2. Equation sheet on last page of this test.

3. **Only tests written in pen will be considered for a re-mark**.

4. Grading indicated by [ ]. Attempt all questions since a blank answer will certainly get 0.

Last Name: ______________________

First Name: ______________________

Student #: ______________________

Question	Mark
1	
2	
3	
4	
5	
Total	

(max grade = 25)

Last Name: ________________

[5] Question 1: Answer the True [T] or False [F] questions below by **circling** the correct answer. Each correct answer is worth 0.5 marks.

T F A filter with a linear phase response in it's passband has a constant group delay in it's passband.

T F The units of group delay is "radians".

T F A complex number of "1+j" has a magnitude of $\sqrt{2}$ and a phase of $\pi/2$ radians

T F $|H(j\omega)|^2$ is always an odd function

T F $|H(j\omega)|^2$ is always an even function

T F A passive RC circuit has all it's poles on the real axis

T F The numerator of an all-pole lowpass filter is a constant.

T F If zeros at ∞ are included, the number of zeros equals the numbers of poles of $H(s)$

T F An integrator is equivalent to a first-order all-pole filter with a pole at $s = 0$

T F Integrators rather than differentiators are generally used to build filters because integrators are smaller.

[5] Question 2:

Find $H(s)$ for a 4'th order Butterworth filter having a passband ripple of 2 dB from dc to 1 rad/s and a dc gain of 1. Write $H(s)$ in root form using ω_0 and Q notation in describing each pair of poles.

[5] Question 3:

Find $H(s)$ in polynomial form for a high-pass notch (HPN) biquad filter having a gain of 1 at high frequency, zeros at 50 Hz, pole-frequencies of 110 Hz and pole-Q of $1/\sqrt{2}$. Also find the dc gain of this filter in both linear and dB scale.

[5] Question 4:

Using only resistors, a capacitor and an inductor, find a circuit that realizes a bandpass filter with a center frequency of 100 MHz, a Q of 10 and a centre frequency gain of 1/3. Let the capacitor have a value of 10 pF. Assume the input is an ideal voltage source and the output is a voltage node in the circuit. Show circuit.

[5] Question 5:

Design a Tow-Thomas active-RC lowpass notch filter with a dc gain of -1, a notch frequency of 50 kHz, a pole frequency of 5 kHz and a pole-Q of 5. Use integrating capacitors of 10 nF each. Show circuit.

(blank sheet for scratch calculations)

Last Name: __________________

ECE512 Analog Signal Processing Equation Sheet

$h(t)$ is impulse response of LTI system; $H(s)$ is the Laplace transform of $h(t)$.

$H(j\omega) = |H(j\omega)|e^{j\phi(\omega)}$; $T_d(\omega) = -\frac{d\phi(\omega)}{d\omega}$; $|H(j\omega)|_{dB} = 20\log|H(j\omega)|$; $H(s) = \frac{a_m s^m + \ldots + a_0}{s^N + b_{n-1}s + \ldots + b_0}$

$|H(j\omega)|^2 = H(s)H(-s)|_{s=j\omega} = H(j\omega)H(-j\omega)$; General Lowpass $|H(j\omega)|^2 = \frac{A_0^2}{1 + F(\omega^2)}$

Butterworth: $F(\omega^2) = \varepsilon^2\left(\frac{\omega}{\omega_p}\right)^{2N}$; $A_{max} = 20\log\sqrt{1+\varepsilon^2}$; $A_{min} \le 10\log\left[1 + \varepsilon^2\left(\frac{\omega}{\omega_p}\right)^{2N}\right]$;

Poles lie on circle of radius $\omega_p\left(\frac{1}{\varepsilon}\right)^{\frac{1}{N}}$ spaced apart by $\frac{\pi}{N}$ with first half angle from $j\omega$ axis

Chebyshev: (for $\omega_p = 1$) $F(\omega^2) = \varepsilon^2 C_N^2(\omega)$; $C_N(\omega) = \cos(N\cos^{-1}(\omega))$ $|\omega| \le 1$

$C_N(\omega) = \cosh(N\cosh^{-1}(\omega))$ $|\omega| \ge 1$; $C_{N+1}(\omega) = 2\omega C_N(\omega) - C_{N-1}(\omega)$;

$A_{max} = 20\log\sqrt{1+\varepsilon^2}$; $A_{min} \le 10\log[1 + \varepsilon^2\cosh^2(N\cosh^{-1}(\omega_s/\omega_p))]$

Second-order polynomial: $s^2 + \left(\frac{\omega_0}{Q}\right)s + \omega_0^2$; for $Q > 0.5$, poles complex at radius ω_0 and real part is $-\frac{\omega_0}{2Q}$

Lowpass and highpass: peaking occurs if $Q > 1/\sqrt{2}$ and $\omega_{max} = \omega_0\sqrt{1 - 1/(2Q^2)}$

Bandpass: for complex poles, peak occurs at ω_0 and has 3dB bandwidth of ω_0/Q

LCR: $\omega_0 = 1/\sqrt{LC}$; $Q = \omega_0 CR$

KHN Biquad: $RC = \frac{1}{\omega_0}$; $2\left(\frac{R_1 \| R_2}{(R_1 \| R_2) + R_3}\right) = \frac{1}{Q}$; $2\left(\frac{R_2 \| R_3}{(R_2 \| R_3) + R_1}\right) = k$

Tow-Thomas Biquad: $RC = \frac{1}{\omega_0}$; damping resistor is QR; numerator is $-s^2\left(\frac{C_1}{C}\right) - s\left(\frac{1}{C}\right)\left(\frac{1}{R_1} - \frac{r}{RR_3}\right) - \frac{1}{RR_2C^2}$