

Robert Koller
Bogdan Wilamowski
Department of Electrical Engineering
University of Wyoming

Analog and Digital Filter Design Using Microcomputers

A package of three programs for the design of analog and digital filters was developed. These programs are as follows: 1) FILTER-for analog cascade filter design; 2) LADDER-for leap-frog and ladder type filters; and 3) DIGITFILT-for the design of digital filters. The first two programs were developed for the IBM PC environment, and DIGITFILT was developed for the Macintosh computer.

The FILTER program was designed for undergraduate courses where the students may exercise not only various types of synthesis such as Butterworth, Chebyshev, Inverse Chebyshev, Bessel-Thompson, and Elliptic, but also they could experience how manually set pole and zero locations effect magnitude, phase, delay, and transient responses. Based on the result of the synthesis, students may choose practical circuit implementations using one of fifteen possible first and second order sub-circuits. The program generates a SPICE input file for final design verification including Monte Carlo analysis.

The most common approach for ladder type filter designs is the use of tables, which are not required when the program LADDER is used. The program LADDER was developed for graduate courses. LADDER designs more advanced forms such as ladder and Girling-Good circuits which are less sensitive to the parameter variations. The LADDER program can also be used to find prototypes for switched capacitor and switched current filters. This program has the unique feature of finding not just one, but many different circuits for each Elliptic or Inverse Chebyshev transfer function. The program also has some analysis methods such as Monte Carlo and parameter sensitivity built in.

The program DIGITFILT is a digital filter program for the use in digital filter design. This program does the designs of IIR filters using the methods of Butterworth, Chebyshev, Inverse Chebyshev, and Elliptic, and the designs of FIR filters using traditional Fourier Series methods and the more modern Parks-McClellan method. Included in the Fourier Series method are many windowing options including the Kaiser window which calculates the optimum order to meet the desired specifications. This program also allows the manual movement of poles and zeros to see their effect on the magnitude and phase responses. DIGITFILT implements common Macintosh User Interface Protocol for ease of use.

These programs are available free of charge for educational purposes.

LOWPASS FILTER - Inverse Chebyshev 7 order

$\alpha_P = 2.200000 \text{dB}$ $\alpha_S = 30.00000 \text{dB}$

$f_P = 500.0000$ $f_S = 600.0000$

normalized $w_P = 1.000000$ $w_S = 1.200000$

NORMALIZED POLE AND ZERO LOCATIONS:

0 SINGLE ZEROS:

6 CONJUGATE ZEROS:

0 $j_1.230860$

0 $j_1.534858$

0 $j_2.765718$

1 SINGLE POLES:

-1.91186 $+j_0$

-0.12466 $j_1.027394$

-1.16556 $j_1.055843$

-0.46717 $j_1.101944$

($s + 0.249324s + 1.071079)$ $Q=4.150941$ $w_0=1.034929$

($s + 2.331120s + 2.473335)$ $Q=0.674647$ $w_0=1.572684$

($s + 0.934339s + 1.432529)$ $Q=1.280994$ $w_0=1.196893$

($s + 1.911869$)

frequency scaling factor 1.2000000000

magnitude scaling factor 0.2657642388

POLYNOMIALS:
power denominator numerator

7 1.00000000

6 5.42665263 1.00000000

5 14.6889641 0.00000000

4 25.9007507 11.52000000

3 31.8578797 0.00000000

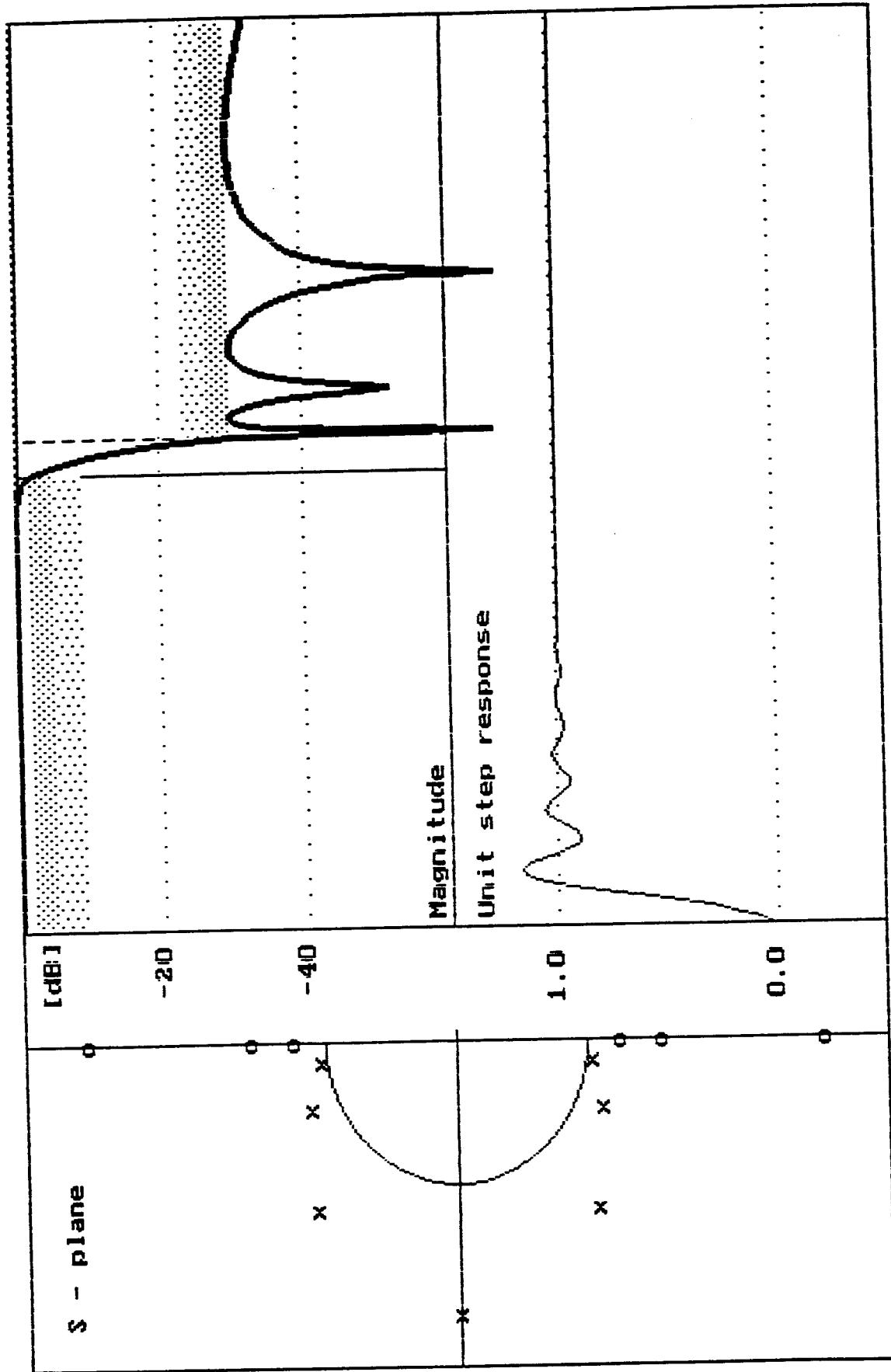
2 28.8611231 33.1776000

1 17.0544202 0.00000000

0 7.25547671 27.3004251

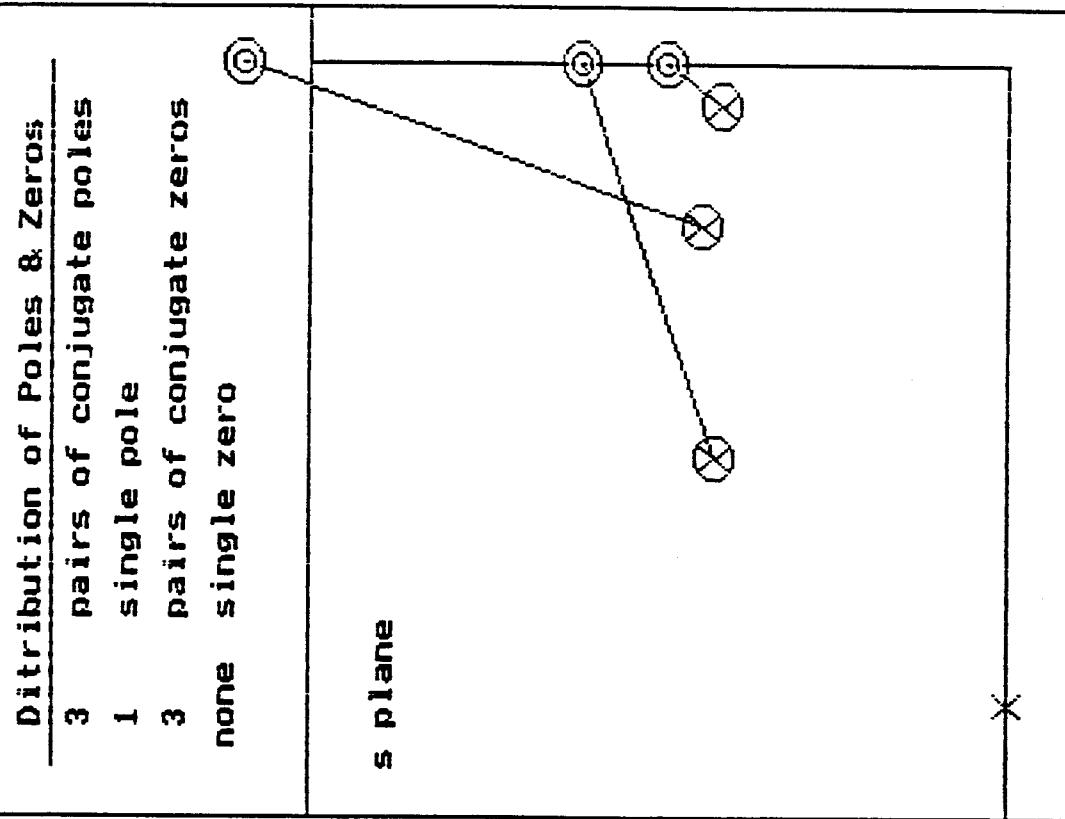
FILTER.

Data of Inverse Chebyshev Approximations.



FILTER. Unit step response of the Inverse Chebyshev filter along with the magnitude response and the pole and zero locations.

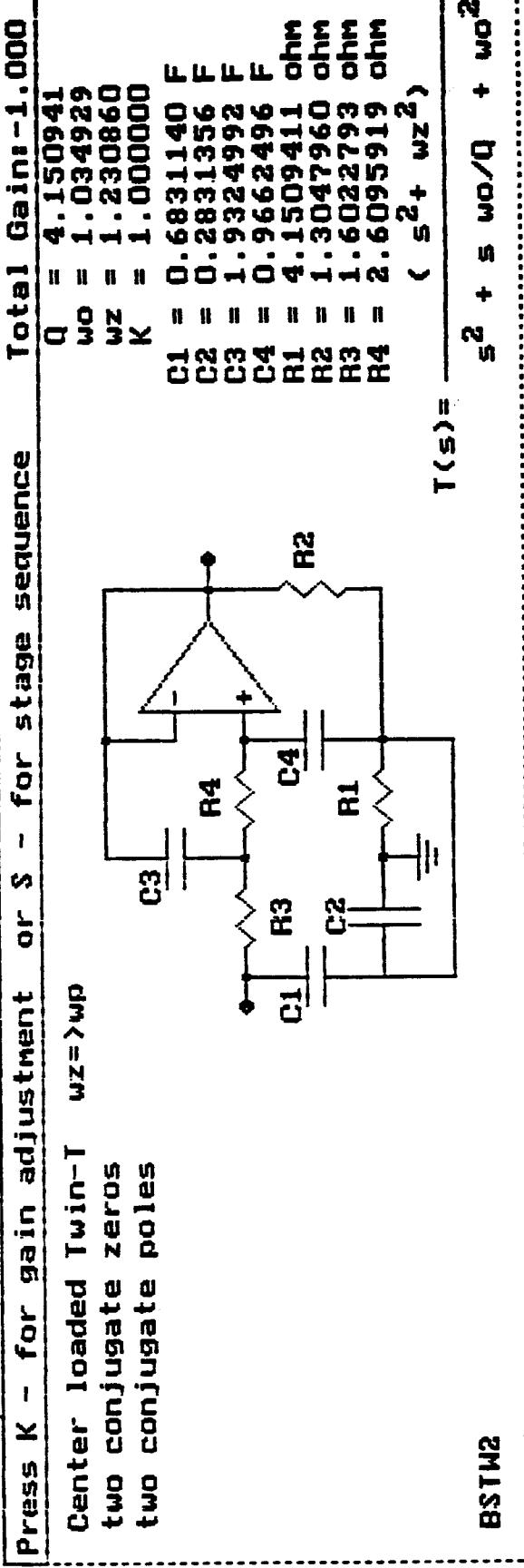
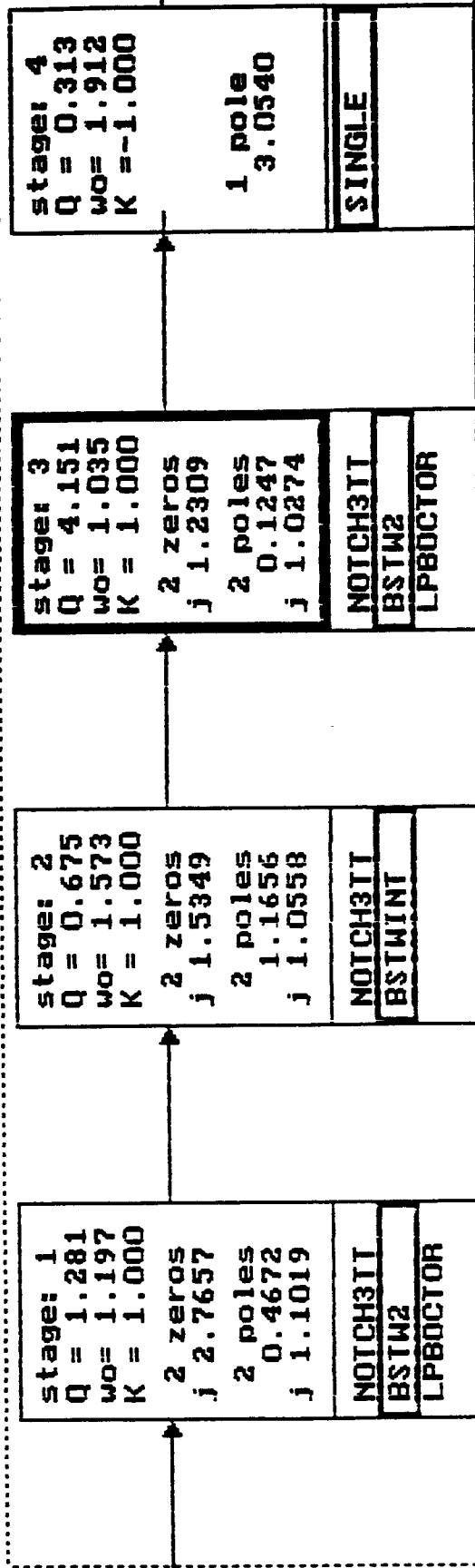
Distribution of Poles & Zeros	
3	pairs of conjugate poles
1	single pole
3	pairs of conjugate zeros
none	single zero
	s plane



stage specification

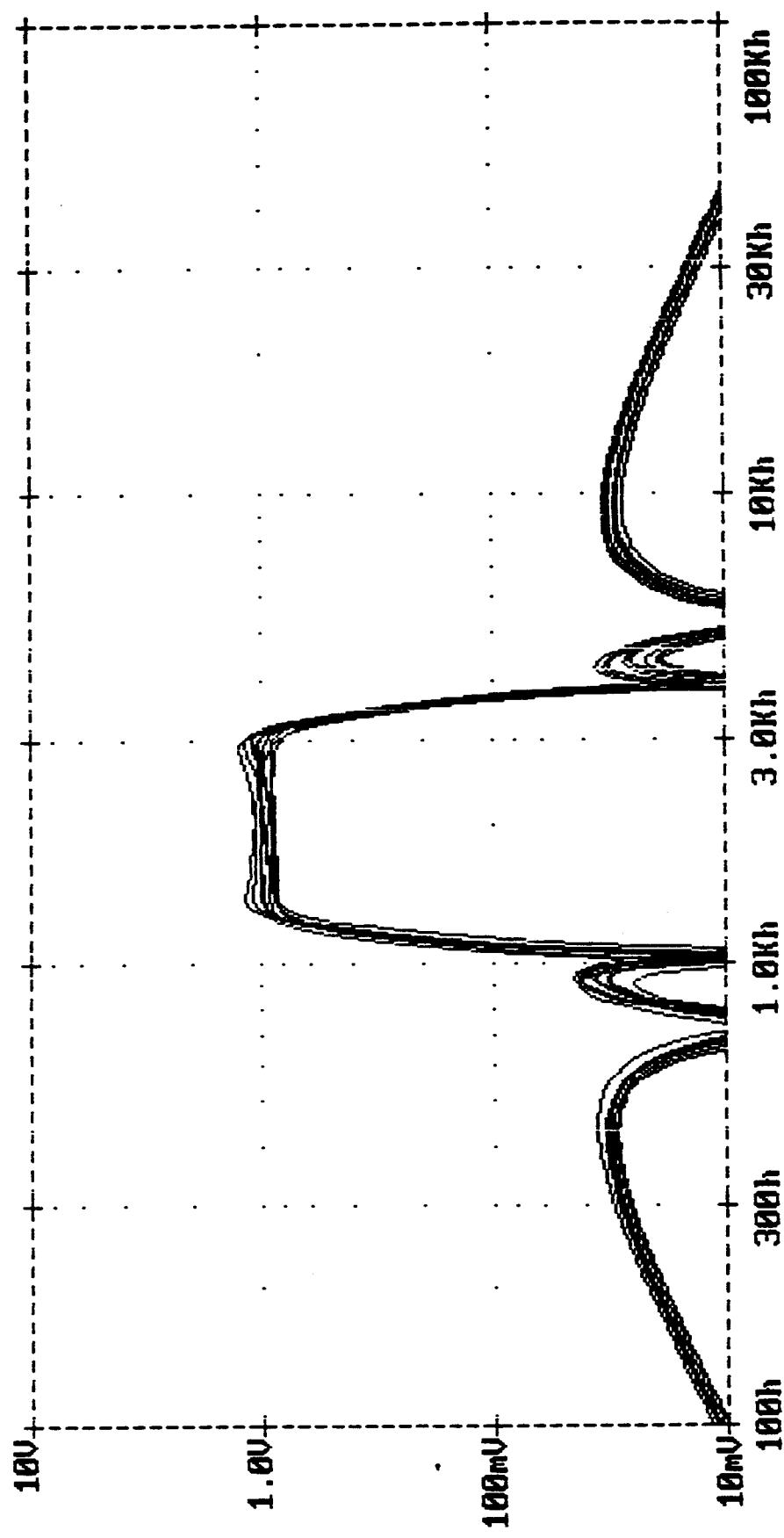
	2 conjugate poles & 2 zeros
1	$Q = 1.281, \omega_0 = 1.197, \omega_z = 2.766$
2	$Q = 0.675, \omega_0 = 1.573, \omega_z = 1.535$
3	$Q = 4.151, \omega_0 = 1.035, \omega_z = 1.231$
4	1 single pole $\omega = 1.912$

FILTER. Distribution of poles and zeros and stage specification of an Inverse Chebyshev filter.

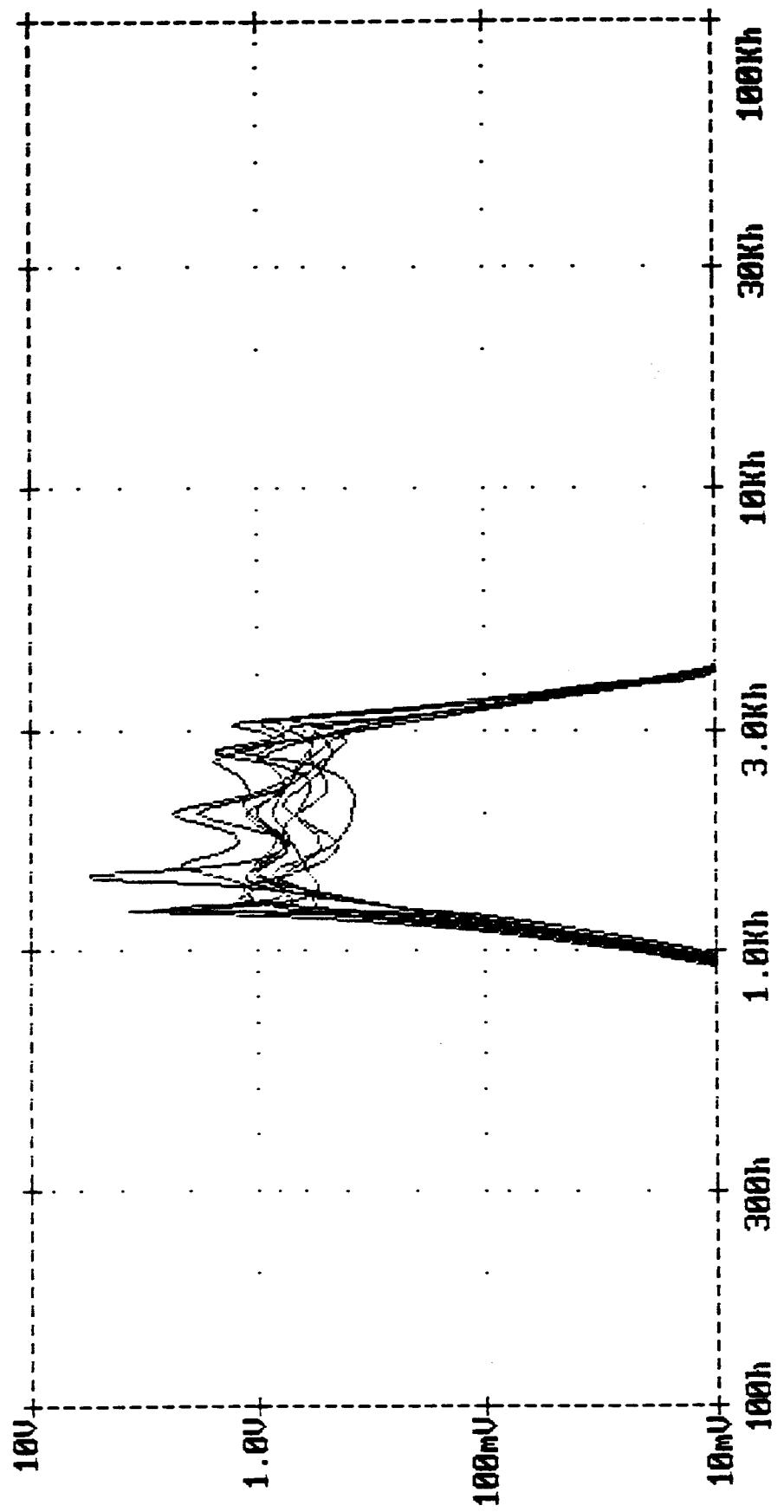


FILTER.

Circuit realization of Inverse Chebyshev filter.



FILTER. Results of Monte Carlo simulation with 10 passes for an Inverse Chebyshev
bandpass filter with 5% element tolerances.



FILTER. Results of Monte Carlo simulation with 10 passes for a Chebyshev bandpass filter with 5% element tolerances.

The Circuit Values

The input resistance is 1.0000000000

Inductor[1]= 0.0000000	Capacitor[1]= 0.2919830	
Inductor[2]= 0.8986623	Capacitor[2]= 0.0523709	Zero = 0.0470638
Inductor[3]= 0.0000000	Capacitor[3]= 1.2513699	
Inductor[4]= 1.3086512	Capacitor[4]= 0.1815771	Zero = 0.2376211
Inductor[5]= 0.0000000	Capacitor[5]= 1.2423217	
Inductor[6]= 0.7410824	Capacitor[6]= 0.2062053	Zero = 0.1528151
Inductor[7]= 0.0000000	Capacitor[7]= 0.1627212	

The output resistance is 1.0000001738

The Circuit Values

The input resistance is 1.0000000000

Inductor[1]= 0.0000000	Capacitor[1]= 0.0366754	
Inductor[2]= 0.6079212	Capacitor[2]= 0.3908749	Zero = 0.2376211
Inductor[3]= 0.0000000	Capacitor[3]= 1.3067763	
Inductor[4]= 1.4418124	Capacitor[4]= 0.1059882	Zero = 0.1528151
Inductor[5]= 0.0000000	Capacitor[5]= 1.3129612	
Inductor[6]= 0.8986623	Capacitor[6]= 0.0523709	Zero = 0.0470638
Inductor[7]= 0.0000000	Capacitor[7]= 0.2919829	

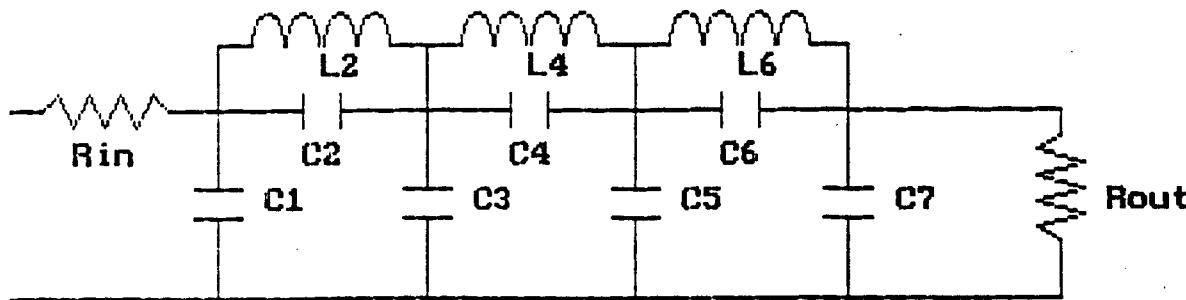
The output resistance is 1.0000000867

The Circuit Values

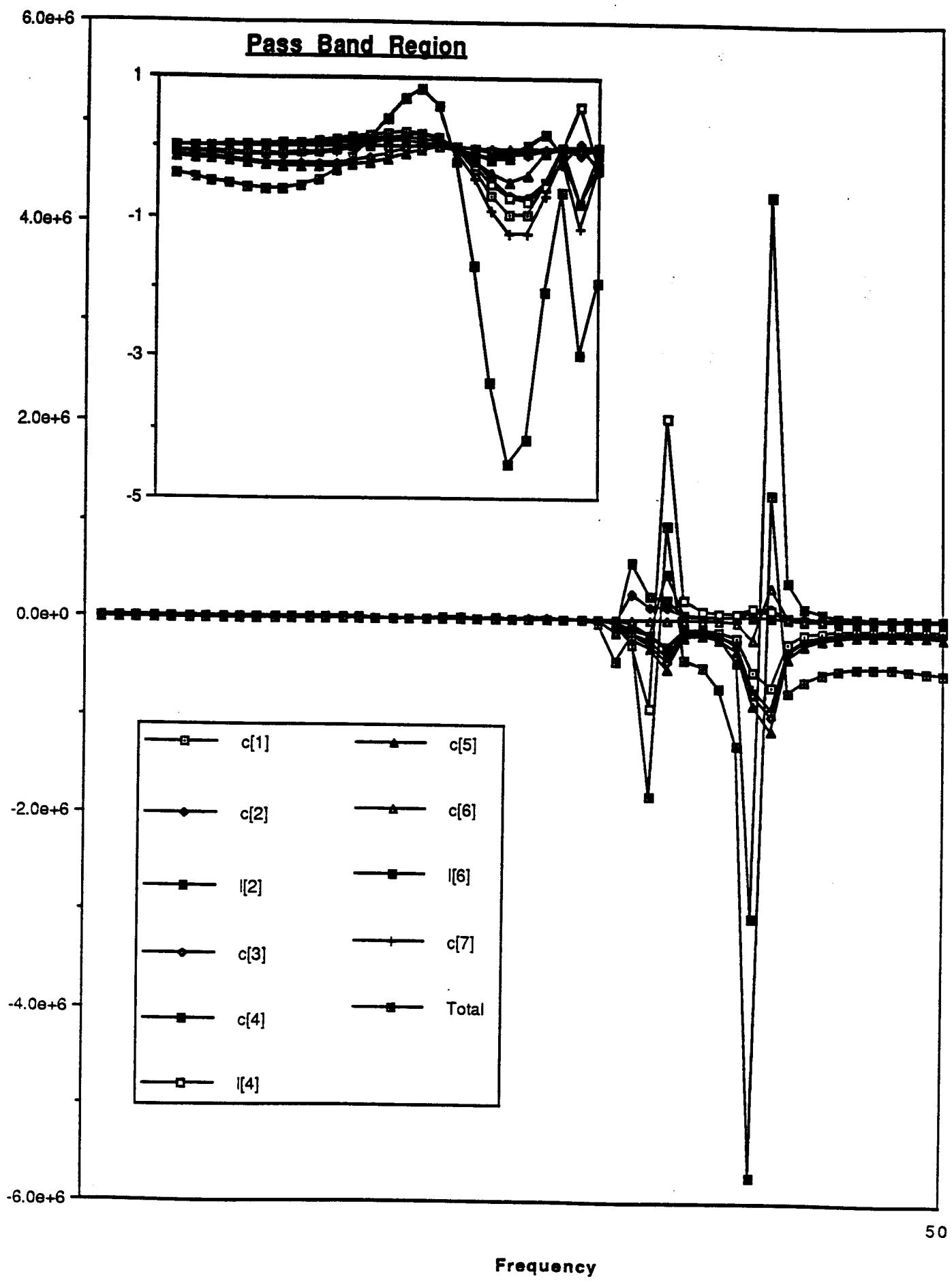
The input resistance is 1.0000000000

Inductor[1]= 0.0000000	Capacitor[1]= 0.0366754	
Inductor[2]= 0.6079212	Capacitor[2]= 0.3908749	Zero = 0.2376211
Inductor[3]= 0.0000000	Capacitor[3]= 1.3762419	
Inductor[4]= 1.5993922	Capacitor[4]= 0.0294260	Zero = 0.0470638
Inductor[5]= 0.0000000	Capacitor[5]= 1.3727574	
Inductor[6]= 0.7410824	Capacitor[6]= 0.2062053	Zero = 0.1528151
Inductor[7]= 0.0000000	Capacitor[7]= 0.1627212	

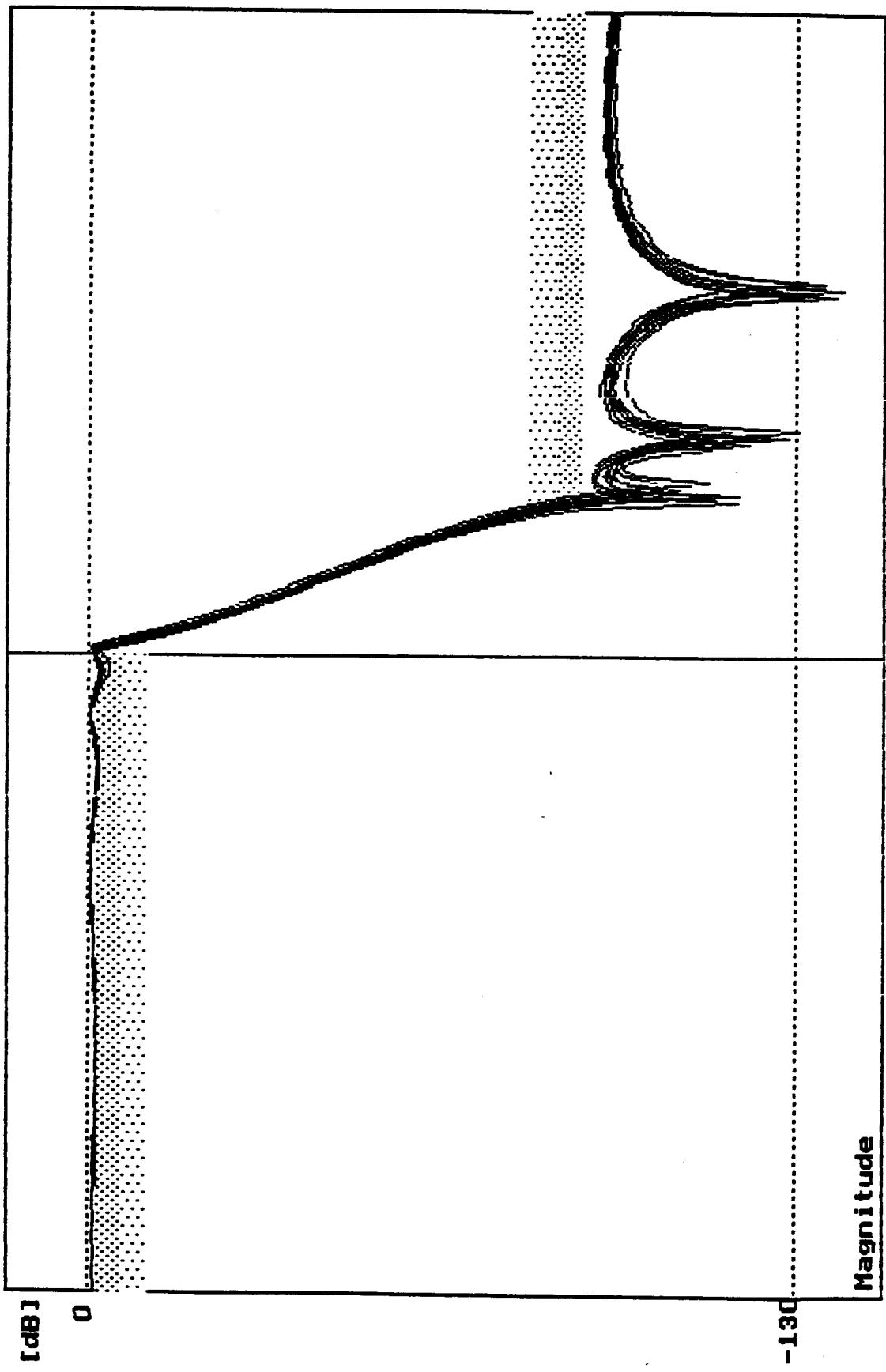
The output resistance is 1.0000002041



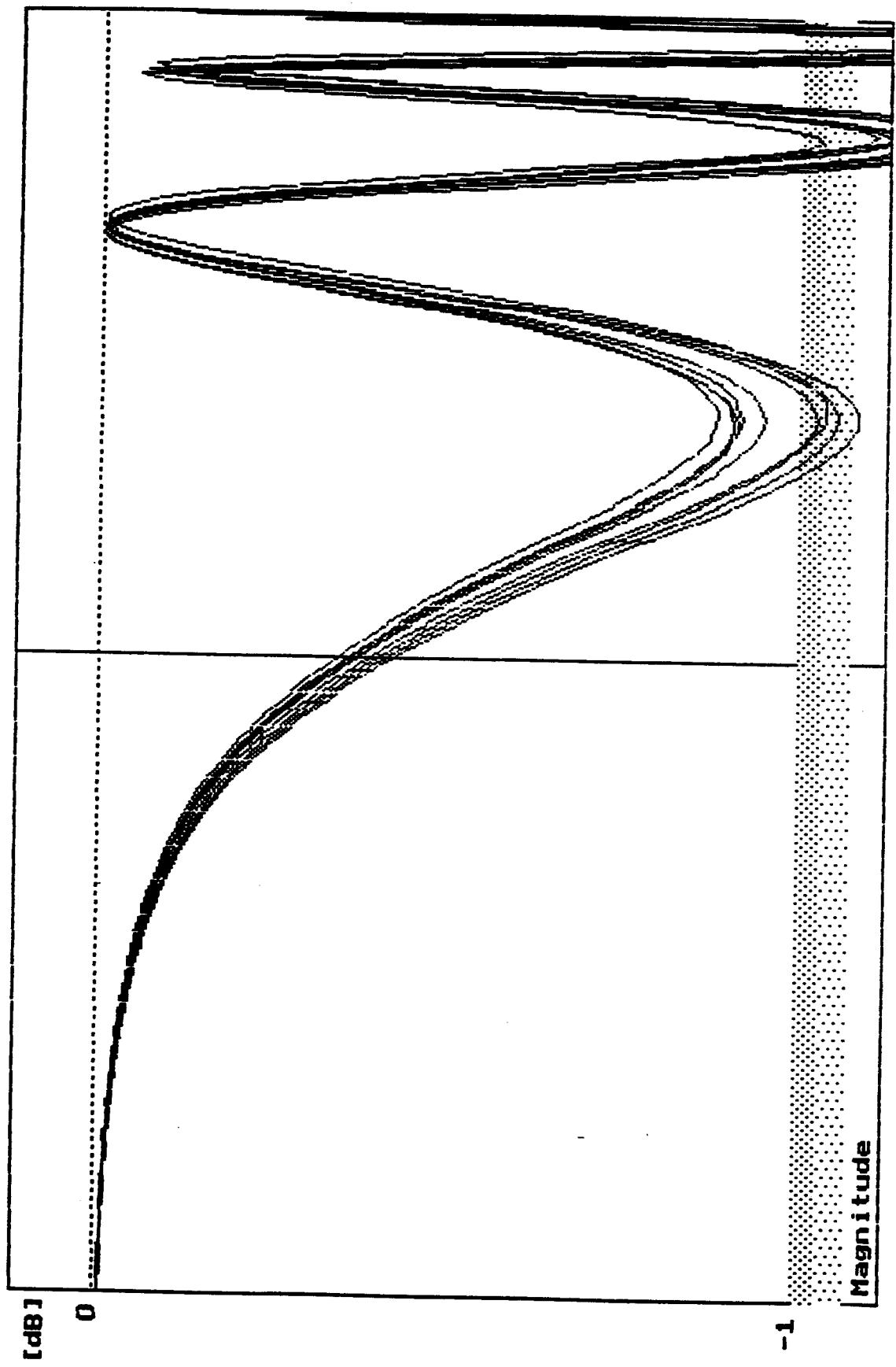
LADDER. 3 of 6 possible circuits for a 7th order Inverse Chebyshev transfer function and the corresponding circuit diagram.



LADDER. Graph of sensitivity data, generated using the sensitivity analysis in LADDER, for a

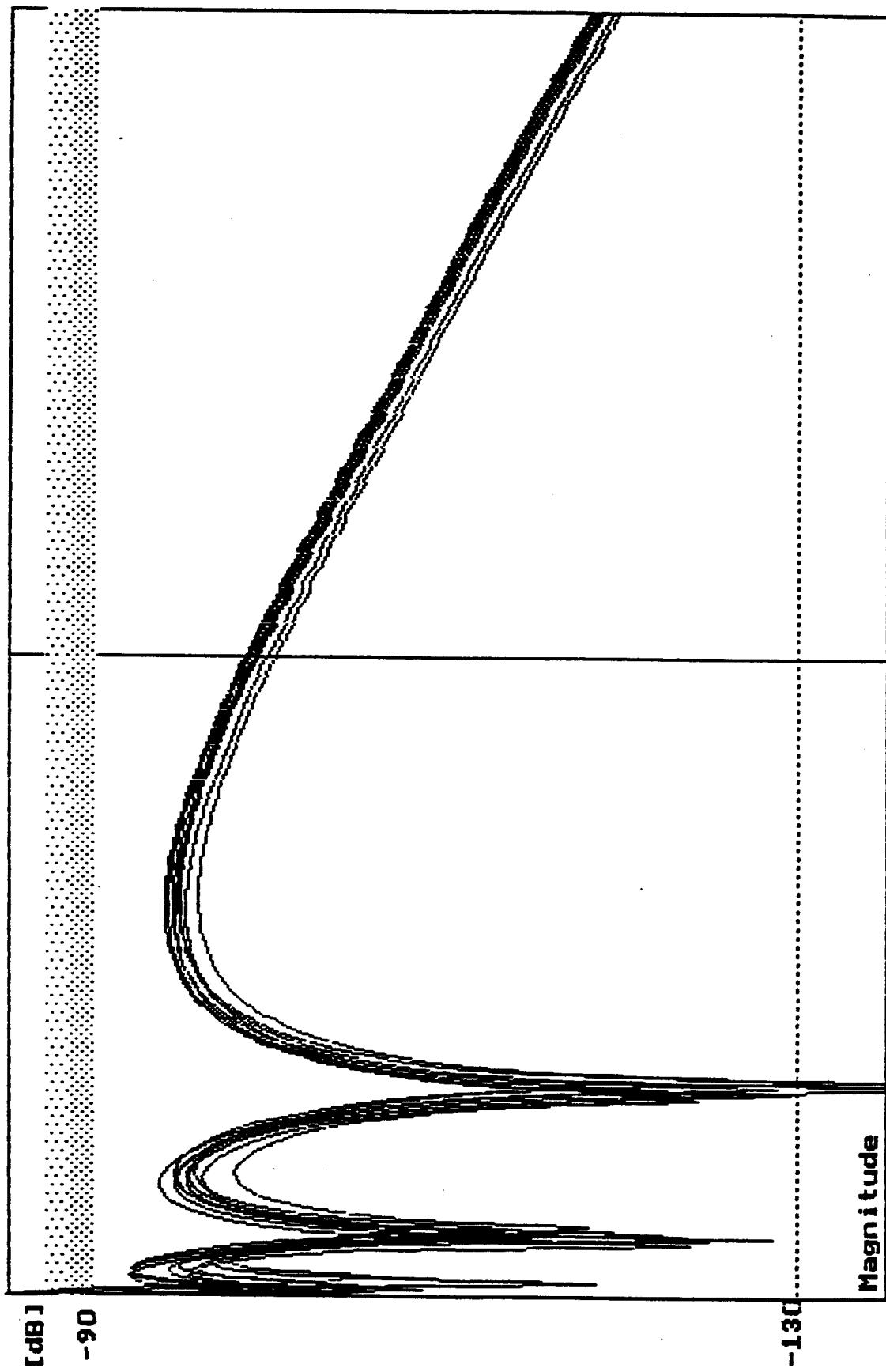


LADDER. Results of Monte Carlo simulation with 9 passes and 10% element tolerances for a
7th order Elliptic filter.



LADDER.

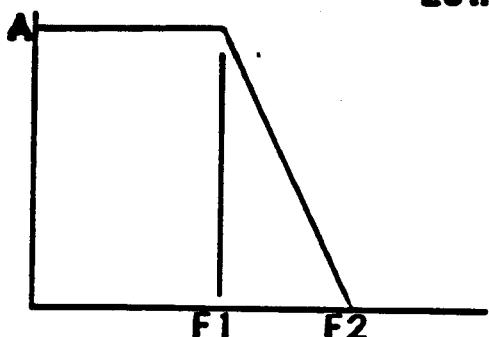
Results of Monte Carlo simulation showing only the passband.



LADDER.

Results of Monte Carlo simulation showing only the stopband.

Lowpass Filter Design



Type the desired filter specifications.

-1 < A (pass band dB) < 0

A (stop band dB) = -20

What is the sampling frequency? (hz)

1000.

What is the corner frequency F_1 ? (hz)

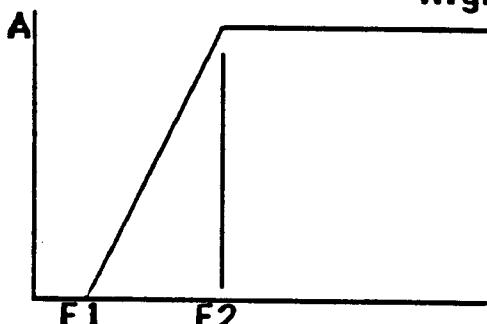
100.

What is the corner frequency F_2 ? (hz)

150.

DONE

Highpass Filter Design



Type the desired filter specifications.

-1 < A (pass band dB) < 0

A (stop band dB) = -20

What is the sampling frequency? (hz)

1000.

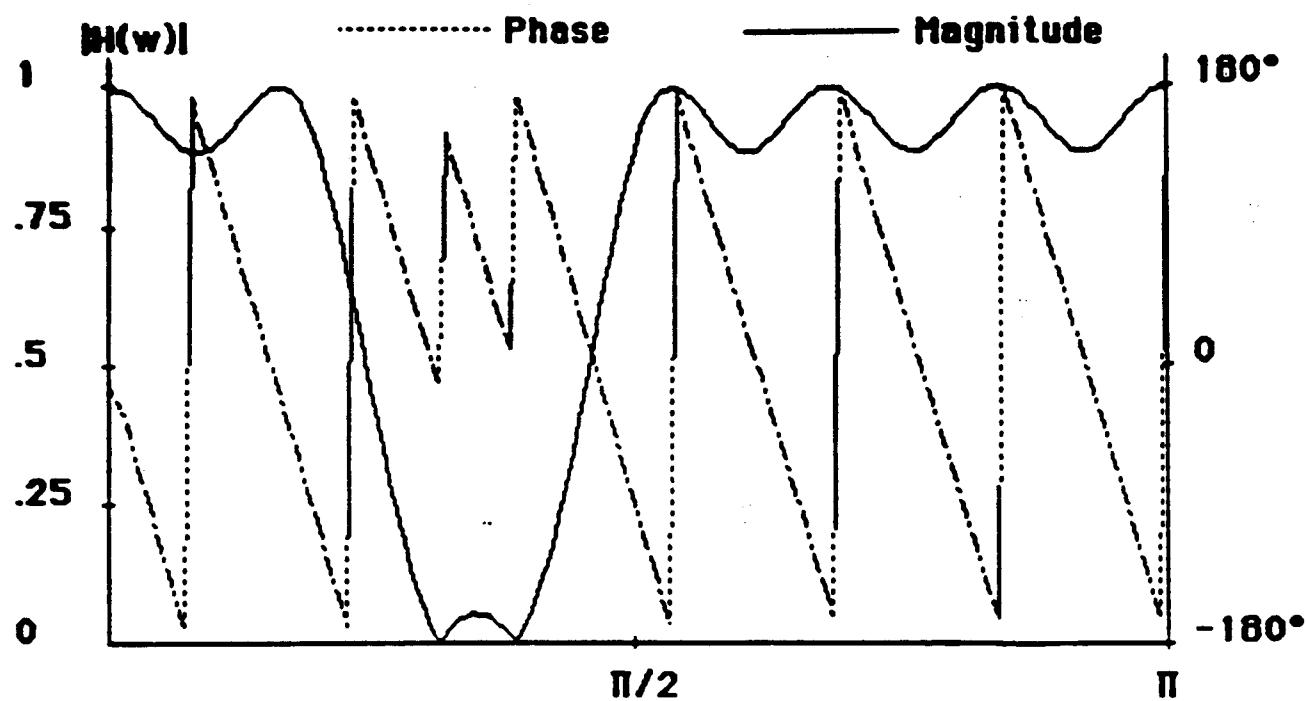
What is the corner frequency F_1 ? (hz)

100.

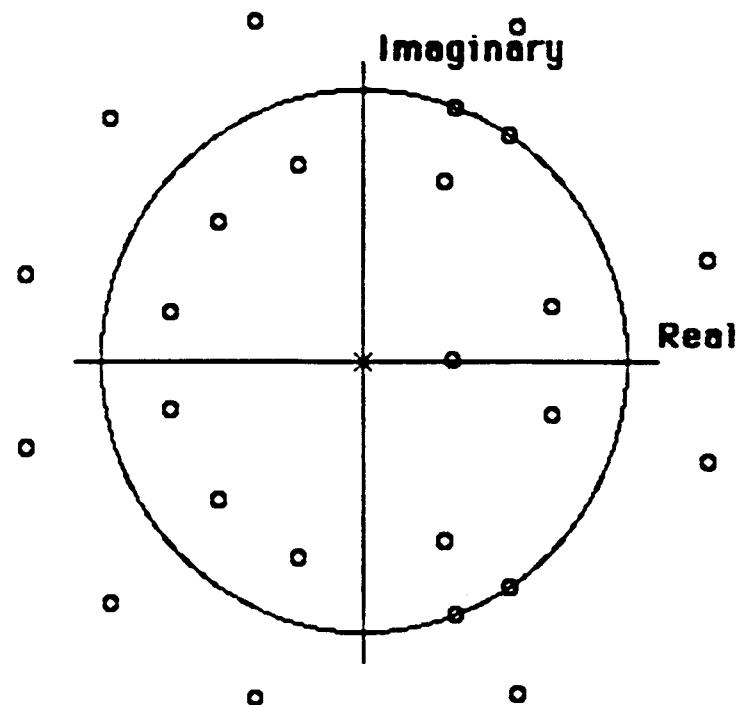
What is the corner frequency F_2 ? (hz)

150.

DONE

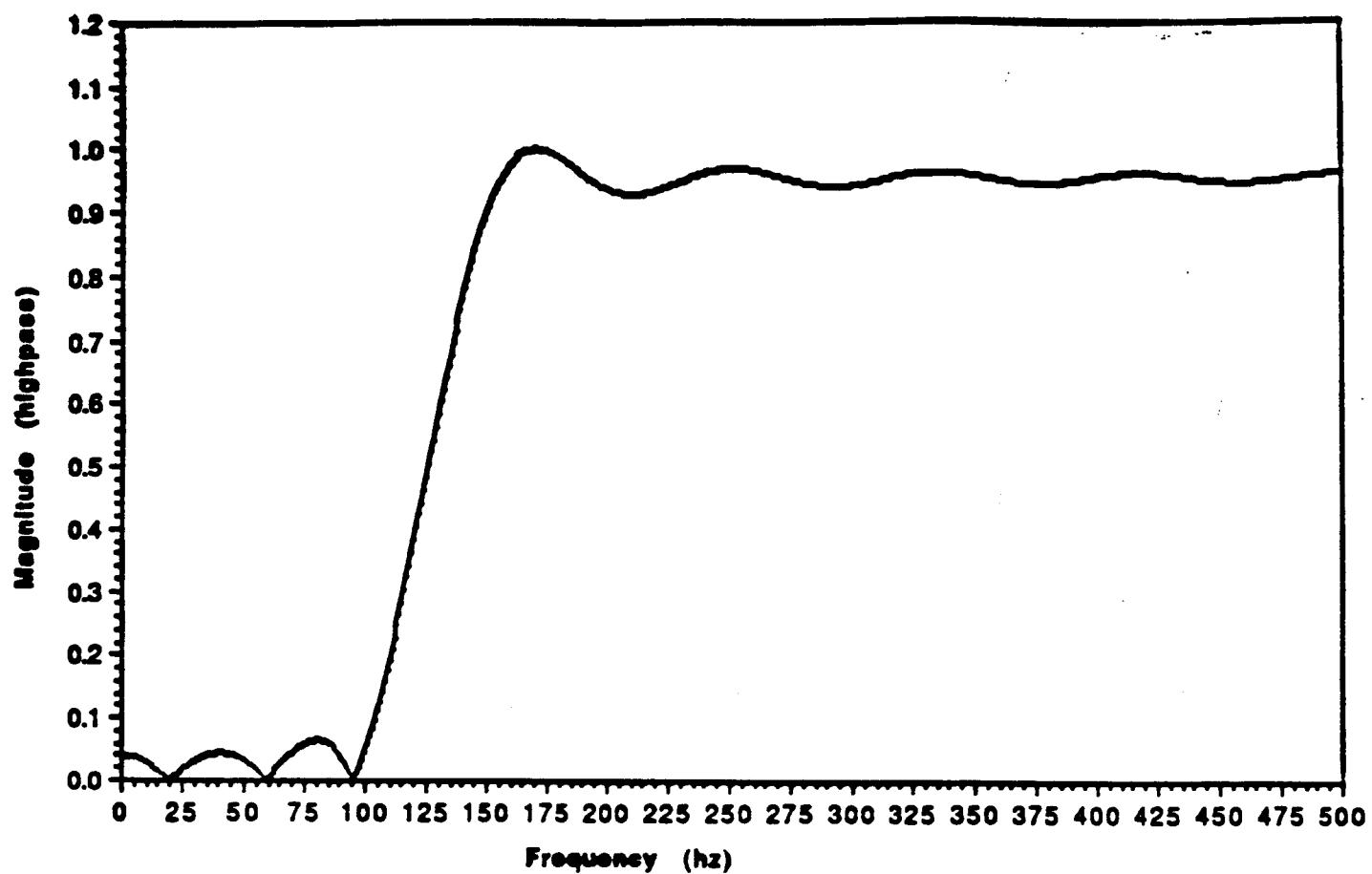


Unit Circle Diagram

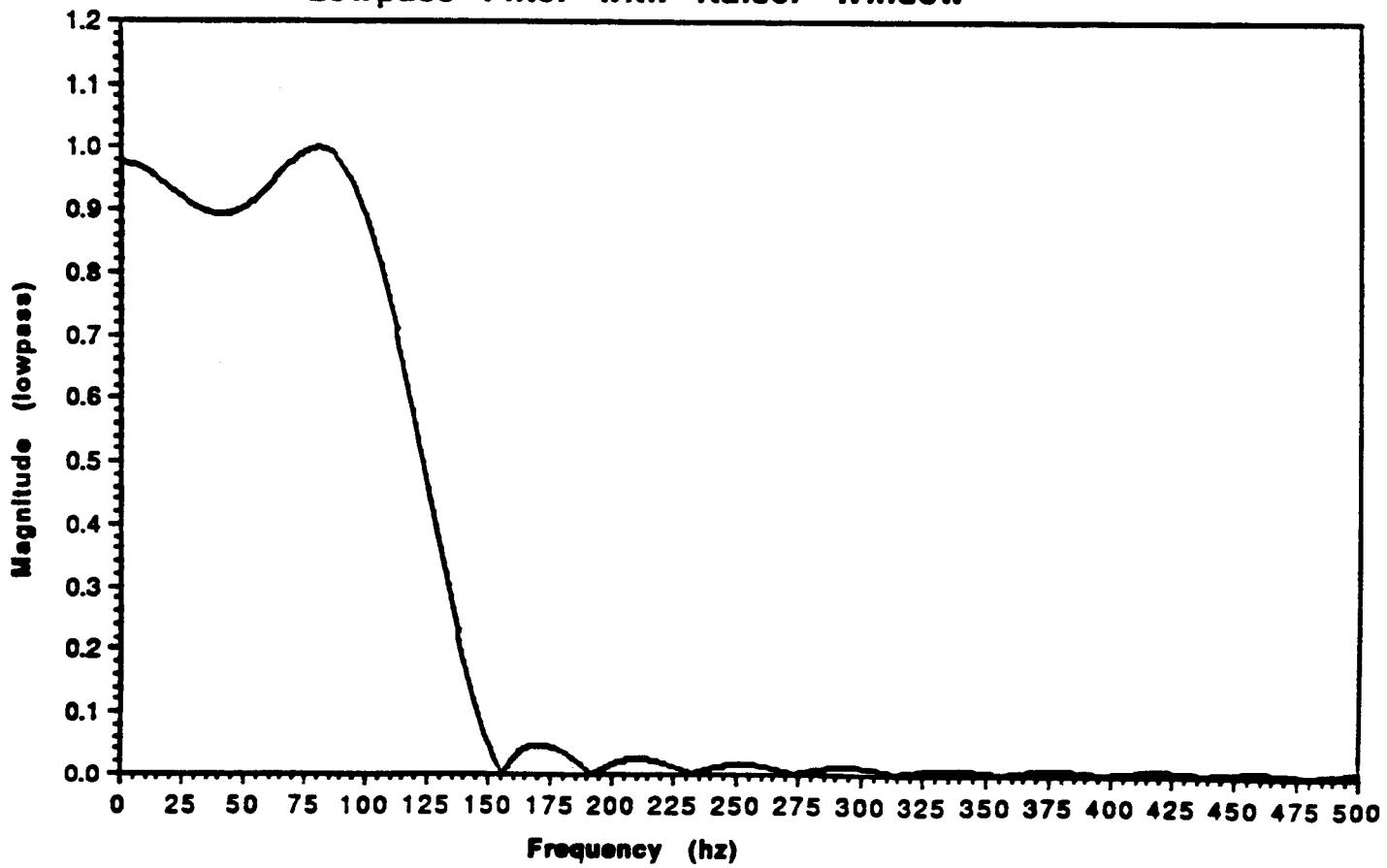


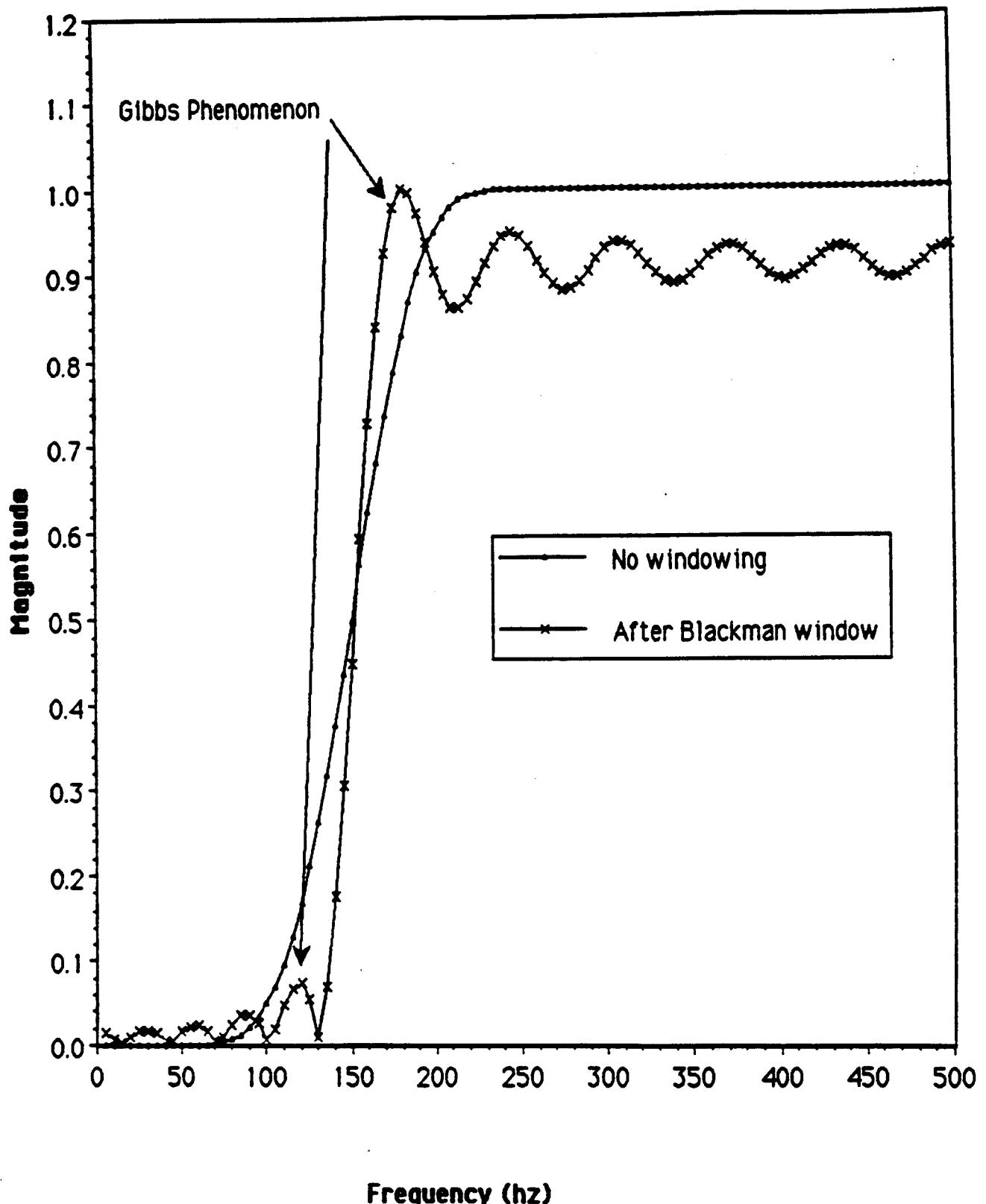
DIGITFILT

Screen prints of the magnitude and phase graph and the unit circle diagram for a Parks-McClellan filter with an order of 27.



Lowpass Filter with Kaiser Window





DIGITFILT. Graph of a Fourier Series filter with a Kaiser window using data generated from DIGITFILT.