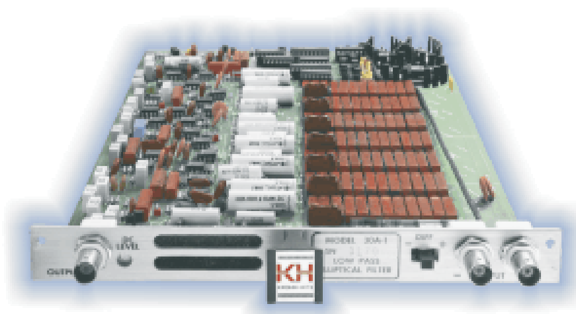
Model 31A

1Hz to 99kHz
Elliptical High-Pass
Plug-In Filter Card
for Model 3905B/3916B Chassis



KROHN-HITE CORPORATION

Operating Manual

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Krohn-Hite Instruments are designed and manufactured in accordance with sound engineering practices and should give long trouble-free service under normal operating conditions. If your instrument fails to provide satisfactory service and you are unable to locate the source of trouble, contact our Service Department at (508) 580-1660, giving all the information available concerning the failure.

DO NOT return the instrument without our written or verbal authorization to do so. After contacting us, we will issue a Return Authorization Number which should be referenced on the packing slip and purchase order. In most cases, we will be able to supply you with the information necessary to repair the instrument, avoiding any transportation problems and costs. When it becomes necessary to return the instrument to the factory, kindly pack it carefully and ship it to us prepaid.

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Modifications to this instrument must not be made without the written consent of an authorized employee of Krohn-Hite Corporation.

MODEL 31 SERIES

HIGH-PASS ELLIPTICAL
PLUG-IN FILTER MODULES

MODEL 31-1 : 1Hz to 99kHz
MODEL 31-2 : 0.1Hz to 9.9kHz
MODEL 31-3 : 0.01Hz to 990Hz

OPERATING AND MAINTENANCE
MANUAL

FILTER MODULES			
MODEL ______	S/N ______	MODEL ______	S/N ______
MODEL ______	S/N ______	MODEL ______	S/N ______
MODEL ______	S/N ______	MODEL ______	S/N ______
MODEL ______	S/N ______	MODEL ______	S/N ______
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MODEL ______	S/N ______	MODEL ______	S/N ______
MODEL ______	S/N ______	MODEL ______	S/N ______

MAINFRAME	
MODEL ______	S/N ______

MICROPROCESSOR	
MODEL ______	S/N ______

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Model 31 Plug-In Filter Module

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SECTION 1
GENERAL DESCRIPTION

1.1 INTRODUCTION

The Model 31 Series are high-pass, 7-pole, 6-zero elliptical plug-in filters providing 115dB/octave rolloff, a minimum stopband attenuation of >80dB, and a typical passband ripple of 0.22dB peak-to-peak. The Model 31-1 covers the range from 1Hz to 99kHz. The Model 31-2 operates from 0.1Hz to 9.9kHz and from 0.01Hz to 990Hz in the Model 31-3.

With its 115dB/octave rolloff rate, The Model 31 provides a much narrower transition region than an 8-pole Butterworth, and much less passband attenuation near cutoff. The transition region from –3dB to –85dB is 38% of f_c (cutoff), compared to 71% for the 8-pole Butterworth. From –0.3dB to –85.6dB, it becomes 41% of f_c compared to 89%. This means the fast transition from passband to stopband of the Model 31 makes it the ideal filter for the rejection of interfering signals near the passband.

The Model 31 Series is part of an ever expanding line of plug-in filter cards for use in the Models 3905 and 3916 Mainframes, which accommodates 5 to 16 filter cards respectively.

1.2 SPECIFICATIONS

FILTER CHARACTERISTICS

Function: High-pass, 7-pole, 6-zero elliptical.

Frequency Range f_c: Model 31-1: 1Hz to 99kHz.
Model 31-2: 0.1Hz to 9.9kHz.
Model 31-3: 0.01Hz to 990Hz.

Resolution:

Model 31-1 Band	Frequency	Resolution
1	1Hz to 99Hz	1Hz
2	100Hz to 990Hz	10Hz
3	1kHz to 9.9kHz	100Hz
4	10kHz to 99 kHz	1000Hz

Model 31-2 Band	Frequency	Resolution
1	0.1Hz to 9.9Hz	0.1Hz
2	10Hz to 99Hz	1Hz
3	100Hz to 990Hz	10Hz
4	1kHz to 9.9kHz	100Hz

Model 31-3 Band	Frequency	Resolution
1	0.01Hz to 0.99Hz	0.01Hz
2	1Hz to 9.9Hz	0.1Hz
3	10Hz to 99Hz	1Hz
4	100Hz to 990Hz	10Hz

Relative Gain at f_c: –0.22dB at $0.99f_c$ nominal.

Cutoff Frequency Accuracy: ±2%.

Bandwidth: f_c to upper 3dB cutoff, >500kHz at 1Vrms with 0dB gain.

Passband Ripple: 0.22dB p-p theoretical, 0.4dB p-p max.

Attenuation: 115dB/octave.

Stopband Attenuation: >80dB.

Stopband Frequency (f_s) = $0.59f_c$.

GAIN

Input (prefilter): 0dB, 10dB, 20dB, 30dB, 40dB; ±0.2dB.

Output (postfilter): 0dB, 10dB, 20dB; ±0.2dB.

INPUT

Coupling: ac in Model 31-1; dc in Models 31-2 and 31-3.

Impedance: 1 megohm in parallel with 100pf.

Maximum Input: ±10V peak at 0dB gain in Model 31-1. Combined dc plus peak ac should not exceed ±10V peak at 0dB gain in Models 31-2 and 31-3.

Maximum dc Component: ±100V in ac coupled mode.

OUTPUT

Impedance: 50 ohms.

Maximum Voltage: ±10V peak into >500 Ohms; ±3V peak into 50 ohms.

Noise:

Total Hum and Noise (Ref. to Input, 2MHz Detector Bandwidth)						
Output Gain (dB)	f_c	Input Gain (dB)				
		0	10	20	30	40
0 10 20	≤1kHz	500μV	200μV	100μV	100μV	100μV
	99kHz	1mV	500μV	100μV	50μV	50μV

Harmonic Distortion: >80dB below full scale at 1kHz.

Intermodulation Distortion: >80dB below full scale volts at 0.7 and 0.9 of max input frequency.

DC Offset: Adjustable to zero volts.

DC Offset Drift: ±25mV at 0dB gain; 15°C to 40°C.

Crosstalk Between Channels: >85dB below full scale with input source <50 ohms.

Spurious Components: >80dB below full scale with input source <50 ohms.

Phase Match Between Channels: 1° typical, 2° max from 1.3f_c to 10f_c; 2° typical, 4° max from f_c to 1.3f_c. For like Models in same chassis, otherwise consult factory.

Amplitude Match Between Channels: ±0.1dB typical, ±0.2dB max from f_c to 1.3f_c; 0.1dB max from 1.3f_c to 10kHz, 0.2dB max to 100kHz.

POWER: 15 watts.

WEIGHT: 1.75 lbs (0.8kg) net.

INPUT/OUTPUT CONNECTORS: BNC.

Specifications apply at 25°C ±5°C.

NOTE: Model 31 Series filter cards must be used with the Model 3905(A) and 3916(A) Mainframes.

SECTION 2
OPERATION

2.1 INTRODUCTION

The Model 31 Series are high-pass plug-in filter modules covering the frequency range from 1Hz to 99kHz (Model 31-1); 0.1Hz to 9.9kHz (Model 31-2); 0.01Hz to 990Hz (Model 31-3). It is one of a series of filter modules available for the five channel Model 3905 or the sixteen channel 3916 Mainframes. All filter parameters are programmable via the Mainframes front panel or remotely over the IEEE-488 (GPIB) bus. For detailed information of the front panel controls and remote programming, refer to Sections 2 and 3 of the Model 3905/3916 Mainframes Operating and Maintenance Manual. Section 2.4 of this manual briefly describes the operation of the principal front panel controls and data key operation.

2.2 TURN-ON PROCEDURE

a. The line voltage range of the Model 3905/3916 Mainframes has been preset at the factory for either 115V or 230V operation. This range switch is located internally if a line voltage change is required. Check to see that a fuse with the correct rating is in the fuse receptacle.

b. Make certain that the POWER switch on the front panel of the unit is in the off position.

c. Plug the line cord into the unit first, then into an ac outlet.

CAUTION

For safety purposes, the line cord must be connected to a grounded 3 terminal ac outlet. Because of potentially dangerous voltages that exist within the Mainframe, the covers should be removed by qualified personnel.

d. If the Model 3905/3916 is remotely programmed via the IEEE-488 GPIB, connect the bus cable to the rear panel outlet of the Model 39/39A microprocessor module at this time. Programming information is provided in Section 3 of the Model 3905/3916 Operating and Maintenance Manual.

e. The POWER switch is a toggle type, located on the front panel of the 3905/3916. After familiarizing yourself with the self-test feature described next, turn on the 3905/3916.

NOTE

If there is a malfunction in the micro processor, such as a defective RAM or ROM, the sequence will stop and the word "bAd" will appear in the display followed by a number from 1 to 3. Refer to Section 7.6, Digital Circuit Maintenance, to find which RAM or ROM is defective.

2.3 SELF-TEST FEATURE

When turned on, the Model 3905/3916 microprocessor performs a Self-Test routine whereby the entire RAM and ROM operation are verified. During the test the front panel LED's and display will light up sequentially.

When the Self-Test program is complete, the Model 3905/3916 will return to the last set-up prior to turning off the unit.

The Model 3905/3916 is now ready to be programmed for operation.

2.4 FRONT PANEL CONTROLS and DISPLAY

Data Keys:

Data entry keyboard controls, [0]-[9] and [.], and associated 4 digit display set the numeric value of the parameter selected. If a cutoff frequency of 1.5kHz is required, press the [1][.][5] data keys and parameter keys [KILO] and [FREQ]. The frequency will be indicated in the 4 digit display.

[MODE] key:

Indicates the mode of operation in the channel displayed, alternating between high-pass, "H.P.-1" and by-pass, "bYP.", which connects the input to the output. The "-1" indicates the suffix of the filter module Model 31, i.e. "H.P.-1" is the Model 31-1.

[Type] key:

Displays "EL-7", indicating a 7-pole Elliptical filter.

Channel:

The two channel controls [⇑] [⇓] and associated display increment or decrement the channel setting. When held, the Model 3905/3916 will cycle through all the channels continuously. The Model 3905 has a 1 digit display, the Model 3905A has 2 digits. The Model 3916 has a 2 digit display, the Model 3916A has 3 digits.

Gain Set:

Input and Output gain is controlled by the two GAIN SET controls [⇑] [⇓] and associated 2 digit displays in 10dB steps. Input gain 0dB to 40dB. Output gain 0dB to 20dB.

Input Overload:

With 0dB Input gain, the input overload indicator will turn on with approxi mately 8Vrms input signal. At 10dB, approximately 2.5Vrms. At 20dB, approximately 0.8Vrms. At 30dB, approximately 0.25Vrms. At 40dB, approximately 80mVrms.

Output Overload:

With 0dB Input and Output gain, the output overload indicator will turn on with approximately 8Vrms output signal. At 10dB, approximately 2.5Vrms. At 20dB, approximately 0.8Vrms.

[CE] Clear Entry key:

Display will reset to the previous entry or toggle between present and previous settings.

[ALL CHANNEL] key:

When on, parameter changes will be made simultaneously to all identical filter channels.

2.5 FILTER CHARACTERISTICS

2.5.1 INTRODUCTION

The Model 31 is an Elliptical (Cauer) filter used in applications where frequency response (fast rolloff) is the primary objective and phase distortion, transient and passband response are secondary requirements. It is an ideal filter for applications requiring signal conditioning.

2.5.2 1kHz AMPLITUDE RESPONSE

The theoretical 7-pole, 6-zero elliptic high-pass filter response, shown in Figure 2.1, has 0dB gain at high frequencies with three peaks and valleys of 0.22dB p-p amplitude as the frequency approaches the cutoff frequency of f_c. The cutoff fre quency occurs where the filter response is equal to the most negative excursion of the ripple amplitude.

The response of the filter at frequencies lower than the cutoff frequency is attenuated at an average rate of 115dB/octave, and as shown in Figure 2.1 has three peaks and nulls of attenuation in the stopband. Minimum attenuation (A min) occurs at frequency f_s ($0.59f_c$) and at three frequencies where minimum attenuation peaks in the stopband.

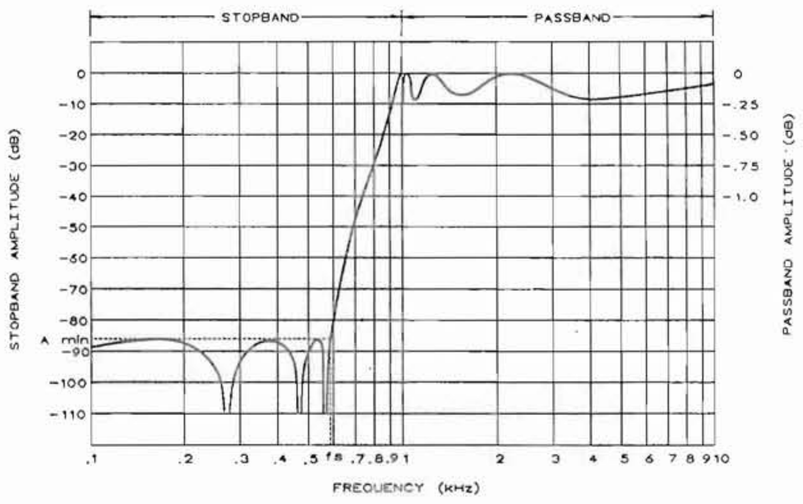

Figure 2.1 Normalized Ripple Response

2.6 VARIABLE BANDPASS and BAND REJECT OPERATION

Variable bandpass response can be obtained easily using a Model 31 high-pass filter in series with a Model 30 low-pass filter and setting the low-pass filter to an equal or higher cutoff frequency than the high-pass filter. Selecting the cutoff frequencies provides the desired bandpass response.

Variable band reject response is obviously obtained in a manner similar to the variable bandpass response except that the low-pass cutoff frequency is set at a lower cutoff frequency than the high-pass filter to provide the desired band reject range.

Null operation is obtained by setting the low cutoff frequency, of the Model 30 (Curve A of Figure 2.2), a factor of 0.58 below the desired null frequency and the high cutoff frequency, of the Model 31 (Curve B), a factor of 1.7 above the null frequency.

When maximum selectivity (Curve C of Figure 2.2) at a specified frequency is required to obtain minimum bandwidth, the Model 30 and Model 31 should be set to the same cutoff frequency. To prevent the possibility of excessive attenuation due to calibration error, when both cutoffs are set to the same frequency all Krohn-Hite elliptical filters are offset by 1% from the keyboard frequency setting. The low-pass filter at 100Hz cutoff frequency is actually tuned to 101Hz and the high-pass filter to 99Hz to minimize potential amplitude loss in narrowband operation.

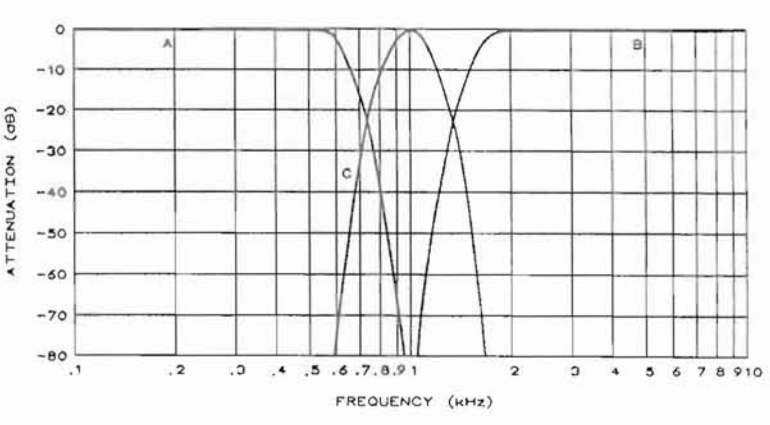

Figure 2.2 Band-Pass/Band-Reject Response

2.7 PHASE RESPONSE

Phase characteristics of a 7-pole, 6-zero elliptical filter as shown in Figure 2.3, provides output phase relative to the input (Curve A) over a 10/1 frequency range. Curve B shows the phase response of linear phase and Curve C gives the phase distortion, which is the difference in phase response, between linear phase and an elliptical filter.

When the input frequency of the filter is greater than 2.5 times the cutoff frequency, the phase response is practically linear and can be calculated by using the formula $\theta = 293.17 \times f/f_C$. At a frequency 10 times the cutoff, the phase shift would be 29.317 degrees and 2.9317 degrees at 100 times of the cutoff frequency (not shown on Curve A).

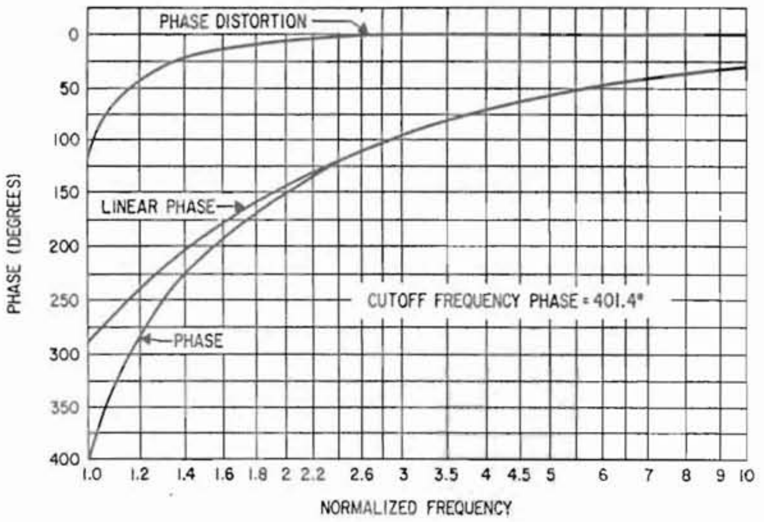

Figure 2.3 Phase Response

SECTION 3
IEEE-488 STD (GPIB) PROGRAMMING

3.1 INTRODUCTION

Complete information on remote programming is incorporated in the Model 3905/3916 Mainframe operating and instruction manual. Detailed information about the filter type, modes of operation and device clear command not described in the 3905/3916 manual are specified below.

3.2 FILTER TYPE

1	Elliptical

3.3 MODE OF OPERATION

1	High-Pass
2	By-Pass

3.4 DEVICE CLEAR

When the device clear command is sent, the following parameters are set as follows:

MODEL	31-1	31-2	31-3
INPUT GAIN	0dB	0dB	0dB
OUTPUT GAIN	0dB	0dB	0dB
CUTOFF FREQUENCY	1kHz	100Hz	10Hz

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SECTION 4
INCOMING ACCEPTANCE

4.1 INTRODUCTION

The following procedure should be used to verify that the Model 31 filter module, inserted in a Model 3905 or 3916 Mainframe is operating within specifications.

These checks may be used for incoming acceptance and periodic performance checks. Tests must be made with all covers in place on the Model 3905/3916, with filter modules inserted, operating for a minimum time of ½ hour to reach thermal equilibrium. If not operating within specifications refer to Section 5, Calibration, before attempting any detailed maintenance. Before testing, follow the initial set-up and operating procedures given in Section 2 of this manual, or if necessary, in Section 2 of the Model 3905/3916 Operating and Maintenance Manual.

4.2 TEST EQUIPMENT REQUIRED

The test equipment below is required to perform the following tests:

a. RC Oscillator, with a frequency range of .01Hz to 1MHz. Krohn-Hite Model 4100A or equivalent.

b. RC Oscillator, with a frequency range of 10Hz to 10MHz. Frequency response of ±0.025dB from 10Hz to 500kHz. Krohn-Hite Model 4200B/4300B or equivalent.

c. Oscilloscope, bandwidth of DC to 50MHz, vertical input sensitivity of 5mV/cm, Tektronix 465 or equivalent.

d. AC Voltmeter, capable of measuring 100μV to 10Vrms, Fluke Model 8920A or equivalent.

e. Frequency Counter.

4.3 PRE-FILTER AND POST-FILTER GAIN ACCURACY

Set all filters to a cutoff frequency of 10Hz with 0dB Input and Output gain and apply 50mVrms at 1kHz to INPUT of each filter module. Monitor the OUTPUT with an ac voltmeter and record the OUTPUT voltage. Set gain of pre-filter (input) to 10dB, 20dB, 30dB and 40dB. Fluke on the OUTPUT of the filter should be within ±0.2dB of all four pre-filter gain settings.

Set gain of pre-filter and post-filter to 0dB and apply a 0.7Vrms signal to the INPUT of the filter. Monitor the OUTPUT of the filter with an ac voltmeter and record the OUTPUT voltage. Set gain of post-filter (output) to 10dB and 20dB. Fluke on the OUTPUT of the filters should be within ±0.2dB of both post-filter gain settings.

4.4 PASSBAND GAIN AND DISTORTION TESTS

To verify that the filter is functioning correctly in the passband, set all filter modules to a cutoff frequency of 10Hz and pre-filter and post-filter amplifier gain to 0dB (unity gain). Apply a 7Vrms signal at 1kHz to the INPUT of each filter module and monitor the OUTPUT of each filter with a scope, ac voltmeter and a distortion analyzer. The OUTPUT should be within ±0.2dB of the INPUT and the distortion should be <0.1%.

CAUTION *If the distortion is excessive, verify that the distortion of the oscillator being used is <0.1%.*

4.4.1 LOW BANDS RIPPLE RESPONSE (Figure 4.1)

Connect oscillator at 3Vrms at 9kHz to INPUT of filter. Set front panel channel indicator to the channel of the filter under test. Set filter to 90Hz cutoff frequency with 0dB of INPUT and OUTPUT gain. Monitor OUTPUT of filter with ac voltmeter. Record OUTPUT voltage and use as reference.

Check the response of the three peaks at 189Hz, 110Hz and 90.9Hz. Check the response of the three valleys at 363Hz, 134Hz and 97.1Hz. The adjacent peak-to-valley ripple should not exceed 0.4dB. If necessary, refer to Section 5, Calibration.

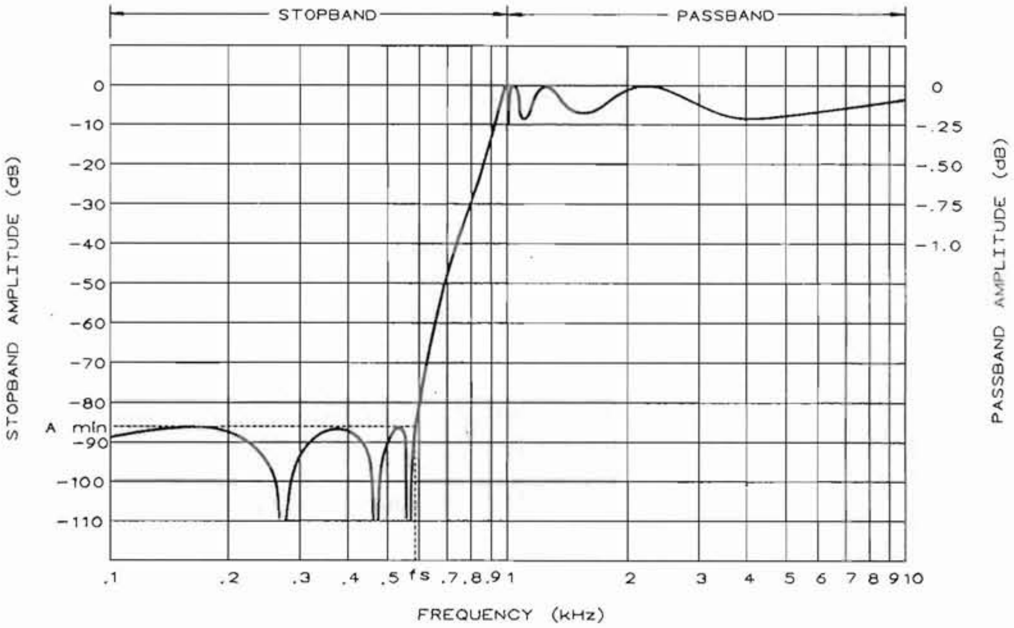

Figure 4.1 Normalized Ripple Response

4.4.2 HIGH BAND RIPPLE RESPONSE (Model 31-1)

Connect oscillator at 3Vrms at 10kHz to INPUT of filter. Set front panel channel indicator to the channel of the filter under test. Set the filter to 100Hz cutoff frequency with 0dB Input and Output gain. Monitor OUTPUT of filter with ac voltmeter. Record OUTPUT voltage and use as reference. Set the filter to 10kHz.

Check the response of the three peaks at 21.0kHz, 12.2kHz and 10.1kHz. Check the response of the three valleys at 40.3kHz, 14.9kHz and 10.8kHz. The adjacent peak-to-valley ripple should not exceed 0.4dB. If necessary, refer to Section 5, Calibration.

4.4.3 HIGH BAND RIPPLE RESPONSE (Model 31-2)

Connect oscillator at 3Vrms at 1kHz to INPUT of filter. Set front panel channel indicator to the channel of the filter under test. Set the filter to 10Hz cutoff frequency with 0dB Input and Output gain. Monitor OUTPUT of filter with ac voltmeter. Record OUTPUT voltage and use as reference. Set Filter to 1kHz.

Check the response of the three peaks at 2.10kHz, 1.22kHz and 1.01kHz. Check the response of the three valleys at 4.03kHz, 1.49kHz and 1.08kHz. The adjacent peak-to-valley ripple should not exceed 0.4dB.

4.4.4 HIGH BAND RIPPLE RESPONSE (Model 31-3)

Connect oscillator at 3Vrms at 100Hz to INPUT of Filter. Set front panel channel indicator to the channel of the Filter under test. Set the Filter to 1Hz with 0dB Input and Output gain. Monitor OUTPUT with ac voltmeter. Record OUTPUT voltage and use as reference. Set Filter to 100Hz.

Check the response of the three peaks at 210Hz, 122Hz and 101Hz. Check the response of the three valleys at 403Hz, 149Hz and 108Hz. The adjacent peak-to-valley ripple should not exceed 0.4dB.

4.5 STOPBAND ATTENUATION

4.5.1 BAND 1

Model 31-1
Set Filter to 90Hz with 0dB Input and 20dB Output gain. Set oscillator to 52.3Hz at 7Vrms. Connect scope to OUTPUT. Signal should be less than 20mV p-p. Set oscillator to 48.0Hz, 34.8Hz and 12.9Hz. Signal should be less than 20mV p-p (Disregard noise contained with signal or use a 10kHz low-pass filter).

Model 31-2
Do in same manner as 31-1 setting Filter to 9Hz and oscillator to 5.23Hz, 4.80Hz, 3.48Hz and 1.29Hz.

Model 31-3
Do in same manner as 31-1 setting Filter to 0.9Hz and oscillator to 0.523Hz, 0.480Hz, 0.348Hz and 0.129Hz.

4.5.2 BAND 2

Model 31-1
Same as Band 1 setting Filter to 100Hz and oscillator to 58.1Hz, 53.4Hz, 38.6Hz and 14.3Hz.

Model 31-2
Same as Band 1 setting Filter to 10Hz and oscillator to 5.81Hz, 5.34Hz, 3.86Hz and 1.43Hz.

Model 31-3
Same as Band 1 setting Filter to 1Hz and oscillator to 0.581Hz, 0.534Hz, 0.386Hz and 0.143Hz.

4.5.3 BAND 3

Model 31-1
Same as Band 1 setting Filter to 1kHz and oscillator to 581Hz, 534Hz, 386Hz and 143Hz.

Model 31-2
Same as Band 1 setting Filter to 100Hz and oscillator to 58.1Hz, 53.4Hz, 38.6Hz and 14.3Hz.

Model 31-3
Same as Band 1 setting Filter to 10Hz and oscillator to 5.81Hz, 5.34Hz, 3.86Hz and 1.43Hz.

4.5.4 BAND 4

Model 31-1
Same as Band 1 setting Filter to 10kHz and oscillator to 5.81kHz, 5.34kHz, 3.86kHz and 1.43kHz.

Model 31-2
Same as Band 1 setting Filter to 1kHz and oscillator to 581Hz, 534Hz, 386Hz and 143Hz.

Model 31-3
Same as Band 1 setting Filter to 100Hz and oscillator to 58.1Hz, 53.4Hz, 38.6Hz and 14.3Hz.

4.6 CUTOFF FREQUENCY ACCURACY

Connect oscillator at 3Vrms at 900Hz to Input. Set Filter to 10Hz with 0dB Input and Output gain. Monitor OUTPUT with ac voltmeter. Record voltage at Output. Set Filter to 900Hz. Adjust Input frequency near 891Hz to obtain –0.22dB (–0.077V). Frequency should read between 873Hz and 909Hz.

Set Filter and oscillator to 90Hz — adjust oscillator frequency for –0.22dB (–0.077V). Frequency should read between 87.3Hz and 90.9Hz.

Model 31-1 and 31-2 Only

Set Filter and oscillator to 1kHz — adjust oscillator frequency for –0.22dB (–0.077V) Frequency should read between 970Hz and 1.01kHz.

Model 31-1 Only

Set Filter and oscillator to 10kHz — adjust oscillator frequency for –0.22dB (–0.077V). Frequency should read between 9.70kHz and 10.1kHz.

4.7 NOISE MEASUREMENTS (2MHz Detector Bandwidth)

Short the Input. Connect ac voltmeter to OUTPUT of Filter. Set Filter to 900Hz with 0dB Input and Output gain. Output should be less than 500μVrms.

Set to 0dB Input and 20dB Output gain. OUTPUT should be less than 5mVrms.

Set to 40dB Input and 20dB Output gain. OUTPUT should be less than 100mVrms.

Set to 40dB Input and 0dB Output gain. OUTPUT should be less than 10mVrms.

Model 31-1 Only

Set Filter to 99kHz with 0dB Input and Output gain. OUTPUT should be less than 1mVrms.

Set to 0dB Input and 20dB Output gain. OUTPUT should be less than 10mVrms.

Set to 40dB Input and 20dB Output gain. OUTPUT should be less than 50mVrms.

Set to 40dB Input and 0dB Output gain. OUTPUT should be less than 5mVrms.