Model 3901

GPIB Programmable Elliptical Filter
115dB/Octave Slope
1Hz to 99kHz
HP, LP, BP, BR

Operating Manual

KROHN-HITE CORPORATION

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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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Model 3901

1Hz to 99kHz
Low-Pass, High-Pass
Band-Pass, Band-Reject
GPIB Programmable Elliptical Filter

Serial No. ______________________

Operating Manual

15 Jonathan Drive, Unit 4, Brockton, MA 02301-5566 U.S.A.
Tel: (508) 580-1660; Fax: (508) 583-8989
www.krohn-hite.com; info@krohn-hite.com

Ver. 05.16.05

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Section 1
General Description

1.1 Introduction

The Krohn-Hite Model 3901 programmable, two channel, high-pass/low-pass elliptical filter/voltage gain amplifier is one of a family of programmable filters from Krohn-Hite. As an elliptical filter, the Model 3901 has two independent filter channels, one low-pass and the other high-pass, allowing for band-pass operation with a tunable cutoff frequency range from 1Hz to 99kHz and a role-off rate of 115dB/octave.

Each filter section has a minimum stopband attenuation of >80dB and a passband ripple of typically 0.22dB. The 3901 provides either a single-ended or differential input with a common mode rejection of >60dB. Input gains up to 40dB in 10dB steps and output gains to 20dB in 10dB steps are also provided. The 3901 will accept input signals of ±10V peak at 0dB gain and has selectable ac or dc coupling. The filter is GPIB bus programmable and is complimented with non-volatile memory for storage of up to 99 front panel set-ups. Overload detectors are standard and assist the user in detecting excessive input signals or incorrect gain settings.

The 3901q is also a programmable voltage gain amplifier for applications that require a low-noise amplifier. The amplifier has a bandwidth of 1MHz and gains to 60dB, selectable in 10dB steps, and a wideband noise <100µV.

Typical applications for the Model 3901 are: distortion measurements, separating specific bandwidths of information, enhancing signal-to-noise ratio, low noise pre-amplification and many more.

1.2 Specifications

1.2.1 Function

Two independent filter channels. Channel 1, high-pass or amplified by-pass; Channel 2, low-pass or amplified by-pass; one channel of band-pass or band-reject with external connections.

1.2.2 Filter Mode

Type: 7-pole, 6-zero elliptical.

Attenuation: 115dB/octave.

Passband Ripple: 0.22dB typical, 0.4dB max.

Tunable Frequency Range fc: 1Hz to 99kHz

Frequency Control: Keypad entry or increment, decrement keys.

Bandwidth: High-Pass, fc to upper 3dB cutoff, >500kHz at 1Vrms with 0dB gain. Low-Pass, dc coupled, dc to fc; ac coupled, 0.32Hz to fc.

Relative Gain at fc: Low-Pass, –0.22dB at 1.01fc nominal; High-Pass, –0.22dB at 0.99fc nominal.

Cutoff Frequency Accuracy: ±2%.

Frequency Resolution: 1Hz, 1Hz to 99Hz; 10Hz, 100Hz to 990Hz; 100Hz, 1kHz to 9.9kHz; 1kHz, 10kHz to 99kHz.

Stopband Attenuation: >80dB.

Stopband Frequency (fs): Low-Pass, 1.7fc; High-Pass, 0.59fc.

Insertion Loss: 0dB ±0.1dB.

Pre-Filter Gain: 0dB, 10dB, 20dB, 30dB, 40dB ±0.2dB.

Post-Filter Gain: 0dB, 10dB, 20dB ±0.2dB.

Input Coupling: ac or dc.

Wideband Noise (RFI): min. gain, 1kHz cutoff, <400µV, 99kHz cutoff, <1mV; Max. gain, <20µV.

Harmonic Distortion: –80dB at 1kHz.

Inter-Modulation Distortion: –80dB below full scale volts at 70kHz and 90kHz input frequency.

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

DC Stability: Typically ±10mV/°C.

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

1.2.3 Amplifier Mode (Each Channel)

Bandwidth: dc coupled, dc to >1MHz min gain, >400kHz max. gain; ac coupled, 0.32Hz to >1MHz min gain, >400kHz max gain.

Insertion Loss: 0dB ±0.05dB.

Gain: 10dB to 60dB in 10dB steps ±0.1dB.

Input: Differential or single-ended +(in phase), –(inverted).

CMRR: >60dB to 10kHz; approximately 50dB at 100kHz.

Sensitivity: 10mV peak with 60dB total gain for 10V peak output.

Maximum Input: ±10V peak at 0dB gain reduced in proportion to gain setting.

Impedance: 1 megohm in parallel with 100pf.

Coupling: ac or dc.

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

Output: Maximum Voltage (o.c.): 7Vrms to 200kHz; 3Vrms to 500kHz; 1Vrms to 1MHz.

Impedance: 50 ohms.

DC Offset: Adjustable to zero volts.

Harmonic Distortion (1V output): –80dB (0.01%) to 10kHz; –60dB (0.1%) to 100kHz..

Wideband Noise (referred to input, 2MHz BW detector): 100µV min. gain; 20µV max. gain.

DC Stability (RFI): Typically ±10mV/°C.

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

1.2.4 General

Memory: 99 selectable groups; memory is non-volatile battery-backed CMOS.

Overload Modes: Three selectable modes; non-latching, that monitors all channels and displays the first channel to have an overload; latching, that maintains the overload display until it is cleared; and no indications.

Overload Indicators: LEDs for input and output. Gain display flashes when overload occurs on displayed channel.

Input Indicators: Green LEDs to indicate active input BNC.

Self-Test Diagnostics: MPU checks unit upon power-up. Display indicates failure mode.

Displays: 7 segment, green, LED; 0.3" high.

Remote Programming: IEEE-488.1 interface. Subsets: SH1, AH1, T6, L4, SR1, RL1, PP1, DC1, DT0, C0, E1.

Operating Temperature: 0ºC to 50ºC.

Isolation to Chassis: ±100Vdc.

Storage Temperature: –20°C to 70°C.

Input/Output Connectors: BNC, front and rear.

Power Requirements: 90-132/180-264 volts ac, 50Hz-400Hz, 40 watts.

Dimensions: 3.5" (9cm) high, 8.5" (21.8cm) wide, 18" (46.2cm) deep.

Weights: 12 lbs (5.4kg) net; 14 lbs (6.3kg) shipping.

Accessories: 6 foot, 3 terminal line cord; operating manual.

1.2.5 Options

Rack Mounting Kit: Part No. RK-37, permits installation of the Model 3901 into a standard 19" rack spacing.

Band-Reject Kit: Part No. BR-30, connectors and cables to adapt two channels for series (band-pass) or parallel (band-reject) operation.

Extended 1 Year Warranty: Part No. EW3901.

Specifications apply at 25°C ±5°C.

Specifications subject to change without notice.

1.3 Shipping to Krohn-Hite for Repair or Calibration

All shipments of Krohn-Hite products should be made via United Parcel Service (UPS) or "Best Way" prepaid. The product should be shipped in its original shipping carton; or if not available, use any suitable container that is rigid and of adequate size. If a substitute container is used, the product should be wrapped in 4 inches of excelsior or similar shock-absorbing material.

1.4 Claim for Damage in Shipment to Original Purchaser

The product should be thoroughly inspected immediately upon original delivery to purchaser. All material in the container should be checked against the enclosed packing list. Krohn-Hite will not be responsible for shortages against the packing list unless notified immediately. If the product is damaged in any way, a claim should be filed with the carrier immediately. (To obtain a quotation to repair the damage, contact Krohn-Hite at (508) 580-1660.) Final claim and negotiations with the carrier must be completed by the customer.

1.5 External Cleaning

Note: To avoid electrical shock or instrument damage, never get water inside the case. To avoid instrument damage, never apply solvents.

Should the Model 3901 need cleaning, wipe the instrument with a cloth that is lightly dampened with water or a mild detergent solution.

Section 2

Operation

2.1 Introduction

The Model 3901 is an elliptical filter with two independent channels, one low-pass and one high-pass, covering the frequency range from 1Hz to 99kHz. All filter parameters are programmable via front panel keyboard controls or remotely over the GPIB interface bus.

The filter has two modes of operation: filter mode and amplifier mode. Each mode will be explained in detail in this section.

2.2 Turn-On Procedure

The Model 3901 line voltage range has been either preset for 115V or 230V operation. To change this setting, remove the bottom cover to expose the line switch. Be sure to change the fuse to the proper rating for the line switch setting selected.

Make certain the power switch on the front panel is set to off.

Plug the line cord into the unit, then the ac outlet.

If the Model 3901 is to be programmed remotely, connect the GPIB bus cable to the rear panel connector of the 3901.

After reviewing the Self-Test feature below, turn on the Model 3901.

2.3 Self-Test

When the Model 3901 is turned on, the microprocessor performs a self-test routine whereby the entire RAM and ROM operation is verified. During the test, the front panel LEDs and Displays will light sequentially. If there is a malfunction on the microprocessor board, such as a defective RAM or ROM, the sequence will stop and the word “bad” will appear in the display followed by a number 1, 2 or 3. The table below give a description of each failure.

Table 2.1 Self-Test Part Failure

Display Indication	Bad Internal Part
“Bad 1”	U210
“Bad 2”	U209
“Bad 3”	U208

When the self-test program is complete, the Model 3901 will return to the last set-up prior to turning the unit off. The 3901 is now ready to be programmed for operation.

2.4 Front Panel Controls and Display

2.4.1 Data Keys and Display

Data entry keyboard controls [0] to [9] and [.] set the numeric value of the parameter selected. To enter 1.5kHz, press the [1][.][5] keys and the parameter key [KILO] and [FREQ]. The cutoff frequency entered will be indicated in the display.

2.4.2 Parameter and Control Keys

[KILO]	When pressed, multiplies the numeric value of the keyboard entry by 10^3.
[MEGA]	When pressed: multiplies the numeric value of the keyboard entry by 10^6.
[FREQ]	When pressed, enters and/or displays frequency in Hertz.
[TYPE]	When pressed, display indicates the filter type, “EL - 7” (7-Pole Elliptical).
[MODE]	When pressed, display indicates the mode of operation for the channel displayed.
[RECLL]	When preceded by a number, it will recall the entire instrument set-up from the memory location selected. When first pressed, the display indicates the number of the next memory location to be recalled. For example, the display will indicate the following: “n=09”. Pressing the [RECLL] key again will recall the entire instrument set-up from the memory location “09”. When pressed to indicate the next memory location to be recalled only, pressing the [CE] (clear entry key) will restore the display to the cutoff frequency setting.
[ALL CH]	Used on other models.
[SHIFT]	The [SHIFT] key in conjunction with other keys,

Overload Detection	When [SHIFT][MODE] is first pressed, the display will indicate the overload mode currently selected. Pressing a number form [1] to [3] then [SHIFT][MODE] will select the following overload conditions. [1}[SHIFT][MODE] will select no overload indication. [2][SHIFT][MODE] will select the non-latching mode. The 3901 will monitor all channels and display the first channel to have an overload condition. [3][SHIFT][MODE] will select the latching mode. In this mode, the 3901 will maintain the overload display until it is cleared.
Store	When [SHIFT][RECLL] is first pressed, the display indicates the number of the next memory location available. For example, the display will indicate the following: “n=09”. Pressing [RECLL] again will store the entire instrument set-up into that memory location. If another location is desired, enter that location on the keyboard and then press [SHIFT][RECLL]. When [SHIFT][RECLL] is preceded by a number from [0] to [98], the 3901 will store the entire instrument set-up into the memory location selected. The maximum number of memory groups is 99. When [SHIFT][RECLL] is pressed to indicate the next memory location only, the clear entry [CE] key restore the display to the cutoff frequency setting.
AC/DC Coupling	Pressing the [SHIFT] key followed by the [TYPE] key will display the input coupling, indicating “AC” or “dC”, and will alternate between the two.
GPIB Address	When the [SHIFT] key followed by the [MEGA] key are pressed, the display will indicate the existing GPIB address setting. To select a different address setting, enter a number from [0] to [30] followed by the [SHIFT][MEGA] keys. See Section 3 for GPIB address information.
GPIB Line Termination	When the [SHIFT]followed by the [ALL CH] are pressed, the display will indicate the GPIB Line Termination code sequence. To select a different line termination, enter a number from [0] to [4] followed by the [SHIFT][ALL CH] keys. See Section 3 for line termination information.
Software Version	When the [SHIFT] key followed by the [KILO] key are pressed, the display will indicate the software version installed.

[CE]	When entering a numeric value, but not specifying a parameter, pressing the [CE] key will function as an error correction procedure and restore the display to the current frequency cutoff setting. When a numeric value and its parameter has been entered and the numeric value is then changed, pressing [CE] will restore the display to the previous value of that parameter. When either the [STORE] or [RECLL] key is pressed, the next memory location will be indicated on the display. Pressing the [CE] key will restore the display to the current cutoff frequency setting. If the Model 3901 is operating over the GPIB bus (front panel remote LED is “on”), pressing the [CE] key will return the 3901 to local operation.

2.4.3 Channel Selection

The up [⇧] or down [⇩] control keys below the CHANNEL display alternates the channel setting.

2.4.4 Cutoff Frequency

The Data Entry Keyboard controls [0] through [9] and [.] set the numeric value of the cutoff frequency desired. To select 1.5kHz, press the [1][.][5][KILO][FREQ]. The cutoff frequency for the channel selected will be indicated in Hertz on the four digit display. The [KILO] and [FREQ] keys will be lit.

2.4.5 Input Gain (Pre-Filter)

The up [⇧] or down [⇩] INPUT GAIN SET controls increase and decrease the input amplifier by 10dB. The two digit display will either indicate 0dB, 10dB, 20dB, 30dB or 40dB.

2.4.6 Output Gain (Post-Filter)

The up [⇧] or down [⇩] INPUT GAIN SET controls increase and decrease the output amplifier by 10dB. The two digit display will either indicate 0dB, 10dB or 20dB.

2.4.7 Digit Select/ Increment and Decrement

When the [SHIFT] key is pressed, followed by the digit select up [⇧] or down [⇩] keys, the display will intensify the first or second digit. Pressing the [SHIFT] key followed by the up [⇧] or down [⇩] again, will intensify the next digit or will turn the DIGIT SELECT off. Pressing up [⇧] or down [⇩] keys will then increment or decrement the intensified digit.

2.4.8 Key Click Feature On/Off

When the [SHIFT] key is pressed, followed by the up [⇧] key under the CHANNEL DISPLAY, the Key Click feature will either turn on or off.

2.5 Rear Panel Controls

2.5.1 Introduction

The Model 3901 rear panel consists of the following:

4 input BNC connectors
2 output BNC connectors
DC level adjustments
Fuse holder
GPIB bus connector
AC receptacle

2.5.2 BNC Connectors and Indicators

2.5.2.1 Input Connectors

The Model 3901 has four input BNC connectors on both the front and rear panels. The inputs are labeled on the front panel CH1+ and CH1- for high-pass and CH2+ and CH2- for low-pass; the rear panel is simply labeled - and + for each input respectively.

Note: a slide switch is provided on the rear panel for selecting the input BNC connector desired. The selections are +, DIFF, and - for each channel. The + is a non-inverting input, the - is an inverting input and the DIFF is for differential operation.

2.5.2.2 Output Connectors

The Model 3901 has two output BNC connectors on both the front and rear panels.

2.5.2.3 Indicators

Four LED indicators are provided on the front panel to indicate which input BNC is active. A slide switch on the rear panel selects the desired input.

2.5.3 DC Level Adj (Rear Panel)

There are two DC Level potentiometers located on the rear panel for adjusting the DC level at the output BNC connector.

Proper procedure for adjusting input and output dc levels can be found in Section 4 - Incoming Acceptance.

2.5.4 Power

The Power Receptacle is a standard 3-pin ac connector. The fuse rating is a 0.5 amp for 115V operation and 0.25 amp for 230V operation. To change the ac line voltage from 115V to 230V, refer to Section 2.2.

2.5.5 GPIB Connector

The 3901 GPIB connector is a standard 24-pin D-type IEEE-488 interface. The subsets are as follows:

SH1, AH1, T6, L4, SR1, RL1, PP1, DC1, DT0, C0 and E1.

2.6 Filter Operating Characteristics

2.6.1 Introduction

The Model 3901 is a filter with one high-pass channel and one low-pass channel that function independently. As a filter, each channel has a roll-off rate of 115dB/octave, and as an amplifier each channel becomes a voltage gain amplifier with a total gain of 60dB. Gain steps are adjustable in 10dB steps.

2.6.2 Amplitude Response

Each channel of the 3901 has a roll-off rate of 115dB/octave. The amplitude response characteristics is shown in Figure 2.1.

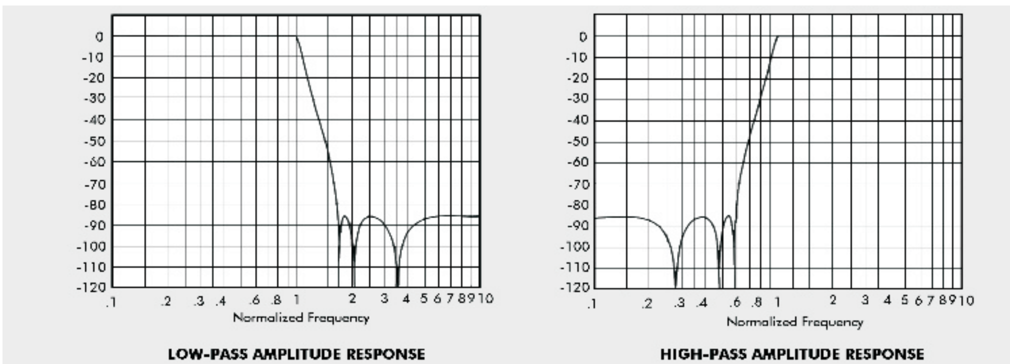


Figure 2.1 - Normalized Amplitude Response

2.6.3 Low-Pass Phase Response

The phase characteristics of the Model 3901 is shown in Figure 2.2. When in the low-pass mode, the 3901 provides output phase relative to the input over a 10:1 frequency range.

When the input frequency of the filter is less than 4/10 the cutoff frequency, the phase response is practically linear and can be calculated by using the formula $\Theta = -293.17 \times \frac{f}{f_c}$, which is referred to as the zero frequency phase response. At a frequency 1/10 the cutoff, the phase shift would be -29.317º and -2.9317º at 1/100 of the cutoff frequency (not shown).

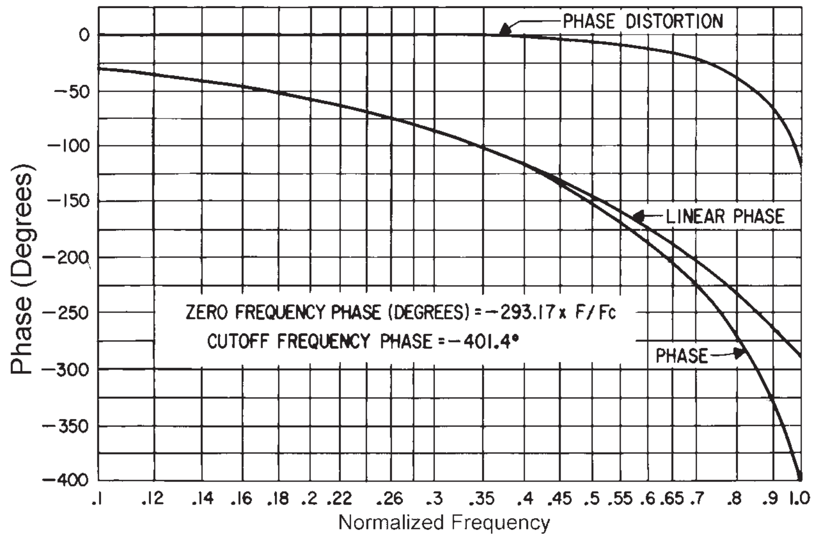


Figure 2.2 - Normalized Low-Pass Phase Response

2.6.4 High-Pass Phase Response

The high-pass output characteristics of the Model 3901, shown in Figure 2.3, provides output phase relative to the input over a 10:1 frequency range.

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 $\Theta = -293.17 \times \frac{f}{f_c}$. At a frequency 10 times the cutoff frequency, the phase shift would be 29,317º. At 100 times the cutoff frequency, the phase shift would be 2.9317º.

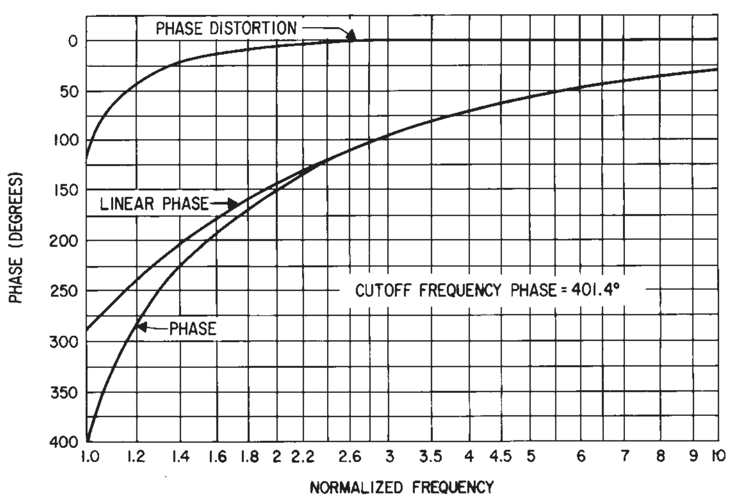


Figure 2.3 - Normalized High-Pass Phase Response

2.6.5 Group Delay

Group delay shown in Figure 2.4 for low-pass, is defined as the derivative of radian phase with respect to radian frequency, which is the slope of the phase curve.

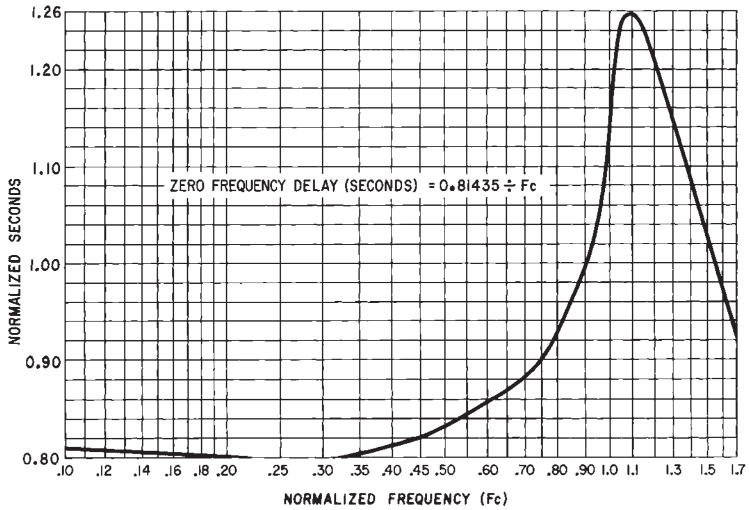


Figure 2.4 - Normalized Group Delay

In numeric terms, the zero frequency phase slope is -293.17º/Hz when normalized for a cutoff frequency of 1Hz. This will be 2π times greater in º/Hz for a cutoff of 1 radian/sec or 1842º/Hz. Dividing by 360 converts º/Hz to radians/radians-per-sec yields a group delay time of 5.12s.

2.6.6 Transient Response

The normalized response for a unit step voltage applied to the low-pass input of the Model 3901 is shown in Figure 2.5. A delay time in seconds for the output of the filter to reach 50% of its input voltage is determined by the formula 0.869/fc. With a cutoff frequency fc of 1Hz, the delay time on the response curve is 0.869 seconds. Since the delay time is inversely proportional to frequency, the delay time for fc of 10Hz would be 1/10 that of 1Hz or 0.0869 seconds.

The time for the output voltage of the filter to increase from 10% to 90% of its input voltage is determined by the formula 0.541/fc or 0.541 seconds for a normalized frequency of 1Hz. The inverse relationship reduces the time delay proportionally at higher cutoff frequencies.

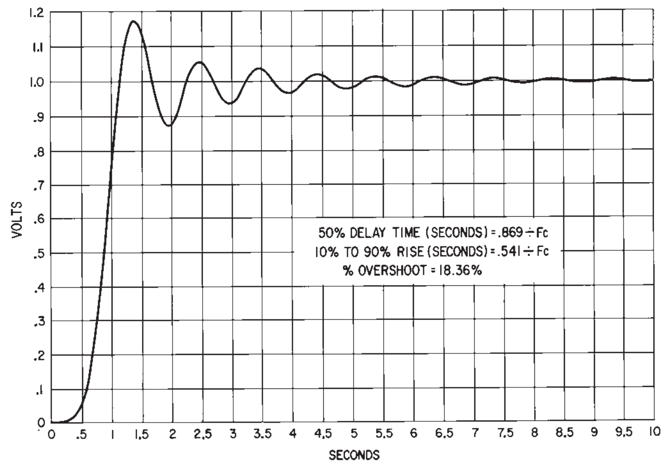


Figure 2.5 - Normalized Unit Step Response

2.6.7 Impulse Response

The normalized input impulse response of the Model 3901 low-pass is shown in Figure 2.6. An impulse will produce a damped sinewave whose maximum amplitude overshoot will be 30% of the input pulse amplitude, and the damped sinewave will approach zero amplitude in approximately 10 cycles.

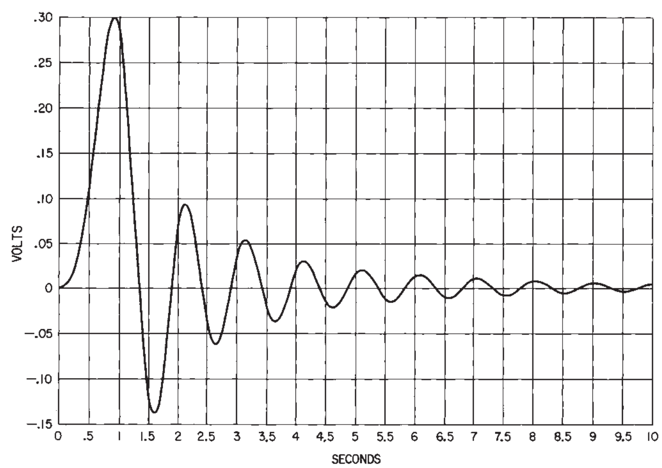


Figure 2.6 - Normalized Impulse Response

2.6.8 Variable Band-Pass Operation

Variable band-pass operation can be obtained easily by externally connecting the output of channel 1 to the input of channel 2. Channel 1, being the high-pass filter, will set the low-cutoff frequency. Channel 2, being the low-pass filter, will set the high-cutoff frequency. This coincides with the customary graphical representation of a band-pass filter. This may be disadvantageous though, since the output is dc coupled and not ac coupled, which is desirable in some applications where minimum dc fluctuations on the output are needed.

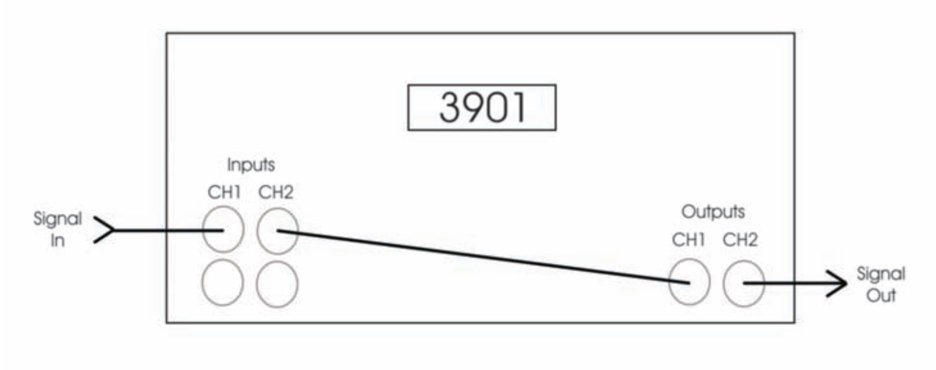
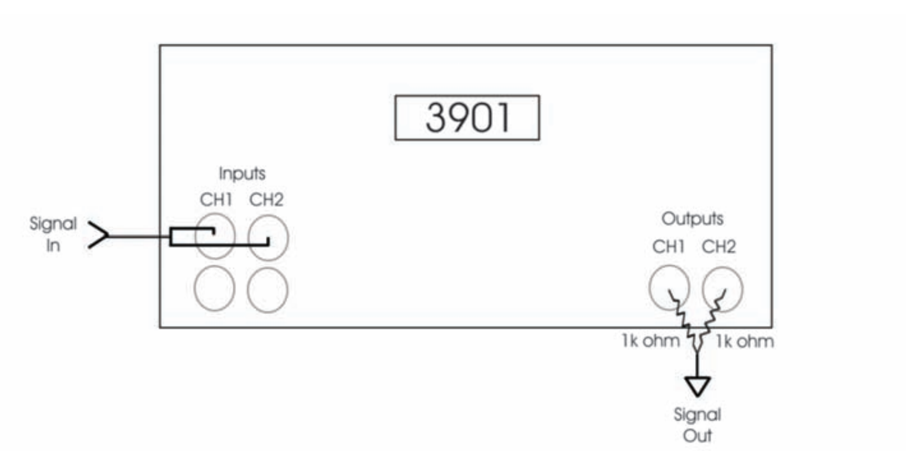


Figure 2.7 - Band-Pass Configuration

The minimum passband is obtained by setting channel 1 frequency equal to channel 2 frequency.

2.6.9 Band-Reject Operation

Variable band-reject operation can be obtained by externally connecting in parallel the input signal to both channels. The output from both channels should be added together through two equal external resistors in series with each output (an external band-reject kit, part no. BR-30, is available and consists of matched cables and connectors to adapt the filter channels for parallel operation). The junction of the two resistors becomes the output for the filter. If the resistors are not equal, the gain on one side of the notch will be different from the other.



Section 3

GPIB Programming

3.1 Introduction

The Model 3901 remote programming interface accepts both ASCII data commands and IEEE-488 standard commands (ATN true) for control of the unit remotely.

In presenting the information required to program the Model 3901 via the GPIB bus, this manual presupposes a user knowledge of both ASCII data and IEEE-488 bus commands.

3.2 Preliminary Programming Information

3.2.1 GPIB Primary Bus Address

The GPIB primary address and software line-termination-character-sequence (LTCS) selection is set via the front panel keyboard as listed in Table 3.1 and 3.2. These two parameters are stored in non-volatile memory and will be remembered by the 3901 indefinitely, even when the power to the unit is removed. They do not need to be re-entered each time the unit is turned on.

The LTCS affects the GPIB in the Talker mode only (data output from the 3901 to the GPIB). After the printable characters have been sent, non-printable characters, such as carriage return (CR) and line feed (LF), are often required to achieve the desired results in various computers. Table 3.2 lists the various key sequences with the LTCS it selects.

Setting and Displaying the GPIB Primary Address

Function	Keyboard Entry
To set the primary address from 0 to 30	[X][SHIFT][MEGA]
To display the primary address	[SHIFT][MEGA]

Table 3.1

Line-Termination-Character-Sequence	
Line-Termination-Character-Sequence	**Keyboard Entry**
None (EOI only)	[0][SHIFT][ALL CH]
Carriage return (with EOI)	[1][SHIFT][ALL CH]
Line feed (with EOI)	[2][SHIFT][ALL CH]
Carriage return followed by line feed (with EOI)	[3][SHIFT][ALL CH]
Line feed followed by carriage return (with EOI)	[4][SHIFT][ALL CH]
Display present LTCS	[SHIFT][ALL CH]

Table 3.2

3.2.2 GPIB Bus Interface Programming Connector

The rear panel programming connector, labeled "IEEE-488 PORT" (Figure 3.1), is the standard bus interface connector as specified in the IEEE-488 STD.

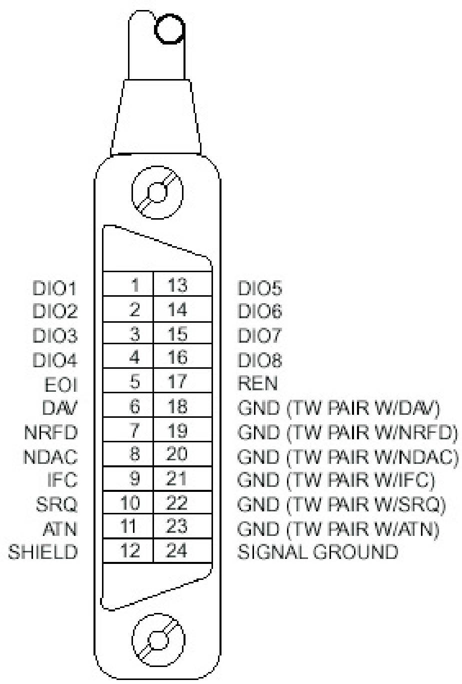


Figure 3.1
Rear panel GPIB Connector

3.3 ASCII Data Commands

3.3.1 Format

The Model 3901 employs free-format software commands, allowing the user to program a specific function in several different ways. See Section 3.3.3

3.3.2 Types of Data Commands

A. Commands fall into two types:

a. Those involving numeric parameters

b. Those that do not.

Commands that involve numeric data contain 3 types of fields.

1. Numeric: Numeric fields may be floating point or scientific notation.

1	=	1.0
1.0	=	1.0
2.7E3	=	2.7×10^{3}
-2E3	=	-2×10^{3}
2E-3	=	2×10^{-3}

2. Multiplier: "KILO", "MEGA"

3. Parameter: Parameter (frequency, gain, channel, etc.) is included in Section 3.3.3.

a. Delimiters which may separate commands are the following: ;, :, /, \

b. Two consecutive character strings (i.e. parameter and multiplier) must have a space between them or they will be treated as one string.

c. The 3901 uses an internal 32 character buffer for command processing. A line may be composed of multiple commands, separated by delimiters mentioned above. No commands are executed until the line is terminated with a line feed ASCII character (Hex 0A) or carriage return (Hex 0D) or by sending the end-or-identify (EOI) command with the last character.

3.3.3 Table of ASCII Commands

In this section there are characters underlined and not underlined. Underlined characters MUST BE SENT for the command to be recognized properly. Any additional characters may be sent once all the underlined characters are sent. Commands are case sensitive; upper case characters MUST BE USED.

Model 3901 GPIB Commands

Command	Character String	Comment
Input Gain	IG	sets input gain
	IU	increases input gain (up)
	ID	decreases input gain (down)
Frequency	F	frequency
	H	frequency (Hz)
	K	kilo (10^3 multiplier)
	ME	mega (10^6 multiplier)
Channel	CH	set channel
	CU	next channel (up)
	CD	next channel (down)
Output Gain	OG	sets output gain
	OU	increases output gain (up)
	OD	decreases output gain (down)
Type	TY1	Elliptical
Mode	M1	high-pass
	M2	low-pass
	M3	gain
Coupling	AC	ac coupling
	D	dc coupling
Store	ST	store
Recall	R	recall
All Channel	AL	all channel mode
Miscellaneous	CE	clear entry
	OV	overflow (1, 2, 3)
	Q	reports board model number(s)
	SRQON	GPIB service request on
	SRQOF	GPIB service request off
	V	report model number and software version

3.3.4 Examples

3.3.4.1 Example 1

To set channel 1 to10dB input gain, 2kHz cutoff frequency, 0dB output gain, send the following: CH1;10IG,2K,0OG<LF>

3.3.4.2 Example 2

To change the cutoff frequency to 150Hz:

150H	
or	150ƀHZ **
	150F
	.15K
	F150
	H150
	HZ150
	K.15
	1.5E2HZ
	F1.5E2

3.3.4.3 Example 3

To read back the settings of channel 1:

Data sent to filter: CH1

Data received from filter: 10ƀ150.0E+0ƀ01.1ƀ00ƀACƀ

Interpretation:

10dB input gain
150Hz cutoff frequency
channel 1
0dB output gain
ac coupled

** ƀ represents a space

3.4 IEEE-488 Standard Commands

These commands are sent with ATN true as described in the standard.

3.4.1 Multi-Line Messages

IEEE-488 Command	Mnemonic	Result
My Listen Address	MLA	Enables unit to receive data.
Unlisten	UNL	Disables unit from receiving data.
My Talk Address	MTA	Designates unit to send data.
Untalk	UNT	Disables unit from sending data.
Local Lockout	LLO	Disables return-to-local key (CE key on front panel) such that when in remote mode the keyboard can not be activated by pressing a front panel key.
Go To Local	GTL	Puts unit in local control mode such that front panel keyboard is active.
Device Clear	DCL	When the device clear command is sent, the following parameters are changed regardless of their existing settings: Input Gain = 0dB Output Gain = 0dB Response = Elliptical Mode: HP channel 1, LP channel 2 Cutoff Frequency: 1kHz Coupling: AC Clears current settings for both channels. It does not clear set-ups stored with [STORE] key. It does not change interface bus parameters and flags such as: address, SRQ, ON/OFF, parallel poll bit selected, etc.
Selected Device Clear	SDC	Performs same function as device clear (DCL) except only if unit is addressed.

Discussion (see section 2.8 and Figure 10 of the IEEE-488 Interface Standard): Note that there are 4 possible states; local, remote, local-with-lockout, and remote-with-lockout. Front panel control is considered local while control from the system controller is considered to be remote. Selection of local or local-with-lockout and remote or remote-with-lockout is done several ways. When the unit is addressed to talk (MTA) or listen (MLA), it will enter into remote. When GO-TO-LOCAL (GTL) is sent, it enters into local mode or local-with-lockout mode.

Also, if lockout mode is not invoked by the controller (local lockout command LLO), pressing the [CE] key when the remote LED is on will return control to the keyboard.

Note: The lockout mode is not related to whether control is local or remote, only whether control can be returned to local by pressing the [CE] key.

Lockout mode (local-with-lockout and remote-with-lockout vs. local and remote) is controlled by the controller. Sending the local lockout command (LLO) selects the local-with-lockout and remote-with-lockout pair versus remote and local without lockout out. Lockout can only be canceled by the controller, placing the remote enable line false.

3.4.2 Polling Commands

The IEEE standard provides two methods of determining the status of the devices in the system; namely serial poll and parallel poll. The parallel poll provides up to 8 bits of status from up to 8 different units simultaneously. A parallel poll is very fast but provides limited information. The serial poll provides 7 bits of status from one unit at a time.

3.4.2.1 Parallel Polling

The Model 3901 provides for software configuring which bit and which polarity the unit should respond to. This bit is "true" when an error condition exists ("ERR" displayed on the front panel). Configuring needs to done once or anytime the software desires to change the configuration. The commands related to the parallel poll are as follows:

For sample sequences, see Section 6.5.4 of the IEEE-488 standard.

IEEE-488 Command	Mnemonic	Result
Configure	PPC	Place the unit into a state where it expects parallel poll enable and disable commands to establish which bits should be set or selected in response to a parallel poll.
Unconfigure	PPU	Removes unit from PPC state (UNL does the same, but also unlistens the device).
Enable	PPE	When unit is in PPC state, it indicates which bit and which polarity the device should respond. Hex codes 60-67 selects bits 0-7 respectively to be set to 0 for a true error response. Since logic 0 is HI on open collector lines, this provides a logical "OR" of all units designated to respond with a given line. Hex codes 68-6F selects bits 0-7 respectively to be set to 1 for a true (error) response. This can provide logical NAND of all units designated to respond with a given line.
Disable	PPD	Clears any configuration previously entered. This is valid only when unit is in PPC state.

Example: If the Model 3901 to be configured is unit #5, and we want it to respond with a "1" when an error exists.:

IEEE-488 Command	Result
MLA 5	Addresses unit to be configured.
PPC	Places unit into parallel poll configured mode.
PPE 8	Configures bit #0 (Lo 3 bits of command) to respond with a "1" (8 bit's) when an error exists.
UNL	Unlistens unit.

For additional sample sequences, see Section 6.5.4 of the Standard.

3.4.2.2 Service Request And Serial Polling

The IEEE-488 Standard provides serial polling as a method of determining which unit caused a service request. When serial poll enabled (SPE) is sent, the system enters into serial poll state. When a unit is addressed to talk, a single status byte will be sent. The Hex 40 bit in this byte is true if that unit is requesting service. The remaining bits are used to provide status information. The Model 3901 service request capability is enabled or disabled with the SRQON and SQROFF commands. The unit turns on with service request disabled. This is an extension of the standard.

IEEE-488 Command	Mnemonic	Result
Enable	SPE	Unit enters serial poll when a unit is addressed to talk. It will send one status byte in which the Hex 40 bit is true if the unit is requesting service.
Disable	SPD	Unit exits serial poll state.

3.4.2.3 Serial Responses

The chart below lists the error numbers, in decimal notation, resulting a command error either from the bus or not from the bus.

The serial responses are:

1. No error: 0

2. Error (numbers in decimal notation); see the chart below.

Note: If SRQ is "ON" and the command which caused the error came from the bus and not the front panel, then the 64 bit will be sent in the serial poll response, indicating that this unit requires service.

Error #	Description
1	Input gain too high or too low.
2	Frequency too high.
3	Frequency too low.
4	Channel # too high.
5	Channel # too low.
6	Output gain too high or too low.
7	Store page # too high.
8	Recall page # too high.
9	Type # invalid.
10	Mode # invalid.

3.4.3 Uniline Messages

IEEE-488 Command	Mnemonic	Result
End	END	Sent with last byte of data. A line of data may either be terminated by a line feed character or by this command.
Identify	IDY	This command, issued by the controller, causes a parallel response which was previously configured by the PPC, PPD, PPE and PPU commands.
Request Service	RQS	Generated in response to an error when a command came from the bus, and service request is enabled by the SRQON command.
Remote Enabled	REN	When true, allows the unit to respond to remote messages. When this line goes false, the unit will go to local-with-lockout state, activating the front panel.
Interface Clear	IFC	Un-addresses all units and clears all special states.

3.5 Talker Format

The Talker Software allows a GPIB controller to interrogate the Model 3901 and read back over the bus its setting (input gain, frequency, output gain, etc.).

Four types of data can be sent over the bus. Normally parameter information is returned unless an “OS”, “Q” or “V” command is sent to the unit.

3.5.1 Parameter Information Format

1	Two digits of input gain.
1a	space
2	Four difits including decimal for frequency or other alpha.
3	If frequency is displayed: E+ 0 if both kilo and mega LEDs are off E+ 3 if kilo LED is on. E + 6 if mega LED is on otherwise 3 spaces.
3a	space
4	Two digits, a decimal and one digit for channel #.
4a	space
5	Two digits for output gain.
5a	space
6	"AC" if ac coupled, "DC" if dc coupled.
7	"*" if all channel mode, otherwise a space.

3.5.2 Model Number and Software Version Format

After sending the "V" command, the next line of data read from the Model 3901 will be as follows:

KROHN-HITE 3901, V3.5

The version number will reflect the revision level of the firmware in the instrument.

This data is returned only once per command; after that it returns to talking what the front panel is displaying.

3.6 Programming Examples

The following are programming examples in Microsoft Qick Basic, Borland Turbo C and National Instruments IBIC.

3.6.1 Example 1 - Microsoft Quick Basic

```
‘  Microsoft (R) Quick Basic (tm) program for the Krohn-Hite Model 3988
‘
‘   *  Enter this program from DOS by typing: QB 3988 /LQBIB.QLB
‘        (the /L switch means tells Quick Basic to load a library)
‘
‘   *  Set the instrument to GPIB address 1:
‘        Press 1 [SECOND FUNCTION] [MEGA]
‘
‘   *  Set the instrument for no carriage return or line feed (EOI only):
‘        Press 0 [SECOND FUNCTION] [ALL CHAN]
```

```
'
'———————— Initialize National Instruments Interface Board ————————-
'
'$INCLUDE: 'QBDECL.BAS'
 CLS
 CALL IBFIND("GPIB0", BRD0%): 'initialize access to the board
 CALL IBFIND("DEV1", D3988%): 'init access to the instrument, assumes addr 1!
 CALL IBTMO(D3988%, 10): ' set timeout to 300mS
'
'————————————————————- Send/receive the data ————————————————————
'
'  Set to 500 Hz (500HZ), 0dB input gain (0IG), 0db output gain (0OG),
'  DC coupled, re-display the frequency (F) so it will be read over the bus.

 CALL IBWRT(D3988%, "500HZ;0IG;0OG;DC;F"): IF IBSTA%  <0 THEN GOTO gpiberr

 ' allocate a buffer (define a string long enough to hold the response)
 ' and read the meter
 Buf$ = SPACE$(40): CALL IBRD(D3988%, Buf$): IF IBSTA%  <0 THEN GOTO gpiberr

 'Shorten the buffer to the # of characters actually received and print it
 Buf$ = LEFT$(Buf$, IBCNT%)
 PRINT "Read: "; Buf$

 ' Send UNLISTEN(?), UNTALK(_) so the bus will be in an idle state
 CALL IBCMD(BRD0%, "?_"): IF IBSTA%  <0 THEN GOTO gpiberr


'
'  Set to 333 Hz, 20dB input gain (20IG), 20dB output gain (20OG), AC coupled,
'  and again display frequency in the main display window.
'
 CALL IBWRT(D3900%, "333HZ;20IG;20OG;AC;F"): IF IBSTA%  <0 THEN GOTO gpiberr
 Buf$ = SPACE$(40): CALL IBRD(D3900%, Buf$): IF IBSTA%  <0 THEN GOTO gpiberr
 Buf$ = LEFT$(Buf$, IBCNT%)
 PRINT "Read: "; Buf$
 CALL IBCMD(BRD0%, "?_"): IF IBSTA%  <0 THEN GOTO gpiberr
```

```
‘
‘——————————————————————-Cleanup and End——————————————————————
‘
cleanup:
  CALL IBONL(BRD0%, 0): ‘Release the board file handle
  CALL IBONL(D3900%, 0): ‘Release the instrument file handle
END

gpiberr:
  PRINT “IBSTA%=”; HEX$(IBSTA%); “, IBERR%=”; IBERR%: GOTO cleanup
```

3.6.2 Example 2 - Borland Turbo C

```
/*
 *  Borland Turbo C Example Program for the Krohn-Hite Model 3988 multichannel
 *     filter using the NI-488
 *  Should work with Microsoft C also.
 */
*/=============================================================
 *
 *  This sample program sends and receives data from a Krohn-Hite model 3988
 *
 *    *  In the Borland IDE, place “MCIB.OBJ” in your project list
 *
 *    *  Set the instrument to GPIB address 1:
 *         Press [1] [SECOND FUNCTION] [MEGA]
 *
 *    *  Set the instrument for no carriage return or line feed (EOI only):
 *         Press [0] [SECOND FUNCTION] [ALL CHAN]
 *
 *  This program assumes the name of the device at address 1 hasn’t been
 *    changed in IBCONFIG (it’s still called DEV1, which is the default.)
 *
 *  The status variables IBSTA, IBERR, and IBCNT are defined in DECL.H.
 *  Each bit of IBSTA and each value of IBERR are defined in DECL.H as
 *  a mnemonic constant for easy recognition in application programs.  In
 *  this example, these mnemonic definitions are logically ANDed with the
```

```
 *  variable IBSTA to determine if a particular bit has been set.  The mnemonic
 *  definitions are equated with the variable IBERR to determine the error
 *  code.
 *
 *  The function GPIBERR is called when a NI-488 function fails.  The
 *  error message is printed along with the status variables IBSTA, IBERR,
 *  and IBCNT.
 *
 *  The NI-488 function IBONL is called from the main body of the program or
 *  from the function GPIBERR.   When the second parameter of the function
 *  IBONL is zero, the software and hardware are disabled.

 *  Execution of this program is terminated after the call to the function
 *  IBONL to disable the software and hardware.
 *
 *  The function EXIT is used to terminate this program within the function
 *  GPIBERR.  The exit status is set to 1 to indicate an error has occurred.
 *
*/=====================================================================
 */
#include <stdio.h>
#include <stdib.h>
#include <string.h>

/*  DECL.H contains constants, declarations, and function prototypes. */

#include “decl.h”
#define DEVNUM “dev1"  /* Set instrument to GPIB address 1 */

/*  GPIBERR is an error function that is called when a NI-488 function fails. */
void gpiberr(char *msg);

char    rd[255];                    /* read data buffer  */
int     GpibDev,GpibBoard;              /* device handles  */

void main() {
```

```
    printf("\nSending data to the Krohn-Hite model 3988...\n");
    printf("\n");

/*
 *  Assign a unique identifier (a 'handle') to the K-H 3988 and store it in the
 *  variable GpibDev. If GpibDev is less than zero, call GPIBERR with an error
 *  message.
 */
    GpibDev = ibfind (DEVNUM);
    if (GpibDev  <0) gpiberr("ibfind Error");


/*
 *  Assign a handle to the GPIB board so we can use ibcmd to send board
 *  level commands such as UNL and UNT.
 */
    GpibBoard = ibfind ("gpib0");
    if (GpibBoard  <0) gpiberr("ibfind Error");

/*
 *  Clear the K-H 3988 to its default state.  The settings vary depending on the
 *  type of board in each channel.  These settings are listed in the GPIB
 *  section of the manual for each filter board (not the 3988 manual).
 *  If the error bit ERR is set in IBSTA, call GPIBERR with an error message.
 */
    ibclr (GpibDev);
    if (ibsta & ERR) gpiberr("ibclr Error");

/*
 *  Write a string out to the K-H 3988.
 *  If the error bit ERR is set in IBSTA, call GPIBERR with an error message.
 */
    ibwrt (GpibDev,"500HZ;0IG;0OG;DC;F",18L);   /* the 'F' displays the frequency so when*/
    if (ibsta & ERR) gpiberr("ibwrt Error"); /* we read the unit we'll see the freq */
```

```
/*
 *  Read the K-H 3988.  If the error bit ERR is set in IBSTA, call GPIBERR with
 *  an error message.
 */
  ibrd (GpibDev,rd,30L);
  if (ibsta & ERR) gpiberr("ibrd Error");

  /* Append the null character to mark the end of the data */
  rd[ibcnt] = '\0'; /* do this BEFORE calling ibcmd because ibcnt will be */
  printf("Read:  %s\n", rd);       /* changed by any 'ib' calls. */

  ibcmd(GpibBoard,"?_",2L);      /* send unt, unl */
  if (ibsta & ERR) gpiberr("ibcmd Error");

/*
 *  Change the K-H 3988 setting
 */
 ibwrt (GpibDev,"333HZ;20IG;20OG;AC;F", 20L); /* the 'F' displays the frequency so when*/
 if (ibsta & ERR) gpiberr("ibwrt Error");  /* we read the unit we'll see the freq */

/*
 *  Read the K-H 3988 again like before.
 */
  ibrd (GpibDev,rd,30L);
  if (ibsta & ERR) gpiberr("ibrd Error");

  rd[ibcnt] = '\0';
  printf("Read:  %s\n", rd);

  ibcmd(GpibBoard,"?_",2L); /* send unt, unl */
  if (ibsta & ERR) gpiberr("ibcmd Error");

 /*  Call the ibonl function to disable the hardware and software. */
  ibonl (GpibDev,0); /* Release the device handle */
  ibonl (GpibBoard,0); /* Release the board handle */
```

```
    exit(0);  /* exit with no error */

} /* main */


/*===========================================================================
 *                  Function GPIBERR
 *  This function will notify you that a NI-488 function failed by
 *  printing an error message.  The status variable IBSTA will also be
 *  printed in hexadecimal along with the mnemonic meaning of the bit position.
 *  The status variable IBERR will be printed in decimal along with the
 *  mnemonic meaning of the decimal value.  The status variable IBCNT will

*  be printed in decimal.
*
*  The NI-488 function IBONL is called to disable the hardware and software.
*
*  The EXIT function will terminate this program.
*===========================================================================
 */

void gpiberr(char *msg) {
  unsigned int i;

  /* Table of ibsta (interface board status word) bit positions and
     corresponding messages */
  static struct { int bit; char *msg;} ibstaMsg[16]=
   { {ERR,  " ERR"},
     {TIMO, " TIMO"},
     {END,  " END"},
     {SRQI, " SRQI"},
     {RQS,  " RQS"},
     {SPOLL," SPOLL"},
     {EVENT," EVENT"},
     {CMPL, " CMPL"},
     {LOK,  " LOK"},
```

```
    {REM,  " REM"},
    {CIC,  " CIC"},
    {ATN,  " ATN"},
    {TACS, " TACS"},
    {LACS, " LACS"},
    {DTAS, " DTAS"},
    {DCAS, " DCAS"}};

/* Table of iberr error messages */
static struct { int val; char *msg;} iberrMsg[15]=

  { { EDVR," EDVR <DOS Error>\n"},
    { ECIC," ECIC <Not CIC>\n"},

    { ENOL," ENOL <No Listener>\n"},
    { EADR," EADR <Address error>\n"},
    { EARG," EARG <Invalid argument>\n"},
    { ESAC," ESAC <Not Sys Ctrlr>\n"},
    { EABO," EABO <Op. aborted>\n"},
    { ENEB," ENEB <No GPIB board>\n"},
    { EOIP," EOIP <Async I/O in prg>\n"},
    { ECAP," ECAP <No capability>\n"},
    { EFSO," EFSO <File sys. error>\n"},
    { EBUS," EBUS <Command error>\n"},
    { ESTB," ESTB <Status byte lost>\n"},
    { ESRQ," ESRQ <SRQ stuck on>\n"},
    { ETAB," ETAB <Table Overflow>\n"}};

  printf ("%s\n", msg); /* Print the application supplied context message. */
  /*
   *  The ibsta variable provides the primary information about the cause of
   *  the error: print it's value and mnemonic for each bit set.
   */

  printf ("ibsta = &H%x  <", ibsta);
  for (i=0; i<=15; i++)
```

```
  { if (ibsta & ibstaMsg[i].bit)  printf ("%s",ibstaMsg[i].msg); };
printf (" >\n");
/*
 *  Print the iberr value and interpertation
 */

printf ("iberr = %d", iberr);
for (i=0; i<=14; i++)
  { if (iberr==iberrMsg[i].val)  printf ("%s",iberrMsg[i].msg); };
/*
 *  Print ibcnt in decimal
 */

printf ("ibcnt = %d\n", ibcnt);

printf ("\n");
/*  put the board and device offline */
ibonl (GpibDev,0); /* Release the device handle */
ibonl (GpibBoard,0); /* Release the board handle */
exit(1); /* exit with status=1 to indicate error */
```

3.6.3 Example 3 - National Instruments IBIC

Preparation:

Your c:\config.sys file must have the following line in it:

```
device=c:\488\gpib.com
```

After you add this line, you must re-boot (reset) your computer for the driver to be loaded.
For purposes of this demo, set the Krohn-Hite Model 3988 to GPIB address 1:
Press [1][SECOND FUNCTION][MEGA]
Set the talker to only send EOI:
Press [1][SECOND FUNCTION][ALL CHAN]

Prompt	Command You Type	Comments
C:\488>	IBIC	From the DOS command line, enter the IBIC program.
:	ibfind gpib0	Initialize the program to access the board.
gpib0:	ibfind dev1	Initialize the program to access the device at GPIB address 1.

dev1:	ibwrt "5.1K"	Set the unit to 5.1kHz.
dev1:	ibrd 50	Read the unit (50 characters is adequate).
dev1:	set gpib0	The ibrd command does not unaddress the unit; it must be done manually: select the board so you can do a board level command.
gpib0:	ibcmd "?_"	Send "unlisten (UNL)" which is "?" and "untalk (UNT)" which is "_" (underscore).
dev1:	ibwrt "AL;0IG;0OG;1TY;1MO;DC"	Set: all channel mode (AL), 0dB input gain (0IG), 0dB output gain (0OG), type 1 (Butterworth), mode 1 (low-pass), DC coupling.
dev1:	ibwrt "B;CH1;1K;CH2;2K;CH3;5K"	Set: all channel mode off (B), channel 1 to 1kHz cutoff, channel 2 to 2kHz cutoff and channel 3 to 5kHz.
dev1:	e	Exit IBIC

c:\488>

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Section 4
Incoming Acceptance

4.1 Introduction

The following procedure should be used to verify that the Model 3901 Programmable Filter is operating within specifications.

These checks may be used for incoming acceptance and periodic performance checks. Checks must be made with all covers in place and operating for a minimum time of 1/2 hour to reach operating temperature. Before testing, follow the initial set-up and operating procedures given in Section 2 of this manual.

4.2 Required Test Equipment

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

a.	RC Oscillator with a frequency range from 0.01Hz to 1MHz: Krohn-Hite Model 4100A or equivalent.
b.	RC Oscillator with a frequency range from 10Hz to 10MHz. Frequency response of ±0.025dB from 10Hz to 500kHz: Krohn-Hite Model 4200B/4300B or equivalent.
c.	Oscilloscope, bandwidth from DC to 50MHz, vertical input sensitivity of 5mV/cm: Tektronix 465 or equivalent.
d.	DC Voltmeter (DVM) capable of measuring 1mV to 20V: Fluke 8920A or equivalent.
e.	AC Voltmeter capable of measuring 100µV to 10Vrms: Fluke 8920A or equivalent.
f.	Frequency Counter

4.3 Channel 1 - High-Pass

4.3.1 Pre-Filter. Post-Filter and Unity Gain Accuracy

Set CH1 to a cutoff frequency of 10Hz with 0dB input gain and 0dB output gain.

Apply 50mV at 1kHz to the CH1 input.

Monitor the output of CH1 with an ac voltmeter.

Should be 50mV ±1mV.

Set the input (pre-filter) gain of CH1 to 10dB, 20dB, 30dB and 40dB.

Connect the Fluke 8920A to the output of CH1.

Reading should be within ±0.2dB at all four gain settings.

Set CH1 input gain to 0dB and apply a 0.7Vrms signal to the CH1 input.

Monitor the output of CH1 with an ac voltmeter and record the output voltage.

Set the output (post-filter) gain to 10dB and 20dB.

Connect the Fluke 8920A to CH1 output.

Readings should be ±0.2dB on both settings.

4.3.2 Low Bands Ripple Response

Connect RC Oscillator at 3Vrms at 9kHz to CH1 input.

Set the cutoff frequency of the filter to 90Hz.

Set the input and output gain of the filter to 0dB.

Monitor the output of CH1 with ac voltmeter.

Record the voltages and use as a reference.

Check the response of the 3 peaks at 189Hz, 110Hz and 90.9Hz.

Check the response of all three valleys at 363Hz, 134Hz and 97.1Hz.

The adjacent peak-to-valley ripple should not exceed 0.4dB.

4.3.3 High Band Ripple Response

Connect RC Oscillator at 3Vrms at 10kHz to CH1 input.

Set the cutoff frequency of the filter to 100Hz.

Set the input and output gain of the filter to 0dB.

Monitor the output of CH1 with ac voltmeter.

Record the voltages and use as a reference.

Set the filter to 10kHz.

Check the response of the 3 peaks at 20.1kHz, 12.2kHz and 10.1kHz.

Check the response of all three valleys at 40.3Hz, 14.9kHz and 10.8kHz.

The adjacent peak-to-valley ripple should not exceed 0.4dB.

Note: Check the accuracy of the ac voltmeter at low frequencies. If necessary, compare the output with the input to eliminate any error.

4.3.4 Stopband Attenuation

4.3.4.1 Band 1

Set the filter to 90Hz with 0dB input gain and 20dB output gain.

Set RC Oscillator to 52.3Hz at 7Vrms.

Connect oscilloscope to output of CH1.

Signal should be <20mV p-p.

Set RC Oscillator to 48.0Hz, 34.8Hz and 12.9Hz.

Signal should be <20mV p-p.

(Disregard the noise contained within the signal or use a 10kHz low-pass filter.)

4.3.4.2 Band 2

Same as Band 1 setting the filter to 100Hz and RC Oscillator to 58.1Hz, 53.4Hz, 38.6Hz and 14.3Hz.

4.3.4.3 Band 3

Same as Band 1 setting the filter to 1kHz and RC Oscillator to 581Hz, 534Hz, 386Hz and 143Hz.

4.3.4.4 Band 4

Same as Band 1 setting filter to 10kHz and RC Oscillator to 5.81kHz, 5.34kHz, 3.86kHz and 1.43kHz.

4.3.5 Cutoff Frequency Accuracy

Connect the RC Oscillator at 3Vrms at 900Hz to CH1 input.

Set filter cutoff to 10Hz with 0dB input and output gain.

Monitor the output of CH1 with AC Voltmeter. Record the voltage at the output.

Set the filter to 900Hz. Adjust the input frequency near 891Hz to obtain -0.22dB (0.077V).

Frequency should be between 873Hz and 909Hz.

Set filter and RC Oscillator to 90Hz.

Adjust RC Oscillator frequency for -0.22dB.

Frequency should read between 87.3Hz and 90.9Hz.

Set filter and RC Oscillator to 1kHz.

Adjust RC Oscillator frequency for -0.22dB.

Frequency should read between 970Hz and 1.01kHz.

Set filter and RC Oscillator to 10kHz.

Adjust RC Oscillator frequency for -0.22dB.

Frequency should read between 9.70kHz and 10.1kHz.

4.3.6 Noise Measurements (2MHz Detector Bandwidth)

Short CH1 input.

Connect an ac voltmeter to the CH1 output.

Set the filter 1kHz with 0dB input and output gain.

Output should be <400µVrms.

Set input gain to 40dB and output gain to 20dB.

Output should be <20mVrms.

Set the filter to 99kHz with 0dB input and output gain.

Output should be <1mVrms.

Set the filter to the Gain Mode.

Set input gain and output gain to 0dB.

Output should be <150µVrms.

Set input gain to 40dB and output gain to 20dB.

Output should be <25mVrms.

4.4 Channel 2 - Low-Pass

4.4.1 Pre-Filter, Post-Filter, and Unity Gain Accuracy

Set CH2 to a cutoff frequency of 9kHz with 0dB input gain and 0dB output gain.

Apply 50mV at 100Hz to the CH2 input.

Monitor the output of CH2 with an ac voltmeter.

Should be 50mV ±1mV.

Set the input (pre-filter) gain of CH2 to 10dB, 20dB, 30dB and 40dB.

Connect the Fluke 8920A to the output of CH2.

Reading should be within ±0.2dB at all four gain settings.

Set CH2 input gain to 0dB and apply a 0.7Vrms signal to the CH2 input.

Monitor the output of CH2 with an ac voltmeter and record the output voltage.

Set the output (post-filter) gain to 10dB and 20dB.

Connect the Fluke 8920A to CH2 output.

Readings should be ±0.2dB on both settings.

4.4.2 Low Band Ripple Response

Connect RC Oscillator at 3Vrms at 50Hz to CH2 input.

Set the cutoff frequency of the filter to 900Hz.

Set the input and output gain of the filter to 0dB.

Monitor the output of CH2 with ac voltmeter.

Record the voltages and use as a reference.

Set filter to 90Hz.

Check the response of the 3 peaks at 42.9Hz, 73.9Hz and 89.1Hz.

Check the response of all three valleys at 22.3Hz, 60.3Hz and 83.4Hz.

The adjacent peak-to-valley ripple should not exceed 0.4dB.

4.4.3 High Band Ripple Response

Connect RC Oscillator at 3Vrms at 100Hz to CH2 input.

Set the cutoff frequency of the filter to 10kHz.

Set the input and output gain of the filter to 0dB.

Monitor the output of CH2 with ac voltmeter.

Record the voltages and use as a reference.

Check the response of the 3 peaks at 4.7kHz, 8.2kHz and 9.9kHz.

Check the response of all three valleys at 2.4kHz, 6.8kHz and 9.2kHz.

The adjacent peak-to-valley ripple should not exceed 0.4dB.

Note: Check the accuracy of the ac voltmeter at low frequencies. If necessary, compare the output with the input to eliminate any error.

4.4.4 Stopband Attenuation

4.4.4.1 Band 1

Set the filter to 10Hz with 0dB input gain and 20dB output gain.

Set RC Oscillator to 17.5Hz at 7Vrms.

Connect oscilloscope to output of CH2.

Signal should be <20mV p-p.

Set RC Oscillator to 18.7Hz, 25.9Hz and 70Hz.

Signal should be <20mV p-p.

4.4.4.2 Band 2

Same as Band 1 setting the filter to 100Hz and RC Oscillator to 175Hz, 187Hz, 259Hz and 700Hz.

4.4.4.3 Band 4

Same as Band 1 setting the filter to 10kHz and RC Oscillator to 17.5Hz, 18.7kHz, 25.9kHz and 70.0kHz.

4.4.5 Cutoff Frequency Accuracy

Connect RC Oscillator at 3Vrms at 42.9Hz to the input of CH1. Set filter to 90Hz with 0dB input and output gain. Monitor the output with the AC Voltmeter. Record the voltage at the output. Adjust input frequency near 90.9Hz to obtain -0.22dB. Frequency should be between 89.12Hz and 92.7Hz.

Set filter and RC Oscillator to 100Hz. Adjust the RC Oscillator frequency for -0.22dB. Frequency should read between 99Hz and 103Hz.

Set filter and the RC Oscillator to 10kHz. Adjust the RC Oscillator frequency for -0.22dB. Frequency should be between 9.9kHz and 10.3kHz.

4.4.6 Noise Measurements (2MHz Detector Bandwidth)

Short CH2 input.

Connect ac voltmeter to CH2 output.

Set filter to 1kHz with 0dB input and output gain.

Output should be <400µVrms.

Set filter to 99kHz with 0dB input and output gain.

Output should be <1mVrms.

Set filter to 99kHz with 40dB input gain and 20dB output gain.

Output should be <20mVrms.

Set the filter to the Gain Mode.

Set input and output gain to 0dB.

Output should be <150µVrms.

Set input gain to 40dB and output gain to 20dB.

Output should be <25mVrms.

4.4.7 Passband Gain and Distortion Tests

To verify that the filter is functioning correctly in the passband, set both CH1 and CH2 to a cutoff frequency of 900Hz and input and output gain on both channels to 0dB (unity gain).

Apply a 7Vrms signal at 50Hz to CH1and CH2 inputs and monitor each channel's output with oscilloscope, ac voltmeter and distortion analyzer.

The output of each channel 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 is <0.1%.

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