Model 3988

Butterworth/Bessel
8-Pole Dual Channel Filter
0.03Hz to 1MHz Cutoff Frequency Range
0dB to 50dB Pre-Filter Gain in 10dB Steps
0dB to 20dB Post-Filter Gain in 0.1dB Steps

Serial No. ____________

Operating Manual

KROHN-HITE CORPORATION

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

Printed in USA - 4/03.

Service and Warranty

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.

All Krohn-Hite products are warranted against defective materials and workmanship. This warranty applies for a period of one year from the date of delivery to the Original Purchaser. Any instrument that is found within the one year warranty period not to meet these standards, will be repaired or replaced. This warranty does not apply to electron tubes, fuses or batteries. No other warranty is expressed or implied.

Krohn-Hite Corporation reserves the right to make design changes at any time without incurring any obligation to incorporate these changes in instruments previously purchased.

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

TABLE OF CONTENTS

Figure 1 – Model 3988 Programmable Filter

SECTION 1

GENERAL DESCRIPTION

1.1 INTRODUCTION

The Krohn-Hite Model 3988 Butterworth/Bessel dual channel filter is one of a family of filters carefully designed with the user in mind, providing ease of operation, reliability and price competitiveness.

The 3988 provides a tunable frequency range from 0.03Hz to 1MHz in the low-pass mode and 0.03Hz to 300kHz in the high-pass mode. Both modes are extended down to 0.003Hz with the 002 option. The frequency response characteristic is either maximally flat (Butterworth) for clean filtering in the frequency domain, or linear phase (Bessel) to provide superior pulse or complex filtering is operator selectable.

Each channel of the 3988 is an 8-pole, wide range, low-pass/high-pass filter or an amplifier providing gains to 70dB in 0.1dB steps. The 3988 will accept input signals of ±10V peak at 0dB gain and has selectable ac or dc coupling. Overload detectors are standard and assist the user in detecting input signals or incorrect gain settings.

Ninety-nine groups of non-volatile memory for storage of front panel set-ups, which are stored in battery-backed CMOS. Set-ups can then be recalled with a simple command.

Band-pass operation is achieved by simply connecting the two channels in series.

Applications of the Model 3988 are ultra-sound measurements, random noise testing, sound recording, suppressing interference in audio communications and related fields of medical, geological, geophysical, oceanographic, military and many more.

1.1.1 FUNCTIONS (Each Channel)

Low-pass filter, high-pass filter, voltage gain amplifier.

1.1.2 FILTER MODE

Type: 8-pole, Butterworth/Bessel.

Attenuation: 48dB/octave.

Tunable Frequency Range fc: Low-pass, 0.03Hz to 1MHz; high-pass, 0.03Hz to 300kHz; (option 002, 0.003Hz).

Frequency Resolution: 3 digits, 0.5Hz to max fc; 2 digits, 0.03Hz to 0.5Hz; (option 002, 3 digits, 0.05Hz to 0.5Hz; 2 digits, 0.003Hz to 0.05Hz).

Cutoff Frequency Accuracy: ±1%, 0.5Hz to 50kHz; ±2%, 50.1kHz to max fc; ±5%, 0.03Hz to 0.5Hz (option 002, ±5%, 0.003Hz to 0.5Hz).

Relative Gain at fc: –3dB, Butterworth; –12.6dB, Bessel.

High-Pass Bandwidth (0dB Gain): fc to 2.5MHz.

Stopband Attenuation: >80dB.

Insertion Loss: 0dB; ±0.2dB.

Pre-Filter Gain: 0dB, 10dB, 20dB, 30dB, 40dB, 50dB; ±0.2dB.

Post-Filter Gain: 0dB to 20dB in 0.1dB steps; ±0.2dB.

Input Coupling: ac (0.16Hz) or dc.

Wideband Noise (referred to input, 2MHz BW detector):
min. gain, <1mVrms, max. gain, <10mVrms.

Harmonic Distortion: –80dB at 1kHz.

DC Stability: Typically ±2mV/°C.

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

Phase Match Between Channels: ±2° max. to 100kHz.

Gain Match Between Channels: ±0.2dB max. to 100kHz.

1.1.3 AMPLIFIER MODE

Bandwidth: >10MHz min. gain; >1MHz max. gain.

Insertion Loss: 0dB; ±0.05dB.

Response: ±0.1dB typical, ±0.5dB max.

Gain: 0dB to 70dB in 0.1dB steps; ±0.2dB.

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

CMRR: >60dB to 10kHz; >50dB to 99kHz.

Sensitivity: 3mV peak with 70dB total gain for 10V peak output.

Maximum Input: æ10V peak at 0dB gain, reduced in proportion to gain setting (to 500kHz LP).

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): 250mVrms min. Gain; 25mVrms max. gain.

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

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

1.1.4 GENERAL

Switch: For selection of Input, +(in phase), Differential or –(inverted).

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

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

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

Remote Programming: IEEE-488/1978 GPIB interface. Subsets: SH1, AH1, T6, L4, SR1, RL1, PP1, DC1, DT0, C0, E1.

Operating Temperature: 0°C to 50°C.

Isolation to Chassis: ±200Vdc.

Input/Output Connectors: BNC.

Power: 50 watts.

Dimensions and Weights: 3½“ (9cm) high, 8½” (21.8cm) wide, 18" (46.2cm) deep;
12 lbs (5.4kg) net, 14 lbs (6.3kg) shipping.

1.1.5 OPTIONS

002: extends low end cutoff to 0.003Hz.

Rack Mount Kit: Part No. RK-37, permits installation of the Model 3988 into a standard 19" rack spacing.

Specifications apply at 25°C ±5°C.

This page intentionally left blank.

SECTION 2
OPERATION

2.1 INTRODUCTION

The Model 3988 is a filter covering the frequency range from 0.03Hz (0.003Hz with option 002) to 1MHz in low-pass mode and 300kHz in high-pass mode. All filter parameters are programmable via the front panel keyboard controls or remotely over the III-488 (GPIB) bus.

The filter has three modes of operation: high-pass, low-pass and gain only. Each mode will be explained in detail in this section.

2.2 TURN-ON PROCEDURE

The Model 3988 line voltage range has been preset for either 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 off.

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

If the Model 3988 is to be programmed remotely, connect the bus cable to the rear panel connector of the 3988.

After reading the Self-Test feature, described next, turn on the Model 3988.

2.3 SELF TEST

When the Model 3988 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. Refer to Section 6, Maintenance, to find which RAM or ROM is defective.

When the self-test program is complete, the Model 3988 will return to the last set-up prior to turning the unit off. The Model 3988 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 will be indicated in the DISPLAY.

2.4.2 Parameter And Control Key

[KILO] - When pressed, multiplies the numeric value of the keyboard entry by 103.

[MEGA] - When pressed, multiplies the numeric value of the keyboard entry by 106.

[FREQ] - When pressed, enters and/or displays frequency in Hertz.

[TYPE] - When pressed, DISPLAY indicates the filter type, “bu.” (Butterworth) and “bES.” (Bessel). When pressed again, the type will change (i.e. if the type was “bES.”, the change will be to “bu.”.

[MODE] - When pressed, DISPLAY indicates the mode of operation for the channel displayed. “L.P - 1.” for low-pass, “h.P.” for high-pass and “GAin” for gain (amplifier mode).

When pressed again, the MODE will change to the next in the order explained above.

[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 [RCLL] key again will recall the entire instrument set-up from 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] - When frequency, input/output gain, type, mode or coupling are entered or changed, and the LED in the [ALL CH] key is lit, the new setting will be entered in both channels of the filter.

[SHIFT] - The [SHIFT] key in conjunction with other keys (keys with red lettering under them) provide additional filter characteristics, and permits front panel entry of the type of GPIB line termination and address.

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 memory location is desired, enter that location on the keyboard and then press [SHIFT] [RECLL].

When [SHIFT] [RECLL] is preceded by a number (0-98), the filter 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, pressing the clear entry key [CE] will 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 when in the low-pass and gain modes. High-pass mode will indicate “AC” only.

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 the address number in the data keys from [0] to [30] and press the [SHIFT] followed by the [MEGA] key (see Section 3.2.1 for GPIB addressing information).

GPIB Line Termination - When the [SHIFT] key followed by the [ALL CH] key are pressed, the DISPLAY will indicate the existing GPIB Line Termination Code sequence. To select a different one, enter a number from [0] to [4] and press [SHIFT] [ALL CH] keys (see Section 3.2.1 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 (i.e. 3.7).

[CE] - When entering a numeric value in the keyboard, but not specifying a parameter, pressing the clear entry key will function as an error correction procedure and restore DISPLAY to the current cutoff frequency setting.

When a numeric value and its parameter has been entered and the numeric value is then changed, pressing the [CE] key will restore DISPLAY to the previous value of that parameter.

When either the [STORE] or [RECALL] key is pressed, the next memory location will be indicated on the DISPLAY. Pressing the [CE] key will restore DISPLAY to the current cutoff frequency setting.

If the Model 3988 is operating via the IEEE-488 bus (the front panel REMOTE LED is “on”), pressing the [CE] key will return unit to LOCAL operation.

2.4.3 Channel Selection

The up [D] control key below the CHANNEL display alternates the channel settings.

2.4.4 Cutoff Frequency

Data entry keyboard controls [0] to [9] and [.] set the numeric value of the cutoff frequency desired. To select 1.5kHz, press the [1][.][5] data keys and parameter keys [KILO] and [FREQ]. The cutoff frequency for the channel selected will be indicated in Hertz on the four digit DISPLAY (when [ALL CH] mode is selected, the frequency will be changed on both channels). The KILO and FREQ keys will be lit. Also see 2.4.7.

2.4.5 Input Gain (Pre-Filter)

Up [↑] and down [↓] INPUT GAIN SET controls increase or decrease the input amplifier by 10dB. The two digit DISPLAY will indicate either 0dB, 10dB 20dB, 30dB, 40dB or 50dB.

2.4.6 Output Gain (Post Filter)

Up [↑] and down [↓] OUTPUT GAIN SET controls increase or decrease the output amplifier by 0.1dB steps from 0dB to 20.0dB. For gains <10dB, 0.1dB resolution is displayed. For gains >10dB, only 1dB resolution is displayed; however, the up [↑]and down [↓] keys continue to increment and decrement the gain by 0.1dB. The full 3-digit resolution may be seen in the middle display by pressing [SHIFT] the the [D] key under the output gain display. Also for gains >10dB, the decimal point is off for whole dB’s (10, 11, 12, etc.) but on for fractional (10.1 – 10.9, 11.1 – 11.9, etc.).

2.4.7 Digit Select/Increment and Decrement

When the [SHIFT] key is pressed, followed by the DIGIT SELECT [↑] or [↓] keys, the DISPLAY will intensify the first or second digit. Pressing the [SHIFT] followed by the [↑] or [↓] key again, will intensify the next digit or will turn the DIGIT SELECT off. Pressing the [↑] or [↓] keys will then increment or decrement the desired intensified digit.

Pressing [SHIFT] and either the [↑] or [↓] keys again will intensify the next digit in the DISPLAY. The [↑] will move the intensified digit to the left and the [↓] will move the intensified digit to the right (direction is labeled in red to the left of keys).

2.4.8 Key Click Feature On/Off

When the [SHIFT] key is pressed, followed by the [↑] key under the CHANNEL display, the key click feature will either toggle on or off.

2.5 REAR PANEL CONTROLS AND CONNECTORS

2.5.1 Introduction

The Model 3988 rear panel consists of the following: four input and two output BNC connectors, dc level adjustments, a fuse holder, GPIB bus connector and an ac receptacle.

2.5.2 BNC Connectors and Indicators

2.5.2.1 Input Connectors

The Model 3988 has four input BNC connectors on both the front and rear panels. The inputs are labeled on the front panel CH1+, CH1–, CH2+ and CH2–; the rear panel is simply labeled – and +.

NOTE

A slide switch is provided on the rear panel for selecting the INPUT BNC connector desired. The selections are +, DIFF and –. The + is a non-inverting input, the – input is inverting and DIFF is for differential operation.

2.5.2.2 Output Connectors

The Model 3988 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 is active. A slide switch located on the rear panel selects the desired input.

2.5.3 DC Level Adj (Rear Panel)

Proper procedure for adjusting input and output dc levels can be found in the Calibration section of this manual.

The two DC LEVEL potentiometers located on the rear panel of the Model 3988 are for adjusting the DC level at the output BNC connector.

2.5.4 Power

Receptacle: Standard 3 pin.

Fuse: ½ amp slow-blow for 120V operation; ¼ amp slow-blow for 230V operation. To change this setting, refer to section 2.2.

2.5.5 GPIB Connector

Standard IEEE-488 interface. Subsets are SH1, AH1, T6, L4, SR1, RL1, PP1, DC1, DT0, C0 and E1.

2.6 FILTER OPERATION

2.6.1 Introduction

The Model 3988 is a filter with two identical channels that can function independently. Each channel is an 8-pole filter which can be either low-pass, high-pass or gain-only. Each can be either Butterworth of Bessel response type.

2.6.2 Variable Band-Pass and Band-Reject Operation

2.6.2.1 Band-Pass

Variable band-pass response is obtained by connecting the output of channel 1 to the +input of channel 2 (with channel 2 differential switch set to "+"). Apply the signal to the input(s) of channel 1; the output signal will be at the channel 2 output BNC connector. Set channel 1 to high-pass and channel 2 to low-pass. Enter the lower cutoff frequency to channel 1 and the higher cutoff to channel 2.

2.6.2.2 Band-Reject

Variable band-reject response is obtained by connecting the inputs in parallel; and the outputs in series through a band-reject kit (BR-30). Apply the signal to the input of channel 1; the output signal will be at the output of the BR-30 kit. Set channel 1 to low-pass and channel 2 to high-pass. Set the desired cutoff frequencies.

2.6.3 Amplitude Response

Each channel of the Model 3988 can operate in either the low-pass or high-pass mode at 48dB/octave attenuation and provide either maximally flat (Butterworth) amplitude response or linear phase (Bessel) operation. Comparative amplitude response characteristics in both modes are shown in Figure 2.1A and 2.1B.

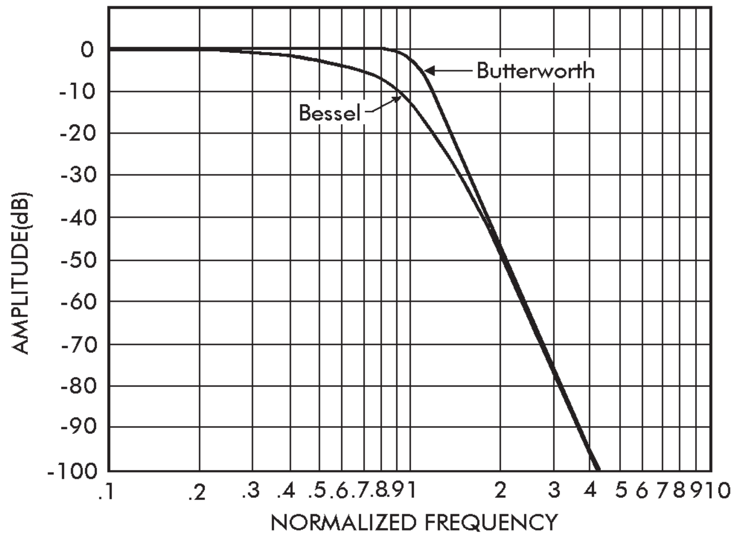

Figure 2.1A Low-Pass Amplitude Response

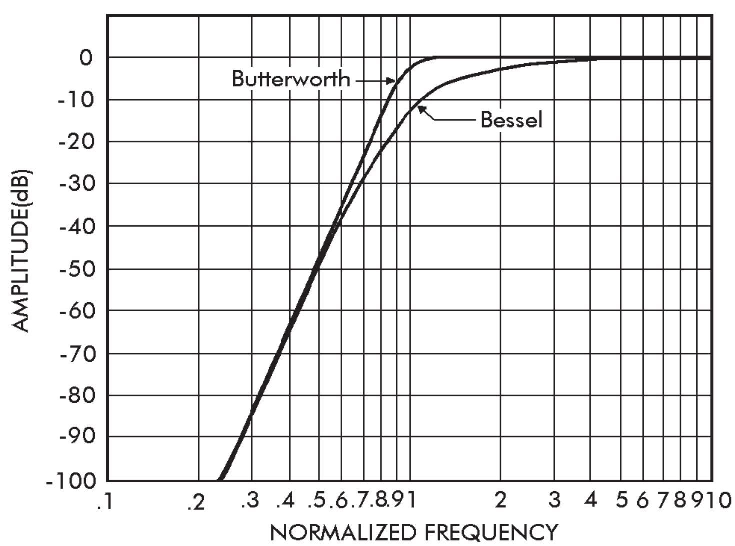

Figure 2.1B High-Pass Amplitude Response

2.6.4 Phase Response

Phase characteristics of the Model 3988 is shown is Figure 2.2. The filter provides output phase relative to the input over a 10:1 frequency range.

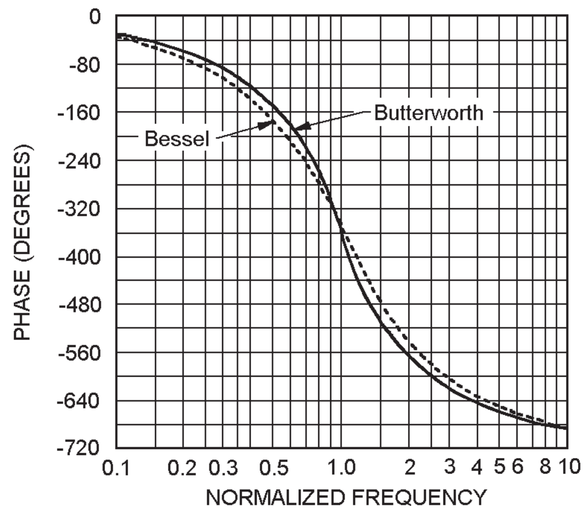

Figure 2.2 Phase Response

2.6.5 Group Delay

Group delay[1] , shown in Figure 2.3, is defined as the derivative of radian phase with respect to radian frequency, which is the slope of the phase curve. A flat group delay is considered a linear phase response which corresponds to a constant slope of the phase curve. With linear phase response, the distortion of complex data signals will be minimized because their various frequency components, due to constant time delay, will not shift relative phase.

In numeric terms, the zero frequency phase slope is –293.7º/Hz for Butterworth and –351.9°/Hz for Bessel, 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 –1845º/Hz and –2211º/Hz respectively. Dividing by 360 converts º/Hz to radians/radians-per-sec yields a group delay time of 5.13s for Butterworth and 6.14s for Bessel.

2.6.6 Transient Response

The normalized response for a unit step voltage applied to the input of the Model 3988 operating in the low-pass mode with both Butterworth and Bessel response is shown in Figure 2.4.

[1] \i IEEE Standard Dictionary of Electrical and Electronic Terms\plain \f1 , Institute of Electrical and Electronic Engineers, IEEE-STD 100-1977, Second Edition, 1977, page 296.

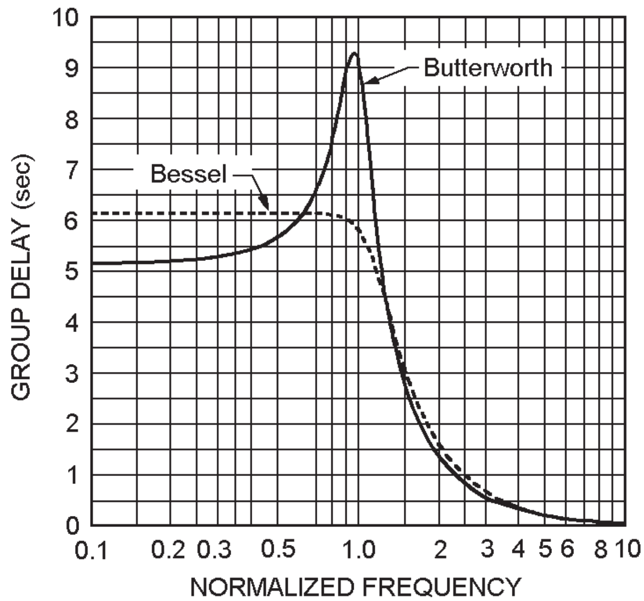

Figure 2.3 Group Delay

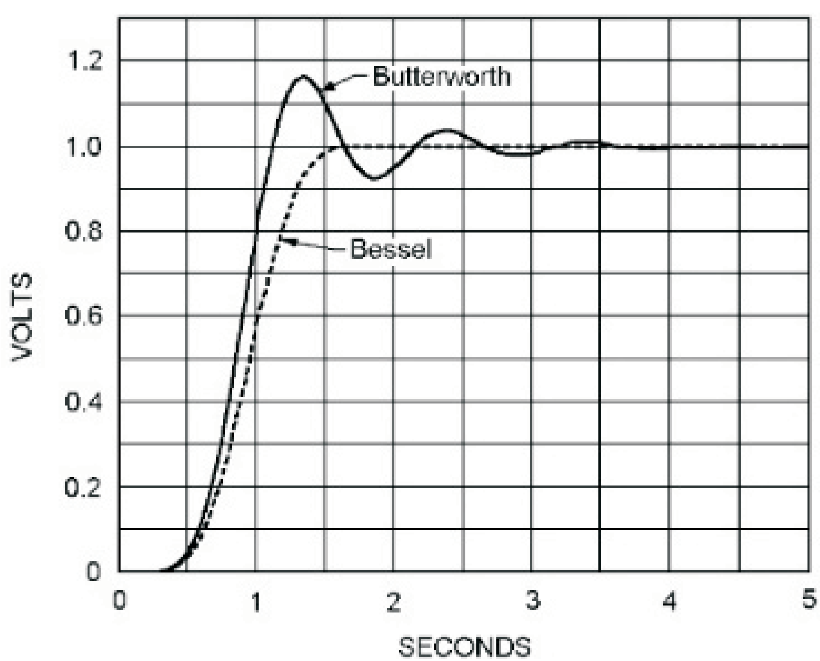

Figure 2.4 Transient Response

SECTION 3

IEEE-488 STD (GPIB) PROGRAMMING

3.1 INTRODUCTION

The Model 3988 remote programming interface accepts both ASCII data commands and IEEE-488 standard commands (ATN true) for control of the unit.

In presenting the information required to program the Model 3988 via the IEEE-488 STD 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 Tables 3.1 and 3.2. These two parameters are stored in non-volatile memory and will be remembered indefinitely, even when the power to the unit is removed. They do not need to be reentered each time the unit is turned on.

The LTCS affects the GPIB in the TALKER mode only (data output from the 3988 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
a.	To set a primary address from 0 to 30	[X][SHIFT][MEGA]
b.	To display the primary address	[SHIFT][MEGA]

LINE-TERMINATION-CHARACTER-SEQUENCE

	Line-Termination Character-Sequence	Keyboard Entry
a.	None (EOI only)	[0][SHIFT] [ALL CH]
b.	Carriage return (with EOI)	[1][SHIFT] [ALL CH]
c.	Line Feed (with EOI)	[2][SHIFT] [ALL CH]
d.	Carriage return followed by line feed (with EOI)	[3][SHIFT] [ALL CH]
e.	Line feed followed by carriage return (with EOI)	[4][SHIFT] [ALL CH]
f.	Display present LTCS	[SHIFT] [ALL CH]

3.2.2 IEEE-488 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.

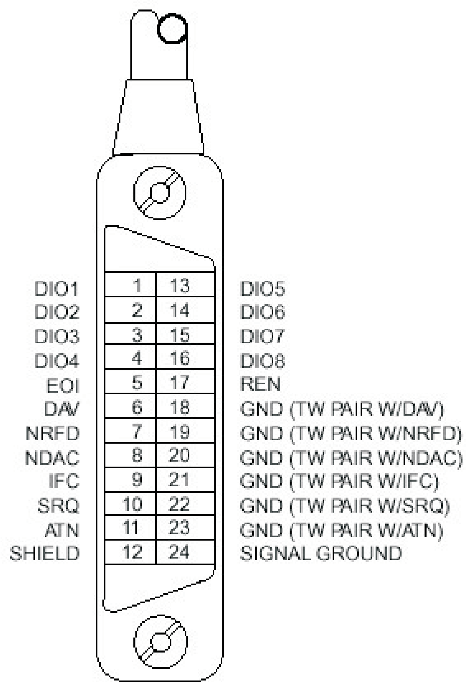

Figure 3.1 Rear Panel GPIB Connector

3.3 ASCII DATA COMMANDS

3.3.1 Format

The Model 3988 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 : Those involving numeric parameters and those that do not.

   Commands which 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 X 103
–2E3	=	–2 X 103
2E–3	=	2 X 10–3

   2. Multiplier: “KILO”, “MEGA”.
   3. Parameter: Parameter (frequency, gain, channel, etc.) is included in Section 3.3.3.

b. Delimiters which may separate commands are the following: (; : / \ .)

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

d. The Model 3988 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 that are underlined and characters that are NOT underlined. The characters that are underlined MUST be sent for the command to be recognized properly. Any additional characters may be sent once all the underlined letters are sent. Commands are case sensitive; upper case characters MUST be used.

MODEL 3988 GPIB COMMANDS

Command Desired	Allowable Character String	
Input Gain	IG	set input gain
	IU	increase input gain (up)
	ID	decrease input gain (down)
Frequency	F	frequency
	H	frequency (Hz)
	K	kilo (103 multiplier)
	ME	Mega (106 multiplier)
Channel	CH	set channel
	CU	next channel (up)
	CD	previous channel (down)
Output Gain	OG	set output gain
	OU	increase output gain (up)
	OD	decrease output gain (down)
Type	TY1	Butterworth
	TY2	Bessel
Mode	M1	low-pass
	M2	high-pass
	M3	gain only
Coupling	AC	ac coupled
	D	dc coupled
Store	ST	store
Recall	R	recall
All Channel	AL	all channel mode
	B	NOT all channel mode

Misc	CE	clear entry
	OV	overflow (1, 2, 3)
	Q	reports board model number(s) (see Section 3.5.4)
	SRQON	GPIB service request on
	SRQOF	GPIB service request off
	V	report model number and software version (see Section 3.5.3)

Alphabetical Listing of Model 3988 GPIB Commands

Character String	Command
AC	ac coupled
AL	all channel mode
B	NOT all channel mode
CD	channel down
CE	clear entry
CH	channel # n
CU	channel up
D	dc coupled
F	frequency
H	frequency (Hz)
ID	input gain down
IG	input gain
IU	input gain up
K	kilo
M1	low-pass mode
M2	high-pass mode
M3	gain mode
ME	Mega (106 multiplier)
OD	output gain down
OG	output gain
OU	output gain up
OV	overflow mode
Q	report board model number(s) (see Section 3.5.4)
R	recall
SRQON	GPIB service request on
SRQOF	GPIB service request off
ST	store
T1	Butterworth Type
T2	Bessel Type
V	report model number and software version (see Section 3.5.3)

3.3.4 Examples

3.3.4.1 Example 1

To set both channels to 10dB input gain, 2kHz, 0dB output gain:

AL; 10IG;2K;0OG <LF>

NOTE

It is only necessary to send those parameters that change, all others remain unaffected.

3.3.4.2 Example 2

To change frequency to 150Hz:

150H

or 150ƀHZ†
or 150F
or .15K
or F150
or H150
or HZ150
or K0.15
or 1.5E2HZ
or F1.5E2

3.3.4.3 Example 3

To read back the settings of channel 2 (see Section 3.5.1):

Data sent to filter: CH2

Data received from filter†: 10ƀ2.000E+3ƀ02ƀ00ƀAC*

Interpretation:

10dB input gain
2kHz cutoff frequency
channel #2
0dB output gain
ac coupled
all channel mode (indicated by the “*”)

† \strike b\plain \ul \f1 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, keyboard cannot be activated by pressing a front panel key.
Go to local	GTL	Puts unit into local control mode such that front panel keyboard is activated.
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 = Butterworth Mode = Low-Pass Cutoff Frequency = 100kHz Coupling = ac Clears current settings for all channels. It does not clear set-ups stored with [STORE] key. It does not change interface bus parameters and flags, such as: addresses, SRQ ON/OFF, parallel poll bit selected, etc.
Selected device clear	SDC	Performs same functions 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 to be 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 the [CE] key.

Lockout mode (local-with-lockout and remote-with-lockout versus 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 produces 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 3988 provides for software configuring of which bit and with which polarity the unit should respond. This bit is "true" when an error condition exists. ("ERR" displayed on the panel). Configuring needs to be done only once or anytime the software desires to change the configuration. The commands related to 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	Places 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 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 3988 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’s bit) 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 enable (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 3988 service request capability is enabled or disabled with the SRQON and SRQOFF commands (see Section 3.3.3). 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 exists 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 (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, not the front panel, then the 64 bit will be set 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 enable	REN	When true, allows the 3988 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 an IEEE-488 (GPIB) controller to interrogate the Model 3988 and read back over the bus it's settings (gain, frequency, etc.)

Four different 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 (2) digits of input gain.

1a. space

2. Four (4) digits plus decimal of 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 (2) digits, a decimal and one digit of channel #

4a. space

5. Two (2) digits of output gain

5a. space

6. "AC" if ac coupled

   "DC" if dc coupled

7. "*" if all channel mode, otherwise a space (See Section 3.3.4.3 for example).

3.5.2 OVERLOAD STATUS INFORMATION FORMAT

After sending the "OS" command, the next line of data the 3988 sends will be four (4) characters; each character represents one channel.

The character will be: "0" if not overloaded, "1" if input is overloaded, "2" if output is overloaded, "3" if both input and output are overloaded. The first character is channel 1, followed by channel 2. Channels which are not present return "0".

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

3.5.3 Model Number and Software Version Format

After sending the "V" command, the next line of data read from the Model 3988 will be as follows:

KROHN-HITE 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 display is showing.

3.6 PROGRAMMING EXAMPLES

The following are programming examples in Microsoft® Quick 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>		

SECTION 4

INCOMING ACCEPTANCE

4.1 INTRODUCTION

The following procedure should be used to verify that the Model 3988 filter 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 and operating for a minimum of 30 minutes to reach operating temperature. If the unit is not operating within specifications, refer to Section 5, Calibration, before attempting any detailed maintenance. Before testing, follow the initial set-up and operating procedure in Section 2.

4.2 TEST EQUIPMENT REQUIRED

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

a. Low Distortion RC Oscillator: Krohn-Hite Model 4400A or equivalent.

b. RC Oscillator: 10Hz to 10MHz, frequency response of ±0.025dB from 10Hz to 500kHz. Krohn-Hite Model 4300B or equivalent.

c. AC Voltmeter: capable of measuring 100mV to 10Vrms, 10MHz bandwidth, Fluke Model 8920A or equivalent.

d. Frequency Counter.

e. Distortion Analyzer: Krohn-Hite Model 6900B or equivalent.

If the [ALL CHAN] key is not lit, press the [ALL CHAN] key to turn on ALL CHANNEL mode. Perform each test on channel 1, then repeat it on channel 2.

4.3 CUTOFF FREQUENCY ACCURACY

Place BNC tees on the oscillator's output and the filter's `+' input and set the filter's differential input switch on rear panel to `+'.

Connect the frequency counter to the oscillator, the oscillator to the filter `+' input, and the AC meter to the filter input.

Set the filter to Butterworth with the [TYPE] key, low-pass with the [MODE] key, 0dB input gain, 0dB output gain and 5kHz with the [FREQ] key.

Set the oscillator to 5kHz, 1VRMS.

Set the meter to read 0dB (dB and REL mode on the Fluke 8920).

Connect the meter to the filter output; adjust the oscillator frequency to get –3.01dB.
The frequency on the counter should be 5kHz ±1%.

Change the filter to high-pass, adjust the oscillator frequency for 3.01dB; the counter should read 5kHz ±1%.

Change the filter to low-pass mode, Bessel type.

Adjust the oscillator frequency for –12.59dB; the frequency on the counter should be 5kHz ±1%.

Change the filter to high-pass, adjust the oscillator frequency for –12.59dB; the counter should read 5kHz ±1%.

Repeat the entire above procedure for 50Hz, 500Hz, 50kHz and 300kHz.

Also check 500kHz and 1MHz in low-pass only.

The tolerance for 300kHz, 500kHz and 1MHz is 2%.

It is important to re-reference the voltmeter at each new frequency since the amplitude of the generator will change with changes in frequency.

4.4 STOPBAND ATTENUATION

Accurate stopband attenuation measurements require some simple precautions because of low level signals. The filter should be shielded with the top and bottom covers in place. BNC cable only should be used between oscillator, filter and voltmeter, and no other instruments should be connected.

Set the oscillator to 5Vrms, 20kHz and connect it to the `+' INPUT with the filter set to a cutoff frequency of 1kHz and 0dB of Input and Output gain.

Connect the OUTPUT through a 6kHz passive high-pass filter, as shown in Figure 4.1, to the ac voltmeter. (Flike 8920 should have `low range enable' pressed in.)

Set the filter to low-pass mode. The filter OUTPUT should be <700mVrms (–80dB)

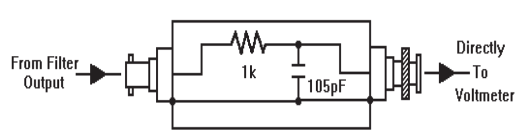

Figure 4.1 Passive High-Pass Filter

.

4.5 PRE-FILTER AND POST-FILTER GAIN ACCURACY

With a BNC tee, connect both the oscillator and the AC meter to the filter `+' Input.

Set the filter to GAIN with the [MODE] key.

With the meter in volts mode, set the oscillator to 1kHz, and about 700mVRMS.

Set the meter to read 0dB (dB and REL mode on the Fluke 8920).

Connect the meter to the filter output.

Set the input gain to 10dB, the meter should read 9.8 to 10.2dB.

Set the input gain to 20dB, the meter should read 19.8 to 20.2dB.

Set the input gain to 0dB, set the output gain to 1dB by pressing `1' and either of the output gain arrows. The meter should read 0.8 to 1.2dB.

Set the output gain to 2dB to 20dB in 1dB steps, checking the meter for æ0.2dB accuracy.

Set the output gain to 0dB.

Connect the meter to the filter `+' Input and set it to volts mode.

Set the oscillator to about 70mVRMS.

Set the meter to read 0dB (dB and REL mode on the Fluke 8920).

Connect the meter to the filter output.

Set the input gain to 30dB, the meter should read 29.8 to 30.2dB.

Set the input gain to 40dB, the meter should read 39.8 to 40.2dB.

Connect the meter to the filter input and set it to volts mode.

Set the oscillator to about 25mVRMS.

Set the meter to read 0dB (dB and REL mode on the Fluke 8920).

Connect the meter to the filter output.

Set the input gain to 50dB, the meter should read 49.8 to 50.2dB.

It is important that the generator be low noise; passive BNC attenuators produce the best results, placed at the filter input.

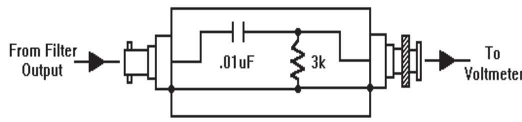

Figure 4.2 Passive 2MHz Low-Pass Filter

4.6 NOISE CHECK

Short the `+' inputs of both filter channels and set the channel being tested to 0dB input gain, 0dB output gain, low-pass ([MODE] key), Butterworth ([TYPE] key), DC coupled (press [SHIFT] then [TYPE], if display shows `AC' press [SHIFT] [TYPE] again; display will show `DC').

Connect a 2MHz low-pass, passive filter, shown in Fig 4.3, to the ac voltmeter and, using a short coax BNC cable, connect it to the model 38's output.

Set the filter to 5kHz. Voltmeter reading should be 300µV or less.

Set the filter to high-pass ([MODE] key). Voltmeter reading should be 300µV or less.

Set the filter to 50kHz, low-pass. Voltmeter reading should be 500µV or less.

Set the filter to high-pass. Voltmeter reading should be 500µV or less.

Set the filter to 1MHz, low-pass. Voltmeter reading should be 1mV or less.

Set the filter to high-pass. Voltmeter reading should be 1mV or less.

Set input gain to 50dB and output gain to 20dB (press 20 and either of the output gain arrows). Voltmeter should read 80mV or less.

4.7 COMMON MODE REJECTION

Turn off the ALL CHANNEL [ALL CH] mode for this test.

Connect a BNC tee to the `+' input of the filter, connect a short coax cable from the tee to the `–' input and connect the oscillator to the other side of the tee.

Connect the ac voltmeter to the output.

Set the filter to GAIN mode (using the [MODE] key) and 0dB input and output gain.

With the differential input switch set to `+' set the oscillator to 10kHz and adjust the amplitude for 7VRMS on the meter.

Set the rear panel differential input switch to the center (DIFF) position and set the output gain to 20dB (press 20 then either of the output gain arrows).

The meter should read 70mV or less (–60dB common mode rejection).

Set the oscillator to 100kHz and the meter should read 220mV or less (–50dB).

Set rear panel differential switch to `+’ and turn [ALL CH] mode on.

4.8 DISTORTION AND MAXIMUM SIGNAL CHECKS

Set the filter to a cutoff frequency of 5kHz in the low-pass mode with 0dB of Input and Output gain.

Connect a low distortion oscillator to the INPUT and apply a 1Vrms signal at 500Hz.

CAUTION

If the distortion is excessive, verify that the distortion of the oscillator being used is <0.005%.

Monitor the OUTPUT of the filter with a distortion analyzer. The reading should be <0.01%.

Connect a 50 ohm terminator to the OUTPUT of the filter. Distortion should be <0.01%. Remove the terminator.

Disconnect oscillator and distortion analyzer.

4.9 AC/DC COUPLING CHECK

Apply a 1Vdc signal to the INPUT of the filter.

Set the filter to low-pass mode with 0dB Input and Output gain.

In the DC COUPLED mode, the OUTPUT of the filter should be approximately 1Vdc and approximately 0Vdc in the AC COUPLED mode.

This page intentionally left blank.