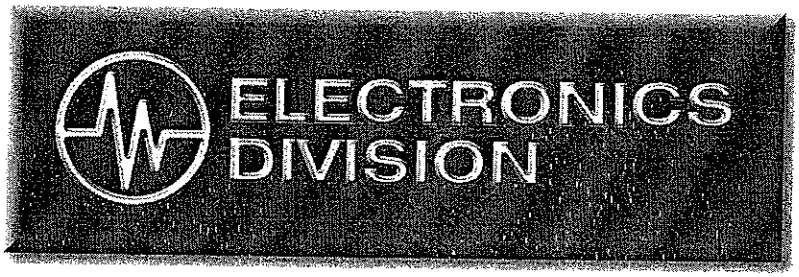

CAUTION!
Please read all instructions before attempting to operate this product.
Damage to circuitry and components due to incorrect
power is NOT covered by warranty.

Models 790A01, A04, A06

Power Amplifiers

Installation and Operating Manual

19614

For assistance with the operation of this product, contact the Electronics Division of PCB Piezotronics, Inc.

Electronics Division toll-free 800-828-8840
24-hour SensorLine™ 716-684-0001
Fax 716-684-0987
E-mail electronics@pcb.com

PCB PIEZOTRONICS INC
ELECTRONICS DIVISION

PCB PIEZOTRONICS INC.
A PCB GROUP COMPANY

Warranty, Service, Repair, and Return Policies and Instructions

The information contained in this document supersedes all similar information that may be found elsewhere in this manual.

Total Customer Satisfaction – PCB Piezotronics guarantees Total Customer Satisfaction. If, at any time, for any reason, you are not completely satisfied with any PCB product, PCB will repair, replace, or exchange it at no charge. You may also choose to have your purchase price refunded in lieu of the repair, replacement, or exchange of the product.

Service – Due to the sophisticated nature of the sensors and associated instrumentation provided by PCB Piezotronics, user servicing or repair is not recommended and, if attempted, may void the factory warranty. Routine maintenance, such as the cleaning of electrical connectors, housings, and mounting surfaces with solutions and techniques that will not harm the physical material of construction, is acceptable. Caution should be observed to insure that liquids are not permitted to migrate into devices that are not hermetically sealed. Such devices should only be wiped with a dampened cloth and never submerged or have liquids poured upon them.

Repair – In the event that equipment becomes damaged or ceases to operate, arrangements should be made to return the equipment to PCB Piezotronics for repair. User servicing or repair is not recommended and, if attempted, may void the factory warranty.

Calibration – Routine calibration of sensors and associated instrumentation is recommended as this helps build confidence in measurement accuracy and acquired data. Equipment calibration cycles are typically established by the users own quality regimen. When in doubt about a calibration cycle, a good "rule of thumb" is to recalibrate on an annual basis. It is also good practice to recalibrate after exposure to any severe temperature extreme, shock, load, or other environmental influence, or prior to any critical test.

PCB Piezotronics maintains an ISO-9001 certified metrology laboratory and offers calibration services, which are accredited by A2LA to ISO/IEC 17025, with full traceablility to N.I.S.T. In addition to the normally supplied calibration, special testing is also available, such as: sensitivity at elevated or cryogenic temperatures, phase response, extended high or low frequency response, extended range, leak testing, hydrostatic pressure testing, and others. For information on standard recalibration services or special testing, contact your local PCB Piezotronics distributor, sales representative, or factory customer service representative.

Returning Equipment – *Following these procedures will insure that your returned materials are handled in the most expedient manner.* Before returning any equipment to PCB Piezotronics,

contact your local distributor, sales representative, or factory customer service representative to obtain a Return Materials Authorization (RMA) Number. This RMA number should be clearly marked on the outside of all package(s) and on the packing list(s) accompanying the shipment. A detailed account of the nature of the problem(s) being experienced with the equipment should also be included inside the package(s) containing any returned materials.

A Purchase Order, included with the returned materials, will expedite the turn-around of serviced equipment. It is recommended to include authorization on the Purchase Order for PCB to proceed with any repairs, as long as they do not exceed 50% of the replacement cost of the returned item(s). PCB will provide a price quotation or replacement recommendation for any item whose repair costs would exceed 50% of replacement cost, or any item that is not economically feasible to repair. For routine calibration services, the Purchase Order should include authorization to proceed and return at current pricing, which can be obtained from a factory customer service representative.

Warranty – All equipment and repair services provided by PCB Piezotronics, Inc. are covered by a limited warranty against defective material and workmanship for a period of one year from date of original purchase. Contact PCB for a complete statement of our warranty. Expendable items, such as batteries and mounting hardware, are not covered by warranty. Mechanical damage to equipment due to improper use is not covered by warranty. Electronic circuitry failure caused by the introduction of unregulated or improper excitation power or electrostatic discharge is not covered by warranty.

Contact Information – International customers should direct all inquiries to their local distributor or sales office. A complete list of distributors and offices can be found at www.pcb.com. Customers within the United States may contact their local sales representative or a factory customer service representative. A complete list of sales representatives can be found at www.pcb.com. Toll-free telephone numbers for a factory customer service representative, in the division responsible for this product, can be found on the title page at the front of this manual. Our ship to address and general contact numbers are:

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3425 Walden Ave.
Depew, NY 14043 USA
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E-mail: info@pcb.com

DOCUMENT NUMBER: 21354
DOCUMENT REVISION: B
ECN: 17900

1.0 Introduction

The 790 Series amplifiers are designed specifically for driving the capacitive loads presented by piezoelectric actuators. The 790 Series includes models 790A01, 790A04, and the 790A06 (one, four, and six channels, respectively). These units are intended primarily for laboratory use and feature adjustable gain for flexibility. An internal calibration reference allows the user to determine the gain of each channel of the amplifier. The 790 Series amplifiers can generate outputs up to ±200 V peak at 50 mA. Since the input impedance of the amplifier is 10 kΩ, a low impedance source should be used. The OUT ÷ 20 BNC jack provides a means of observing the amplifier output at a voltage 1/20 the actual value. This feature allows the user to view the output via a standard oscilloscope and eliminates the need for special high-voltage probes.

Note: The operation of all the 790 Series amplifiers is the same and will be described generically in this manual unless otherwise noted.

2.0 Initial Turn On and Set Up

The 790 amplifier is ready to use as shipped. Ensure that the unit is properly set up for the power source you will be using. The detailed instructions for setting up the input power of the model 790A01 amplifier are given in Section 2.1, and the instructions for setting up the model 790A04 and 790A06 amplifiers are given in Section 2.2. Plug in the line cord and turn the front panel switch on. The switch will illuminate to indicate that power has been applied. As a precaution, ensure that when a signal is connected to the IN BNC jack, it is set to a low voltage level initially (0.1 V or less), so that the output voltage is not too high.

Before connection to the OUT BNC jack, the actuator should be shorted to dissipate any charge that may have accumulated on the piezoelectric material. The amplifier output is protected against transients, but shorting serves as a good precautionary measure.

2.1 Changing the Input Power to the model 790A01

The model 790A01 amplifier will accept either 120 or 220 VAC at 47 to 63 Hz. To select the input power, simply slide the switch on the rear panel to the correct position. Note that the fuse should also be changed as specified by the sticker near the switch. Fuses for each input power are incorporated into the fuse holder in the line cord receptacle.

2.2 Changing the Input Power to the models 790A04 and 790A06

The models 790A04 and 790A06 amplifiers will accept 100, 120, 220, or 240 VAC at 47 to 63 Hz. To determine the voltage that the input is set for, look through the plastic window next to the line cord receptacle, and read the number printed on the small printed circuit board. To change the input power, remove the line cord from the receptacle, slide the plastic window to the left, and remove the small printed circuit board inside. Orient the printed circuit board so that the desired voltage can be read right side up and reinsert the board. Change the fuse if necessary as specified on the rear panel label. Slide the plastic window to the right and reinsert the line cord. The unit is now ready for operation at the new voltage.

3.0 OUT ÷ 20 BNC Jack

The OUT ÷ 20 BNC jack provides a low voltage version of the output signal to facilitate observation with standard readout equipment. This signal is actually an attenuated (by 20) version of the output and thus is a faithful representation of what is being applied to the load.

4.0 CAL Feature

The 790 amplifier has an internal +1.00 VDC reference that allows the user to determine the gain of the unit. When the CAL button on the front panel is depressed, the IN BNC is disconnected, and the +1.00 VDC reference is connected to the amplifier input. The output of the amplifier in volts will then be the gain of the 790 amplifier in volts/volt. For example, when the CAL button is depressed, the DC voltage at the OUT BNC is -29.4 volts, therefore the gain of the 790 amplifier is set at -29.4 V/V. The amplifier is inverting so the gain will always be negative.

5.0 Operating Considerations

When using the 790 amplifier to drive capacitive loads, three factors must be considered. They are stability of the 790, the gain and bandwidth of the 790 (they are interdependent), and the current requirements of the load. All of these must be considered to ensure optimum performance.

5.1 Stability

The maximum capacitive load for which the 790 amplifier is *stable* is proportional to its gain. The maximum capacitive load can be computed using the following formula:

$$C_{max} = gain \times 20\,nF \qquad (1)$$

Thus at a gain of 5 the unit can drive 100 nF and at a gain of 50 it can drive 1000 nF (1 μF). Loads that are larger than these values may cause oscillation of the output and are not recommended. It is possible to modify the unit to drive larger capacitive loads. Please consult the factory if this is necessary.

5.2 Gain and Bandwidth

The gain of the 790 amplifier is factory set at 30.0 ±0.3 V/V. The gain may be set to any value between 5 and 50 by using a small screwdriver to turn the GAIN potentiometer on the front panel. Turning the pot clockwise increases the gain, and turning the pot counterclockwise decreases the gain. The gain may be checked using the CAL button as described in Section 4.0.

It is important to note that the bandwidth of the 790 amplifier is inversely proportional to the gain. The -3 dB bandwidth is simply:

$$bandwidth = \frac{250\,kHz}{gain} \qquad (2)$$

Note: *Bandwidth* as discussed here refers to the no load maximum frequency of the amplifier. If the amplifier is operated above its maximum frequency, attenuation of the signal will occur.

5.3 Output Current Limitations

5.3.1 Sinusoidal Inputs

The impedance of piezoelectric actuators is inversely proportional to frequency because they are capacitive loads. Thus, output voltage, and the size of the load capacitance will determine the frequency at which the 790 amplifier becomes current limited. Since the maximum output current of the 790 amplifier is 50 mA peak, the maximum operating frequency for a sinusoidal input may be calculated using the following formula:

$$f_{\max} = \frac{0.05}{2 \times \pi \times V_{pk} \times C_{load}} \quad Hz \qquad (3)$$

where: V_{pk} *= the peak voltage of the sinusoid in volts*
C_{load} *= the capacitance of the load in Farads*

If the amplifier is operated at frequencies higher than this, the output signal will be slew rate limited. This means that a sine wave input will begin to look like a triangular wave on the output.

5.3.2 Non-Sinusoidal Inputs

For non-sinusoidal waveforms, the slew rate may be determined mathematically by differentiating and finding the maximum slope of the signal (in volts/sec). The slew rate may be determined empirically by viewing the time domain signal and trying to read the maximum slope. To avoid distortion due to current limiting, this result must be less than the maximum slew rate of the 790 amplifier, which is a function of the capacitive load and is determined as follows:

$$\frac{dv}{dt} = \frac{0.05}{C_{load}} \quad \frac{volts}{\text{sec}} \quad \text{for } C_{load} > 6.25\ nF \qquad (4)$$

and $\quad 8 \times 10^6 \quad \frac{volts}{\text{sec}} \quad$ *for* $C_{load} < 6.25\ nF$

6.0 Applications

To determine the maximum frequency at which the 790 amplifier/load system can be operated, follow these steps (as discussed in section 5):

A) Stability - determine if the 790 amplifier is stable with the desired capacitive load using equation (1):

$$C_{\max} = gain \times 20\ nF \qquad (1)$$

If so, continue to step B). If not, either reduce the capacitance of the load, increase the gain, or contact the factory to determine the modifications necessary to accommodate the desired load.

B) Bandwidth/Current Limitations - determine the bandwidth of the 790 amplifier using equation (2):

$$bandwidth = \frac{250kHz}{gain} \qquad (2)$$

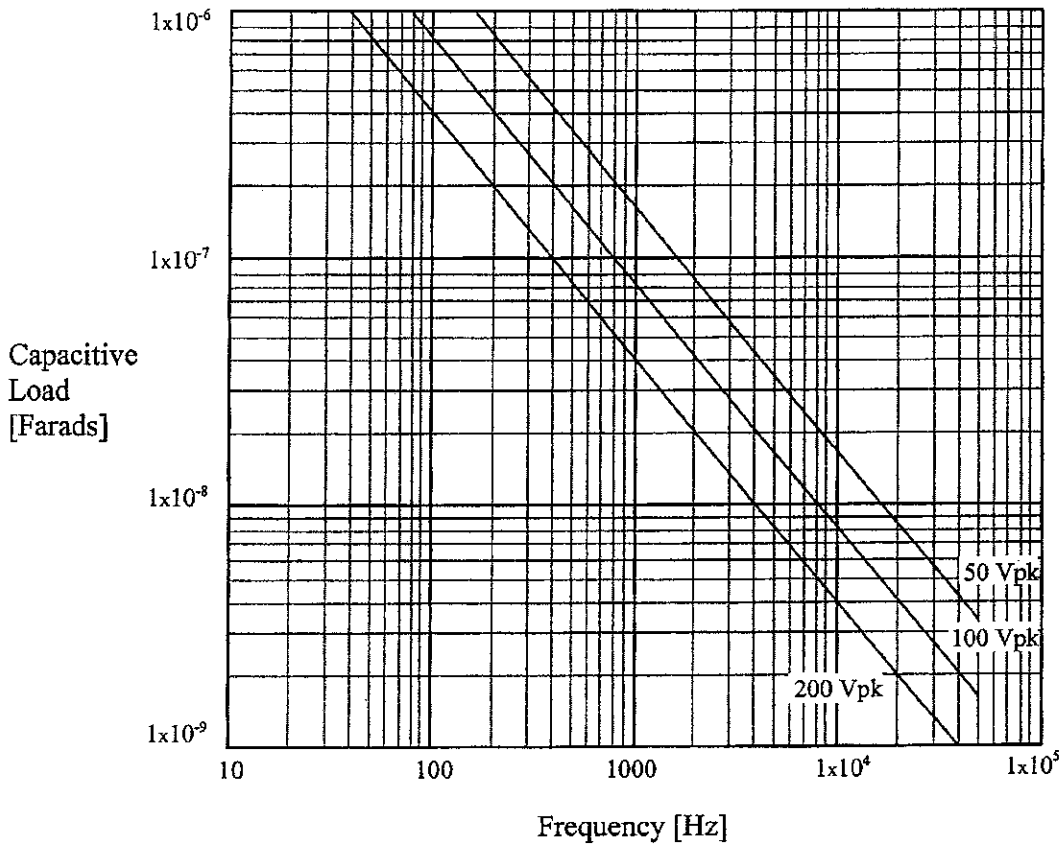
Then determine f_{max}, the frequency at which current limiting begins using equation (3):

$$f_{\max} = \frac{0.05}{2 \times \pi \times V_{pk} \times C_{load}} \quad Hz \qquad (3)$$

The lower of the results from equation (2) and (3) is the maximum system frequency for sinusoidal signals.

6.1 Graphical Determination of System Frequency

The following chart is useful in expressing the drive capabilities of the 790 amplifier for sinusoidal signals and allows one to determine the maximum operating frequency graphically (remember the amplifier must be stable for the load in question as per equation (1)).



The graph shows the maximum load capacitance as a function of frequency for several different peak output voltages. Notice that the capacitance is limited to 1 μF and the frequency is limited to 50 kHz since these are the limits of the 790 amplifier. To use the chart, first draw a vertical line to represent the bandwidth of the amplifier for the gain at which it will be used (250 kHz/gain). For example, if a gain of 10 is used, draw a vertical line at 25 kHz. The amplifier should not be used at frequencies to the right of this vertical line, because attenuation will occur at a rate of about -20 dB/decade above 25 kHz.

Next, find the capacitance of the load on the y axis of the chart and follow it horizontally to the right until it meets the diagonal line that represents the peak output voltage you will be using. Remember that you can not cross the vertical line drawn in the previous step. If you meet the vertical line, the amplifier will be bandwidth limited at that frequency. Follow the vertical line downward from the intersection point to locate the maximum frequency at which the amplifier may be operated.

7.0 Application Examples

The following examples are intended to help the user better understand the proper application of the 790 amplifier.

Example 7.1: Find the maximum frequency at which the 790 amplifier can drive the AVC model 712A01 (45 nF) inertial actuator with a peak output voltage of 150 volts. The gain of the 790 amplifier is set to 30.

At a gain of 30, the amplifier is stable up to 600 nF, so 45 nF is within the operating range. The bandwidth of the amplifier is 250 kHz / 30 = 8.33 kHz. Using equation (3) with 45 nF for C_{load} and 150 for V_{pk}, the amplifier becomes current limited above 1180 Hz. Taking the lowest of these two, the system bandwidth is 1180 Hz.

Example 7.2: Find the maximum frequency at which the 790 amplifier can drive a load capacitance of 5 nF with a peak output voltage of 200 V. The gain of the 790 amplifier is set to 50.

The 790 amplifier is stable up to 1 μF at a gain of 50, so 5 nF is within the operating range. The bandwidth of the 790 amplifier is 250 kHz/50 = 5kHz. Solve equation (3) with 5 nF for C_{load} and 200 V for V_{pk} to determine the frequency at which the 790 amplifier becomes current limited. The result is 8 kHz. The system bandwidth is the lower of these two values, 5 kHz.

Note that in this example, the maximum operating frequency could be extended by reducing the gain of the 790 amplifier. For instance, if the gain were reduced to 25, the 790 amplifier bandwidth would be 10 kHz, and the system bandwidth would be 8 kHz.

Example 7.3: Find the maximum voltage the 790 amplifier can drive an AVC model 713A01 (32 nF) patch actuator with at a frequency of 3 kHz. The gain of the 790 amplifier is set to 20.

The 790 amplifier is stable up to 400 nF at a gain of 20, so 32 nF is within the operating range. The bandwidth of the 790 amplifier is 250 kHz/20 = 12.5 kHz, so it will not be bandwidth limited at 3 kHz. Solve equation (3) for V_{pk} using 32 nF for C_{load} and 3 kHz for f_{max}. The maximum voltage is 82.9 volts peak.

Example 7.4: Find the maximum gain setting for which the 790 amplifier is stable if the load is 800 nF.

The maximum gain is 800 nF/20 nF = 40 as per equation (1). Loads more than 800 nF at this gain may cause oscillation of the output.

Model Number		Revision: C
790A01	**POWER AMPLIFIER**	ECN #: 10835

ELECTRICAL

Output Voltage Range	volts pk	200 ±5%	
Output Current	mA pk	±50 ±5%	[5]
Output Voltage Monitor	volts	Volts Out/20 ±5%	
Calibration	type	Internal	
Calibration Voltage	VDC	1.00 ±2%	[1]
Slew Rate	volts/µ s	>30	
Voltage Gain (inverting)	volt/volt	5 to 50 Adjustable	
Input Impedance	ohms	10,000 ±10%	
Maximum Capacitive Loading	nF	100-1,000	[2]
Large Signal Bandwidth (-3 dB)	kHz	50-5	[3]
Low Frequency Response		DC	
Power Requirements:	VAC	120/220	[4]
	Hz	60/50	

PHYSICAL

Dimensions: (h x w x d)	in	6.2 x 4 x 11
	[mm]	[155,6 x 101,6 x 279,4]
Weight	lb [kg]	7.5 [3,4]
Connectors	type	BNC Jack

NOTES:

[1] Calibration voltage is applied to the input when front panel CAL button is depressed.

[2] Capacitive loading is proportional to gain; at a gain of 5, the 790A01 can drive 100 nF; at a gain of 50, the 790A01 can drive up to 1,000 nF (1µF). Exceeding these specifications may cause instability.

[3] Bandwidth is inversely proportional to gain; at a gain of 5, the 790A01 has a bandwidth of 50 kHz; at a gain of 50, the 790A01 has a bandwidth of 5 kHz.

[4] Selectable using rear panel switch.

[5] Serial numbers less than 302, except #290, 100 mA pk ±5%.

SUPPLIED ACCESSORIES:

Model 017 Power Cord

In the interest of constant product improvement, we reserve the right to change specifications without notice.

PCB PIEZOTRONICS

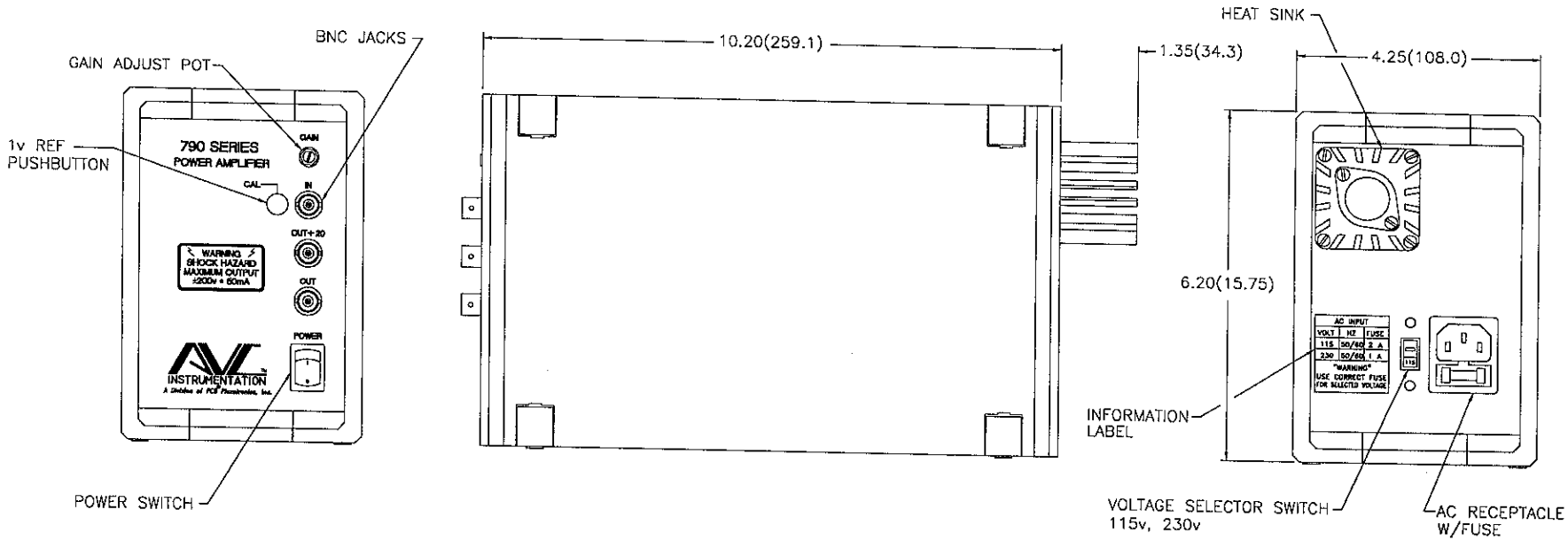
INSTRUMENTATION

Drawn		8/31/99	Spec No.
Engineer		9/13/99	790-1010-80
Sales		9/13/99	
Approved		9/13/99	Sheet 1 of 1

790-1010-95

APPLICATION		
NEXT ASS'Y	USED ON	VAR
	790A01	-01

REVISIONS					
ZONE	REV	DESCRIPTION	ECN	DATE	APP'D
	A	REVISED PER ECR #	4961	5/11/94	
	B	ADDED WARNING LABEL TO F.P.	9990	1/20/99	
	C	UPDATED NEW ENCLOSURE	10495	5/26/99	
	D	REVISED WORDING ON F. PANEL	10929	9/29/99	



UNLESS SPECIFIED TOLERANCES	
DIMENSIONS IN INCHES DECIMALS XX ±.02 XXX ±.010 ANGLES ±2 DEGREES	DIMENSIONS IN MILLIMETERS (IN PARENTHESIS) DECIMALS X ±0.3 XX ±0.13 ANGLES ±2 DEGREES
DD013 REV. B 03/13/98	

DRAWN			MFG		
CHK'D			ENGR		
APP'D					

TITLE: OUTLINE DRAWING
MODEL 790A01
POWER AMPLIFIER

PCB PIEZOTRONICS
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(716) 684-0001 EMAIL: SALES@PCB.COM

CODE IDENT. NO.	DWG. NO.
52681	790-1010-95
SCALE: 1=1.5	SHEET 1 OF 1