AE SENSORS
&
PREAMPLIFIERS

USERS MANUAL

Rev 0

June 18, 2002

Part # 1220-1001

AE Sensors and Preamplifiers
Users Manual

Table of Contents

1. INTRODUCTION: AE SENSORS

THE MOST IMPORTANT SINGLE FACTOR IN SUCCESSFULLY PERFORMING AN AE APPLICATION IS THE RELIABILITY OF AN AE SENSOR

High reliability is achieved by PAC's long experience in the successful design and production of numerous types of electroacoustic sensors for AE research, field and production applications. After years of continuous research and development by several members of our engineering staff, PAC is now becoming the recognized leader in the manufacturing of AE sensors. PAC's production flexibility provides the user with a large selection of transducers to fit many individual applications. The selection of the proper AE sensor depends on the specific application. Individual specification sheets have been prepared with specific recommended applications and features. Our engineers are also available to discuss your requirements, and, if necessary, to custom design sensors for your unique applications at moderate costs.

2. DETECTION OF ACOUSTIC EMISSION SIGNALS

Because an acoustic emission sensor converts the mechanical energy carried by the elastic wave into an electrical signal, the sensor is more properly termed a transducer. The transducer most often used in AE applications is the piezoelectric transducer. This choice has been dictated by the ease with which it may be built, its inherently high sensitivity, and a ruggedness which allows its use in industrial applications.

The active element of a piezoelectric transducer is a thin disk of piezoelectric material (a material which can convert mechanical deformation into electrical voltage). This disk is metalized on both faces for electrical contact, and mounted in a metal cylinder to provide electromagnetic interference shielding. The piezoelectric ceramics commonly used in AE transducers are made of small crystals of titanates and zirconates which are mixed with other materials, molded to the desired shape, and fired in a kiln. The ceramic material is then made piezoelectric by poling, which is the process of heating the material above its Curie temperature while the material is in a strong electric field.

To take advantage of the extreme sensitivity of the piezoelectric transducer, it must be attached to the material under observation in such a manner that the acoustic energy passes into the transducer with minimum loss at the transducer-material interface. The required intimate mechanical contact is achieved on flat surfaces by mechanical clamping using thin films of grease, oil or epoxy adhesive between the transducer and the material. In general, the problem of coupling is much more severe for shear wave observation because the coupling medium must be sufficiently viscous to support the shear motion.

Though it appears that a piezoelectric transducer properly coupled to a specimen should be an ideal sensor for acoustic emission work, there are some important limitations. Though the theory of piezoelectricity accurately relates the output voltage of a piezoelectric material to the stress on its free surface, complications arise when the transducer is coupled to a real material. The tightly coupled material changes the mechanical boundary conditions that existed at the previously free surface of the transducer. Hence the displacement and stress at the transducer are quite different from their values in the absence of the material.

The very complicated interaction between the transducer and what it is trying to measure has made it difficult to relate the transducer output voltage exactly to what is happening within the sample. If the acoustic wave is not a plane wave, further complications arise because of the variation in phase over the transducer surface. While these problems of the piezoelectric transducer have been troublesome in basic research aimed at trying to uncover the nature of the AE source event, the piezoelectric transducer has proven time and again to be more than adequate for most general nondestructive testing applications.

3. AE TRANSFER COUPLING

When a sensor has simply been placed on the surface of the material containing the acoustic wave it is found that the sensor produces a very weak signal. If a thin layer of a fluid is placed between the sensor and the surface, a much larger signal is obtained. The use of some type of couplant is almost essential for the detection of low level acoustic signals. Physically, this can be explained by looking at the acoustic wave as a pressure wave transmitted across two surfaces in contact. On a microscopic scale the surfaces of the sensor and the material are quite rough, only a few spots actually touch when they are in contact. Stress is force per unit area and the actual area transmitting a force is very small. If the microscopic gaps are filled with a fluid, the pressure will be uniformly transferred between the surfaces. For a shear wave with a variable strain component parallel to the surfaces, again very little strain will be transferred between the surfaces because of the few points in actual contact. In this case filling the gaps with a low viscosity liquid will not help much since such a liquid will not support a shear stress. However, a high viscosity liquid or a solid will help transmit the parallel strain between surfaces. The purpose of a couplant, then, is to insure good contact between two surfaces on a microscopic level.

A couplant is any material which aids the transmittal of acoustic waves between two surfaces, while a bond is a couplant which physically holds the sensor to the surface. Water is couplant and cured epoxy resin is a bond. Many problems have come about from using a bond in an inapplicable way. If a rigid bond is used to attach a sensor to a sample which elastically deforms during the test, the normal result is a broken bond and poor or no sensitivity to the acoustic wave. Similarly, in an experiment where the temperature is changed appreciably, the use of a rigid bonding material can lead to broken bonds due to differential thermal expansion between the sensor and the sample.

Bonding agents, then, must be chosen with great care and the primary emphasis must be put upon the compatibility of the materials under the test conditions. Usually if the bond will hold the sensor on, it will be an adequate couplant. For a compressional wave any fluid will act as a couplant. A highly viscous fluid will transfer some shear stress across the boundary which may or may not be an advantage. The most practical rule is to use as a couplant a thin layer of any viscous fluid which wets both surfaces. The sensor should be held against the surface with some pressure furnished by magnets, springs, tape, rubber bands, etc. The secret is to use as thin a layer as possible. If a rigid bond is used there must be no differential expansion between the two surfaces. In Table 3.1 a few commonly used couplants are listed along with the temperature range where they can be used.

Table 3.1

Some Common Acoustic Emission Couplants and the Approximate Temperature Range Where They Can Be Used

Dow Corning V-9 resin	-40° to 100° C
High vacuum stop cock grease	-40° to 200° C
Ultrasonic couplants	room temperature
Petroleum grease	room temperature
Water	1° to 99° C
Dow Corning 200 fluid	-273°C to -70°C and -30°C to 200°C
Salol	-40°C to 40°C
Nonaq stop cock grease	-273°C to 100°C
Dental cement	0° to 50°C
50% Indium - 50% Galium mixture	20° to 700°C

4. INTEGRAL PREAMPLIFIER SENSORS

The R3I, R6I, R151, R30I, R50I and WDI integral preamplifier sensors represent a significant advancement for the field of acoustic emission by enclosing a low-noise FET input 40 dB pre-amplifier inside a standard high sensitivity sensor. These rugged, small size AE integral pre-amplifier/sensors eliminate the need for cumbersome pre-amplifiers by incorporating two functions into one, thereby reducing equipment costs and decreasing set-up time for field applications. These sensors also come with optional "Auto Sensor Test" capability designated with an "AST" suffix after the sensor model type (e.g. R15I-AST). AST models offer an internal sensor pulsing capability when used with A or AST-capable AE systems with the AST capability such as DiSP, MISTRAS, LAM or SPARTAN 2000. AST provides an automated means of pulsing and receiving a simulated AE burst that is coupled to the structure. AST tests the entire AE signal processing chain starting with the sensor coupling, through the sensor and preamplifier, cabling and AE system electronics. This is useful for testing individual sensor coupling, verifying the response of other sensors attached nearby to the same structure, establishing inter-sensor timing parameters that can be used to determine sensor spacing and providing verification of the repeatability of the AE sensors throughout the AE test.

These integral preamplifier sensors were developed with the purpose of attaining high sensitivity and the capability of driving long cables without the need of a separate pre-amplifier. In addition, they connect directly to all existing PAC AE instruments and systems and are also compatible with other manufacturers' systems.

4.1 Features

- Small size, stainless steel construction
- Operation range — 45°C–80°C (-25°C–80°C for AST versions)
- Good RFI/EMI immunity
- Wide dynamic range (>80 dB)
- Low noise pre-amp (~2 μV)
- Single BNC input/output (power signal)
- Interchangeable with existing pre-amp/sensors
- Ideal for field/lab testing
- Auto Sensor Test option allows for sensor pulsing or self-test

4.2 Functional Description

The integral sensors are completely enclosed in a stainless steel case and coated to minimize RFI/EMI interference. In addition, care has been taken to thermally isolate the critical input stage of the pre-amplifier, in order to provide excellent temperature stability over the range of -45°C to +80°C. For ease of use, the integral sensors utilize a standard coaxial cable with BNC connector to power the pre-amp and carry the output signal. The complete block diagram of the integral sensor is shown below in Figure 1.

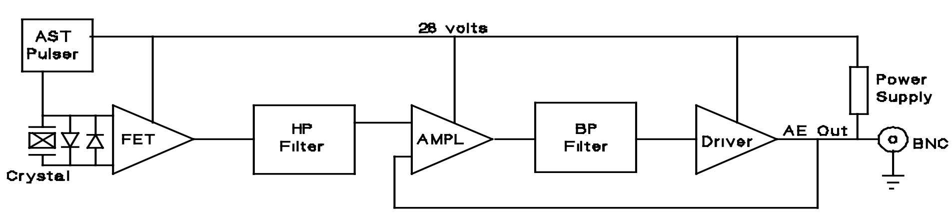

Figure 1. Integral Sensor Block Diagram

4.3 Specifications

Electrical Specifications:

- Gain: 40 ± 1 dB
- Peak Sensitivity: 30 dB ref 1 V/mBar
- Noise (RMS rti): ~2 µV
- Dynamic Range: >80 dB
- Output Voltage: >15 Vpp into 50 Ohms
- Power Required: 28 V at 100 mA
- AST Pulse: -24 Volt, 0.4 microseconds into crystal
- AST Trigger: < 2 Volts at preamplifier output (power)
- Completely enclosed crystal for RFI/EMI Immunity

Physical Specifications:

- Temperature (°C): -45 to +80 (-25–80 for AST)
- Shock Limit (g): 500
- Case material: Stainless steel (304)
- Face material: Ceramic
- Grounding: Case grounded and isolated from mounting surface
- Connector type: BNC
- Connector location: Side (TC option provides a Top mount connector)
- Directionality (dB): ±1.5
- Seal type Epoxy
- Pressure: <400 psi hydrostatic pressure

Model Related Specifications	Sensor Model				
	R6I	R15I	R30I	R50I	WDI
Sensor drive capability (w/RG-58 AU cable)	up to 3000 ft. (1000 m)	up to 1000 ft. (300 m)	up to 500 ft. (160 m)	up to 300 ft. (100 m)	up to 300 ft. (100 m)
Dimensions (dia. x ht. (mm)	29 x 40	29 x 31	29 x 31	29 x 30	29 x 30
Dimensions (dia. x ht. (in.)	1.13 x 1.6	1.13 x 1.23	1.13 x 1.23	1.13 x 1.16	1.13 x 1.16
Weight (gm)	98	70	75	70	70
Peak sensitivity Ref V/m/s)/[Ref V/mbar]	120† [-26]*	109† [-24.5]*	98† [-24]*	86† [-28]*	87† [-28]*
Operating frequency range (kHz)	40–100	70–200	125–450	300–550	100–1000
Resonant frequency (kHz)[1]	50† [90]*	125† [153]*	225† [350]*	320† [500]*	125† [500]*

NOTE 1: † Denotes response to plane waves (angle of incidence normal to face of sensor).
* Denotes response to surface waves (angle of incidence transverse or parallel to face of sensor).

5. PREAMPLIFIER INTRODUCTION

Physical Acoustics has a wide range of preamplifiers for use with our systems. There is a need for different types of preamplifiers due to different applications, specific environmental needs and cost constraints. Below is a short description of each preamplifier family in PAC's line of preamps. Following that is a specification sheet and additional information regarding each type.

2/4/6 Preamplifier Family: The 2/4/6 preamplifier family includes the 0/2/4 (meaning gain ranges of 0dB, 20 dB and 40 dB) and 2/4/6 (meaning 20 dB, 40 dB and 60 dB gain ranges). Other family members include the 0/2, 2/4 and 4/6 preamplifiers. This family of preamplifiers is meant to replace the industry's most famous preamplifier, the 1220A. This is our premiere preamplifier and is meant for laboratory use when the customer is not sure about the gain that his/her application will need or the frequency bandwidth. These preamplifiers were designed to be used with all available AE systems that have their power supplied via the output signal BNC. Provided with three selectable gain settings (switch selectable), this preamplifier operates with either a single-ended or differential sensor. Plug-in filters provide the flexibility to optimize sensor selectivity and noise rejection. These filters are supplied in the Low Pass (LP), High Pass(HP) and Band Pass (BP) configurations, and offer constant insertion loss for easy filter swapping without the need for recalibration. Auto Sensor Test (AST) allows the sensor to characterize its own condition, as well as send out a simulated acoustic emission wave that other sensors can detect. There's also a "C" version available.

1220 Series Preamplifiers: PAC's family of 1220 Preamplifiers offers the versatility of interchangeable filters for matiching different sensors and dealing with diverse noise environments. Low noise, outstanding dynamic range and superior techniques for avoiding the pickup of EMI are the cornerstones for PAC's long-standing leadership in this vital area. The family of 1220 Preamplifiers features single and differential input, switchable 40/60 dB gain and replaceable bandpass filters with values from 10 kHz to 1.5 MHz.

There are three versions of the 1220 Preamplifier: the **1220A** is powered by +28 volts, which uses the single BNC for both power and singal. This model has been replaced with the 0/2/4 and 2/4/6 family of preamplifiers. However, if there is need for this preamplifier to match those already in use, PAC is happy to supply it.

The **1220B** is powered by a separate +/-15 volt source. This uses a BNC connector for signal output and a Lemo connector for power input.

1220C also separates the power input from the signal output . It uses two separate BNC connectors, one for 28 volt power and one for signal output.

In-Line "IL" Series Preamplifiers: The In-Line series of preamplifiers are small (~1" square x 2.2" long), low cost preamplifiers, that are available for those applications where there is a known specific preamplifier requirement. These preamplifiers have a fixed gain (0, 20, 40 or 60 dB), fixed frequency bandwidth (various filters are available) and specific sensor input connection (single or differential), all which are specified at the time of purchase. The result is a very small, simple (just two connectors) and lower cost preamplifier that is easy to install and use.

1222 Charge Preamplifier: A charge preamplifier is used in cases where there is a need for long lengths of sensor input cable. Charge preamplifiers do not suffer from distance/attenuation effects like a voltage preamplifiers do. They maintain the signal amplitude regardless of distance from the passive sensor to the preamplifier. Our 1222A Charge Preamplifiers work with our entire range of single ended sensors and feature (internally) selectable 40/60 dB gain, standard PAC Pluggable filters with bandwidths of 20 – 600 kHz and built-in test signal and control. They are directly compatible with all PAC systems using the single Power/signal AE input BNC connection.

1225IS Intrinsically Safe Preamp/Sensors/Barriers: The 1225IS family of components are used in hazardous, gaseous environments that require chass IIC, Intrinsically safe (IS) apparatus. They are a direct replacement for the Physical Acoustics standard line of Sensors and 1220A preamplifiers. The IS sensors (R6-IS, R15-IS and RWD-IS) and the preamplifier (1225A) are designed and certified for use within the hazardous area, while the barrier (1225B) is attached to the preamplifier and is installed outside the hazardous area where it is connected to the AE instrument. Therefore, this series of sensor and preamplifier is used when the AE system can be installed outside the hazardous area. The 1225A IS preamplifier must be used in combination with the listed IS sensors and 1225B barrier. It features 20/40 dB selectable gain, pluggable High Pass and Low Pass filters and operates with PAC's standard single Power/Signal BNC.

1227 Series Preamplifiers: This family of preamplifiers offers 20 dB AE signal gain and very low power operation (3 milliamp typical). The 1227A is designed for standard 50 Ohm AE systems while the 1227B is designed for 600 Ohm AE systems. Both models use PAC's standard single Power/Signal BNC. These preamplifiers are very small (~ 0.7" square by 2.5" long) and low cost.

1227WT Preamplifier: The PAC 1227WT preamplifier offers 20dB AE signal gain like the 1227A with the exception that it operates in a wide temperature range of -47°C to +175°C. Also there is an optional "pulse Through" sensor calibration capability.

5.1 0/2/4 & 2/4/6 Preamplifiers

5.1.1 Description

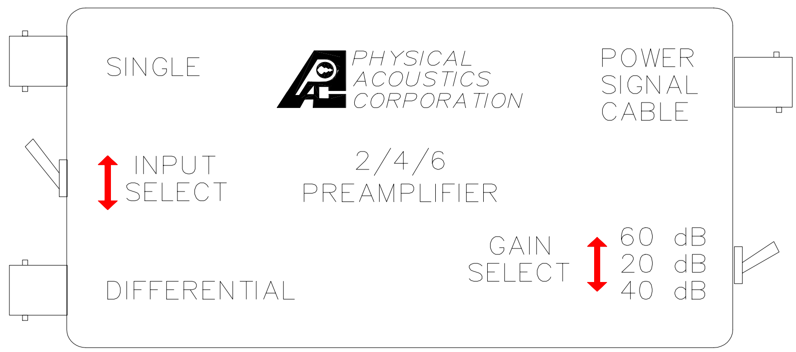

Figure 2. 2/4/6 Preamplifier

The 0/2/4 and 2/4/6 pre-amplifiers were designed to be used with all available AE systems that has its power supplied via the output signal BNC. The 0/2/4 is supplied with 0/20/40 dB gain (switch selectable), while the 2/4/6 is supplied with 20/40/60 dB gain. These pre-amplifiers operate with either a single ended or differential sensor. Plug in filters provide the user with flexibility to optimize sensor selectivity and noise rejection. These filters are provided in the Low Pass (LP), High Pass (HP), and Band Pass (BP) configurations, and offers constant insertion loss for easy filter swapping without the need for recalibration. Automatic Sensor Test (AST) is supplied as an option. This option provides the sensor with the ability to characterize its own condition as well as send out a simulated acoustic emission wave that other sensors can detect.

5.1.2 0/2/4 and 2/4/6 Specifications

Electrical Specifications:

- Gain Selectable: 0/2/4 - 0/20/40 dB ± 0.5% dB
  2/4/6 – 20/40/60 dB ± 0.5% dB
- Input Impedance: 10kΩ // 15pF
- Power Required: 18-28Vdc
- Operating Current: 30mA (With AST Installed)
  28mA (Without AST Installed)
- Dynamic Range: 75dB (Utilizing an R15 Sensor)
  80dB (50Ω Input)

Environmental Specifications:

Temperature: - 40° C to + 65° C

Physical Specifications:

5 1/2in(L) x 2 3/8(W) x 1 3/8(H)
13.97cm x 6.03cm x 3.49cm
Weight: 0.45lb (205grams)

2/4/6 Gain Related Specifications:

Gain Selection	20dB	40dB	60dB
· Bandwidth (-3dB):	10kHz-2.5MHz	10kHz-2.0MHz	10kHz-900kHz
· Output Voltage (50Ω Load):	20Vpp	20Vpp	6Vpp
· CMRR (500kHz):	42dB	42dB	42dB
· Noise(RMS rti):			

Filter Frequency Response Hz	20dB *With R15 Sensor*	40dB *With R15 Sensor*	60dB *With R15 Sensor*	20dB *Input Shorted*	40dB *Input Shorted*	60dB *Input Shorted*
135k-185k	3 µV	1.4 µV	1.5 µV	2.0 µV	1.0 µV	0.42 µV
100k-300k*	3 µV	1.8 µV	1.8 µV	2.3 µV	1.0 µV	0.8 µV
10k-2.0M	5 µV	4 µV	3 µV	4 µV	3 µV	2.5 µV

**Standard filter*

0/2/4 Gain Related Specifications:

Gain Selection	0dB	20dB	40dB
· Bandwidth (-3dB):	10kHz-2.5MHz	10kHz-25MHz	10kHz-800kHz
· Output Voltage (50Ω Load):	3Vpp	20Vpp	20Vpp
· CMRR (500kHz):	29dB	29dB	28dB
· Noise(RMS rti):			

Filter Frequency Response Hz	0dB *With R15 Sensor*	20dB *With R15 Sensor*	40dB *With R15 Sensor*	0dB *Input Shorted*	20dB *Input Shorted*	40dB *Input Shorted*
135k-185k	20 µV	4.8 µV	3.5 µV	20 µV	4.3 µV	2.7 µV
100k-300k*	20 µV	6.2 µV	5.2 µV	20 µV	5.8 µV	4.5 µV
10k-2.0M	30 µV	19.5 µV	11 µV	30 µV	19 µV	10 µV

5.1.3 Installation and Operation

The 0/2/4 and 2/4/6 use similar pluggable filters as the 1220A. Please refer to section 5.7 for standard filter values available for this preamplifier, however, use part number “2-14-40” rather than “1220A” when specifying filters for this family. Also refer to the section 5.7 of the 1220A preamplifier documentation for installation of filters as well as preamplifier installation.

5.2 In-Line Differential Preamplifiers (IL-XX-D)

5.2.1 Description

The Inline Differential Preamplifier was designed to be used with all available AE systems that has its power supplied via the output signal BNC. These preamplifiers are small compact, low noise differential preamplifiers (for use with differential sensors only), with fixed gain and fixed filter bandwidths. On applications where the user knows the specific bandwidth and gain required, these preamplifiers offer the most compact, low noise, low cost solution. Several different gain models are available including 0 dB gain (model IL-D), 20 dB (IL-20D), 40dB gain (IL40D) and 60dB gain (IL60D). It has an active filter built in and optimized sensor selectivity and noise rejection. Various filter values are available and are specified at the time of the purchase. Automatic Sensor Test (AST) is supplied as an option. This option provides the sensor with the ability to characterize its own condition as well as send out a simulated acoustic emission wave that other sensors can detect.

Figure 3. In-Line Differential Preamplifier

5.2.2 Specifications

Physical Specifications:

- 3.25in.(L) x 1.13in.(W) x 0.86in.(H)
  (8.26cm x 2.87cm x 2.22cm)
- Weight: 0.12lb (54 grams)

Electrical Specifications:

- Gain : 0, 20, 40 and 60 dB ± 0.5% dB
- Input Impedance: 10kΩ // 15pF
- Power Required: 18-28Vdc
- Operating Current: 30mA (With AST Installed)
  28mA (Without AST Installed)
- Dynamic Range: 80dB (Utilizing an R15 Sensor)
  90dB (50Ω Input)

Environmental Specifications:

Temperature: - 40° C to + 65° C

	IL-D	IL-20D	IL40D	IL60D
· Gain	0 dB	20 dB	40 dB	60 dB
· Output Voltage (50Ω Load):			15Vpp	15Vpp
· CMRR (500 kHz):			50 dB	50 dB
· Noise(RMS rti):			2 μV	2 μV

5.2.3 Standard Filters

Filters for the In-line differential preamplifiers are installed at the factory. Filter values must be specified at the time of purchase. The following are the standard available filter bandwidths for the In-Line differential preamps.

20 – 100 kHz	20 – 1000 kHz	50 – 500 kHz	100 – 300 kHz
100 – 1200 kHz	135 – 185 kHz	250 – 350 kHz	400 – 1000 kHz

Contact the factory for values other than those listed above.

5.2.4 Installation and Operation

Installation of the In-line differential sensors are very easy since there are only two connectors to connect and no configuration switches. Simply connect a differential sensor to the input of the of the preamplifier and connect the output of the preamplifier to the AE system channel input.

5.3 In-Line Single Ended Preamplifiers (IL-40S)

5.3.1 Description

The Inline Single Preamplifier is the lowest cost preamplifier in PAC's preamplifier line. It has been designed to be used with single ended sensors only and has a fixed gain of 40 dB (model IL-40S). It was designed to be used with all available AE systems that has its power supplied via the output signal BNC. It has "light" band pass filtering to optimize sensor selectivity and noise rejection. Automatic Sensor Test (AST) is supplied as an option. This option provides the sensor with the ability to characterize its own condition as well as send out a simulated acoustic emission wave that other sensors can detect.

Figure 4. In-Line Single Ended Preamplifier

5.3.2 Specifications

<u>Physical Specifications:</u>

- 3.25in.(L) x 1.13in.(W) x 0.86in.(H)
  (8.26cm x 2.87cm x 2.22cm)
- Weight: 0.12lb (54 grams)

<u>Electrical Specifications:</u>

· Gain:	40 dB $\pm$ 0.5% dB (Fixed)
· Input Impedance:	10kΩ // 15pF
- Input type:	Single ended inputs (signal and ground)
· Power Required:	18-28Vdc
· Operating Current:	22mA (With AST Installed) 20mA (Without AST Installed)
· Dynamic Range:	>80dB (Utilizing an R15 Sensor)
· Output Voltage (50Ω Load):	15Vpp
· Noise(RMS rti):	<2 μV

<u>Environmental Specifications:</u>

Temperature: - 40° C to + 65° C

5.3.3 Standard Filters

Filters for the In-line single ended preamplifiers are installed at the factory. Filter values must be specified at the time of purchase. The following are the standard available filter bandwidths for the In-Line single ended preamps.

15 – 65 kHz	30 – 165 kHz	100 – 450 kHz	215 – 490 kHz
350 – 650kHz	32 – 1100 kHz		

Contact the factory for values other than those listed above.

5.3.4 Installation and Operation

Installation of the In-line single ended preamplifiers are very easy since there are only two connectors to connect and no configuration switches. Simply connect a single ended sensor to the input BNC of the of the preamplifier and connect the output BNC of the preamplifier to the AE system channel input. Be careful not to reverse the connections as damage may occur.

5.4 1222 Charge Preamplifiers

5.4.1 Introduction to Charge Preamplifiers

Both voltage preamplifiers and charge preamplifiers can be used in AE applications. The voltage preamplifier is more stable, and easier to use then the charge preamplifier, but the charge preamplifier has some features that make it more desirable for certain applications.

The charge preamplifier has a distinct advantage with long lengths of input cable between the sensor and the preamplifier. For the example where a sensor coax cable length needs to be e.g. 50 meters, the voltage preamplifier (1220A) has a 17 dB loss in signal amplitude, where as the charge preamplifier has no loss in signal amplitude. This has been tested with an R15 sensor with a lead break from a 0.3 mm Pentel mechanical pencil.

The noise of a charge amplifier is slightly larger then the voltage amplifier due to the addition of an additional charge conversion stage. Also the length of cable affects the noise.

With a 3' input cable the Signal to Noise Ratio (S/N) of a charge amp is 5 dB smaller then the voltage amp. With a 150' input cable the signal to noise ratio of the charge amp and voltage amp is the same. The charge amplifier has the advantage in that the signal amplitude is unchanged.

5.4.2 1222 Preamp Description

The figure shows the outline of the 1222 Charge Preamplifier. It has 3 single ended BNC connectors for use with Co-axial cables. The pre-amp accepts inputs from PAC and other single ended AE piezoelectric sensors anywhere in the frequency range of 20 - 600 kHz. The following is a description of each of the connections.

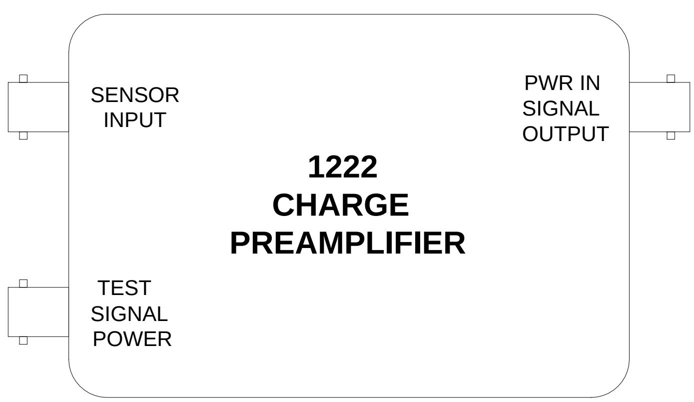

Figure 5. 1222 Charge Preamplifier

Sensor Input.
This is the input from the AE single ended sensor. The sensor cable is connected to this connector.

Power In/Signal Out.
The Power In/Signal Out connection supplies 28 volts DC power from the AE Main unit to the pre-amplifier. Also on the same center conductor is the amplified AE signal output for processing by the AE Main unit. This is accomplished by "floating" the AE signal on the DC voltage.

Test Signal Power
The Test signal power BNC connection allows for the user to initiate a pre-amp/system test by applying a 12 volt DC level to this input. Upon application of this voltage, a relay is energized inside the pre-amp that disconnects the AE sensor from the input of the pre-amp and connects a signal generator with a known voltage into the input. Applying a known signal level at the input of the pre-amplifier allows the user to monitor the entire amplification chain in the main unit thereby insuring that the AE system circuitry is functioning.

Other important features of this pre-amplifier include the following:

- 40 - 60 dB internal gain selection. Factory default set at 40 dB.
- Uses PAC pluggable Band Pass filters for a narrower frequency response which further enhances Signal to Noise and filters out unwanted lower frequency vibrations. See 1220A filter selections.

5.4.3 Specifications

Gain:	100mV/pF & 1000mV/pF (set by internal jumper) (equivalent to 40 - 60 dB gain)
Bandwidth (-1dB)	20K-600kHz
RMS Noise (RTI):	$<10\ \mu V$
Dynamic Range:	80 dB
Maximum Output:	16 Volts peak to peak into 50 Ohms
Quiescent Current:	35 mA
Filter Module:	Requires standard PAC Passive Filters
Gain Accuracy:	+/-1dB
Test Signal:	Constant Sine Wave (1MHz Bandwidth) 0.5V-P Maximum Amplitude (set at 150 kHz)

5.4.4 Installation and Operation

Installation of the 1222 Charge Preamplifier is identical to that of any other typical preamplifier. Attach the single ended sensor to the signal input of the preamplifier. Then connect the Power In/Signal Out BNC to the AE system via a co-ax cable. For the test signal, connect a switched 12 volt power source to the Test signal input. Whenever power is applied, a relay will switch the sensor input to the output of a signal generator and the signal generator signal will be amplified by the preamplifier and sent to the AE system for determination if the preamplifier gain or performance has changed.

The 1222 Charge preamplifier uses the standard 1220 family of pluggable filters. Refer to section 5.7 for specific information relating to the selection and installation of filters in this preamplifier.

5.5 1227A & 1227B Preamplifiers

5.5.1 Description

This family of preamplifiers offers 20 dB AE signal gain and very low power operation (3 milliamp typical). The 1227A is designed for standard 50 Ohm AE systems while the 1227B is designed for 600 Ohm AE systems like the PAC 4610. It has been designed to be used with single ended sensors only and has a fixed gain of 20 dB. Several filter bandwidths are available and must be specified at the time of purchase. Both models use PAC's standard single Power/Signal BNC. These preamplifiers are very small (~ 0.7" square by 2.5" long) and very low cost.

5.5.2 Specifications:

Parameter	1227A	1227B
Output Impedance	50 Ohms	600 Ohms
Gain	20 dB ± 1dB	20 dB ± 1 dB
Noise (μ Volts RTI):	4 μV	4 μV
Maximum Voltage Output (Vp-p):	5 Vp-p	1.4 Vp-p
Dynamic Range:	95 dB	84 dB
Supply Voltage Range:	9 – 28 Volts	7 – 28 Volts
Supply Current:	3 mA @ 12 Volts	3 mA @ 12 Volts

Maximum Operating Temperature:	0°C - 85°C
Preamp Dimensions:	3.4" Long x 0.687" wide x 0.687" high (8.64 cm long x 1.75 cm wide x 1.75 cm high)

5.5.3 Standard Filters

Filters for the 1227 series, single ended preamplifiers are installed at the factory. Filter values must be specified at the time of purchase. The following are the standard available filter bandwidths for the 1227 preamps.

30 – 200 kHz 60 – 400 kHz 150 – 600 kHz 220 – 900 kHz

Contact the factory for values other than those listed above.

5.5.4 Installation and Operation

Installation of the 1227 single ended preamplifiers are very easy since there are only two connectors to connect and no configuration switches. Simply connect a single ended sensor to the input BNC of the of the preamplifier and connect the output BNC of the preamplifier to the AE system channel input. Be careful not to reverse the connections as damage may occur.

5.6 1227WT High Temperature Preamplifier

5.6.1 Description

The Wide Temperature Preamplifier was designed to be used in very extreme temperature environments. It is for use with all available AE systems that has its power and output signal on the center conductor. Both input and outputs of the 1227WT utilize SMA type connector (BNC's are optional). The preamplifier is built in a narrow diameter stainless steel tube for reliability and ruggedness. It is supplied with 20 dB gain and operates with a single ended sensor (only). Pulse through Sensor Testing provides the ability to allow a pulse to travel from the AE system through the preamplifier to the sensor. The magnitude of the impulse going through the preamplifier can be up to 200 volts.

5.6.2 Specifications

Environmental Specifications:

Temperature:	- 47°C to + 175°C (-50°F - +350°F)
Vibration:	>40 G @ 0 - 2 kHz
Shock:	> 5G 5 - 20 msec.

Electrical Specifications: @ - 47° C to + 175° C **(** -50° F- +350 °F)**:**

· Gain Selectable:	20 dB $\pm$ 1 dB
· Bandwidth (-3dB):	$\leq$40kHz to $\geq$1.2 MHZ
· Input Impedance:	10kΩ // 15pF
· Voltage Required at Power/Signal Connector: (In normal ambient temperature environment)	18-24 VDC
· Recommended Operating Voltage: (For maximum dynamic range over full temperature)	22-23 VDC
· Operating Current:	< 35 mA (With Pulse through relay)
· Dynamic Range:	75 dB (Utilizing an R15 Sensor) 80 dB (50° Input)
· Output Voltage (50Ω Load):	2Vpp into 50°
· Noise w/R15 (RMS rti):	$\leq$ 7 µV (20°C/68°F)

Physical Specifications:

Length	4.25 inches (10.8 cm.)
Diameter	0.75 inches (1.9 cm)
Weight	0.16 lbs. (73 grams)
Connector	SMA type

5.7 1220A, 1220B, 1220C Preamplifiers

The Physical Acoustics 1220X Series is a versatile line of low-noise cost-effective preamplifiers. They were developed for use with Acoustic Emission (AE) systems in production and laboratory applications and their circuits were designed with the latest in low noise and high reliability components. The preamplifier gains its versatility by allowing the user to select high pass, low pass, or bandpass filters, single-ended or differential input, 40 dB or 60 dB gain, and choice of three output/power configurations.

The 1220A output and power is supplied by a single conductor 50 Ohm coaxial cable with a BNC connector (PAC Model 1234). The +28 VDC operating voltage and signal run on the same line and are internally isolated in the preamplifier. A variant of the 1220A which is the 1220A-AST is externally, connection and powerwise identical to a 1220A except that a special AST (Auto Sensor Test) circuit has been added to provide a -25 volt pulse directly to the sensor attached to the preamp input when the +28 volt power is momentarily interrupted. Several PAC systems such as SPARTAN 2000, MISTRAS, DiSP and LAM have the capability built in to create an AST pulse in this manner. This capability is advantageous in multiple channel situations for determining the sensor response, coupling efficiency and distance from another pulsing sensor.

In the 1220B preamplifier, the output and power run on separate cables. The preamplifier is powered by +/-15 VDC. A 1234 cable is used for the output and the power cable is a PAC Model 1233.

In the 1220C preamplifier, the output and power are also run on separate cables, but the preamplifier uses a single-ended power supply (+28 VDC). A PAC 1234 (BNC-BNC) cable is used for the output while another PAC 1234 (or PAC 1234A, BNC to pigtail) is used for the power connections.

Below is a table showing the different values of high pass, low pass, and band pass filters available for these preamplifiers.

STANDARD PLUG-IN FILTERS

HIGH PASS		BAND PASS		LOW PASS	
PART #	FREQUENCY	PART #	FREQUENCY	PART #	FREQUENCY
1220-3H	3 kHz	1220-20-100BP	20-100 kHz	1220A-400L	400 kHz
1220-20H	20 kHz	1220-50-200BP	50-200 kHz		
1220-50H	50 kHz	1220-100-300BP	100-300 kHz		
1220-100H	100 kHz	1220-100-1200BP	100-1200 kHz		
1220-200H	200 kHz	1220-200-400BP	200-400 kHz		
1220-300H	300 kHz	1220-300-600BP	300-600 kHz		
1220-400H	400 kHz	1220-400-600BP	400-600 kHz		
1220-500H	500 kHz	1220-600-1200BP	600-1200 kHz		
1220-600H	600 kHz	1220-BP-SYS	No Filtering		

5.7.1. Specifications of the 1220 Series Preamplifiers

Environmental Specifications:

Specifications apply at 25° ± 5° C
Preamplifiers will operate from 0° to 50° C

Electrical Specifications:

Gain:	40 or 60 dB (Switch selectable)
Bandpass:	User selectable from 10 kHz to 1.2 MHz
Input:	Single or differential selectable
Input Impedance:	10 k Ohms in parallel with 15 pF
Output Voltage:	>15 Vpp into 50 Ohms
Dynamic Range:	85 dB
CMRR (500 kHz):	55 dB
Noise (RMS RTI):	<2 μV (input shorted)
Power Requirements:	1220 A, C - +28 VDC
	1220B - ±15 VDC
DC Standby Current:	25 mA

Physical Specifications:

Dimensions:	5.25" Long x 2.25" Wide x 1.38" High
	(13.3 cm) x (5.72 cm) x (3.5 cm)
Weight:	0.55 lb. (0.25 kg)

5.7.2. 1220 Preamplifier Description

Figure 6. shows a sketch of each version of the 1220 series Preamplifier.

Single Ended Connector — Connects an external single ended sensor (PAC R, μ, W, or T series or equivalent piezoelectric transducer) to the 1220 preamplifier via an industry standard single ended BNC connector.

AE Input Select Switch — Selects what mode input is being connected to the 1220 preamplifier. When the switch is positioned toward the differential connector, this means that the 1220 is connected to amplify a differential signal.

AE Differential Input Connector — Connects an external differential sensor (PAC RD, µD, WD, or TD series or equivalent piezoelectric transducer) to the 1220 preamplifier via differential BNC connector.

Power Signal Cable — Output signal and power (+28 VDC) are both present on this line. Both signals are isolated internally. Cable connects via an industry standard BNC connector (PAC 1234 cable).

Gain Select — A total preamplifier gain of 40 dB (x100) or 60 dB (x1000) is selected by this switch.

Output — Output signal is present here. Cable connects via a standard BNC connector (PAC 1234 cable).

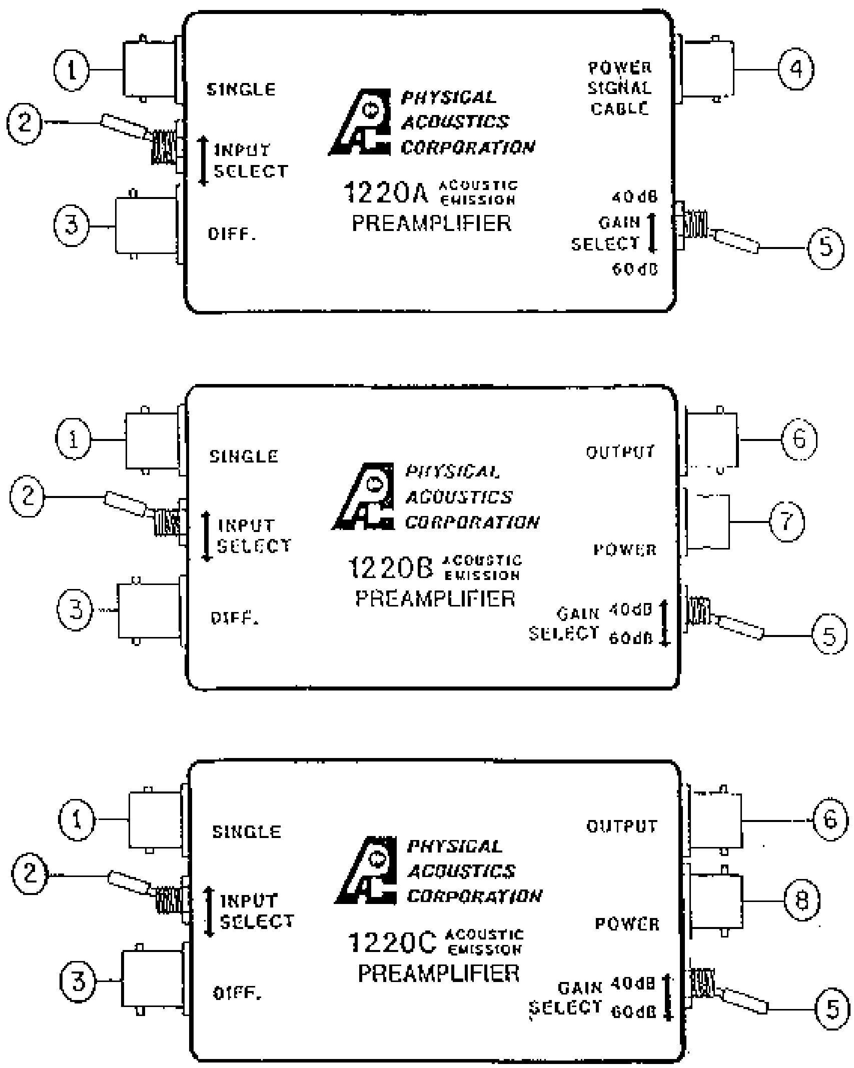

Figure 6. 1220 A, B, C External Connections/Controls

Power — +15 VDC is connected to the preamplifier here via a multipin connector. Use PAC cable #1233 or #1233A.

Pin #1 - Ground 1
Pin #4 - (-15) Volts (Green Lead on 1233 Cable)
Pin #7 - (+15) Volts (Red Lead on 1233 Cable)

Note: When using a 1220B preamplifier with a normally supplied 1233 power cable, no ground connection is made through the cable. Only a shield is provided in order to prevent possible ground loop problems (increased noise in the system). The ground is made through the shield or ground of the Output BNC connection (1234).

Power — (+28) VDC is connected to the preamplifier here via a standard BNC cable (PAC #1234 or #1234A).

Figure 7 shows wiring connections of the preamplifiers. Look up the corresponding number that describes the connection or control.

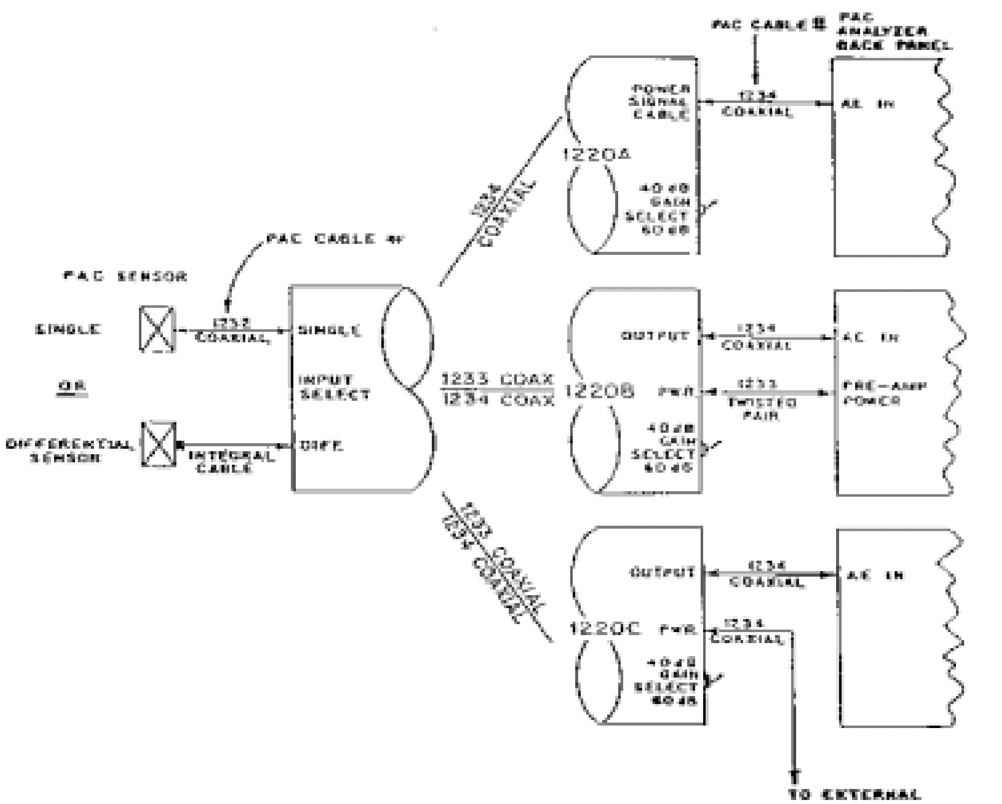

Figure 7. 1220 Wiring Connection

Operation and cable hookups differ only slightly for each version of the preamplifier. Input hookups are identical for the 1220A, B, C (Figure 7), while output connections require a different configuration.

5.7.3. Preamplifier Installation and Operation

1220A Installation and Operation

1. Connect a 1234 BNC to BNC signal cable from the preamplifier "Output" to the jack marked "AE IN" on the analyzer.
2. Select the AE input desired (single or differential).
3. Attach the appropriate sensor and cable to the preamplifier input connector (single or differential).
4. Turn system power on to energize the preamplifier.

1220B Installation and Operation

1. Connect a 1233 power cable from the 1220B connector labeled "Power to the PAC analyzer connector labeled Pre-Amp Power."
2. Connect a 1234 BNC to BNC cable from the preamplifier connector "Output" to the one on the analyzer labeled "AE IN."
3. Select the AE input desired (single or differential).
4. Attach the appropriate sensor and cable to the preamplifier input connector (single or differential).
5. Turn system power on to energize the preamplifier.

1220C Installation and Operation

1. Connect a 1234 (or 1234A BNC to pigtail) cable from the 1220C connector marked "Power" to an external +28 VDC power supply.
2. Connect a 1234 BNC to BNC signal cable from the preamplifier connector "Output" to the one on the analyzer labeled "AE IN."
3. Select the AE input desired (single or differential).
4. Attach the appropriate sensor and cable to the preamplifier input connector (single or differential).
5. Turn the system and external supply power on to energize the preamplifier.

5.7.4. 1220 Series Filter Replacement

Filter placement on the 0/2/4, 2/4/6 and 1220A, B, and C are identical. To replace a filter, remove the four Phillips head screws from the bottom lid; this will expose the preamp's inner circuitry (Figure 8).

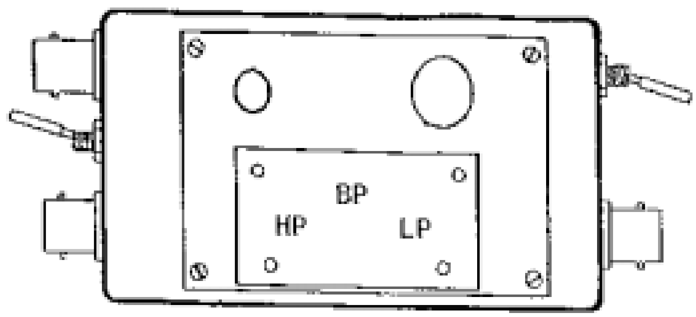

Figure 8. Internal Preamplifier Layout

The connections shown in Figure 9. should be made in order to by-pass (remove) filter in cases where the broadest possible bandwidth is desired.

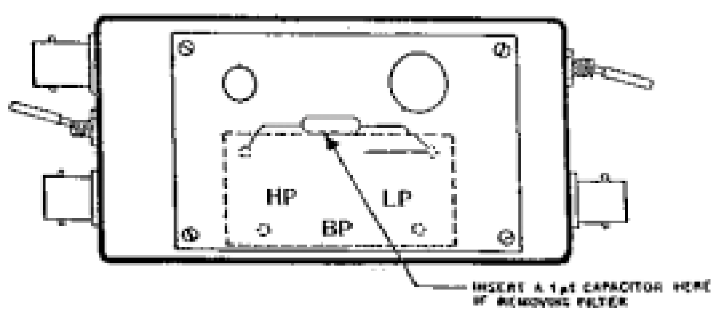

Figure 9. Removing and Bypassing a Filter Using a 1µF Capacitor

5.7.5. Circuit Description

Figure 10. is a block diagram of the 1220 series preamplifier. Internal circuitry for the 1220 A, B, C. is identical except for minor differences in the output and power distribution sections.

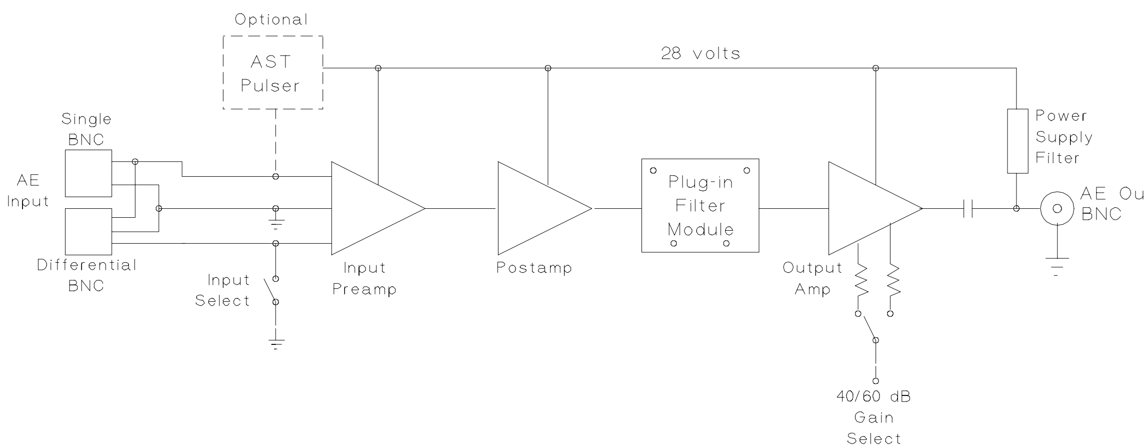

Figure 10. Preamplifier Block Diagram

Input Select — Input selection consists of a low noise differential amplifier for high gain, high common mode rejection and maximum sensitivity to low level input signals. This amplifier is then buffered by a 20 dB gain low output impedance post amplifier, which drives the PAC plug-in fifth order high pass, low pass and bandpass filters.

Gain Select — The output stage consists of a hybrid 20/40 dB gain high speed amplifier and a 50 Ohm output buffer for large power bandwidth while driving long cables. Two user adjustments are provided for calibration.

6. AUTO SENSOR TESTING

Auto Sensor Test (AST) is a unique and special capability that has been built within our SPARTAN 2000, MISTRAS, DiSP, LAM and PCI-8 systems. The AST feature allows our AE systems to control a pulser that is integral to PAC AST equipped preamplifiers and our Integral preamplifier sensors (with AST option). This allows for any AE channel to pulse the sensor, while the receiving electronics remains active. This means that the sensor can be used as a pulser and a receiver at the same time. It can therefore characterize its own condition as well as send out a simulated acoustic emission wave that other sensors can detect, thereby giving feedback as to the arrival time difference and the detection sensitivity of those nearby sensors. The other main important feature of this option is that it operates through the standard 1234 BNC cable which goes between the AE channel input and the preamplifier (and integral preamplifier sensor).

6.1 Other Automatic Sensor Pulsing Techniques

Competing methods for sensor pulsing or automated testing in AE instruments involves the use of at least 2 relays for each channel, one in the AE system for each channel and one in each pre-amplifier. When the AE system decides to pulse the sensor, it turns on a relay in the AE instrument which removes pre-amplifier power and makes connection to a digital output which puts a voltage spike through to the pre-amplifier. A relay in the pre-amplifier de-energizes when power is removed from the pre-amp. This causes the relay contacts to make electrical connection to the sensor crystal directly, and remove the pre-amp output signals from the co-axial cable path. A voltage spike now goes directly to the sensor crystal. Upon pulsing, a simulated AE event is generated that is coupled to the structure in which that sensor was in contact. This causes other sensors that are close by to detect the simulated AE event. This data when processed by the AE system gives the user information about the quality of the sensors that have detected the event. When used often, the user can determine if there has been any sensor degradation during the AE test. Unfortunately this technique is inferior to Auto sensor testing for various reasons including the fact that it cannot be used in situations where only one sensor is involved as well as other reasons that will be discussed below.

6.2 AST Application and Advantages

PAC has improved on the automated pulsing method with a unique and different scheme we call Auto Sensor Test (AST). Our scheme keeps the pulsing sensor active immediately after pulsing. This offers the following advantages in characterizing the AE event response:

1. Reading the response from the same sensor that is being pulsed gives a quality measure of that given AE channel. This includes information on sensor, coupling pre-amplifier and AE system.
2. A single sensor can be evaluated whereas in the above relay based method, this is impossible.
3. The self pulsing/receiving method provides information on the coupling quality of the sensor to the structure, whether the sensor is even attached to the cable or if the cable is shorted.
4. Since the pulsing sensor receives the AE information, it is the first hit sensor. This gives exact "delta T" measurements from this sensor to each other that detects the event. This is useful in calibrating for location. It is also useful in performing measurements such as those used in Acousto-Ultrasonics where the change in flight time is an important feature.

The way that this is accomplished is simply by sending a pulse down the preamplifier cable to the preamplifier. If the amplifier is equipped with AST capability, it has a circuit that detects this pulse. When detected, this pulsing circuitry generates a pulse with a specific pulse shape that excites the AE sensor. Since AE sensors work equally well as pulsers or receivers, the pulse causes the AE sensor crystal to deform and generate shock waves that travels throughout the structure. These sound waves travel to sensors that are on the structure and reflect, even back to the orignial pulsing sensor. The pulsing sensor which immediately reverts to a receiving AE sensor at the end of the pulse, receives the structural response signals and they are processed as a typical AE hit or event. Other sensors on the structure also detect and process the event.

The main disadvantage to the AST method is the receiving of the "main bang". This saturates the peak amplitude response of the AE system so that the pulsing sensor always registers a ~100 dB amplitude, but since this is a high "Q" type response, all the other AE features remain very low in value from the main bang alone. In this way, energy, duration and counts becomes a very good parameter for monitoring the response of the pulse.

6.3 AST Requirements

In order to perform AST on an AE system the following are needed:

1. AST (Auto Sensor Test) circuitry in the AE system. This is built as standard within all PAC multi-channel AE systems including DiSP, MISTRAS, LAM, SPARTAN 2000.
2. Preamplifiers with AST option or Integral Preamplifier Sensors with AST Option,
3. (AST) Auto Sensor Test Software. This is built standard within all PAC multi-channel AE System software including DiSP, MISTRAS, LAM and SPARTAN 2000.

From the above it can be seen that AST circuitry and software is already built into most PAC systems and is immediately ready to be put to good use. The only item that may have to be purchased is the preamplifier with AST option or the Integral Preamplifier sensors with the AST Option. PAC sells AST options with its 0/2/4 and 2/4/6 preamplifiers, its In-Line Preamplifiers, and with the 1220A preamplifiers. It is also available with our Integral Preamp sensors such as the R15I-AST, R30I-AST, WDI-AST, etc. Please consult PAC for more information on closing the loop with our AST preamplifiers and integral sensors.

In terms of software, all PAC multi-channel software has multiple AST modes. AST can be performed before and after a test providing a graphical or line dump report. AST can even be performed during a test on a single sensor or all sensors to verify their integrity, all without affecting the AE test results. One additional mode with AST is the ability of saving a previous test to use as a comparison with a later AST test. In this way, a nice report is generated to indicate the statistical deviation from the “Trained” file and provide pass/fail information as a result. Consult your software manual for more information on the use of AST in PAC’s multichannel AE systems.

7. 1224 SERIES REPEATER AMPLIFIER

7.1 Introduction

Physical Acoustics 1224 series repeater amplifiers are "in-line" driver amplifiers meant to restore the AE signal level when driving long co-ax cables. The 1224 was developed for use with Acoustic Emission (AE) systems in production and laboratory applications. Its circuitry uses low noise and high reliability components. The 1224 series repeater amplifier has been specifically designed to compensate for signal losses over long cable lengths. It is used between the AE system and the AE preamp when cable lengths exceed 1000 feet. Therefore it is recommended that 1224's be used at spacing of 1000 feet.

7.2 Specifications

Typical specifications for the 1224 series repeaters are as shown below:

1224 Specifications @ 28 Volts

Gain:	10 dB min. or 20 dB max.
Frequency response (-3 dB):	1.6 kHz to 2.5 MHz small signal 1.6 kHz to 1.0 MHz large signal
Vpk-pk output (max):	8 Vpk-pk into 50 Ohms
Static current:	20–38 mA, depending on gain setting
Supply voltage:	14–28 Volts DC
Noise "RTI":	23 µV (No filter) 14 µV (with "100 kHz low" filter)

7.3 1224 Configurations/Designations

There are several different models of 1224 as shown in the feature chart below.

Feature Chart

	1224A	1224B	1224C	1224C-LF	1224D
Combined supply/ signal line	Yes	Yes	No	Yes, on differential BNC connector	Yes
Separate supply line	No	No	Yes	Yes*	No
External gain adjust	10 or 20 dB Fixed at 20 dB	None	10 or 20 dB	10 or 20 dB	0 or 20 dB
Internal gain adjust	3 to 20 dB	3 to 20 dB	3 to 20 dB	3 to 20 dB	3 to 20 dB
Frequency range	10 to 900 kHz	10 to 700 kHz	10 kHz to 1 MHz	1.6 kHz to 1 MHz	10 kHz to 1 MHz
Input	50 Ohm or 5 kOhm	50 Ohm or 5 kOhm	50 Ohm or 5 kOhm	50 Ohm or 5 kOhm	50 Ohm or 5 kOhm

* On the differential BNC Connector, one conductor is for power and the other for the AE signal. Please note that using this repeater requires different cabling and connectors on the 5600. The main advantage of using this repeater is in applications where a very low frequency operation is desired.

7.4 Operational Description of the 1224 Repeater Amplifier

The 1224 series repeater consists of a low noise preamplifier with an internally adjustable gain to compensate for filter losses. The output of the preamplifier drives a PAC plug-in filter module. The plug-in filter module can be replaced by removing the four Phillips head screws from the bottom lid. Various high-pass, low-pass and bandpass filter configurations are available to customize the 1224 frequency response. These are the same filters as indicated in the previous section. The filter output is then fed to the output stage. The output stage consists of a hybrid 10 or 20 dB gain high speed amplifier and a 50 Ohm output buffer for large power bandwidth while driving long cables.

The 1224 repeater amplifier can be installed by simply connecting the output of the repeater amplifier toward the jack of the analyzer marked "A.E. Input." The input of the 1224 amplifier should then be connected towards the sensor or preamplifier output. The external gain switch can then be used to control the amount of gain.