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Aircraft Ground Vibration Test Instrumentation System

Richard Talmadge
David Banaszak
Flight Dynamics Laboratory
Air Force Wright Aeronautical Laboratories
Air Force Systems Command
United States Air Force

ABSTRACT

The Structural Vibration Branch (FIBG) of the Air Force Wright Aeronautical Laboratories (AFWAL) is conducting an in-house Ground Vibration Test (GVT) on a full scale F-16 aircraft located inside FIBG's Vibration Aeroelastic (VIAER) facility at Wright-Patterson AFB OH. To measure 120 accelerometer signals simultaneously as required by the GVT, FIBG has designed and fabricated in-house a complete data acquisition system to measure and condition all the required transducer signals.

The GVT instrumentation system includes 120 piezoelectric accelerometers utilizing built in emitter followers, 120 6 pole low pass filters, 120 automatic gain changing (AGC) amplifiers, a digital multiplexer for multiplexing 360 gain code bits into two 12 bit wide digital words, a time code generator, a 14 channel wide-band magnetic tape recorder and a Programmable Data Acquisition System (pDAS). The pDAS encodes and multiplexes all 120 accelerometer signals, gain codes, and time code into a 600 Kilobit/sec Delay Modulation Mark serial bit stream for recording on magnetic tape. Combining AGC amplifiers and 11 bit digital resolution, allows measurement of very low acceleration levels. The GVT instrumentation system allows fast measurement of multiple accelerometer signals required for aircraft modal analysis and will be used on future FIBG in-house conducted tests requiring a large number of transducer signals to be processed. This paper describes the design, configuration, evaluation and calibration of the GVT instrumentation system.

BACKGROUND

The Flight Dynamics Laboratory (FDL) of the Air Force Wright Aeronautical Laboratories (AFWAL) at Wright-Patterson Air Force Base (WPAFB) OH, is responsible for conducting research and development required for the design of future Air Force Weapon Systems. In particular, the Structural Vibration Branch of the Structures and Dynamics Division of FDL (AFWAL/FIBG) is responsible for conducting experiments necessary to define the dynamics and loads environment of current and future Air Force Systems. A Ground Vibration Test (GVT) on Controlled Configured Vehicle (CCV) F-16 Tail Number 01567 was conducted from January-March 1983 in the former large acoustic test facility located in Bldg 461 in Area B at WPAFB. The GVT was conducted under an in-house work unit titled "Vibration Analysis and Testing Technology" (JON 24010414). The project engineer for the work unit was Douglas Henderson and the project engineer for the F-16 GVT was First Lieutenant Richard Wright. The instrumentation system was designed, fabricated, checked-out and calibrated by instrumentation engineers David Banaszak and Richard Talmadge and instrumentation technicians John Self and Claude Orr.

A requirement for the F-16 GVT and future experiments (e.g. the AFTI/F-111 Mission Adaptive Wing (MAW) and Aircraft Ground Induced Advanced Loads Excitation (AGILE) programs), was the capability to simultaneously measure many dynamic signals (120 accelerations over a frequency range of 1.4Hz-100Hz for the F-16 GVT) without losing time correlation or frequency content. Also, the ability to measure very low levels of acceleration was necessary. This paper covers the overall test instrumentation setup, the Data Acquisition System in detail, and summary and conclusions. An appendix contains the referenced tables, photographs, and figures.

OVERALL TEST INSTRUMENTATION SETUP

The overall block diagram of the instrumentation required to conduct the F-16 GVT is shown in Figure 1. A list of equipment used during the test is included in Table I. The F-16 was supported at three aircraft jack points by a vibration isolation system which allowed the aircraft to float on a cushion of air at the three points. See Reference 8 for more details on the two 13,300 pound and one 5,500 pound air bearings used in the vibration isolation system. Using a shaker controller to control from one to four 75-pound force shakers, the aircraft was excited at single or multiple points as specified by the project engineer. Testing methods were sine dwell, sine sweep and random excitation. During aircraft excitation, signals from 120 Vibrameterics M-1000A accelerometers were filtered, amplified, mutliplexed and encoded into a 600-Kilobit/sec pulse code modulation (PCM) signal by the Data Acquisition System (DAS) designed by FIRG. The following sections of this paper describe in more detail, the design, configuration, evaluation, and calibration of this data acquisition system. Referring to Figures 1 and 2 there are a maximum of 120 accelerometer inputs to the DAS, a PCM output, and provisions for 32 channels of digital to analog (D/A) conversion outputs for monitoring or for use by an on-line modal analysis system. The recorded tape was analyzed using Structural Dynamics Research Corporation's "Modal Plus" software package on a DEC VAX 11/780 computer.

INSTRUMENTATION LOCATIONS

Test instrumentation area locations are shown in Figure 1. The F-16, shakers, 120 accelerometers and 3 air bearing suspension systems were located inside the former large acoustic test chamber in Building 461 at WPAFB (Photo 1). The shaker controller, data acquisition system, wideband tape recorder and modal analysis system were located in a control room adjacent to the large acoustic chamber (Photo 2). The VAX 11/780 computer is located in room 216 of building 24. Accelerometer wires (120 microdot cables about 100 feet long) were routed above the F-16, into the control room, and were connected directly into the anti-aliasing filter cards of the Data Acquisition System. The 600 Kilobit/sec PCM signal was routed from the DAS via coax cable and various patch panel connectors to the tape recorder. Standard coaxial cables were used to connect desired analog outputs from the DAS to the Time-Data modal analysis system for test monitoring.

GVT INSTRUMENTATION REQUIREMENTS

Modal analysis requires measurement of many acceleration points simultaneously to ensure time correlation between the various responses. Transfer functions between a reference point and each measured response must be computed in order to determine the modal properties of an entire aircraft. For the F-16 the frequencies of interest covered a range of 1.4Hz to 100Hz for each of a total of 120 accelerometers simultaneously. To meet these requirements, either many tape recorder channels or some form of multiplexing were necessary. Multiplexing onto a single tape track was determined to be the desired approach in order to more fully automate data acquisition and analysis. Since excitation levels in typical GVT's are very low to ensure linear response, the data acquisition system had to be capable of measuring a wide range of acceleration levels. For this reason automatic gain changing (AGC) amplifiers were used. To ensure noise immunity, a digital system was desired. Combining requirements for the F-16 GVT with requirements for future tests, resulted in the DAS described in this paper for measuring 120 low level signals simultaneously over a large dynamic range.

DATA ACQUISITION SYSTEM IN DETAIL

The decision to go digital required the interfacing of FIBG's accelerometers normally used for vibration testing with a digital, programmable Data Acquisition System (pDAS). The resultant block diagram of the DAS is shown in Figure 2. All components and equipment shown in Figure 2 were on hand or designed and fabricated in-house. Fabricated items included the 21 six-channel filter cards and the digital multiplexer. A detailed description of each component of the DAS from accelerometers to PCM output is given in the following sections. A picture of the DAS is shown in Photo 3, with the major system components labeled. Photo 4 shows the DAS with one set of doors open. These doors provided quick front access to the amplifier and filter cards. As shown in the photos, the total system fit into four standard 19 inch equipment racks. The data acquisition equipment is installed in the three left hand racks and a PCM decom system was installed in the right hand rack.

SENSORS

To measure F-16 vibration responses, Vibrametrics Inc., Model M1000A piezoelectric accelerometers which contain a FET follower inside the accelerometer case were used. The light weight accelerometers were glued in tri-axial configurations on a wooden block to provide electrical isolation from the aircraft. For each test condition of the GVT, the block was attached to the location desired on the aircraft by using double stick tape. To overcome the problem of accelerometers vibrating loose, hot melt glue was later used. This also allowed angling and positioning of the blocks for proper orientation. Each accelerometer has an integral two-foot long microdot cable with a microdot connector on the end. Microdot coax was used between the accelerometer and the filter input. The accelerometer output and the dc power input were on the same pair of wires. The constant current source (about 4 milliamps) was required to power the built-in FET follower. This power is provided by a reversed baised diode (IN5313) mounted on the filter card. A blocking capacitor on the filter input passes the dynamic accelerometer output signal to the filter input, but blocks the dc bias voltage produced by the constant current source. These accelerometers are ideal for use on a GVT, since their small size and weight have a negligible effect on the structure being measured. They are usable at frequencies as low as .14Hz if the proper signal conditioning is used and the ambient temperature is relatively constant. A typical accelerometer attached to the F-16 wing is shown in Photo 5. Accelerometer signal flow through the DAS is shown in Figure 3.

FILTERS

FIBG's decision to digitize the 120 accelerometer signals required the use of anti-aliasing filters to avoid aliasing problems in the data. These had to be designed, fabricated, and tested since these items were not available in FIBG's current stock. Based on the final program used for the Base Ten Inc., programmable Data Acquisition System, which effectively sampled each of the accelerometer signals at a rate of 390.63 samples/seconds, the unity gain 6 pole filters were designed to have an upper cutoff frequency of 100 Hertz. A typical filter card consists of National AF-100s (2 chips per filter - 3 poles per chip) as shown in the schematic (Figure 4). Each card contained six complete 6-pole filters and included the IN5313 diode required to provide the constant 4 milliamps of current to power the accelerometer.

A picture of a typical filter card is shown in Photo 6. The low end 3dB cutoff frequency was about 4-5 Hz. Since transfer function measurements were the final objective, this made the data usable to less than 1.4Hz. A typical filter transfer function response is included as Figures 5a & 5b. The filter transfer functions were measured using a Hewlett-Packard Model 3582A Spectrum Analyzer and stored on disk with a Commodore 8032 System. The machine language IEEE handshake program used to transfer data from HP3582A RAM to Commodore 8032 RAM is contained in Reference 2. The routine was relocated to hexidecimal address 6800 to 68ef. In addition, a machine code Commodore 8032 screen to printer dump routine was utilized to produce the printouts shown in Figures 5 and 6. These plots are preliminary versions, since software is still being developed to format the final HP3582 analyzer display into a readable format. Thus, the figures are a hybrid of a dot matrix printer plot and manually typed labels inserted for reader clarification. The 126 filter transfer functions (including spares) were stored on three 5¼ inch minidisks for future analysis. Also, a typical function for filter and amplifier combination is shown in Figures 6a and 6b. The filter transfer functions will be compared to determine maximum, minimum, and variances between various filters. If variations between the filters are statistically small, then it can be assumed that all the filter transfer functions are identical.

AUTOMATIC GAIN CHANGING AMPLIFIERS

The output of each anti-aliasing filter is connected to an automatic gain changing (AGC) amplifier. These AGC amplifiers have been used heavily in most of FIBG's airborne and ground environmental measurements programs in the past ten years. The F-16 GVT required the dedication of 120 of FIBG's amplifiers for the DAS. A typical AGC amplifier card (Intech Model A-2583) is shown in Photo 7. A detailed description of the amplifier's operation can be found in reference 3.

Basically, when in automatic mode the AGC amplifier selects one of eight discrete gains (-10dB, 0dB, +10dB, +20dB, +30dB, +40dB, +50dB, or +60dB) based on the voltage level of the input signal. Typically, these amplifiers are set up to give a voltage output in the range of 200 mv to 500 mv rms. For example, if the input is a sine wave with an amplitude of 10 mv rms, then the amplifier would automatically change its gain to 30dB to provide an amplifier output of 316 mv rms. The card provides both a dc voltage output and a 3-bit binary output proportional to gain setting. The 3-bit binary output (see Table II) were used by the DAS to keep track of the amplifiers gain setting for each accelerometer signal. For the F-16 GVT this meant a total of:

3 bits/accelerometer X 120 accelerometers = 360 bits

of gain information had to be recorded with the 120 analog outputs from the amplifiers. Thus, the digital multiplexer was designed and built in-house by FIBG to implement the DAS as shown in the block diagram in Figure 2. The analog outputs (data signals) from each of the AGC amps were connected directly to the input of the digital encoder shown in Figure 2. The binary outputs (gain setting) were connected directly into a digital multiplexer which will be discussed in the next section.

The normal procedure used for the F-16 GVT was to excite the aircraft with a shaker and allow the acceleration levels to stabilize while the amplifiers were in the automated gain mode. When the test condition was stabilized, all the amplifier gains were inhibited by three remote toggle switchs (on front of the DAS rack) which fixed the amplifier gain at their current gain setting. Then a recording of the response data was made by the project engineer. The amplifiers could also be set for fixed gain if desired for calibration and checkout, or known input signal levels.

DIGITAL MULTIPLEXER

The digital multiplexer was conceived and designed to allow merging all of the 360 binary gain code bits into two 12 bit digital words which could be input into the digital inputs of the programmable Data Acquisition System (pDAS) manufactured by Base Ten, Inc.. The digital interconnect diagram in Figure 7 shows the cabling required between the binary gain status outputs from the three amplifier racks and the digital multiplexer. Each of the three amplifier racks had 40 AGC amplifiers mounted in it, and thus 120 gain status bits were routed out of each rack and into the digital multiplexer. The output from the digital multiplexer consists of two 12 bit digital words for gain codes and a 12 bit digital word for frame count. A sychronization clock is supplied to the digital multiplexer by utilizing the frame clock output from J9 of the pDAS. This frame clock is input to an adjustable counter to allow up to 16 (0-15) levels of subcommutation. The counter was set for 15. This allows for 16 subframes for a major frame. Each subframe has two 12 bit words of gain codes which contains eight 3 bit gain codes. (See Table III). The frame counter is utilized as a frame ID for data playback and recovery.

PROGRAMMABLE DATA ACQUISITION SYSTEM

The programmable Data Acquisition System (pDAS) is the heart of the F-16 GVT DAS. The pDAS samples, digitizes and encodes into 11 bits plus parity, all 120 analog outputs from the AGC amplifiers. Figure 8 shows the analog signal input interconnect cabling going into the pDAS. The gain code digital inputs were described earlier. In addition to the gain codes, the BCD outputs from an IRIG-B time code generator were input into three more 12-bit digital words. The format of the gain and time code bits are shown in Table III. After the start of the test, it was determined that more time resolution was required to recover the data efficiently, so tenths and hundreths of seconds were added in the upper eight bits of the subframe counter.

See reference 4 for detailed instructions for programming the pDAS. Basically, instructions stored on an EPROM described the number and types of inputs and the PCM output formats. The EPROM is then put in a socket which is on a card that fits inside the pDAS. For the F-16 GVT the EPROM was programmed to provide a 600 Kilobit per second (Kbps) serial bit stream which was recorded on one track of the tape recorder. Also the EPROM was programmed to sample and measure 120 analog inputs (±2.5V) which were converted into 120 11 bit digital words and a parity bit. The analog data was identified as words 1-120 corresponding to the accelerometers on the F-16. The EPROM was programmed to accept the six 12 bit digital words (identified as words 121-126) with no parity. No parity required changing a card jumper inside the pDAS. The 120 digitized analog inputs and six digital words were then converted by the pDAS into a serial bit stream which could then be recorded on one track of the tape recorder. The data format for a major frame of data is shown in Table III. Each accelerometer was sampled 390.63 times per second and the gain code for each amplifier was sampled 24.41 times per second.

The playback and monitor equipment was installed in empty rack space to allow quick decoding and check out of the DAS. Utilizing EMR PCM decom equipment, test personnel were able to easily determine the gain code of any given amplifier. The 120 BNC connectors (Photo 3) were installed on the front of the rack to allow easy access to monitor any of amplifier analog outputs directly. Also the PCM playback equipment had several digital to analog (DA) outputs which could be used to view recovered PCM data from the pDAS.

RECORDING DATA

The Delay Modulation Mark (DMM) serial PCM data from the pDAS was recorded on tape using direct recording on one of the wide-band recorders shown in Photo 2. The recorder was operated at 30 ips. Four passes were made for each tape. Recorder track assignments for each pass were as follows:

Signal	Type Record	Track Number Pass 1	Pass 2	Pass 3	Pass 4
Analog Time Code	FM	1	5	9	13
PCM	Direct	2	6	10	14
Audio	Direct	3	7	11	15

Data for various test conditions, and the data tapes were taken to FIBG's Data Processing Area for analysis utilizing Modal Plus software on the VAX 11/780 computer.

CALIBRATION AND CHECKOUT

System checkout included filter evaluation as mentioned earlier (Figures 5 and 6), and digital multiplexer checkout to verify correct locations of gain codes in the PCM bit stream. In addition a per channel calibration for each accelerometer was performed. Initially, all the piezoelectric accelerometers were calibrated on a one g shaker in FIBG's calibration facility to check the sensitivity. This sensitivity value was then used as a insert voltage in place of the accelerometer to simulate a 1g signal. For a typical accelerometer with a sensitivity of 9.6 mvolts/g, a 9.6mv 80 Hertz signal was inserted and the AGC amplifier gain was set to the 40dB gain step. The amplifier gain pot was then adjusted until the amplifier had an output of 1 vrms. This normalized the sensitivity at the amplifier output to be 1g/volt in the 40dB gain step: 10g/volt in the 20dB gain step; 100g/volt in the 0dB gain step and .1g/volt in the 60dB gain step. Amplifier outputs were measured with the HP3582 spectrum analyzer.

Verifying location of gain code status in the PCM bit stream required substantial time due to having to troubleshoot several wiring problems. The PCM playback system was used to check gain code bits on a single word at a time basis. When it was available, a more capable EMR708 PCM playback system was used since all 360 gain code bits could be displayed at the same time on a CRT.

SUMMARY AND CONCLUSIONS

The described GVT instrumentation system allows for fast measurement of 120 accelerometer signals simultaneously as desired for ground vibration tests. Dedicated tape tracks are not required for each accelerometer and all data can be recorded for later analysis with just one tape recorder. The system is flexible and can be used for measurements of signals from transducers other than piezoelectric transducers. The system described will be used on an Air Force research test program called Aircraft Ground Induced Loads Excitation (AGILE) which will be conducted in the Flight Dynamics Laboratory's static test facility. After the AGILE test, the DAS rack is scheduled to be mounted into one of FIBGs mobile data acquisition vans for transportation to Edwards AFB where it will be used to acquire ground vibration data on the Mission Adaptive Wing (MAW). Thus this system provides the Air Force with a quick response data acquisition system.

In addition, the system has the capability to measure very low level signals. For example, in the F-16 GVT the 11 bit A/D converter for ±2.5 volts input gives a resolution of about 2.4 millivolts. If the AGC amplifier is in the 60dB gain step this is equivalent to 2.4 microvolts at the amplifier input, which for the accelerometers used on the F-16 GVT (about 10mv/g) is an acceleration level of approximately 240 micro g's. Since the pDAS can be programmed for an input range of ±10mv for digitization into 11 bits, even finer resolution than 240 micro g's can be obtained assuming the transducer and/or amplifier noise floor is not encountered. One problem with the pDAS is that the next range below ±2.5 volts input is ±50 mvolts. If the pDAS had a ±500mv range, better results could have been obtained.

As with any digital system, the F-16 GVT instrumentation system required anti-aliasing filters. The sampling rate can be changed quickly by reprogramming the pDAS EPROM, but each filter cutoff frequency change requires changing component values. This means time to reconfigure 120 filter cards and time to get new components.

A future system to meet FIRG needs will have to be small in size and capable of handling up to 150 10KHz bandwidth transducer signals simultaneously in a digital format. This planned system is required for measurement of vibration and acoustic environments on current and future space limited aerospace vehicles. The described Data Acquisition System worked successfully on the F-16 GVT and will be used on the AGILE and MAW tests; however, future systems will need to be physically smaller and capable of wider bandwidths per channel.

REFERENCES

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6. Operating Manual Model 3582A Spectrum Analyzer, Hewlett-Packard Company, Loveland CO, 1978.

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11. User's Reference Manual Commodore Base Version 4.0, Commodore Business Machines, Inc., July, 1980.

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APPENDIX

Figures - Photographs - Tables

TABLE I. LIST OF COMPONENTS

Manufacturer	Description	Quantity
Vibrametrics	M-1000A Accelerometers	120
FIBG In-house	Low pass filter cards, 6-pole, 6 per card	21
Intech, Inc	Model A-2583, Automatic Gain Changing Amps	120
Base 10 System, Inc	Model 7-128, Programmable Data Acquisition System	1
FIBG In-house	Digital Multiplexer	1
CGS/Datametrics	Time Code Generator - Model SF-400	1
FIBG In-house	AGC Amplifier & Display, ±15VDC, ±5, power supplies	3
Power-One, Inc	Power Supply 28VDC - 3 Amps	1
DEC	VAX 11/780	1
EMR	720 Bit Synchronizer, 708 PCM processor, Power Supply	1
Base Ten Systems, Inc	Model 500-520 Airborne Encoder Test Unit	1
Bruel & Kjaer	Type 4291-Accelerometer Calibrator	1
Honeywell	Model 96 Wide-Band Tape Recorders	1
Tektronix	465M Oscilloscope	1
Hewlett-Packard	3582A Spectrum Analyzer	1
EMR-Schlumbeger	720 Bit Synchronizer	1
EMR-Schlumbeger	2746 PCM Decommutator	1
EMR-Schlumbeger	2795 PCM Simulator	1
EMR-Schlumbeger	2748 Patch Board Demultiplexer	1
Unholtz-Dickie	Vibration Testing System No. TA100-4-6, including 2 ea Model 4 shakers	1
General Radio	Time Data System	1
Barry Wright Corp.	Serva-levl Vibration Isolation System	1
GHI, Inc	TRIAD IIA Transient Recorder System	1

TABLE II BINARY GAIN CODES FROM AGC AMPS

Binary Output MSB		LSB	Decimal Value	Gain
0	0	0	0	+60dB
0	0	1	1	+50dB
0	1	0	2	+40dB
0	1	1	3	+30dB
1	1	0	4	+20dB
1	0	1	5	+10dB
1	1	0	6	0dB
1	1	1	7	-10db

Binary Output: +5VDC = false = 0
Ground = true = 1

TABLE III FORMAT OF PCM SERIAL DATA

GAIN CODES AND FRAME COUNTER									TIME CODE IRIG - B 17 BIT BCD			
Word #121				Word #122				Word #123 FRAME COUNTER*	Word #124 HOURS Tens Unit	Word #125 MINUTES Tens Unit	Word #126 SECONDS Tens Unit	
5	6	7	5	6	7	5	0		1 9	3 9	5 8	Decimal
101	110	111	101	110	111	101	000	cntr	XX0100001001	X01100001001	X10100001000	Binary
25	17	9	1	89	81	65	57	000000000000	XX0100001001	X01100001001	X10100001000	1
26	18	10	2	90	82	66	58	000000000001				2
27	19	11	3	91	83	67	59	000000000010				3
28	20	12	4	92	84	68	60	000000000011				4
29	21	13	5	93	85	69	71	000000000100				5
30	22	14	6	94	86	70	62	000000000101				6
31	23	15	7	95	87	71	63	000000000110				7
32	24	16	8	96	88	72	64	000000000111				8
49	41	73	33		113	105	97	000000001000				9
50	42	74	34		114	106	98	000000001001				10
51	43	75	35		115	107	99	000000001010				11
52	44	76	36		116	108	100	000000001011				12
53	45	77	37		117	109	101	000000001100				13
54	46	78	38		118	110	102	000000001101				14
55	47	79	39		119	111	103	000000001110				15
56	48	80	40		120	112	104	000000001111				16
25	17	9	1	89	81	65	57	000000000000	XX0100001001	X01100001001	X10100001000	0
AMP # GAINS												

FRAME NUMBER

*Hundreths and tenths of seconds in 8msb of word #123 added later.

Sync Word 1	Sync Word 2	Word #1	Words 2-120	Words 121-126	Sync Word 1	Sync Word 2
111110101111	011100110100	010010101101 From Amp 1	101001100111 Amps 2-120	101010100110	111110101111	
Major Frame 390.63 times per second					Next Major Frame	

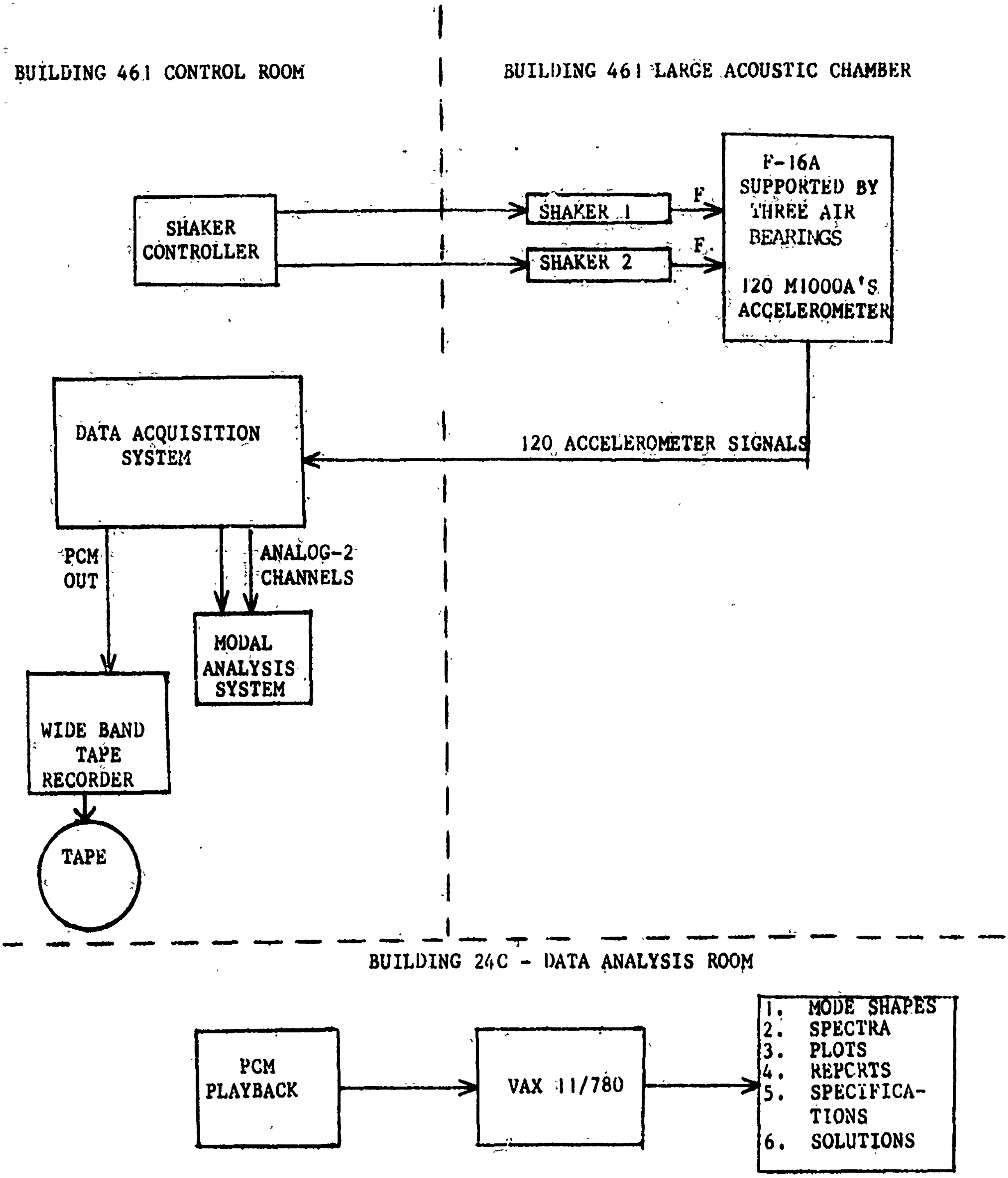


Figure 1. Overall Block Diagram F-16 GVT

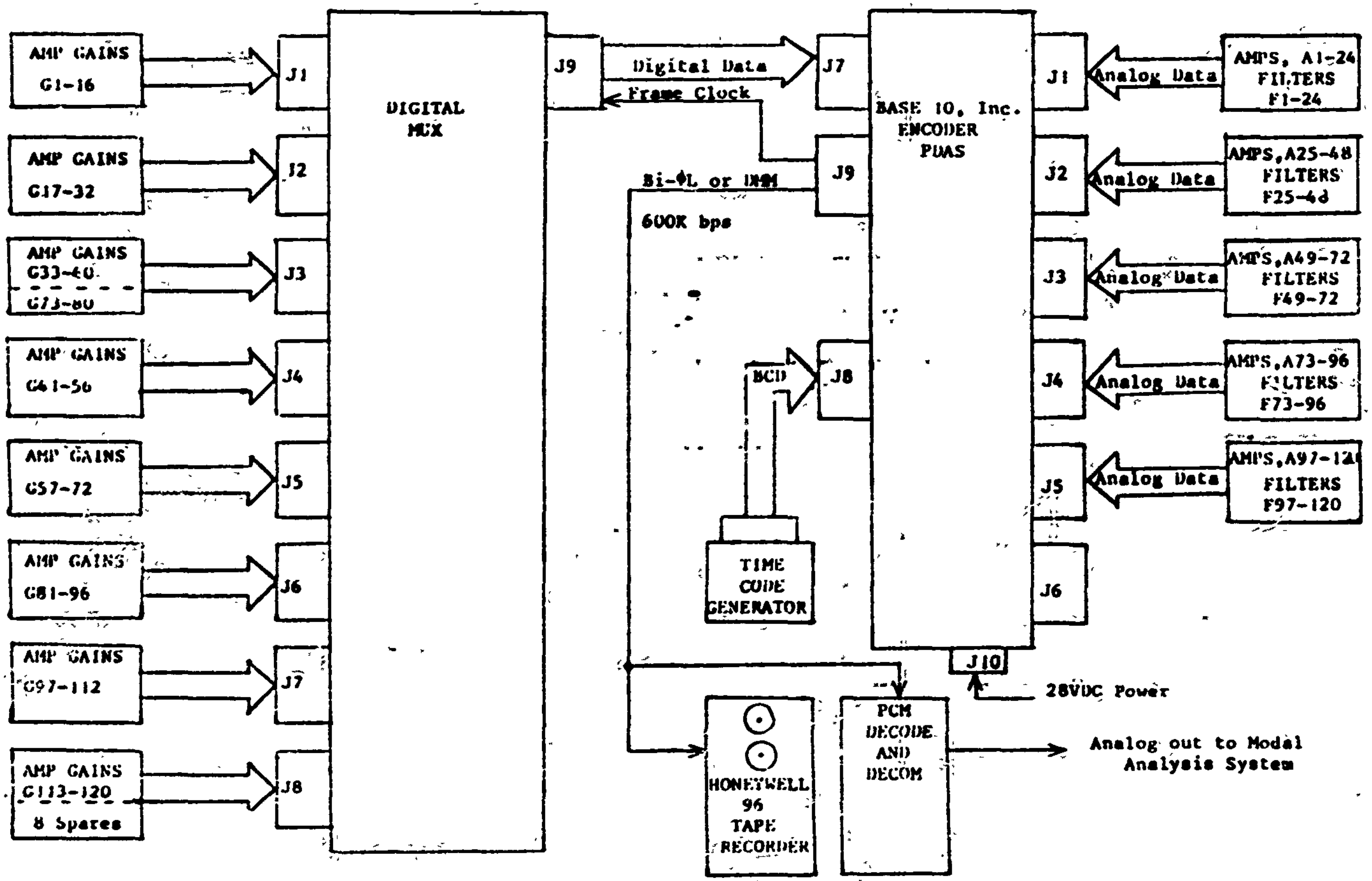


Figure 2. Block Diagram of F-16 GVT Data Acquisition

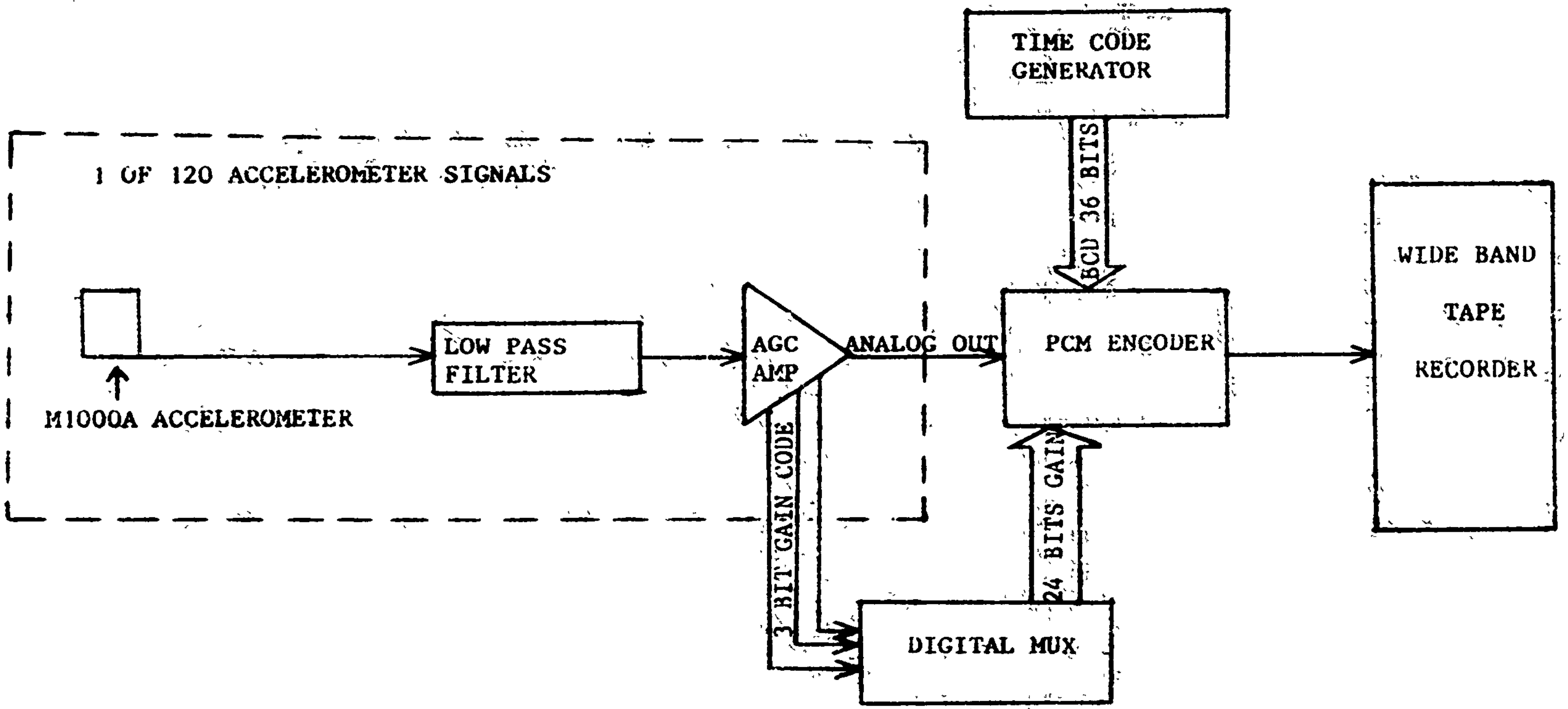
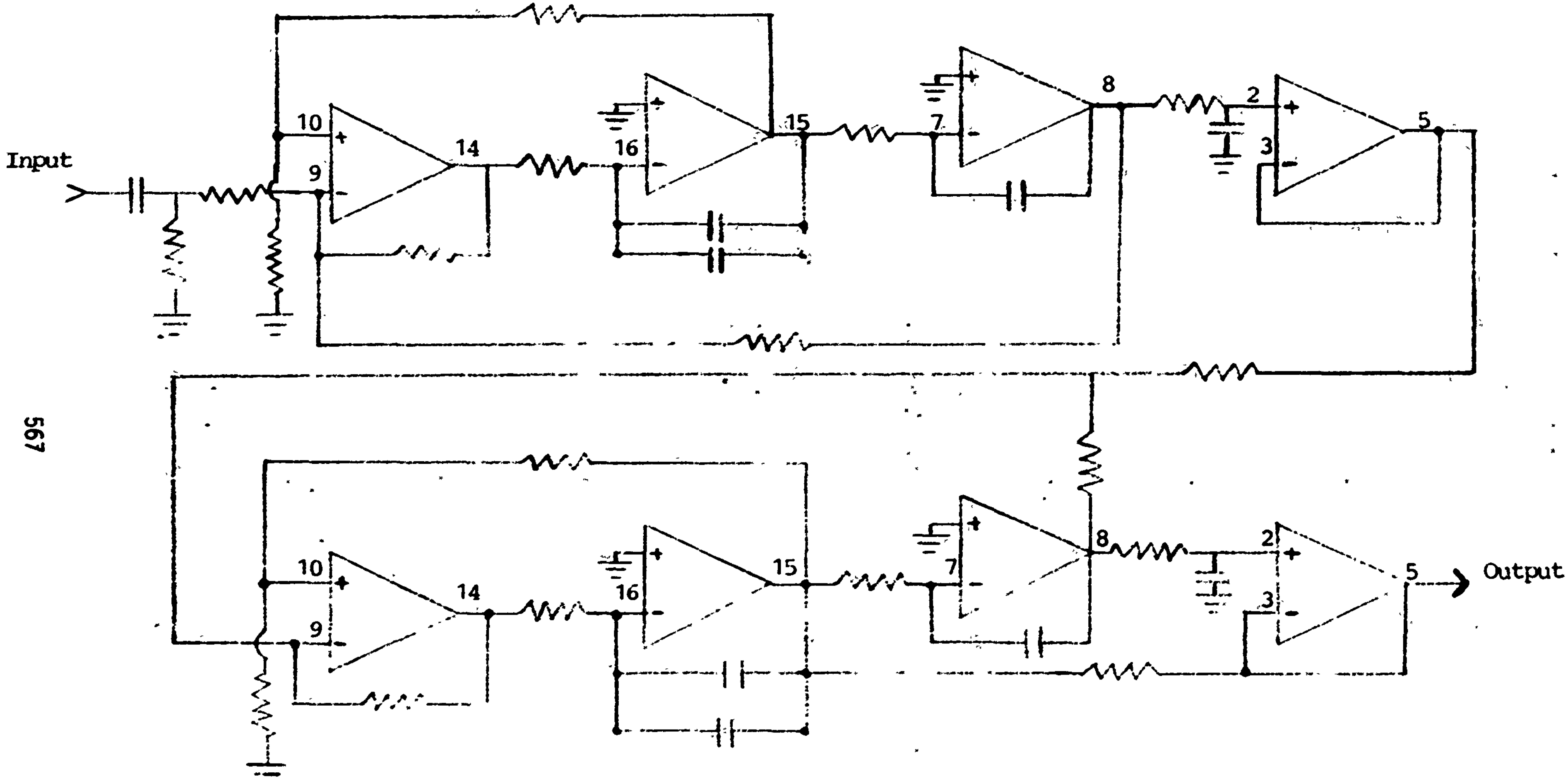


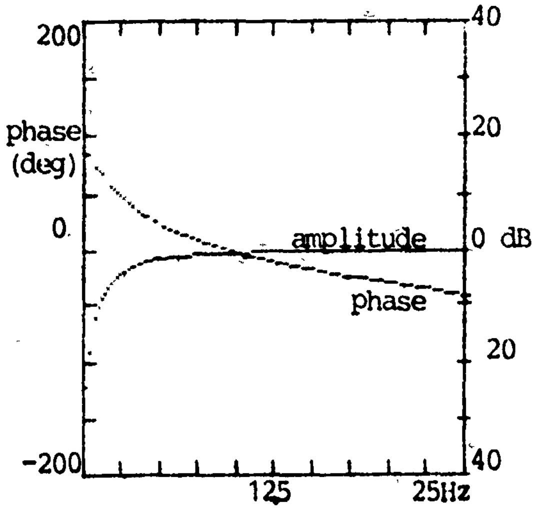
Figure 3. Data Acquisition System Accelerometer Signal Flow



NOTES: 6-pole filter
2 AF-100-CNs per filter
6 filters per card
1-V, 4 GND, 6 +V, 11-13 NC

Figure 4. Filter Schematic

FILENAME: LF1 DATE: 8 NOVEMBER 1982
TIME: 131511
XFR FCTN + 40dB FS 10dB/DIV
XFR FCTN 0* CENTER 50*/DIV

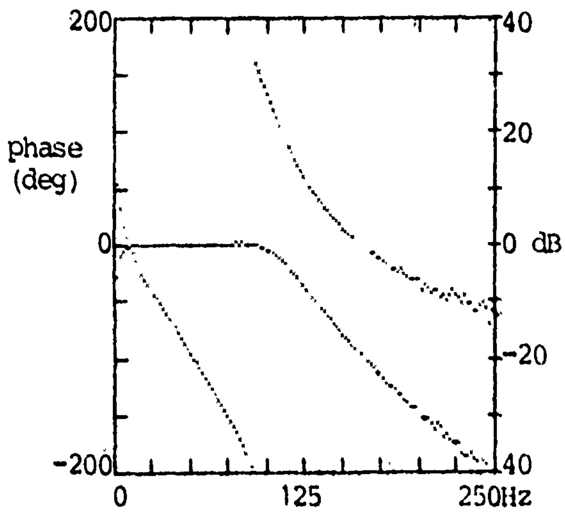


\ 0 Hz 25 Hz /

AVERAGE 4 BW 200 mHz

Figure 5a. Low Frequency Response of Filter 1

FILENAME: HF1 DATE: 8 NOVEMBER 1982
TIME: 132102
XFR FCTN + 40dB FS 10dB/DIV
XFR FCTN 0* CENTER 50*/DIV

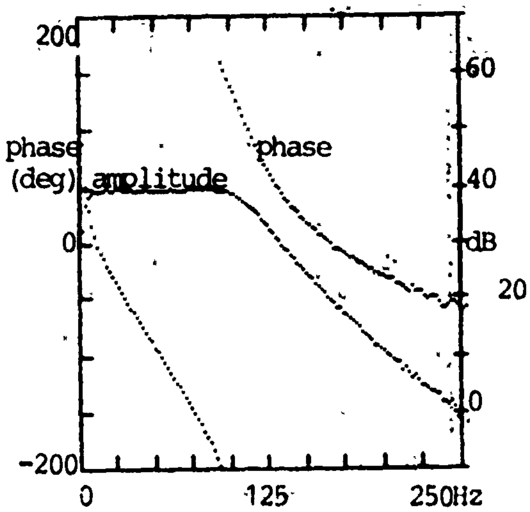


\ 0 Hz 250 Hz /

AVERAGE 4 BW 2.00 Hz

Figure 5b. High Frequency Response of Filter 1

FILENAME: HFA6 DATE: 12 NOVEMBER 1982
TIME: 135959
XFR FCTN + 70dB FS 10dB/DIV
XFR FCTN 0* CENTER 50*/DIV

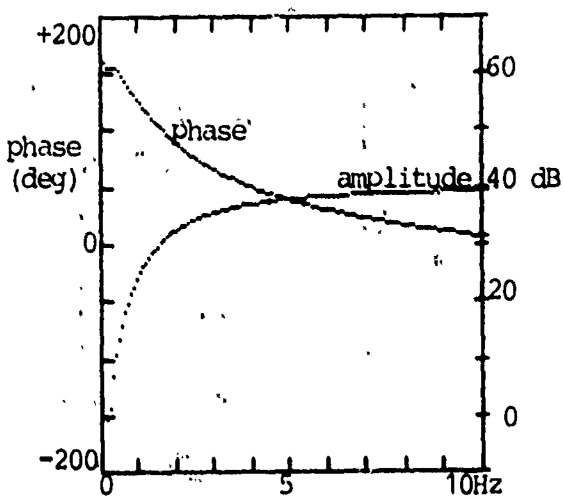


\ 0 Hz 250 Hz /

AVERAGE 4 BW 2.00 Hz

Figure 6a. High Frequency Response of Filter 6 and Amp 6.

FILENAME: LFA6 DATE: 12 NOVEMBER 1982
TIME: 144402
XFR FCTN + 70dB FS 10dB/DIV
XFR FCTN 0* CENTER 50*/DIV



\ 0 Hz 10 Hz /

AVERAGE 4 BW 80.0 mHz

Figure 6b. Low Frequency Response to Filter 6 and Amp 6.

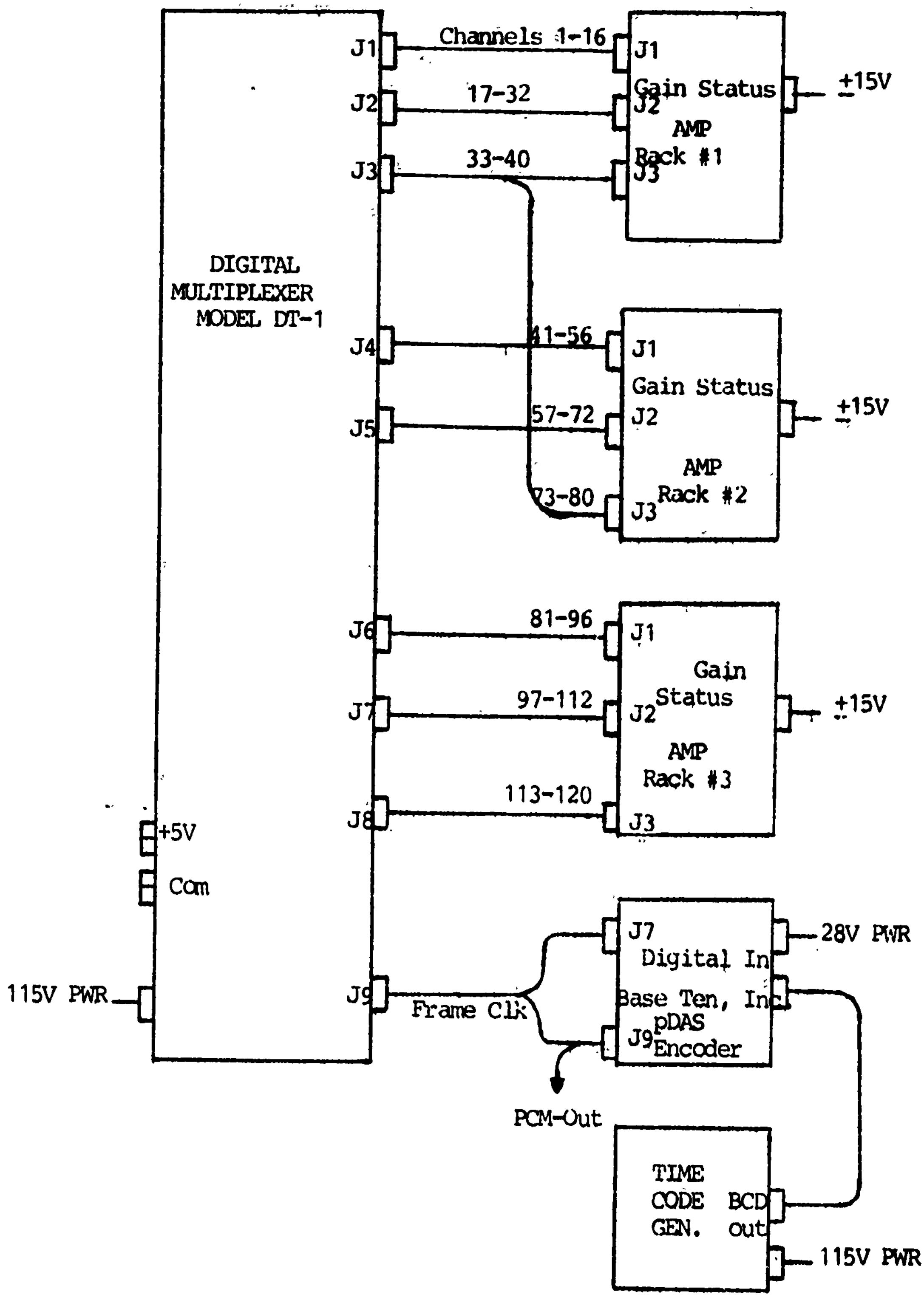


Figure 7. Digital Interconnect Cabling

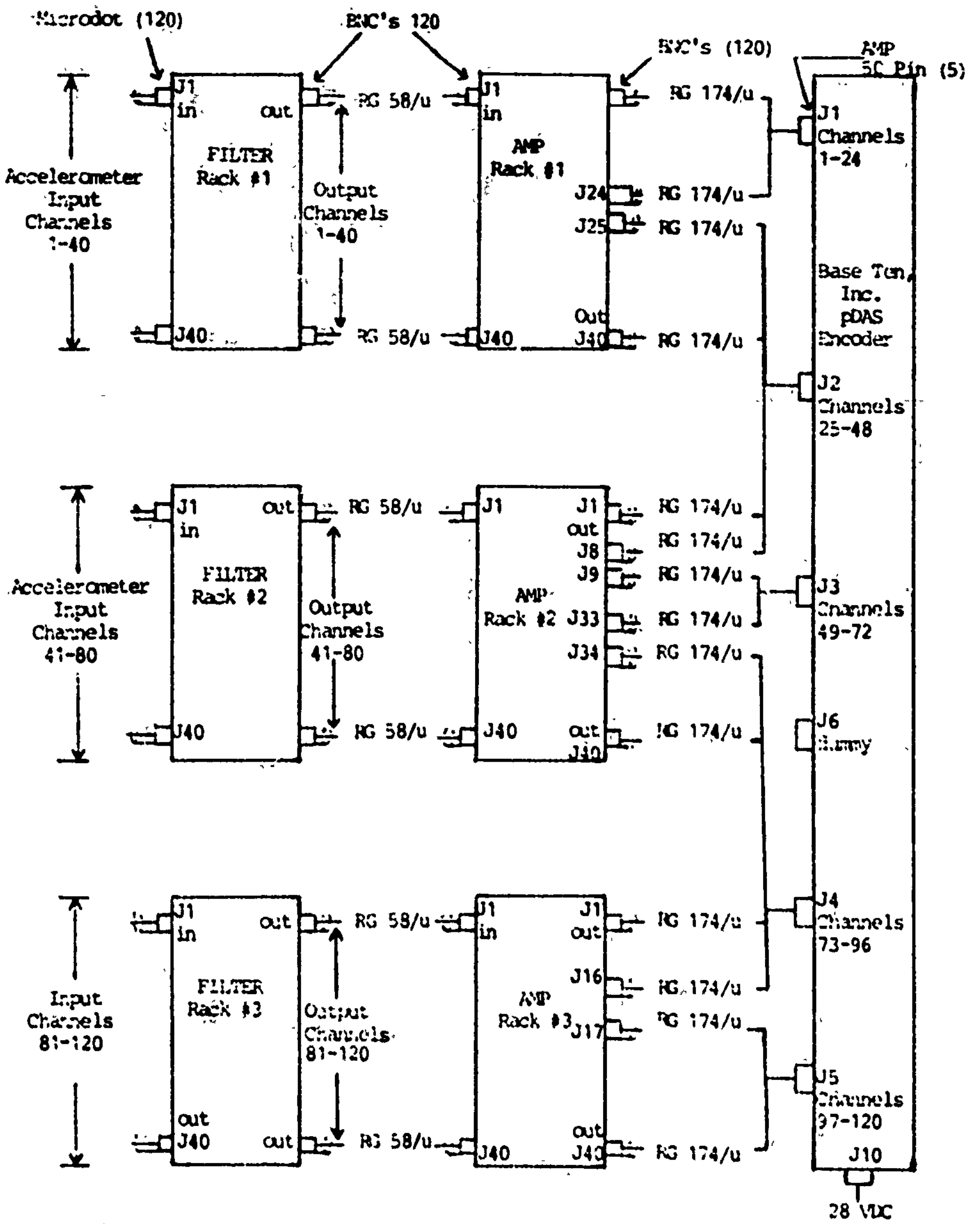
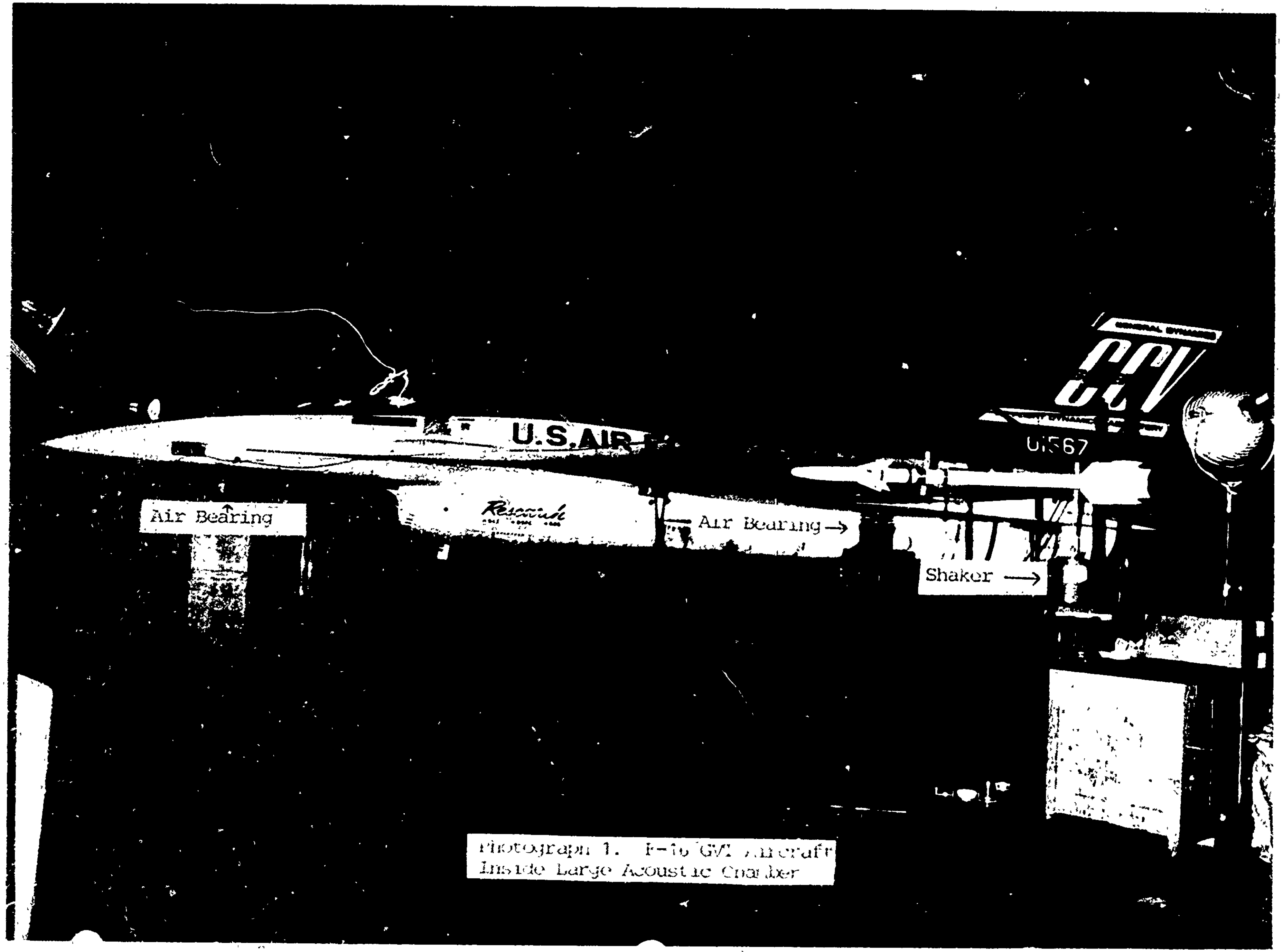
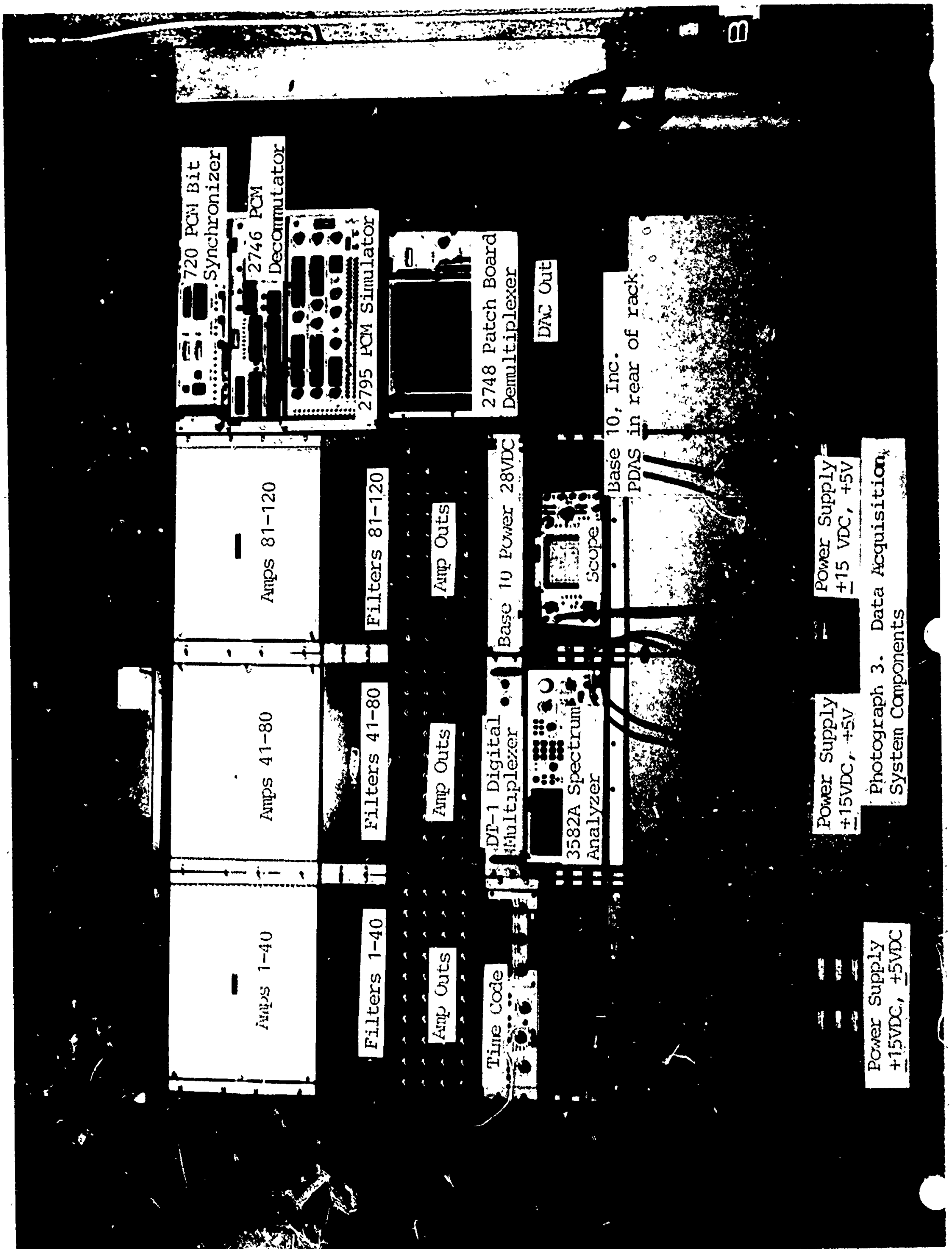


Figure 8. Analog Signal Input Interconnect Cabling

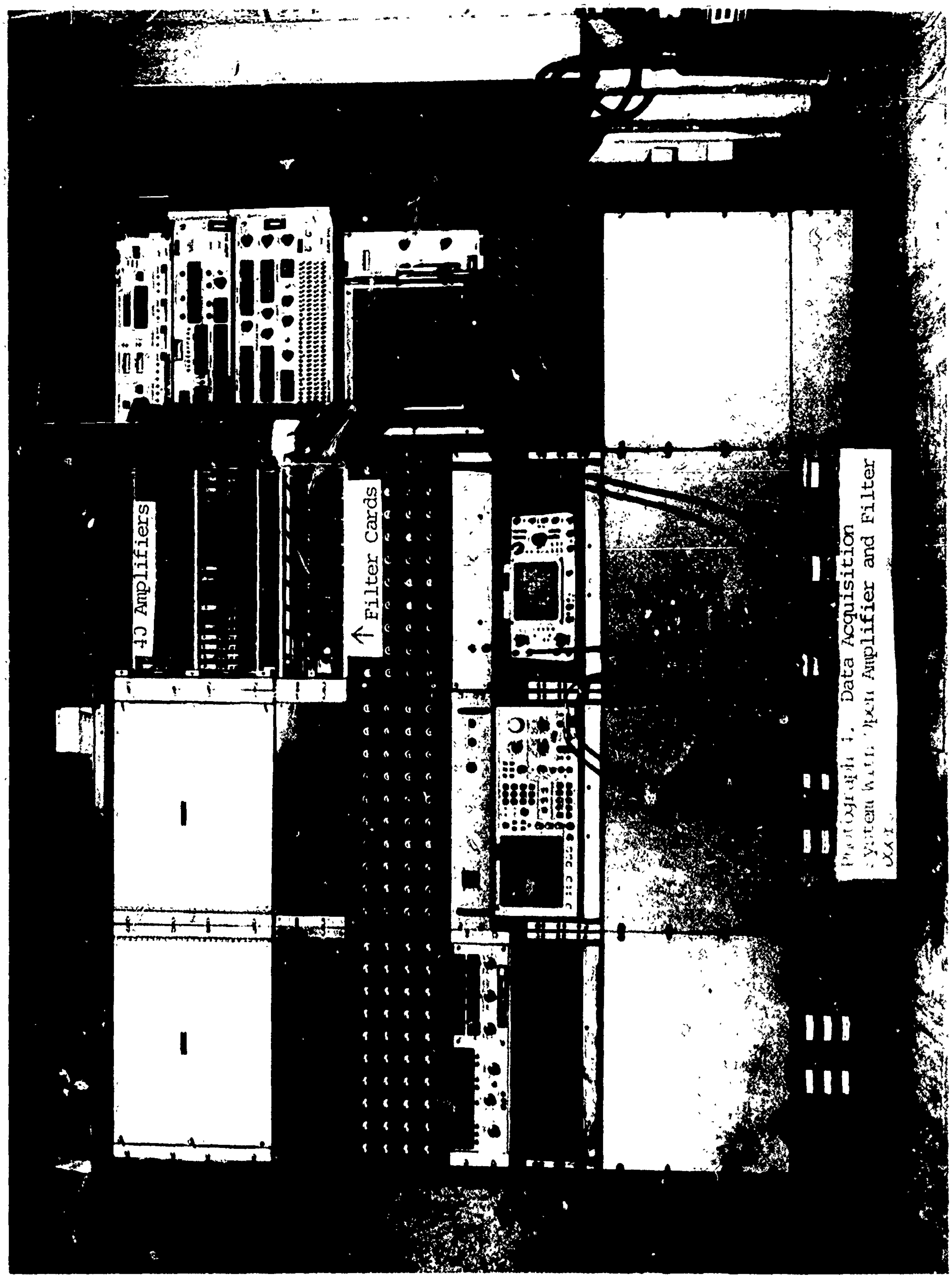


Photograph 1. F-16 GVT Aircraft Inside Large Acoustic Chamber

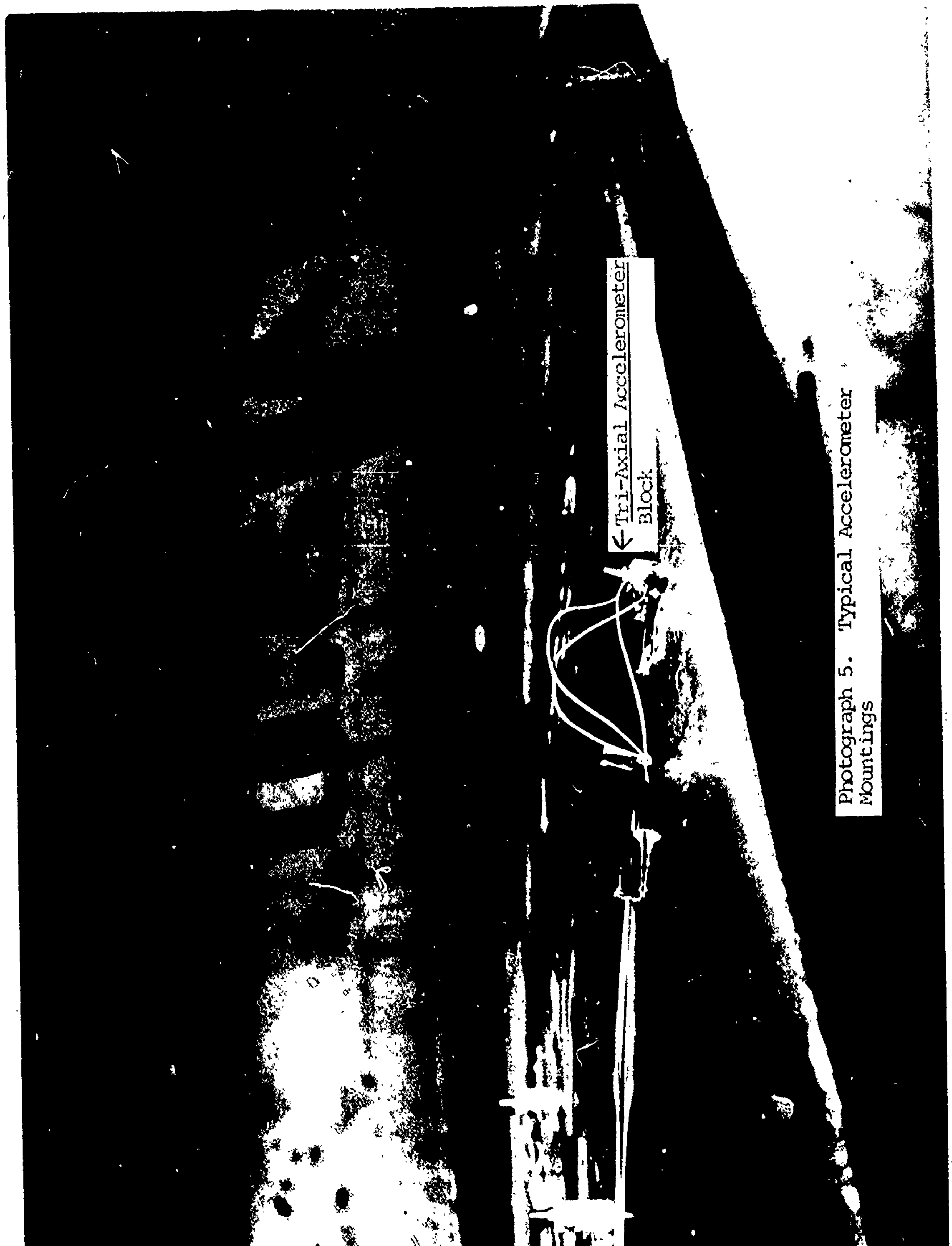
Photograph 2. Overall View of Bldg 461 Control Room



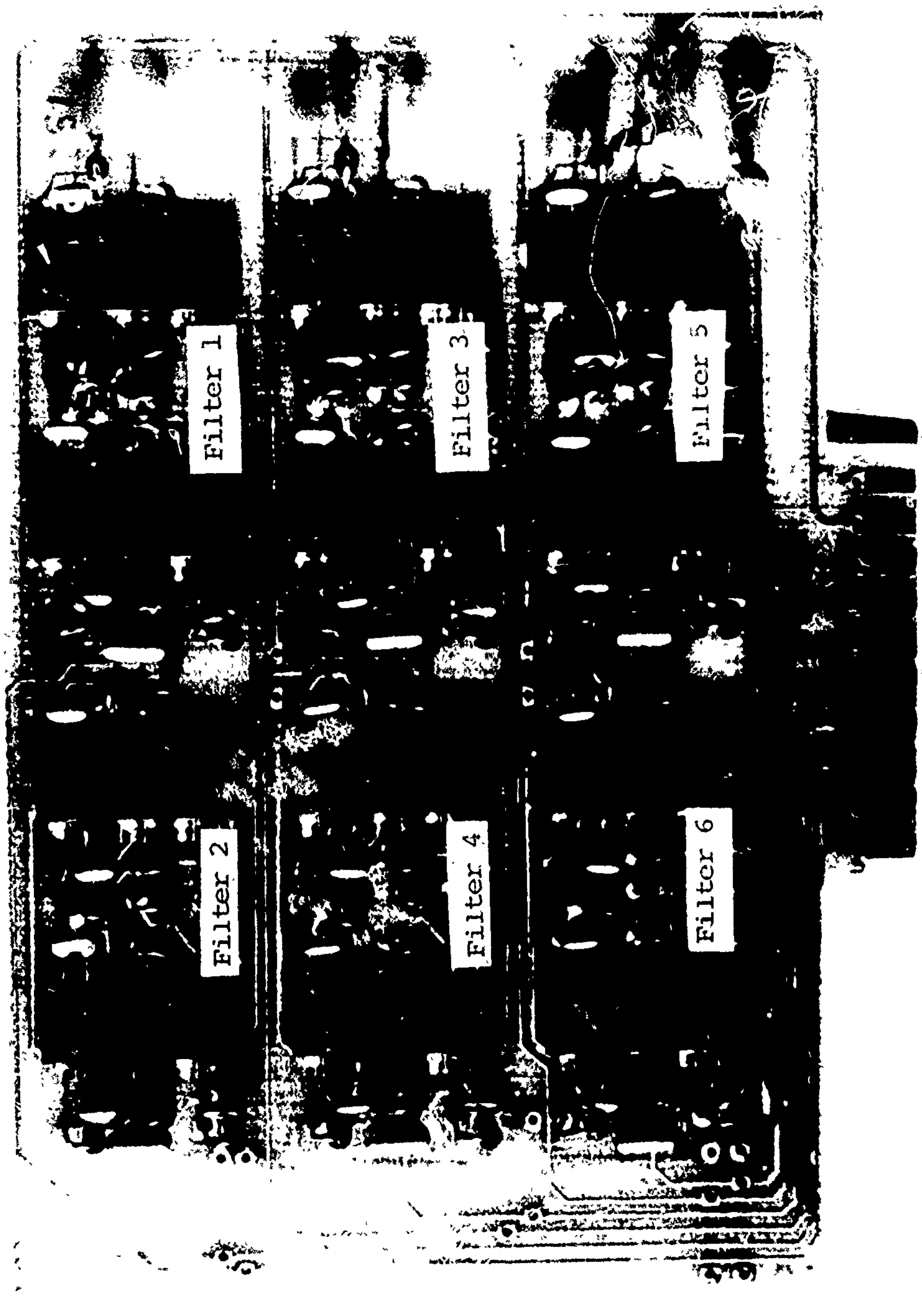
Photograph 3. Data Acquisition System Components



Photograph [illegible]. Data Acquisition System with Open Amplifier and Filter [illegible]

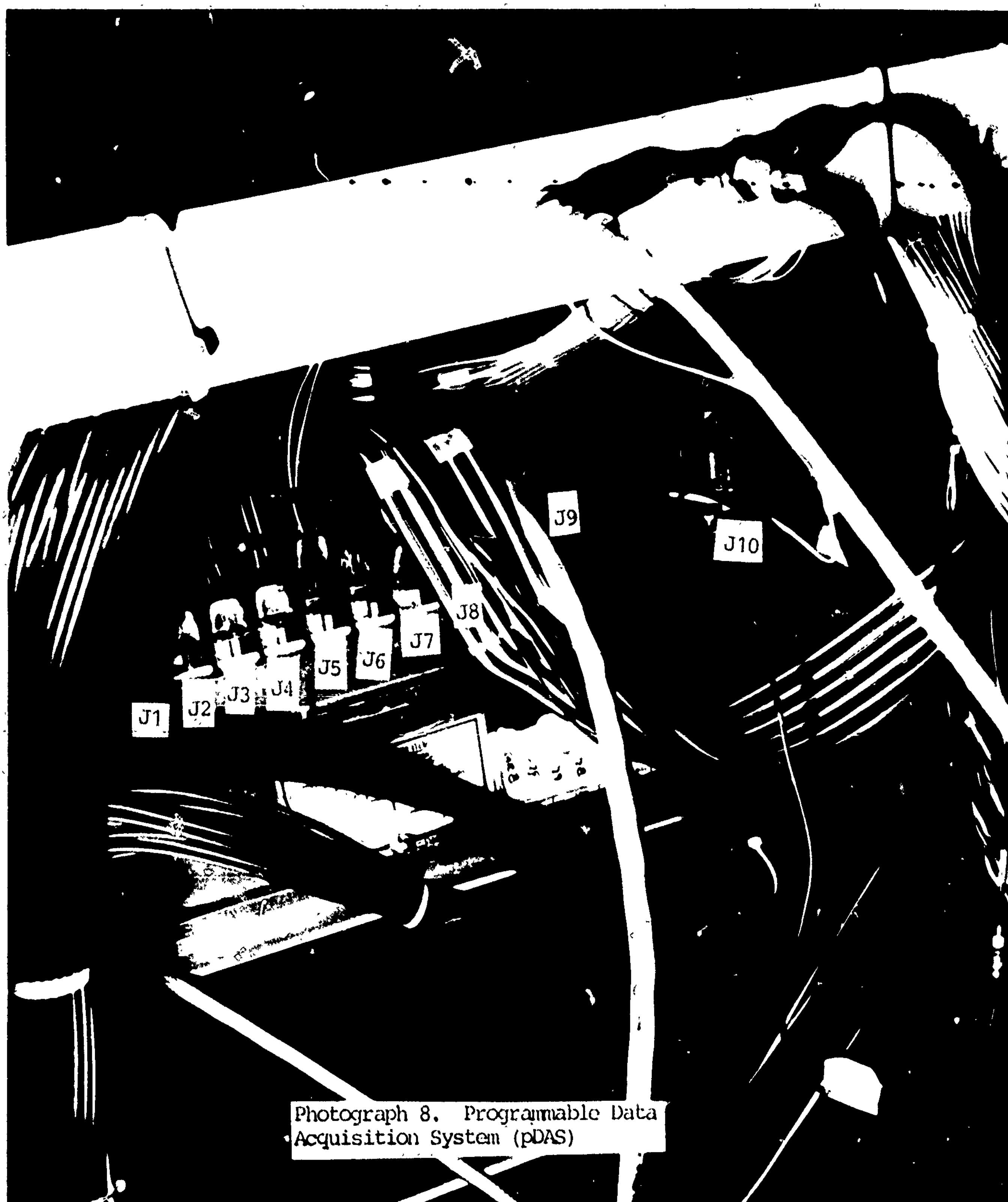


Photograph 5. Typical Accelerometer Mountings



[illegible] Channel Filter

Photograph 7. Automatic Gain Changing (AGC) Amplifier Card



Photograph 8. Programmable Data Acquisition System (pDAS)