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DATA ACQUISITION SYSTEM FOR NASA LaRC IMPACT DYNAMICS RESEARCH FACILITY

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By

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SUMMARY

This paper describes the data acquisition system at LaRC's Impact Dynamics Research Facility. The data system is designed to permit the simultaneous recording of 90 data channels on one 28-track magnetic tape recorder using a constant bandwidth FM multiplexing technique. Dynamic signals from transducers located in the test aircraft are amplified and fed to voltage controlled oscillators where they are converted to discrete FM signals. The signals from each group of five VCO's are fed to a mixer/distribution amplifier where they are combined into one composite signal and recorded, using direct recording techniques, on one magnetic tape recorder track. Millivolt signals from the recorders reproduce heads are amplified to one volt (RMS) and then electronically switched to an FM demultiplexing system where appropriate frequency discrimination and signal filtering recover the original analog information.

INTRODUCTION

The Impact Dynamics Research Facility at LaRC was originally designed and built for training astronauts in Lunar Excursion Module (LEM) moon landing flight profiles. Since moon landings have been suspended by NASA, the facility has been adapted to study general aviation aircraft crash safety.

Before the Lunar Landing facility was converted to study general aviation aircraft crashworthiness, the private sector knew little of crash safety because few private aircraft have on-board flight parameter recorders. All crash data were really assumptions made by investigators on the basis of studies of the wreckage. By dropping instrumented test aircraft, dynamic impact data is obtained and can be scientifically analyzed. The data emanates from numerous transducers mounted at strategic points of the airframe and engine, and from anthropomorphic figures used as passengers which have been weighted to simulate human parameters. These data are made available to aircraft manufacturers and are of great value for designing safety features into future aircraft.

The purpose of this paper is to describe the data acquisition capabilities of the Impact Dynamics Research Facility, with emphasis on the constant bandwidth (CBW) FM multiplexing techniques employed to record 90 channels of research data on a single 28-channel magnetic tape recorder.

Facility

The Impact Dynamics Research Facility's large gantry (fig. 1), with hoist winches mounted in the superstructure, provides the setting for the controlled aircraft crash. These hoists are used to raise the aircraft to a pre-determined height and crash angle, where the vehicle is then released to crash land in a designated area at various sinking speeds and impact accelerations.

The dynamic data are coupled to the data recording equipment by means of a multi-wire umbilical cable terminating in four special 55 pin connectors. Six conductors of the umbilical are assigned to deliver power to precision 10 VDC regulators located onboard the test aircraft. These regulators supply a constant voltage to transducers used to measure physical variables such as acceleration, vertical velocity, force, and motion. Four conductors are used to activate onboard lighting and to start three strategically placed high speed film cameras that provide a visual record of occurrences inside the aircraft during a crash. An explosive device, built into the unbilical connectors at the test model, activates 1 second after impact releasing the umbilical line and preventing damage to the data lines.

Previous Data Acquisition System

Prior to updating the data acquisition system of the Impact Dynamics Research facility, six 14-channel magnetic tape recorders were used to record 84 channels of data. With this system, channel arrangement for data time correlation and data records was very complicated. Each of the six tape recorders required record and reproduce amplifier calibration prior to each crash test, a procedure which consumed eight man-hours of set-up time providing no other electrical or mechanical complications were encountered. After tape recorder calibration, the test operator would record a system calibration on each tape track of the six recorders individually. This calibration consisted of substituting a switchable dc voltage in place of the data input to deviate the FM center frequency of each tape channel to plus, zero, and minus full scale. These signals, termed PRE-CAL, were used, during data playback, to verify the levels and validity of the recorded data.

The signals from piezoresistive accelerometers, strain gages, load cells, and extensiometers are cabled via the umbilical wires to the control room through junction boxes located on the gantry umbilical platform and in the control room. The input data signal conditioning amplifiers for piezoresistive accelerometers (fig. 2), and for strain gages (fig. 3), were designed and built at LaRC. Amplifiers for both applications feature 12 dB/octave roll-off, passive R-C filtering above 1 kilohertz (fig. 4), thereby virtually eliminating any noise frequencies that are induced into the long data cables that occur above the band-pass frequency of the filter.

New Data Acquisition System

The new data acquisition system (fig. 5) makes use of a Metraplex model 161 Autoset Control Unit to control 90 constant bandwidth high level VCO's, multiplexers, and a 28-channel direct-record magnetic tape recorder to record the 90 channels of information simultaneously. The control unit has built-in provisions for automatically setting the system quiescent parameters and applying specified voltages to all voltage controlled oscillator (VCO) inputs in order to verify dynamic system calibration. An outstanding feature of the automatic calibration unit is that the operator can, with the push of a button, electronically check and zero the entire system a few seconds prior to data "start", thus correcting for DC drift and assuring more accurate data. A rackmounted control panel is provided to enable the test operator to configure the auto set control unit for the specific test parameters. Three multiplexing modes are provided: IRIG Constant Bandwidth (CBW), standard constant bandwidth (st. CBW), or external; the latter is used for externally generated frequencies such as Proportional Bandwidth (PBW) or Wide Band 1 (WB 1) FM. Next, the operator sets the CBW deviation by selecting one of eight deviation frequencies, ranging from ±0.5 KHz to ±64 KHz. The bandwidth selected must be higher than the highest test data frequency anticipated by the researcher. The system input calibration voltage is selected with thumbwheel switches which numerically indicate calibration voltage level and are selectable from 0.0 to 10.0 volts in 0.1 volt increments.

The type of electronic modules to be calibrated, i.e., high level VCO, medium level VCO or demodulators (Demod), are selected by pushbutton switches which automatically set up the auto-cal function of the modules being calibrated. Once the above switch selections have been made, the operator proceeds with the system calibration. The auto-set control unit is stepped through the calibration modes (zero, span, and back to data ready mode) by means of a dual sequence switch. When VCO's are selected and the unit is sequenced to the zero mode, all VCO inputs are automatically zeroed by means of internal electronic circuitry in each module. If one or more of the VCO's are out of tolerance, the calibrate indicator light will flash on and off to alert the operator to an error. A small red LED then lights on the individual modules that failed to electronically adjust so that the operator can manually adjust or replace the defective module.

Satisfied with the zero check, the operator will again push the sequence controls to place the control unit in the span mode wherein DC cal. voltages (selected by thumbwheel switch) are applied to all VCO's; this voltage deviates the VCO center carrier frequencies to the value selected earlier by the pushbutton deviation selectors. Again, if any VCO has a span or deviation limit error in excess of 0.2% of its rated values, the red deviation error indicator will flash and the red light on the faulty module will indicate the need for module adjustment or replacement. Demodulators are calibrated in exactly the same sequence as the VCO's after selection by the Demod pushbutton. Here again, a red flashing control unit light indicates an error and the individual module fault indicator is lighted, calling for corrective action.

When system calibration is complete, another push of the sequence pushbuttons deactivates all calibration circuitry in the VCO's and demodulators, and lights the green control unit data light which indicates that the multiplex system is calibrated and ready to accept data.

Constant Bandwidth Hi-Level FM Multiplexers

The conditioned data signals leaving the input amplifiers are divided into sequential data line groups of five: group 1 = data lines 1 through 5; group 2 = 6 through 10; etc. Each of the five data lines in each group is assigned an individual constant bandwidth VCO (fig. 6). The VCO's operate at five distinct center frequencies: (1-1) 25 KHz, (1-2) 40 KHz, (1-3) 55 KHz, (1-4) 70 KHz and (1-5) 85 KHz. Selectable by plug-in units in each VCO module this VCO frequency arrangement is identical for each group of five data channels. The FM data from the VCO's are fed to a distribution amplifier where all five discrete modulated carriers are linearly mixed along with a master reference frequency of 100 KHz supplied by a system master oscillator and applied through a BNC connector. From the distribution amplifier (fig. 6), the mixed modulation signal goes to a direct record module of the magnetic tape recorder where the five mixed FM-modulated data channels and reference frequency are recorded on one tape track.

CBW FM Demultiplexers

Playback is initiated through a reproduce pre-amplifier which receives the signal from the reproduce head and amplifies it from a low millivolt value to approximately 1 VRMS. The signal is then routed to a reproduce amplifier which further amplifies and equalizes the signal over the designed band-pass of the equalizer. The conditioned output of the reproduce amplifier is then fed into the FM demultiplexers. The demultiplexer system consists of a group of five separate discriminators, programmable by means of plug-in filters, that correspond to the five VCO center carrier frequencies. The filter in each discriminator sets the peak filter bandpass of the unit. The filter frequency bandpass is sufficient to pass its corresponding center carrier frequency and its modulating frequencies on to the demodulator where the FM signal is converted and filtered to produce a replica of the original data signal. A 100 KHz discriminator filter in the demultiplexer housing extracts the reference frequency and makes it available at a BNC output connector. The playback tape unit uses this 100 KHz reference signal for servo capstan control. This signal compensates for errors in the data caused by tape speed variations.

Tape Recorders

One 28-track Honeywell model 96 magnetic tape recorder is the heart of the data acquisition system. The recorder offers a 28-track data recording capability which is further expanded, by use of the FM data multiplexing technique to 5 data channels per track or 5 x 28 = 140 data channels. Only 90 data channels are being recorded at 5 channels/track for the crash facility applications. This complement occupies 18 tape tracks and allow the recording of time code, servo signals, and other wide band data on the remaining 10 tape tracks.

CONCLUDING REMARKS

An FM multiplexing data acquisition system has been developed and installed at the LaRC Impact Dynamics Research Facility. The system employs a 90 channel voltage controlled oscillator frequency modulating technique which can handle data rates from D.C. to 2 KHz. The 90 channels of modulated data are divided into data groups of five. Each data group is fed to a distribution mixer/amplifier where the 5 data channels are linearly mixed with a 100 KHz servo reference signal. The complex composite signal from the distribution amplifier is then recorded on one channel of a 28-channel magnetic tape recorder. By dividing the data channels into data groups of 5, and linearly mixing them into one composite signal, the 90 channels of data are compressed into 18 channels. These 18 FM multiplexed signals are then recorded in normal fashion on magnetic tape. Data reproduction is accomplished by conditioning the signal off of the tape through playback equalization amplifiers and routing to demultiplexers containing 5 discrete precision bandpass filters. Each of the 5 filters corresponds to the center frequency of the voltage controlled oscillator used to modulate the data. The demodulated signals from the 5 filter/demodulators appear at the system output as a replica of the original data.

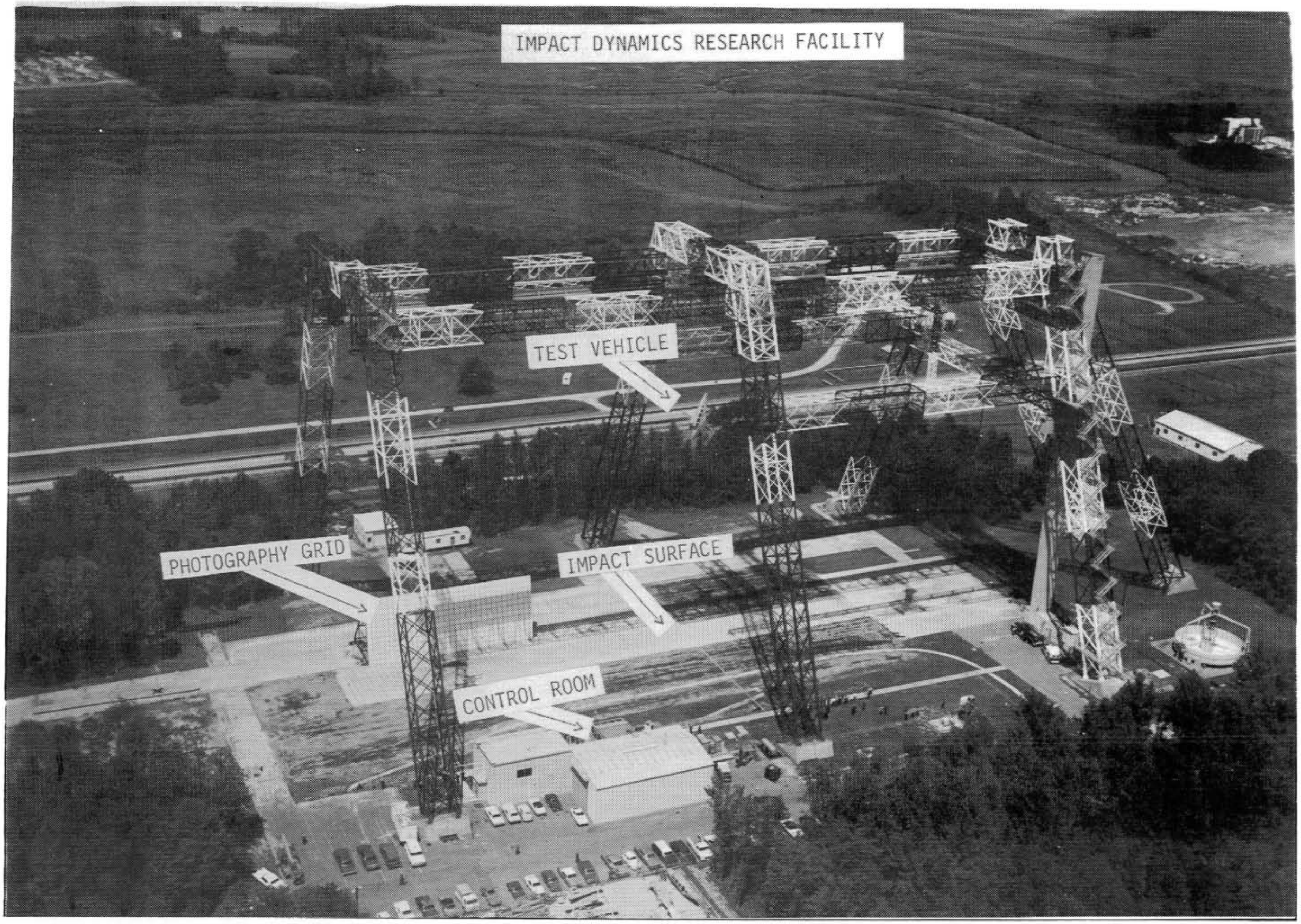

Figure 1 - Impact Dynamics Research Facility - showing test vehicle hoisted to test drop position.

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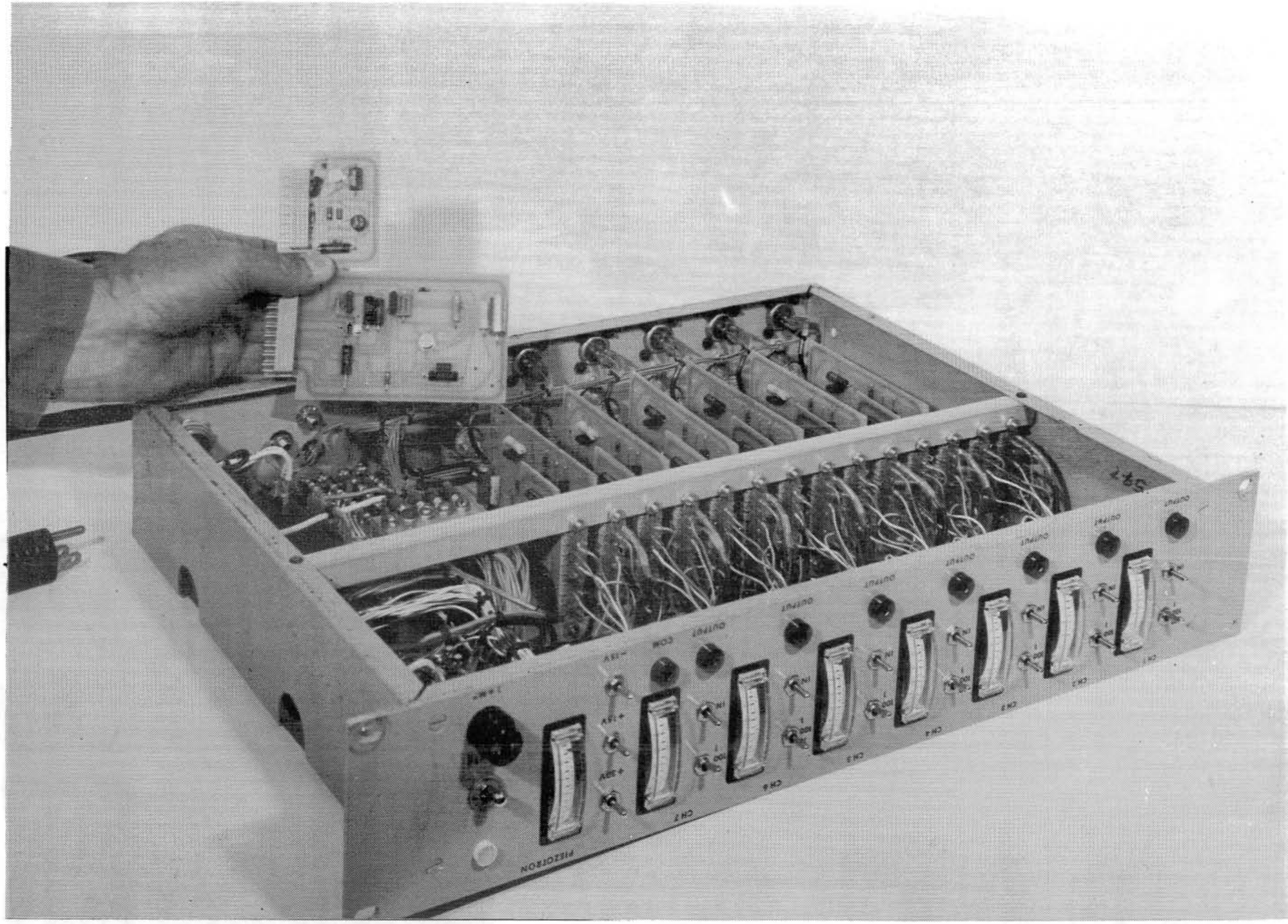

Figure 2 - Piezotron Amplifier Chassis - showing front panel controls and signal conditioning printed circuit cards.

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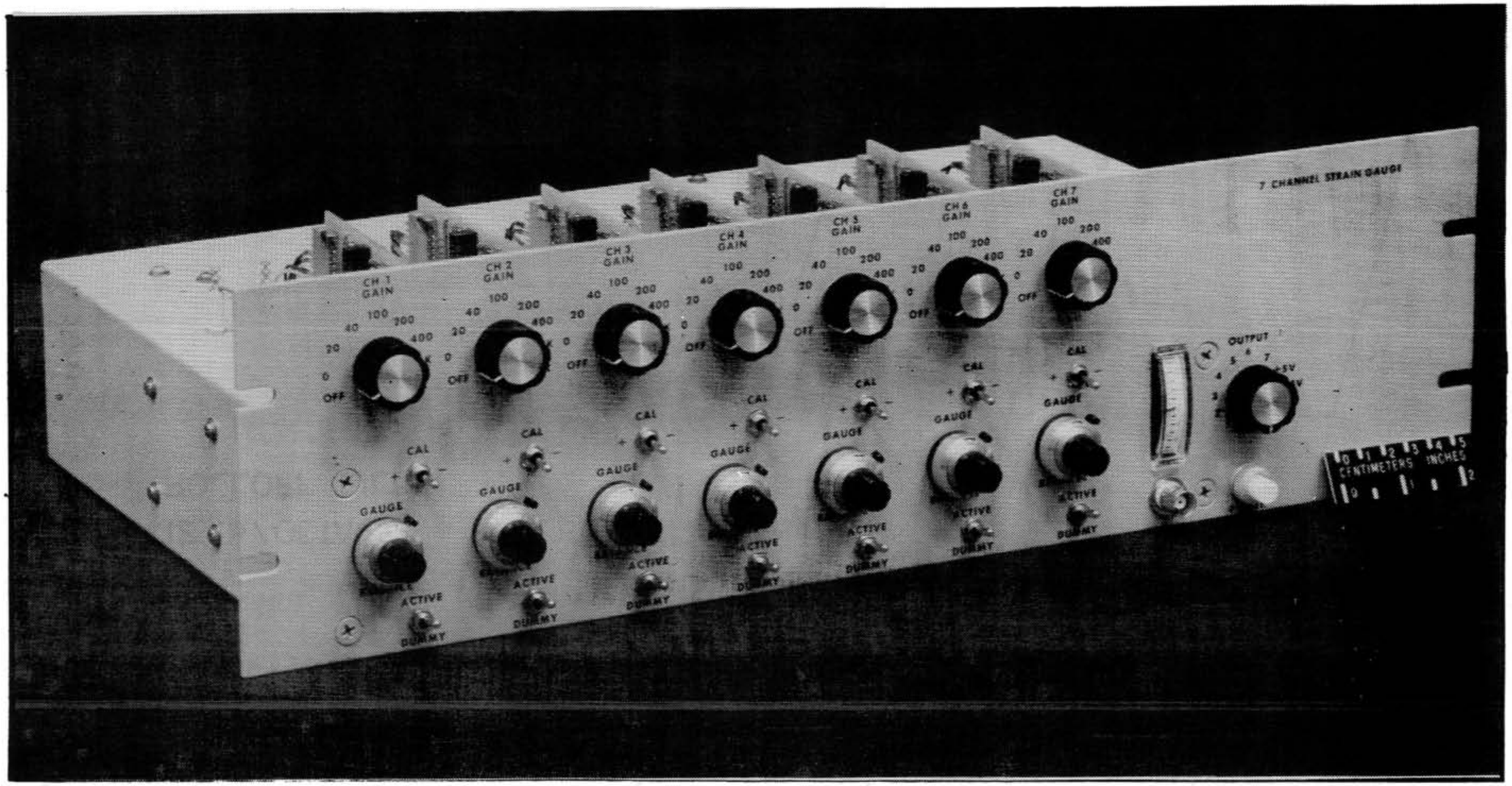

Figure 3 - Strain Gage Amplifier - front panel control layout.

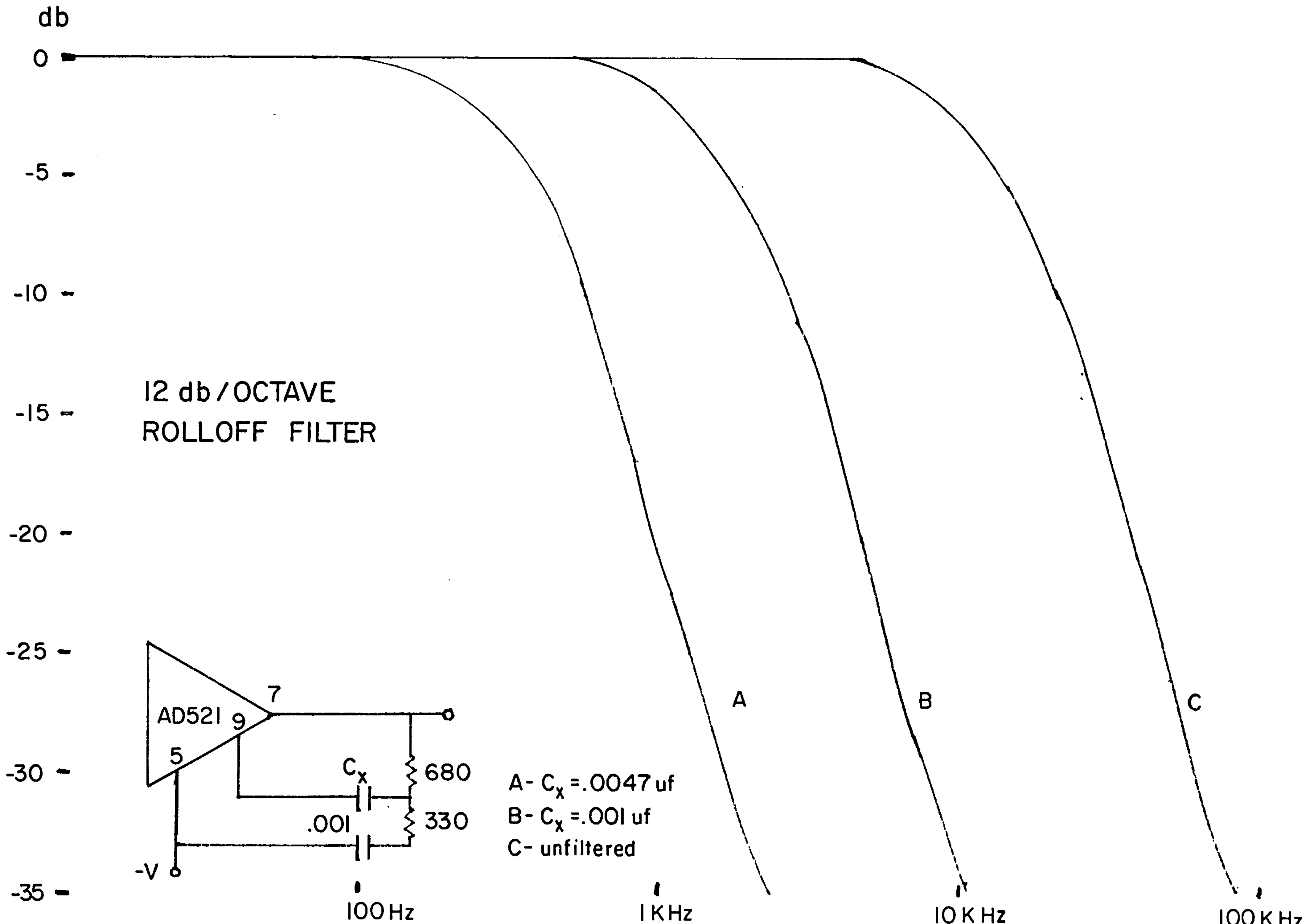

Figure 4 - 12 db/octave active roll off filter showing basic circuit design and circuit roll off characteristics.

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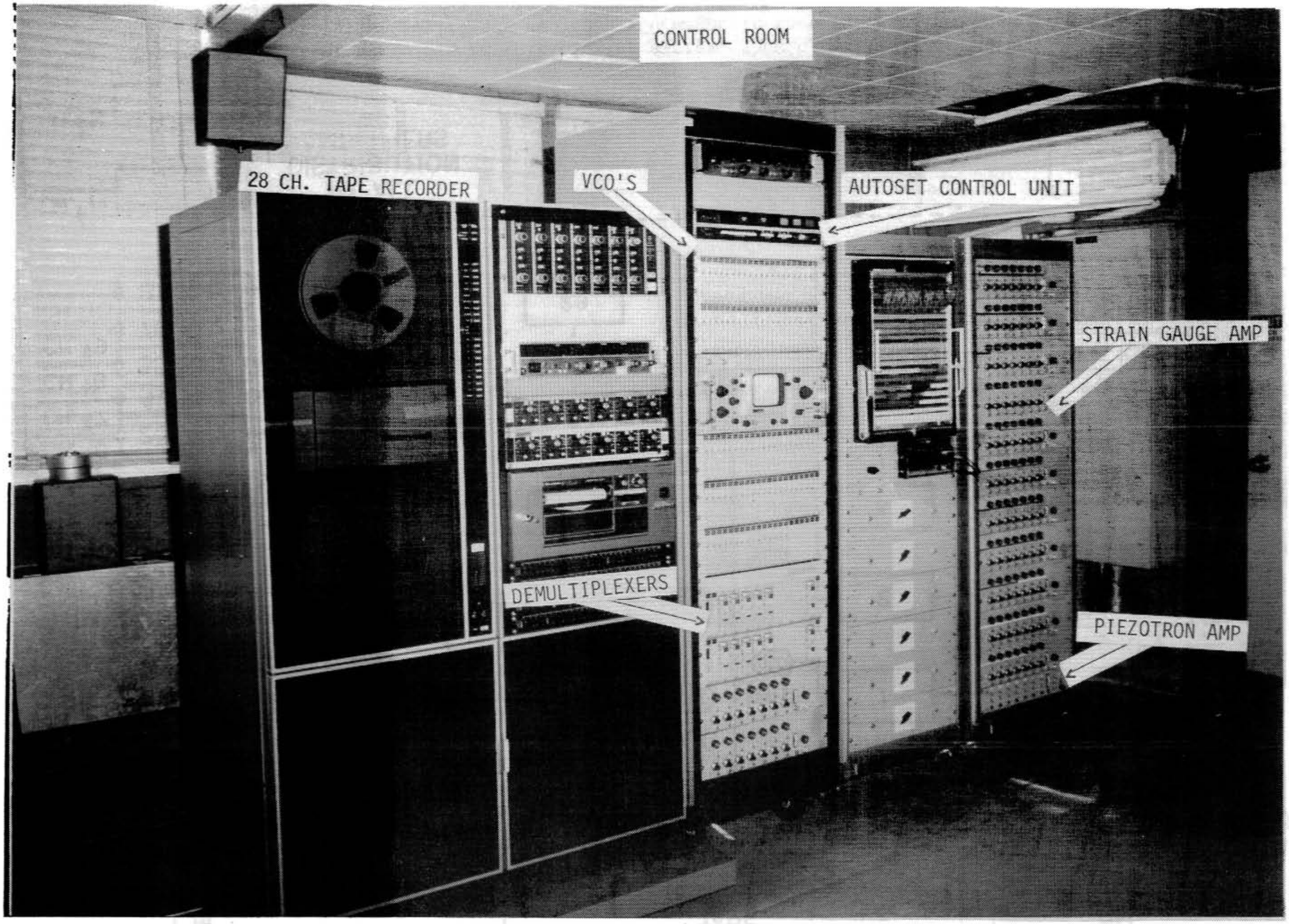

Figure 5 - Impact Dynamics Research Facility's analog data acquisition system - 28-channel **tape recorder,** FM 5 channel/track multiplex/demultiplexes and signal conditioning **amplifiers.**

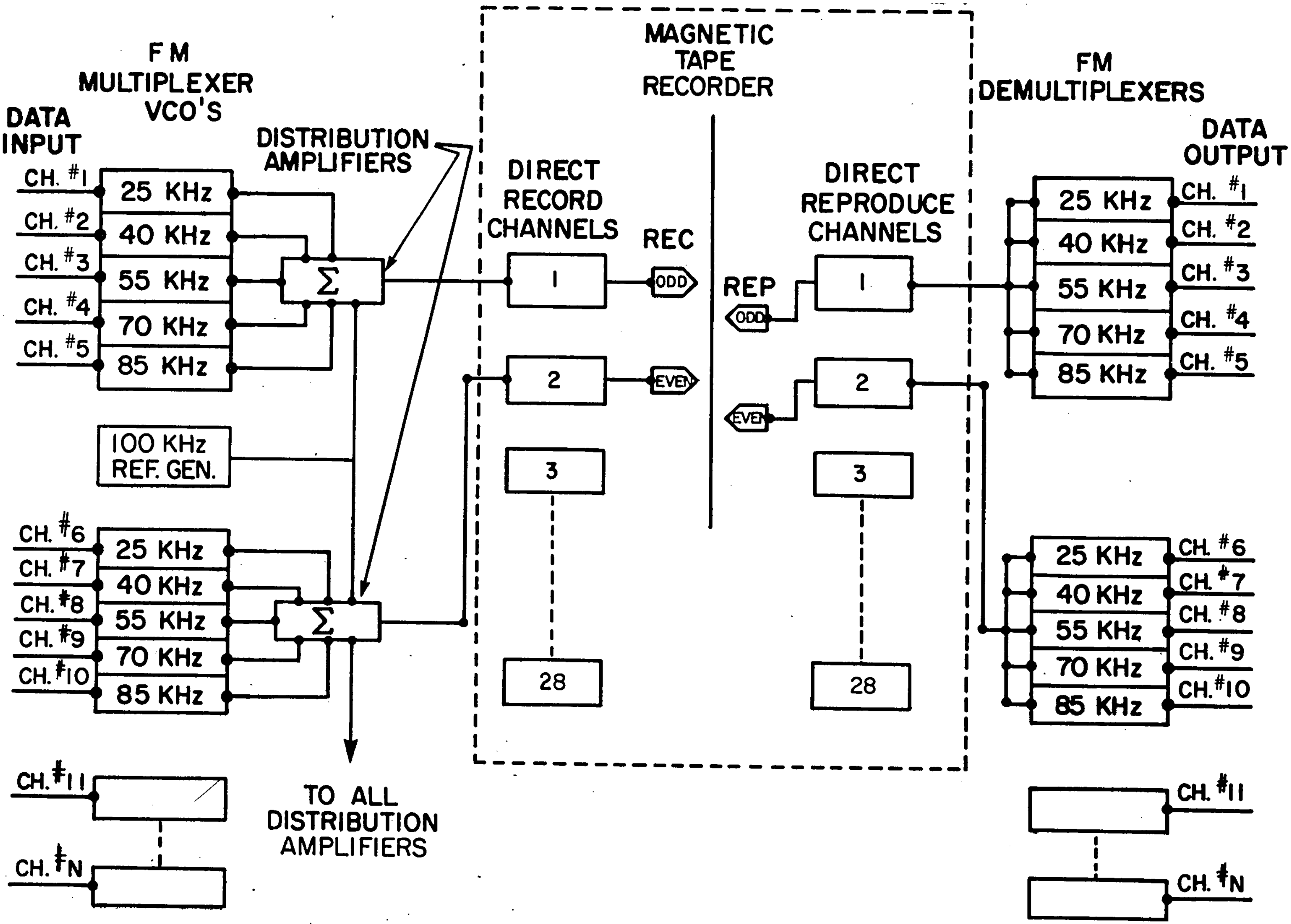

Figure 6 - Constant bandwidth FM multiplexing system, showing multiplexer VCO's, distribution amplifiers and data VCO/magnetic tape track arrangement.

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16. Abstract

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