WADC TECHNICAL REPORT 55-194

# A FOUR-CHANNEL NOISE SOURCE

*GEORGE H. BARNES*

*THE FRANKLIN INSTITUTE LABORATORIES FOR RESEARCH AND DEVELOPMENT*

*APRIL 1955*

WRIGHT AIR DEVELOPMENT CENTER

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AERO MEDICAL LABORATORY
CONTRACT No. AF 33(038)-10420
PROJECT No. 7182

WRIGHT AIR DEVELOPMENT CENTER
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

Carpenter Litho & Prtg. Co., Springfield, O.
100 - 10 November 1955

# FOREWORD

This report presents a design for the four-channel noise source that was designed and built at The Franklin Institute Laboratories. The report was prepared by FIL under USAF Contract No. AF 33(038)-10420, Human Frequency Response, with Mr. Ezra S. Krendel as the Project Leader. The contract was initiated under a project identified by Research and Development Project No. 7182-71510, Servo-Analysis of Human Control Systems, which was sponsored by the Aero Medical Laboratory and the Aircraft Laboratory both of Wright Air Development Center. Messrs. John W. Senders and Melvin J. Warrick were the Project Engineers for the Aero Medical Laboratory, and Mr. Charles B. Westbrook was the Project Engineer for the Aircraft Laboratory.

ABSTRACT

A low-frequency four-channel noise source has been constructed for use in human response studies. This device is useful in determining frequency response characteristics for jet pilots. The amplitude on each channel is variable from zero to one-quarter volt rms, and the bandwidth is variable from 0.08 cps to 0.64 cps in four discrete steps.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

JACK BOLLERUD
Colonel, USAF (MC)
Chief, Aero Medical Laboratory
Directorate of Research

Contrails

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# A FOUR-CHANNEL NOISE SOURCE

## INTRODUCTION

This report describes a noise source for use in human response studies. The use of stationary random inputs to characterize the quasi-linear behavior of a human operator has been discussed in a previous report (1). One immediate application of the noise source described below is that of generating time signals, typical, in a sense, of those found in visual display stimuli which evoke human operator responses in several common control problems. One can study such visual display and manual control response problems by means of stationary random inputs. This enables the experimenter to obtain descriptions of performance which, in an average sense, are typical of human operator performance under conditions to be expected in practice. It is hoped that this description of the four-channel noise source will be helpful to psychological laboratories faced with similar problems. A maintenance manual, prepared for limited distribution, contains operating details of the device herein described (2).

The noise source produces four independent, low-bandwidth, Gaussian noises on its four outputs. In addition, a single source of broadband white noise is available.

## I. DESCRIPTION OF EQUIPMENT

Basically, the method used is not new. A broadband noise is generated and then sampled periodically. The same broadband noise is used as the prime source for all four channels. Each channel is made independent by using voltage values from the original broadband noise source which have been sampled at times different from the sampling times used for the other three channels. Sufficient time elapses between taking a sample for one channel and sampling for the next channel so that the correlation between any two channels should be less than $10^{-6}$.

There are three chassis to do this job, as shown in Figure 1. The first chassis (middle one in the Figure) contains the source of broadband noise and a generator of the various switching waveforms needed. The second (top one in the Figure) contains coincidence circuits for properly combining the switching waveforms, as well as the electronic switches that do the sampling, and the low-pass filters for the output. The third chassis holds all necessary power supplies.

To switch filter bandwidths, 16 filter-element plug-in units were constructed. There are four filters for the 1/2; the 1; the 2; and the 4 radians/second bandwidths. Amplitude of output is read directly on the meter which is built into the equipment. Full scale on the meter corresponds to 0.225 volts rms noise at the corresponding output when the meter switch is in the channel 1, 2, 3 or 4 position. This means that a full scale output signal, when applied to an indicator with a one volt full scale range, will drive the pointer off scale 3% of the time when the d-c signal level is midscale on the indicator. Filter plug-ins could be constructed for bandwidths up to 30 radians per second before trouble is encountered with the 50 cps sampling rate used.

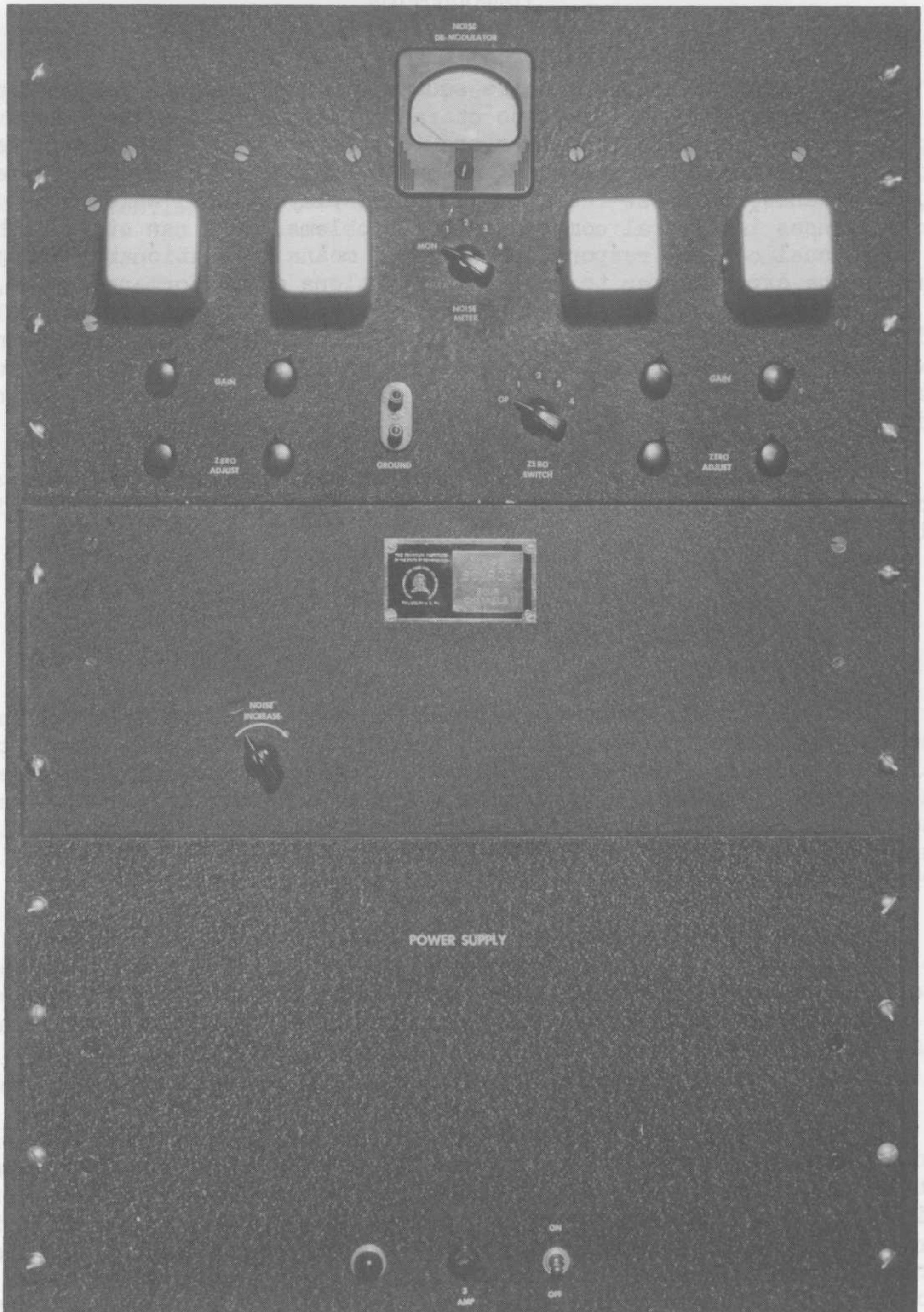


Figure 1. View of Noise Source

## II. THEORY OF OPERATION

The basic noise source is a 2D21 thyratron in the first chassis. In Figure 5, which is a circuit diagram of the first chassis, the 2D21 is $V_1$. Its noise is amplified by 12AT7's $V_2$ and $V_3$; the output of $V_3$ is relayed to the output point of the first chassis by a cathode follower, half of $V_4$.

The generated broadband noise then is carried down to the second chassis where the sampling takes place. Since all four channels are identical, except for the phasing of the sampling pulse inputs, the sampling will be described for one channel only. For concreteness, let us say this is channel 1. Channels 2, 3, and 4 will be similar. The broadband noise is applied to a gain control in the second chassis; the output of the gain control is put through a cathode follower consisting of both halves of a 6J6 in parallel. The output of the cathode follower is connected for 20μsec to a 0.01 μfd storage condenser. This switch closure is repeated at a 20 cps rate. The switch itself is a four-diode switch of a type described in the literature (3). A boxcar noise waveform then exists at the storage condenser. This boxcar waveform is low-pass filtered through a direct-coupled amplifier with feedback (4). This is a maximally-flat, low-pass filter with a cut-off of 18 db per octave. Part of the feedback elements are mounted on plug-in units so that cut-off frequencies can be changed. A block diagram is shown in Figure 2. This filter produces an output noise whose power spectrum is

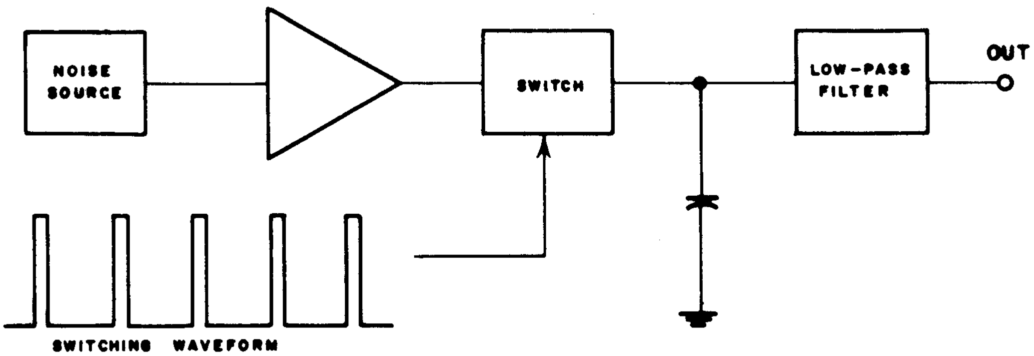


Figure 2. Block Diagram of Chassis No. 2
(One of four channels)

approximately $\Phi_{nn} = \frac{A}{(1 + (\frac{\omega}{\omega_o})^6)}$, where $\omega_o$ - 1/2, 1, 2, or 4 radians/second, according to which filter-element plug-in is used.

To make the four noises independent, the times of switching noise into each channel are separated. Figure 3 shows the four switching waveforms for the four channels. The switching waveform for channel 1, for example, is produced by the combination of three waveforms in a coincidence circuit. The coincidence circuit is a trio of diodes in the second chassis. Its three inputs are: first, a series of 20 µsec positive pulses at a 200 cps repetition rate; second, a 100 cps square wave; and third, a 50 cps square wave. The output is negative, except when all three inputs are positive, so that the output is a chain of 20 µsec positive pulses at a repetition rate of 20 cps. Every fourth 20 µsec pulse has been selected. For each of the remaining channels, one or both of the square wave inputs are inverted so that the switching waveform arises from different ones of the 20 µsec, cps input pulses. The output of another channel's coincidence circuit is still a 20 µsec, 50 cps train of pulses, but the sampling pulses will be interlaced with those of channel 1, as shown in Figure 3. The coincidence circuit waveforms and its output are shown in Figure 4 for channels 1 and 2.

The square waves and the 20 µsec, 200 cps pulse train are generated in the first chassis. The method is straightforward. A basic 200 cps square wave is generated by a free-running multivibrator. This tube is $V_5$ of Figure 5, a 12AU7. The 200 cps frequency is divided by two, and by two again, by $V_6$ and $V_7$, to form the 100 cps and 50 cps square waves. The 200 cps multivibrator also triggers a single-shot multivibrator $V_8$ to give 20 µsec switching pulses at a 200 cps repetition rate. Every fourth 20 µsec pulse is selected in channel 1 by the first coincidence circuit in the second chassis. With different polarities of square waves, different 20 µsec pulses are selected in channels 2, 3, and 4.

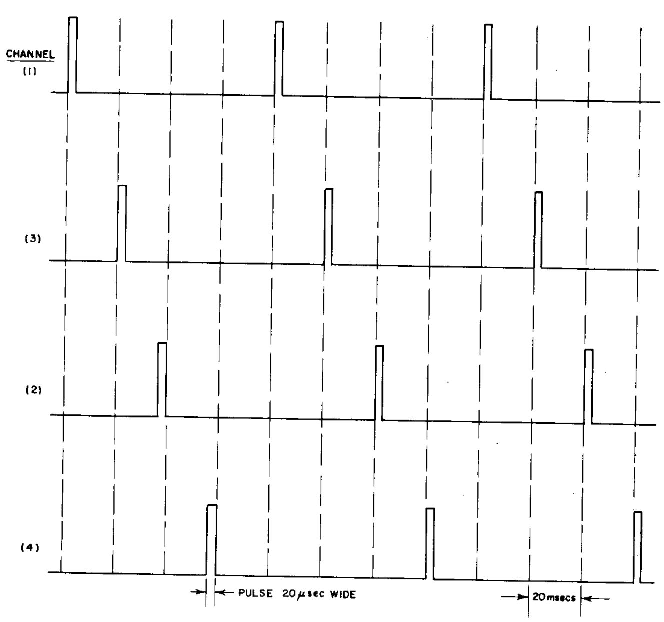


Figure 3. Switching Waveforms

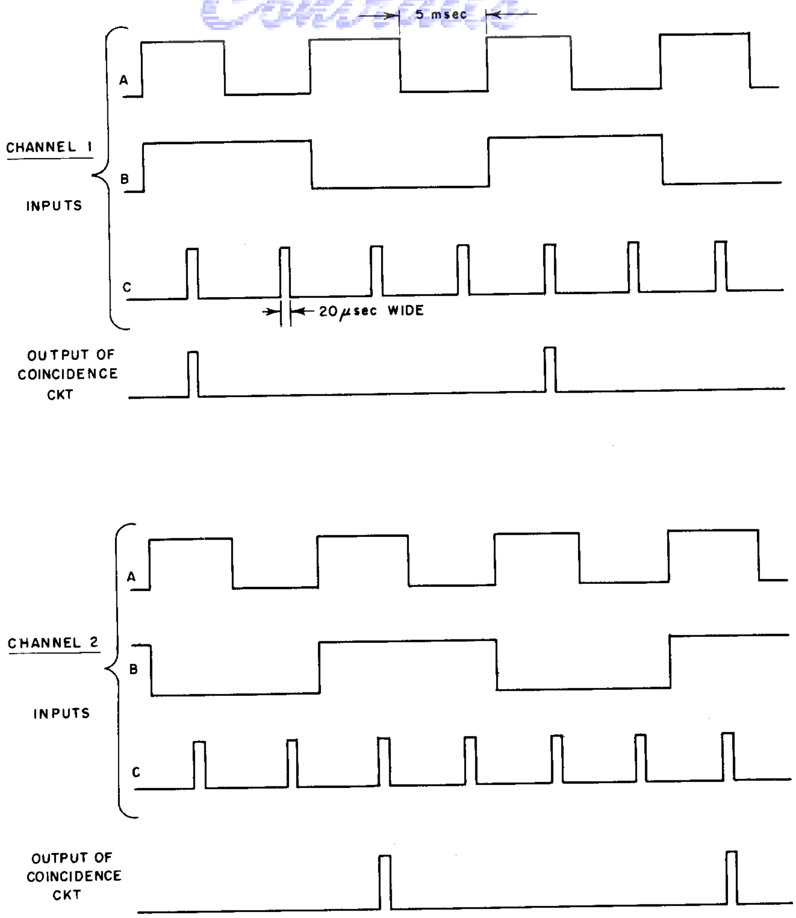


Figure 4. Coincidence Circuit Waveforms

## III. OTHER CONSIDERATIONS

Figures 5 through 10 specify all the circuits and connections that have been designed. The first chassis containing the noise source and gate generator is shown in Figure 5. Figure 6 is the second chassis with the diode switches and filters. Figure 7 shows the power supply.

There is at least one obvious improvement that could be made if a similar noise source were to be built. Presently, the feedback network around the direct-coupled amplifier loads the 0.01 μfd storage condenser, so that the waveform at the condenser consists of decaying exponentials of random (positive or negative) amplitude. This results in less output voltage than would be available if the boxcar waveform were truly flat. By redesigning the diode switch so that a larger condenser could be used, or by inserting a buffer amplifier between the storage condenser and the feedback filter, this difficulty could be eliminated.

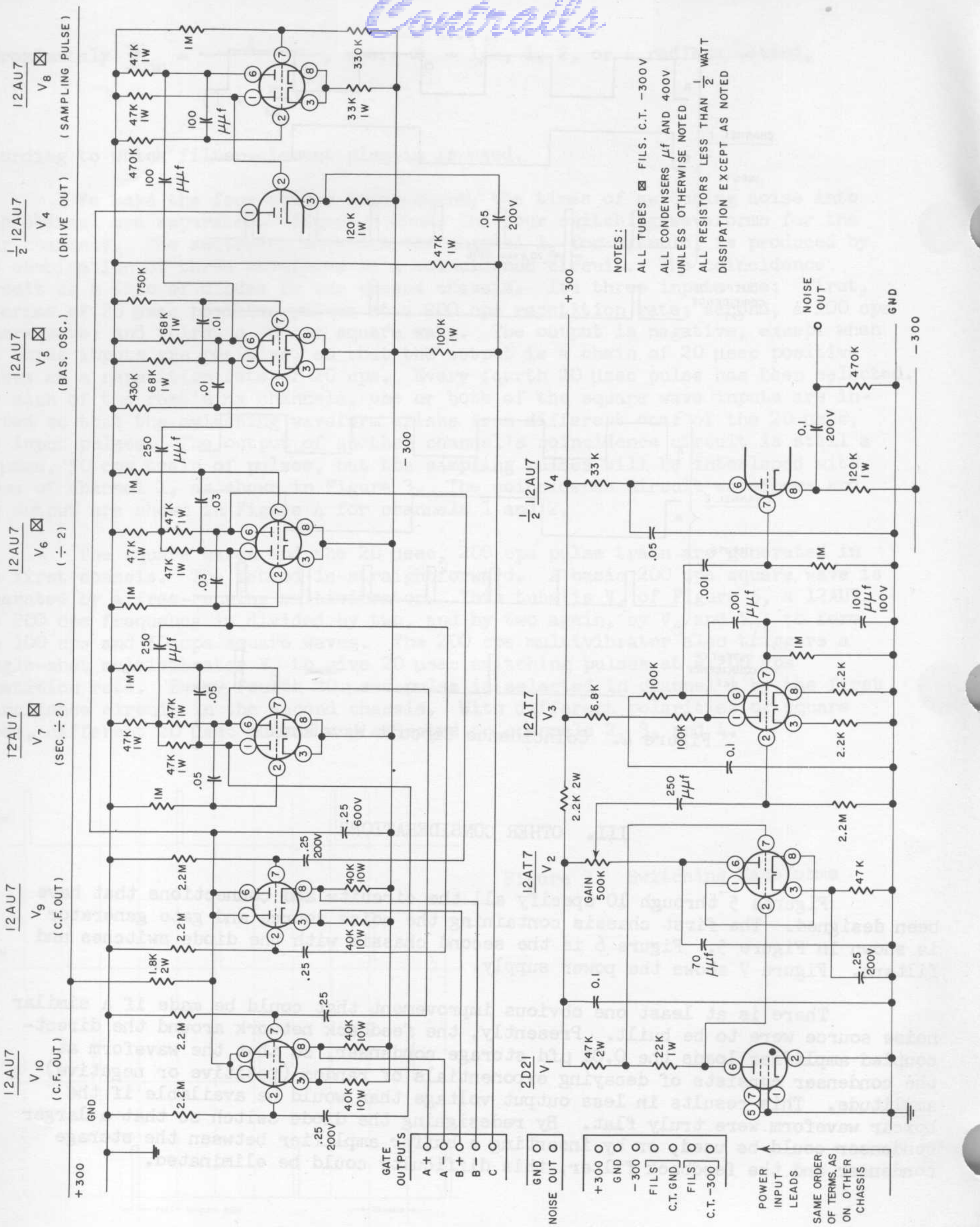


Figure 5. Noise and Gate Generator

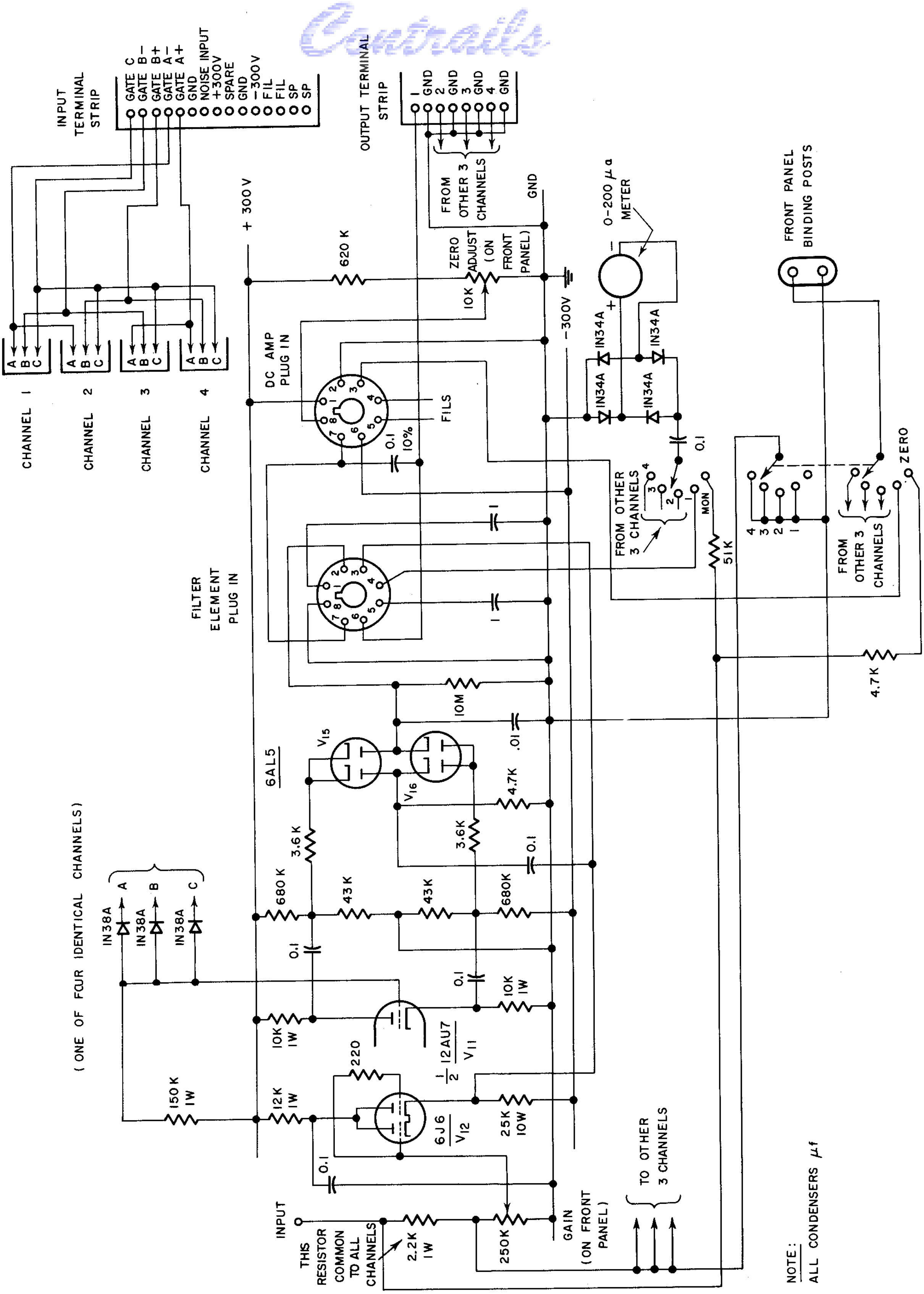


Figure 6. Sampling Switch and Filter (One of four identical channels)

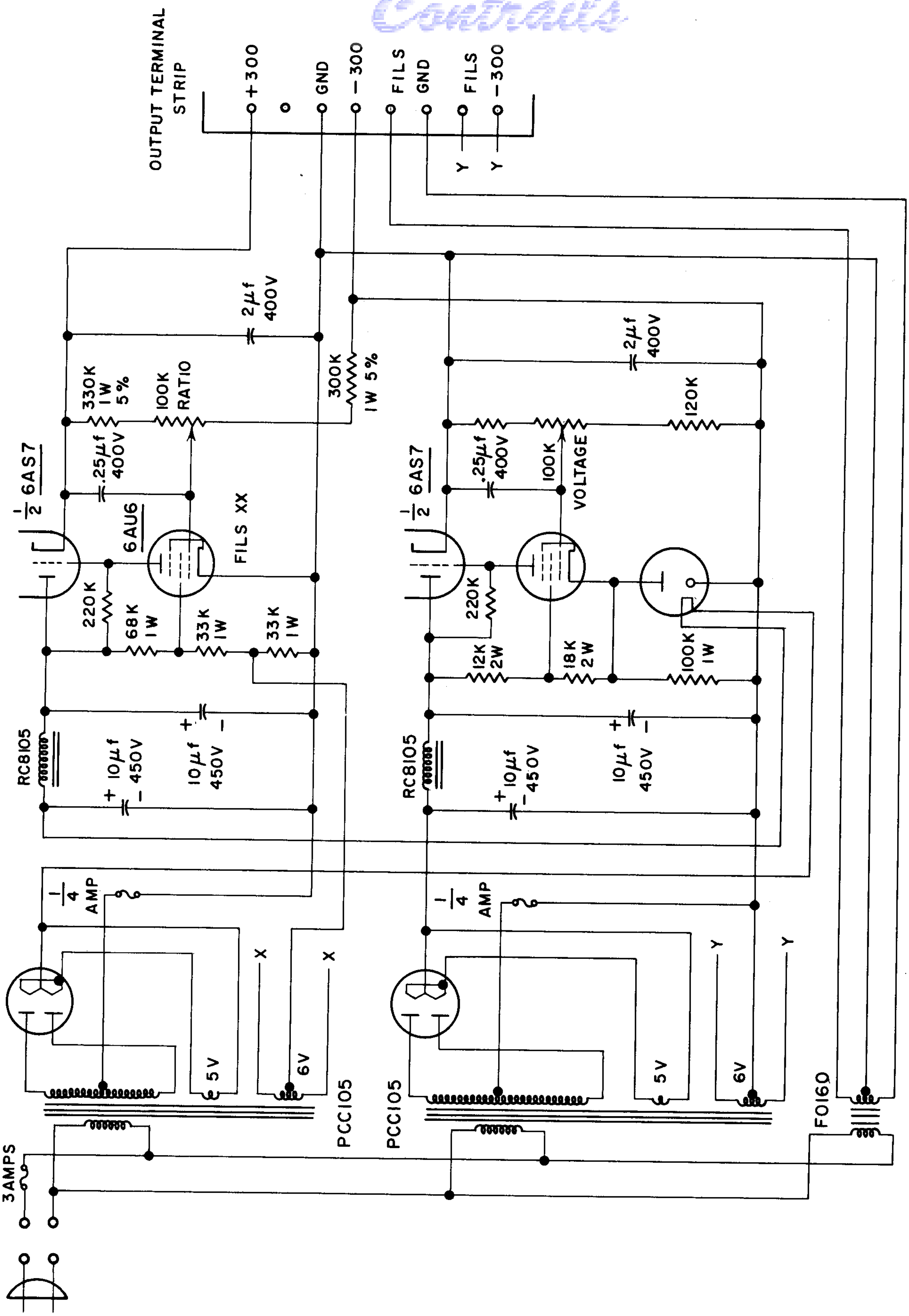


Figure 7. Power Supply

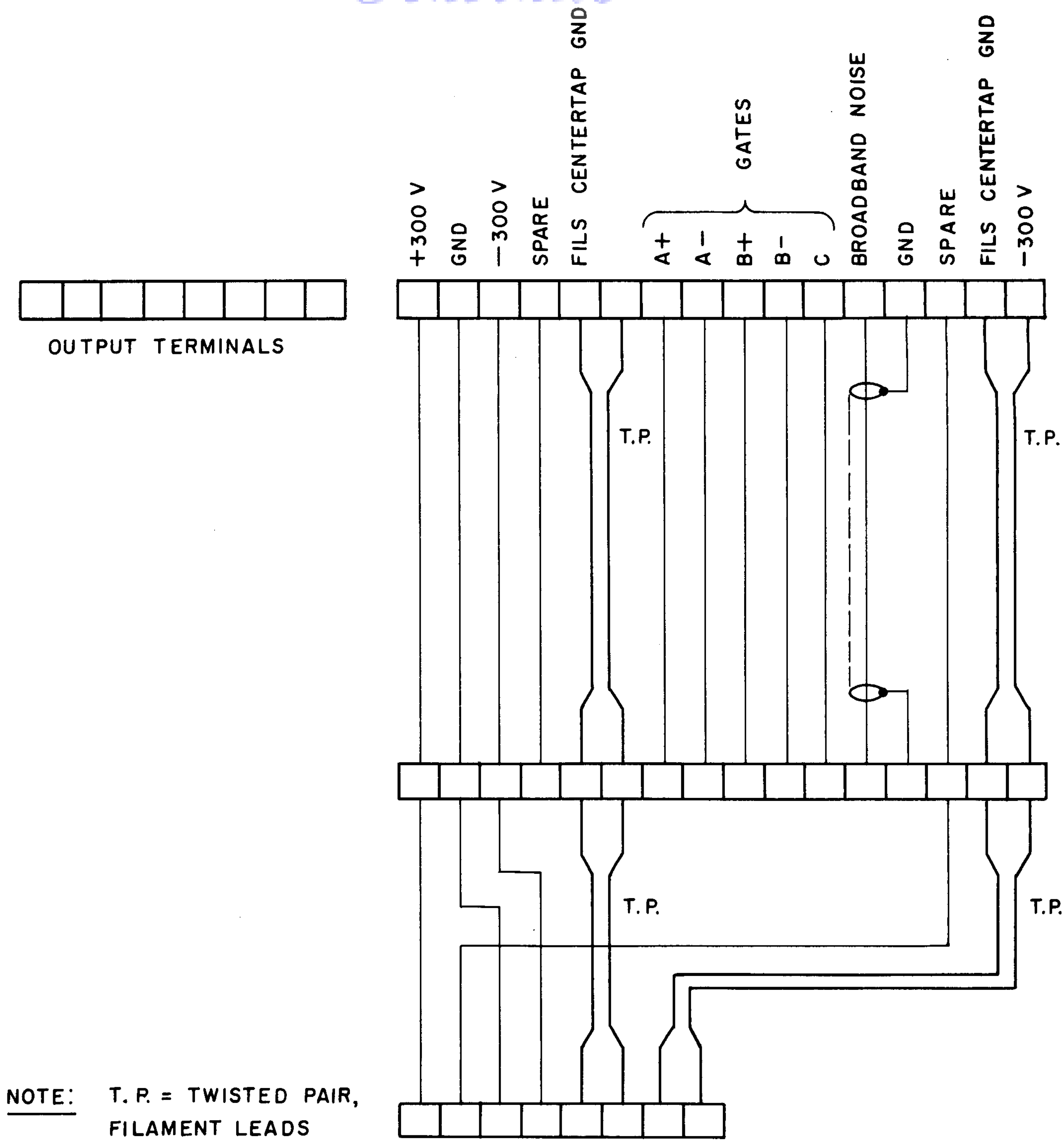


Figure 8. Cabling Diagram (Rear view)

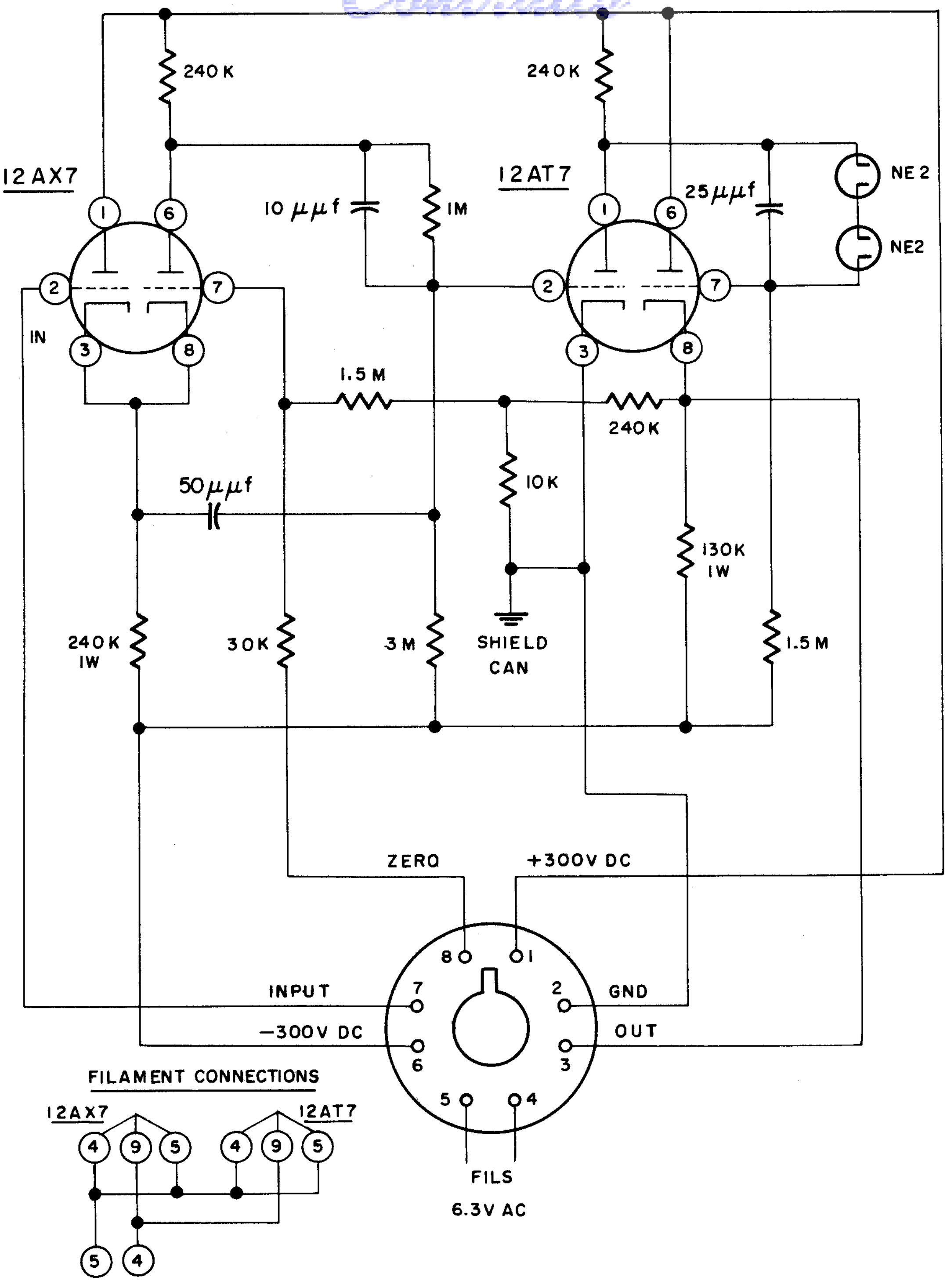


Figure 9. Direct-Coupled Amplifier Plug-in

NOTE:

ON ALL RESISTORS 1st (TOP) VALUE IS THAT USED IN PLUG-IN FOR $\frac{1}{2}$ RADIAN BANDWITH

ON ALL RESISTORS 2nd VALUE IS THAT USED IN PLUG-IN FOR 1 RADIAN BANDWITH

ON ALL RESISTORS 3rd VALUE IS THAT USED IN PLUG-IN FOR 2 RADIAN BANDWITH

ON ALL RESISTORS 4th (BOTTOM) VALUE IS THAT USED IN PLUG-IN FOR 4 RADIAN BANDWITH

ALL RESISTORS 5%

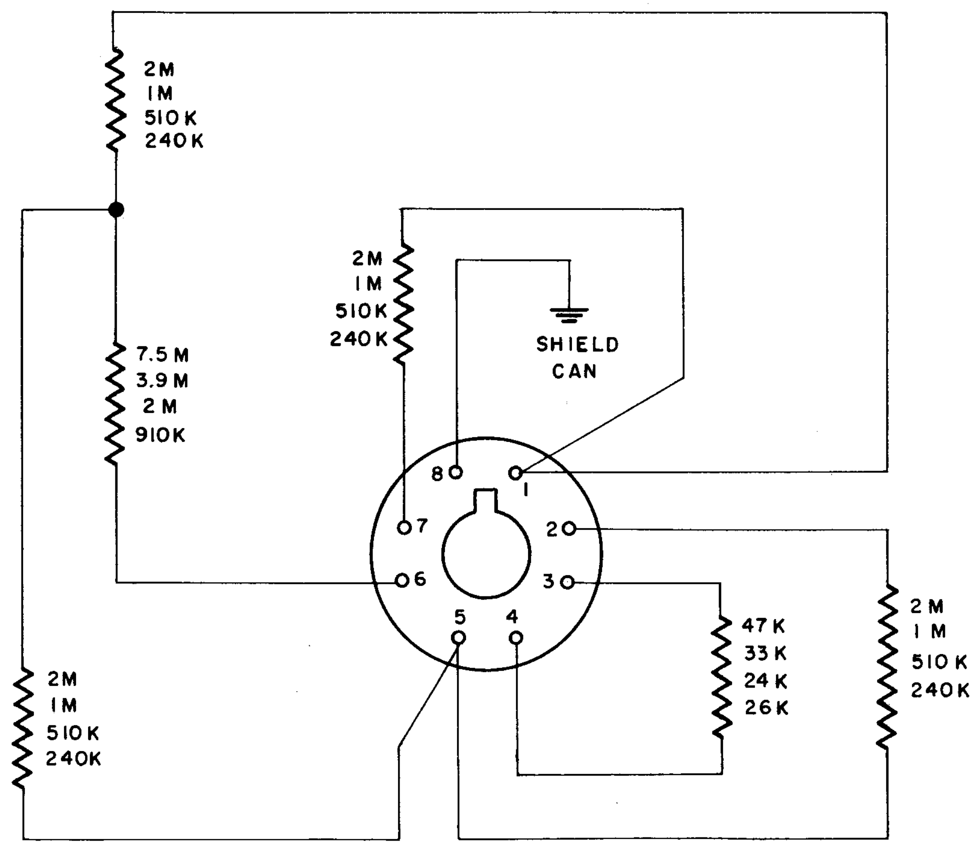


Figure 10. Filter Element Plug-ins

# IV. CONCLUSIONS

This report has described a four-channel noise source which has been designed as a source of input signals for human response studies. The four outputs are random, but they have known spectra and, hence, known autocorrelation functions. Since they are also Gaussian and time stationary, all other statistical parameters of these random output functions are also known quantities.

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