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DATE - November 9, 1967

SLIDING PULSE GENERATOR FOR TESTING MULTICHANNEL ANALYZERS

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ABSTRACT

A sliding pulse generator was developed for checking the linearity of 4000-channel multichannel analyzers in the field. This instrument is packaged in the U. S. Nuclear Instrument Module (NIM) configuration. The amplitude of the output pulses, which occur at a rate of 250 per sec, vary directly with a generated, continuously running ramp having a slope of 66.7 mv/sec. The nonlinearity of this ramp is less than 1 part in 10^4.

The output amplitude can be varied, by a selector knob on the front panel, between any two voltage levels from 0 to ±10 v. By means of a differentiating circuit, the ramp slope can be monitored on a chart recorder for long-term runs.

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INTRODUCTION

A sliding pulse generator was designed specifically for checking the differential linearity of multichannel analyzers having up to 4000 channels. Prior to the development of this instrument, there had not been an instrument containing all the features desired for periodically checking the performance of analyzers at the point of usage. Instead, the analyzers had to be sent to a shop equipped with testing instruments and devices. The cost of the instrument is estimated to be $1500.

PURPOSE

Basically, the sliding pulse generator operates much the same as a conventional mercury relay pulse generator; however, for the sliding pulse generator, a linear ramp rather than a fixed dc reference voltage is chopped by a mercury-relay chopper to give a continuously varying magnitude of output pulse.[1]

When connected to a multichannel analyzer, the pulse generator will produce ideally a flat spectrum, because for ideal channel profiles, an equal number of counts will be accumulated in each channel. However, variations in channel widths, creating undesirable channel profiles, will cause an unequal number of counts to appear in each channel. These deviations in channel counts indicate the nonlinearity in the analyzer.

For a pulse generator of this type, the ramp should be as long as practical and the chopping rate should be as fast as possible for the RC time constant of the pulse being generated. These conditions will ensure the largest number of counts per channel on a single ramp period.[2] This pulse generator is designed to place approximately 20 counts in each channel during one ramp period when connected to a 4000-channel analyzer.

DESCRIPTION

This instrument has four major sections: ramp generator, ramp control circuitry, ramp slope monitor, and mercury relay chopper. The basic circuit is shown in Fig. 1.

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[1] L. B. Robinson, "A 'Ramp-Pulser' for Testing Linearity of Pulse Analysis Systems," pp. 216-219 in Instrumentation Techniques in Nuclear Pulse Analysis, Publ. 1184 NAS-NRC, Washington D. C., 1964.

[2] Personal communication from J. W. Woody, ORNL.

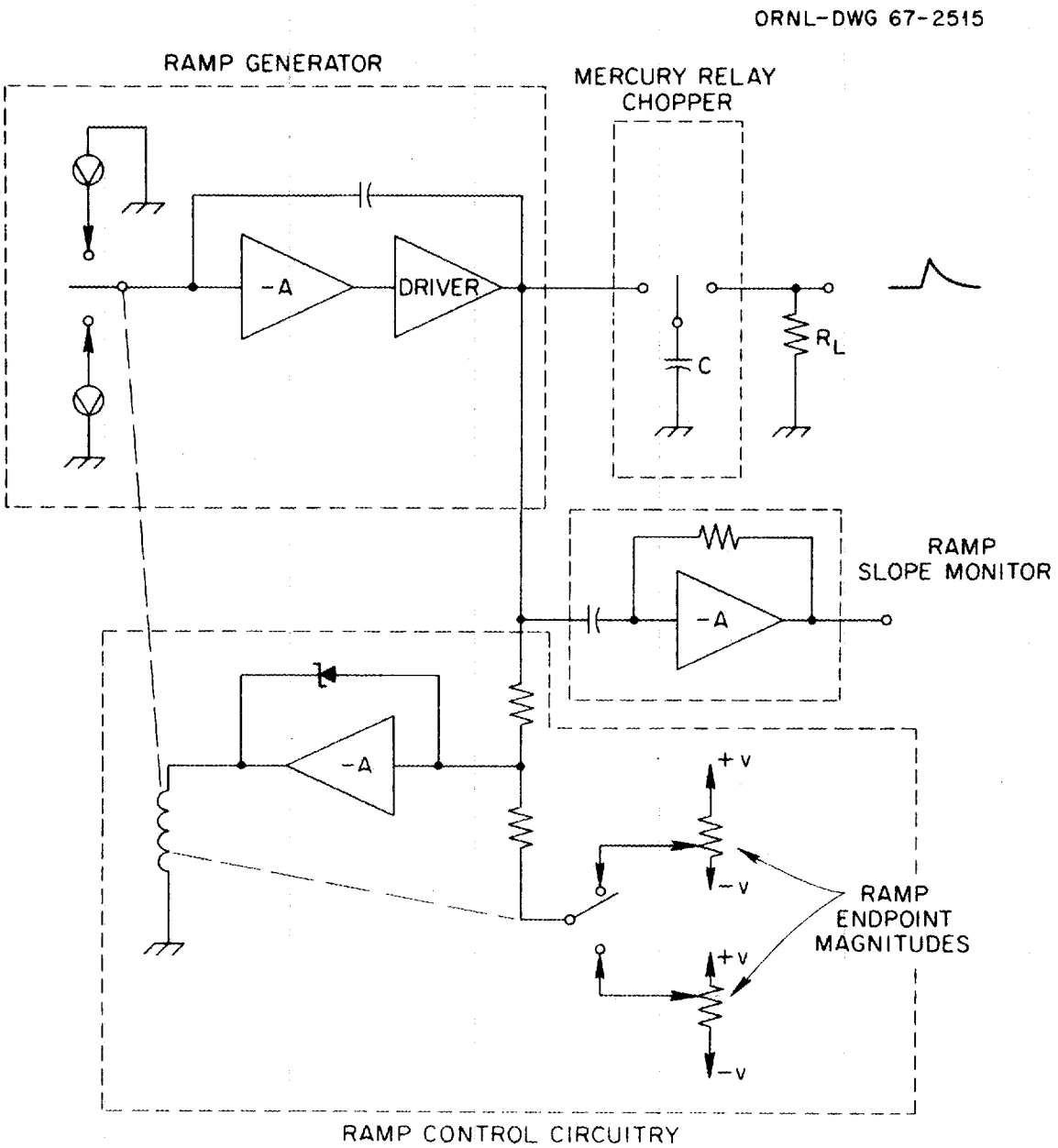

Fig. 1. Block Diagram of the Sliding Pulse Generator.

Ramp Generator

The ramp generator is the most important part of the circuit, because its linearity determines the linearity of the pulse output. The ramp generator consists of a high-impedance current source driving an operational amplifier integrator. Since an attenuation of 2 is encountered in the ramp chopping circuit, the ramp is required to have a 20-v peak amplitude to produce output pulses that have a 10-v peak amplitude. Since the operational amplifier used in the integrator circuit had an output voltage swing of about 10 v maximum, and an output current capability of only a few milliamperes, a drive circuit was added to the output of the operational amplifier to supply the necessary voltage and current drive for the ramp chopper. The integrating capacitor was connected from the operational amplifier input to the driver circuit output. Two values of integrating capacitance were provided to give a choice of two ramp slopes. A selector switch on the front panel allows the operator to choose the desired ramp slope. With the current source adjusted for plus or minus 2 μa, depending on whether the ramp is going negative or positive respectively, the two capacitance values will give 20-v ramp periods of either 30 or 300 sec.

The 30-sec ramp is obtained with a 3-μf capacitor. This capacitor is a Mylar dielectric type which creates over a ramp excursion of 20 v a ramp slope nonlinearity of about 5 parts in 10^3 because of dielectric absorption. This 30-sec ramp period is provided so that unnecessarily long periods of time will not be required to adjust the pulse generator for an analyzer check.

For actual linearity checks, the ramp should be operated in the 300-sec mode. In this mode a 30-μf polystyrene dielectric capacitor is used as the integrating capacitor. Since this capacitor has low dielectric absorption, it produces excellent linearity over the 300-sec ramp.

Because input leakage currents of the operational amplifier input will cause nonlinearities in the ramp, an operational amplifier having a field-effect transistor in the input was used.

A front panel calibration was provided for the current source, allowing an adjustment of about 10% in the current magnitudes, which are nominally 2 μa. The output impedance of the current source is approximately 300 megohms; consequently, the total time constant for the integrating circuit is approximately 6 years. Since only an extremely small portion of one constant is actually used, the ramp slope error due to the second and higher order terms of the power series of an exponential function is very small. The power supplies should be very stable, because a power supply variation of 1 mv will produce a nonlinearity of about 50 ppm in the current source.

The output voltage of the ramp generator should be 0 v with no input current and with the integrating capacitor short-circuited; thus, initial and possibly periodic adjustment of the ramp generator will be necessary. As an initial adjustment, the integrating operational amplifier should be removed and a 200-ohm resistor placed from its output pin to ground. Trimpot R26 (see Fig. 2) should be adjusted until the output of the ramp generator (test point 2) is 0 v dc. With the operational amplifier replaced, the integrating capacitor shorted from terminal to terminal, and switch S2 at the ramp generator input switched to the calibrate position, trimpot R26 can be adjusted again to give 0 ± 0.1 v dc at test point 1. Trimpot R19 can then be adjusted to give 0 v dc at the ramp generator output (test point 2). Since long-term drift might occur, the voltage at test point 2 should be checked from time to time with the integrating capacitor shorted (terminal to terminal) and the ramp generator input open-circuited (switch S2 set at the "calibrate" position).

Ramp Control Circuitry

To check any range of channels desired, a discriminator circuit detects the arrival of the ramp at some preselected value and causes the ramp to change slope polarity at that point. This circuit consists of an operational amplifier discriminator and two reference potentiometers that can be adjusted to desired endpoint values. Both potentiometers are on the front panel. With the potentiometer labeled "high magnitude discriminator" the operator can select the highest magnitude of voltage that he wants the ramp to reach, whether it be a positive or a negative voltage. The potentiometer labeled "low magnitude discriminator" allows the operator to select the low magnitude endpoint, whether it be a positive or a negative voltage. Thus, two endpoints can be selected for the ramp to run between, and these two endpoints can be positive or negative voltages. Switch S4, also on the front panel, allows the choice of operating the ramp between two positive or two negative endpoints. Plots of the ramp generator output (test point 2) are shown in Fig. 3.

For checking channels near 0, switch S5 on the front panel is switched to "zero operate." This allows greater resolution of the low magnitude endpoint in the range of +1 to -1 v.

When an endpoint is reached, the discriminator circuit causes the current to change in the coils of two mercury relays, which changes the position of three sets of contacts. These contacts switch the polarity of current supplied to the ramp generator, changes the discriminator input to detect the opposite endpoint, and changes the differentiator offset voltage polarity.

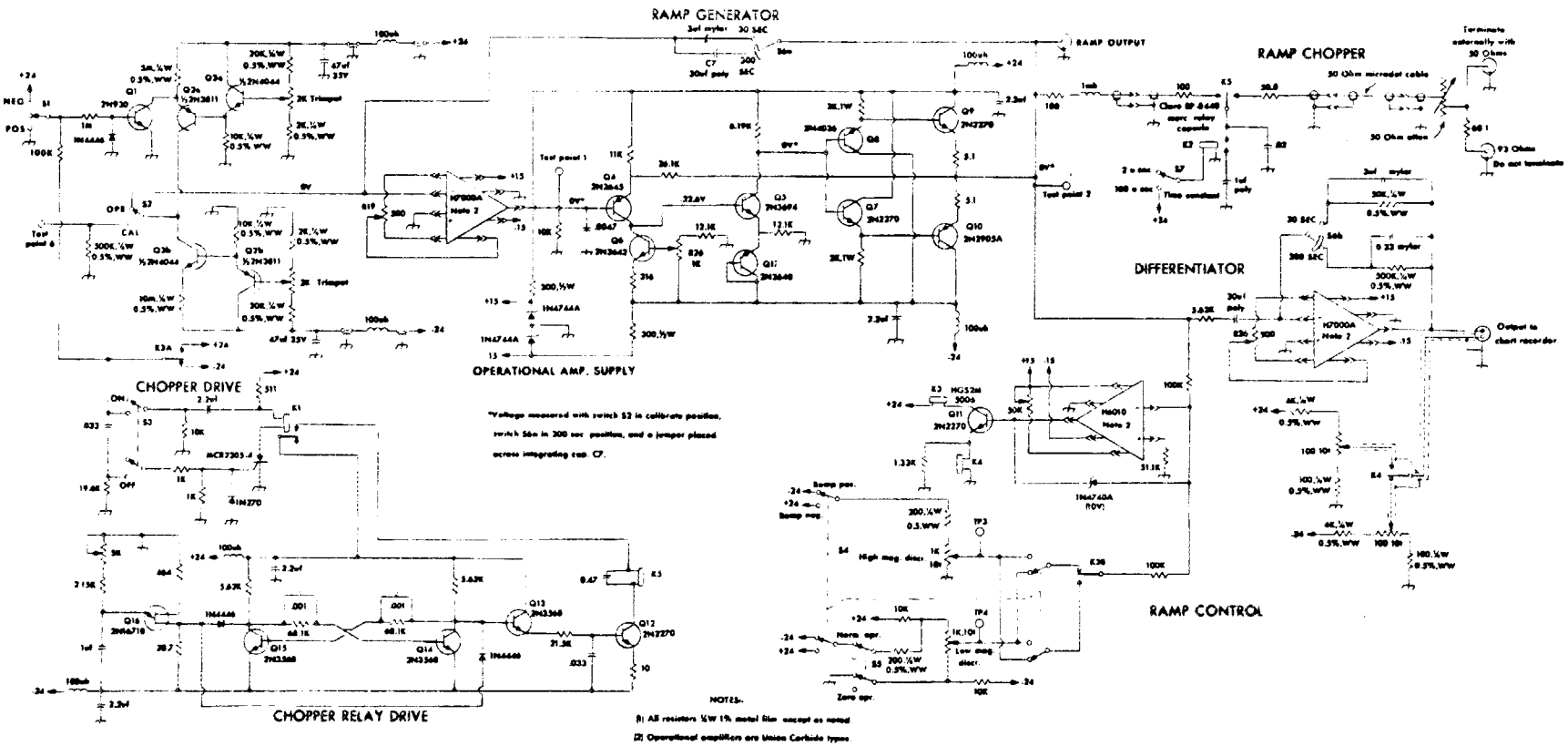

Fig. 2. Schematic Diagram of the Sliding Pulse Generator.

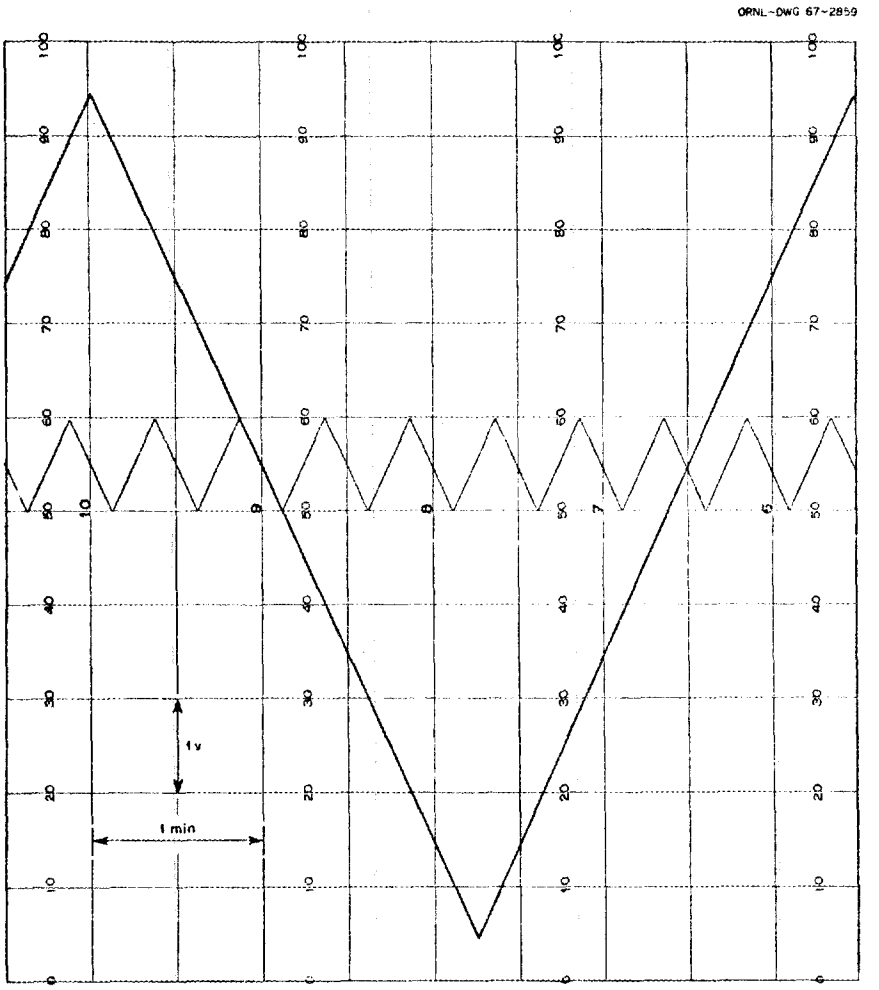

Fig. 3. Sample Plots of the Ramp Generator Output Showing Two Different Endpoint Settings.

Ramp Slope Monitor

To monitor the ramp slope during an analyzer linearity check, the ramp output is sampled by an operational amplifier differentiating circuit. The output of this differentiating circuit will remain constant at approximately 1 v if no disturbances occur in the ramp period. The polarity will be positive when the ramp excursion is negative, and will be negative when the ramp excursion is positive. The differentiator output will be approximately the same magnitude regardless of whether the 30-sec or the 300-sec ramp is used, because the feedback elements of the differentiator are changed when the integrating capacitor is changed.

To plot the ramp derivative on a 10-mv strip chart recorder, offset potentiometers R43A and R43 are provided. These potentiometers place the

same polarity and the same magnitude of voltage as the differentiator output on the chart recorder pin opposite that to which the derivative is applied. This allows only changes in ramp slope to be plotted on the chart (see sample plot in Fig. 4). Transients occur at the end of each ramp period, because the derivative must change polarities with a finite switching time as the ramp changes slope polarity. The plot can be adjusted to any position on the recorder paper by adjustment of the offset potentiometers. With the integrator open-circuited, that is, with switch S2 in the calibrate position, trimpot R36 on the differentiator operational amplifier should be adjusted to give 0 v at the output of the differentiator.

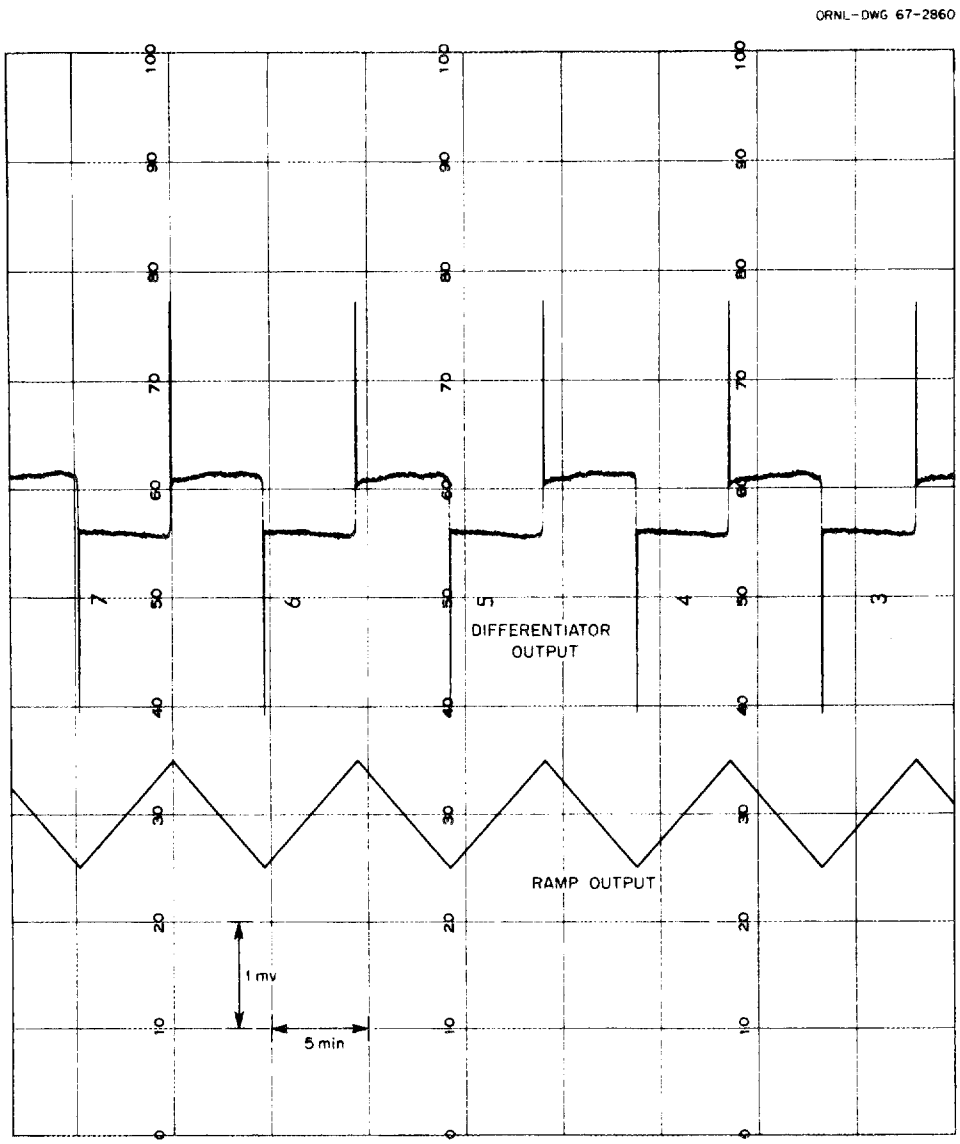

Fig. 4. Sample Chart of Differentiator Output with Ramp Output Indicated for Time Correlation. The Voltage Scale Applies Only to the Differentiator Output.

Mercury Relay Chopper

Pulses are formed by chopping the generated ramp with a mercury relay operating at 250 cps. Decay time constants of 100 μsec and 2 μsec are selected by switch S7 on the front panel. The pulses are routed through a series 50-ohm resistor into a 50-ohm attenuator section having five attenuation factors of 2 and four attenuation factors of 10. An attenuation of 2 is produced by the 50-ohm resistor in series with the attenuator section; therefore, the output has a maximum amplitude of 10 v. This series 50-ohm resistor terminates the attenuator section on the initial portion of the pulse discharge. The chopper start and stop function (S3) is located on the front panel. When the chopper is switched on, the event will not occur until the ramp reaches its most positive endpoint; when the chopper is switched off, the event will not occur until the ramp reaches its most negative endpoint.

PERFORMANCE

For the 300-sec ramp the integral and differential nonlinearities in the ramp generator output are approximately 1 part in 10^4. For the 30-sec ramp, nonlinearities of about 5 parts in 10^3 will be experienced because of dielectric absorption in the Mylar capacitors. The temperature coefficient of the current source supplying the ramp generator is as good as 20 ppm/°C if the 2N3811 transistor used in this circuit has a leakage current not greater than 50 pa at room temperature.

When connected to a 10-mv strip chart recorder, the differentiator circuit will indicate nonlinearities as small as 5 parts in 10^5. The line width of the sample recorder plot shown in Fig. 4 is primarily due to noise in the differentiator circuit. The temperature coefficient of the differentiator circuit is approximately 12 ppm/°C negative; the temperature coefficient of the differentiator circuit offset potentiometers is approximately 70 ppm/°C, increasing in magnitude as the ambient temperature increases. Therefore, as the temperature changes, the plot of the ramp slope will change. Most of this change, however, is due to the differentiator circuit and its associated offset potentiometers and not to the ramp linearity.

The discrimination levels marking the ramp endpoints are sufficiently stable to within 2 or 3 channels out of 4000. The discriminator circuit will exhibit a slight temperature coefficient due mainly to the discriminator potentiometers.

Since the ramp chopper drive circuit switches approximately 60 ma at 250 cps, and since the ramp drive circuit might require up to 100 ma of current during the charge portion of the chopping cycle, noise created on the power supply bus might be of sufficient magnitude to interfere with

other instruments. For the NIM[3] power supply, power bus transients having amplitudes as high as 50 mv have been measured. For this reason, the module should be located as near the power supply sensing point as possible.

As a future improvement of this instrument, a solid-state chopper is being developed to replace the mercury relay chopper. The solid-state chopper will increase the chopping rate to several kilocycles. Thus several hundred counts could be placed in each channel of a 4000-channel analyzer on each ramp period.

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[3]L. Costrell, Standard Nuclear Instrument Modules, TID-20893 Revised (July 1966).

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