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COMMON-MODE AND INTEGRAL BIAS TESTS WITH A DIFFERENTIAL CURRENT-PULSE PREAMPLIFIER

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ABSTRACT

Common-mode rejection tests and integral bias measurements with a fission counter were made with a differential preamplifier to verify its superior performance as compared to a single-ended unit. The counter was constructed to provide separate signal and high voltage connections. Tests with a vacuum tester coil used as a wideband noise generator show only a slight alteration of the normal noise background curve by the differential preamplifier but a great alteration by a single-ended unit. The integral bias measurements show an improvement of signal-to-noise ratio for electronic noise by the differential operation by nearly a factor of $\sqrt{2}$.

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1. INTRODUCTION

Current pulse preamplifiers are desirable for use in source range monitors for Liquid-Metal Fast Breeder Reactors. These preamplifiers can be placed at any distance from the counter within the limitation of cable losses and degradation of the signal by noise pick-up.

A differential preamplifier was developed (ORNL model Q-5095) to reduce the effect of this electrical pick-up when connected to the counter with a balanced cable. Additionally, a differential current pulse from the counter could improve the signal-to-noise ratio for electronic noise generated in the input stage of the preamplifier.

The noise rejection capability of the differential preamplifier was measured with a vacuum tester coil used as a wideband noise source. These tests consisted of simultaneously exposing a differential preamplifier (with a balanced input cable) and a single-ended preamplifier (with a single cable) to the electrical radiation of the tester coil and counting the noise pulses as a function of pulse height, using identical electronics.

Integral bias curves obtained with both differential and single-ended operation of a fission counter were used to determine the improvement in signal-to-noise ratio due to the differential operation.

2. COMMON-MODE TESTS

A differential and a single-ended system were operated simultaneously to obtain data to determine the effectiveness of common-mode differential operation. The simultaneous operation eliminated the effects of variations of the noise generator and required a duplicate set of electronic components, i.e., amplifier, discriminator, and scaler to obtain the data. The single-ended preamplifier was an ORNL Q-5095 differential unit with one half of its input stage deactivated.

Each preamplifier was connected with two coaxial cables (~ 10 m long) to a small metal box which simulated a fission counter and contained three capacitors to represent the the interelectrode capacitance. The two boxes were enclosed in a steel box and insulated from it. All four cables were enclosed in a common braid to complete the shielding. Only one cable was active for the single-ended preamplifier, and the second cable was connected to its deactivated input and terminated with 50 Ω. Data were recorded during operation of the system with two arrangements of the input cable bundle: a coil and a hairpin (Fig. 1). (These two arrangements were arbitrarily chosen and do not represent any specific application.)

The noise generator was a vacuum tester coil, and measurements were made at two positions of the coil relative to the input cable system. One location was selected so that the noise signals induced by the radiative interference would be close to the saturation limit of the input stage of the

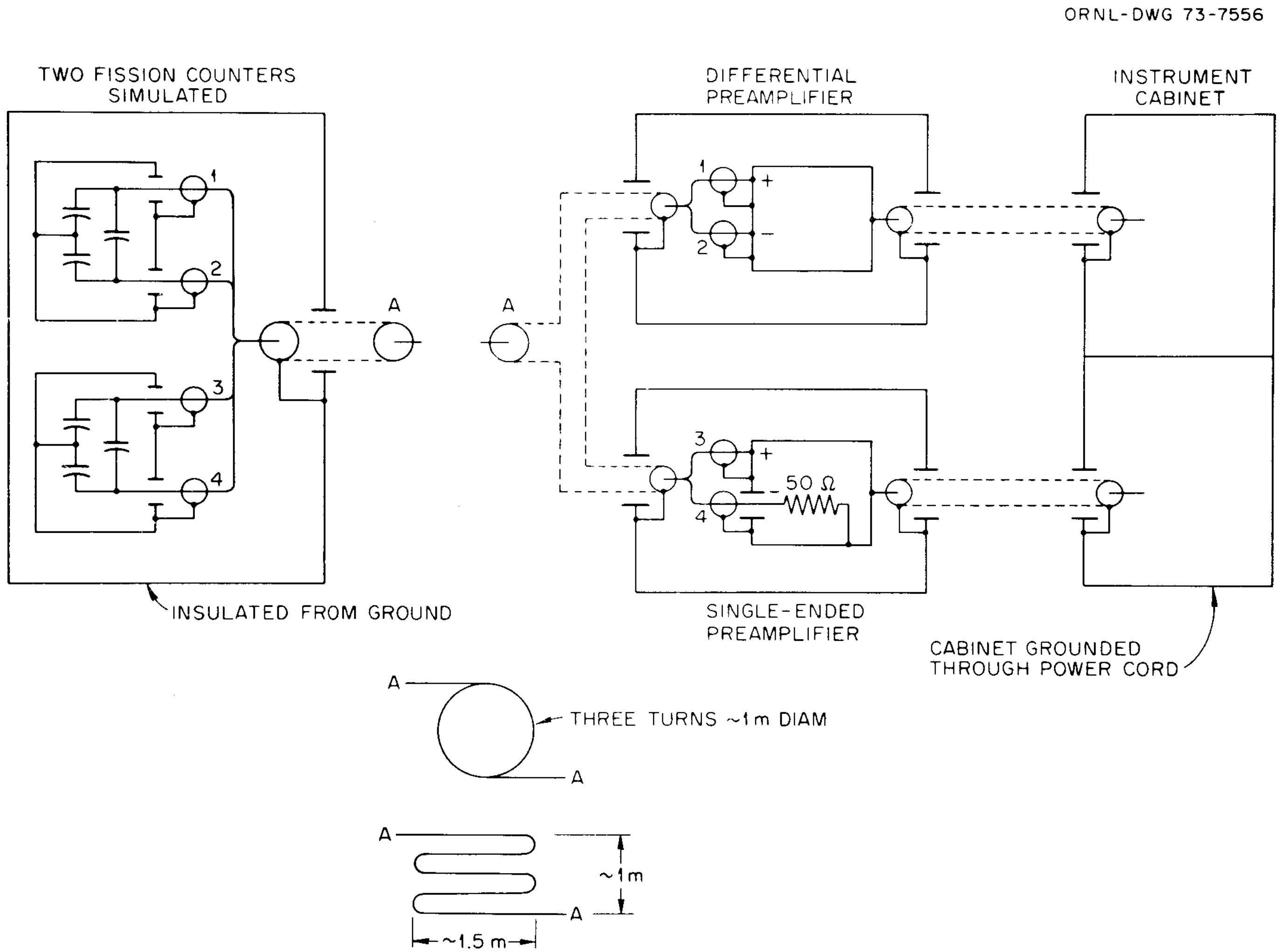

Fig. 1. Common-mode test input cable and preamplifier system.

preamplifier. This was determined by observing the output of the single-ended preamplifier with an oscilloscope, and at this location of the coil, the output noise signal consisted of peak-to-peak noise bursts of ~300 mV, with some evidence of being limited in the positive direction. (The output stage of the Q-5095 preamplifier will transmit negative pulses linearly to 0.5 V and positive pulses to ~0.2 V.) For a single-ended gain of 200, the range of the amplitude of the induced input noise pulses would be approximately 1.0 to 2.0 mV.

Analysis of the data plotted in Figs. 2 and 4 shows that the electrical interference only slightly increased the electronic noise background for the differential operation of the preamplifier, but that the count rate was $\sim 10^4$ counts/sec for the single-ended operation at a pulse height level of 10 units and above. (A normal operating pulse height level with typical fission counters and gamma levels of 10^6 R/hr will range between 20 and 30 units.) The data of Fig. 2 represent that of the coiled arrangement. Results with the hairpin arrangement were very similar.

With the noise generator moved to a position nearer the input cable system (approximately one-half the distance previously used), the noise background of the differential and single-ended preamplifiers increased similarly, as shown in Fig. 3. In this case, the output of the single-ended preamplifier showed noise bursts with negative peaks to nearly 1.0 V and positive peaks limited to 0.2 V in amplitude. This implies that input noise signals of nearly 5 mV were being induced on the input cables.

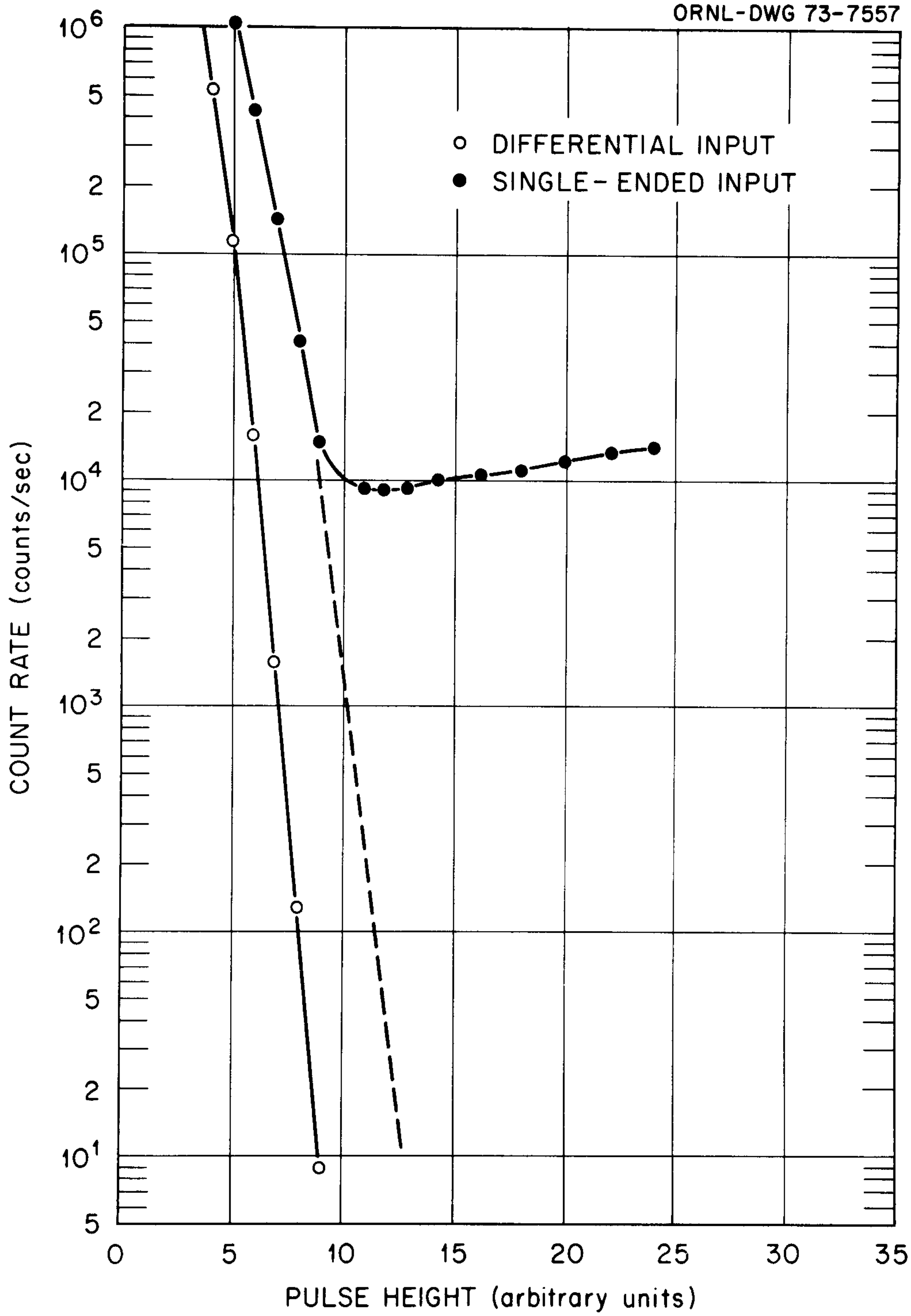

Fig. 2. Common-mode test noise curve for far position of noise generator.

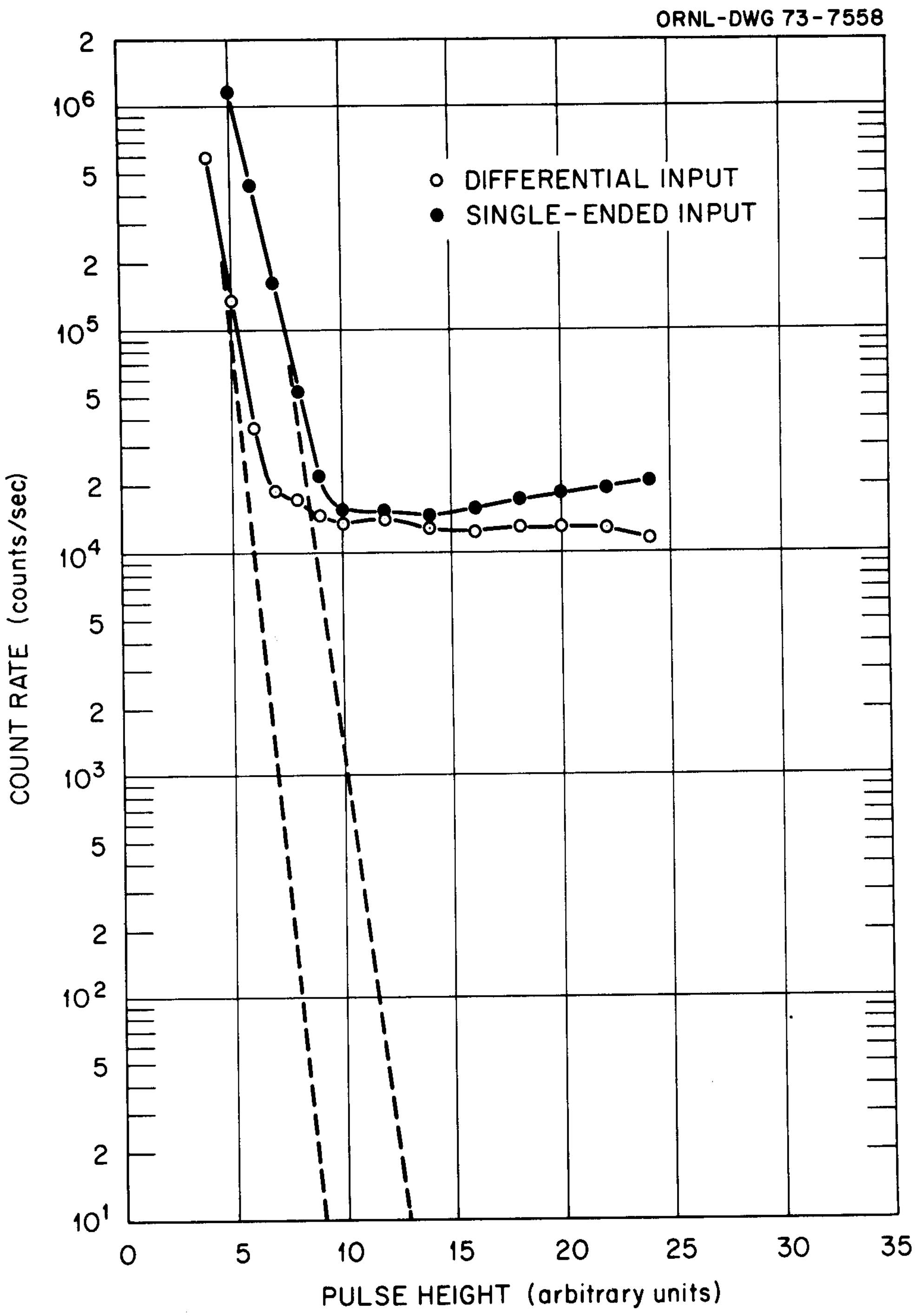

Fig. 3. Common-mode test noise curve for near position of noise generator.

3. INTEGRAL BIAS CURVES

The enhancement of the signal-to-noise ratio by a differential signal from a fission counter is illustrated in Fig. 4. The "electronic plus alpha" noise curve intercepts the 10-count/sec coordinate at 9.3 pulse height units for differential operation and 13.0 units for the single-ended operation. The pulse height units were normalized to account for the difference in gain of the two preamplifiers. The ORNL fission counter PCP-II-102[1] was used to obtain the data for these tests. One set of plates was grounded to obtain the data for the single-ended operation.

4. DISCUSSION AND CONCLUSIONS

The common-mode tests show that the effects of electrical interference can be reduced by a differential preamplifier. The Q-5095 preamplifier, with ~40 dB common-mode rejection from 50 kHz to 20 MHz, can suppress common-mode noise spikes as large as 2 mV with a main amplifier RC-CR filter time constant of 27 nsec. From the results obtained with the near-location of the noise source, the value of 2 mV is close to the limiting value for common-mode rejection. This value does not appear to be consistent with the value of signal required to saturate the input stage--~20 mV--if the input stage is expected to be the limiting element. Further investigation

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1. D. P. Roux et al., "A Neutron Detection System for Operation in Very High Gamma Fields," Nucl. Appl. Technol. 9 (5), 736-43 (November 10, 1970).

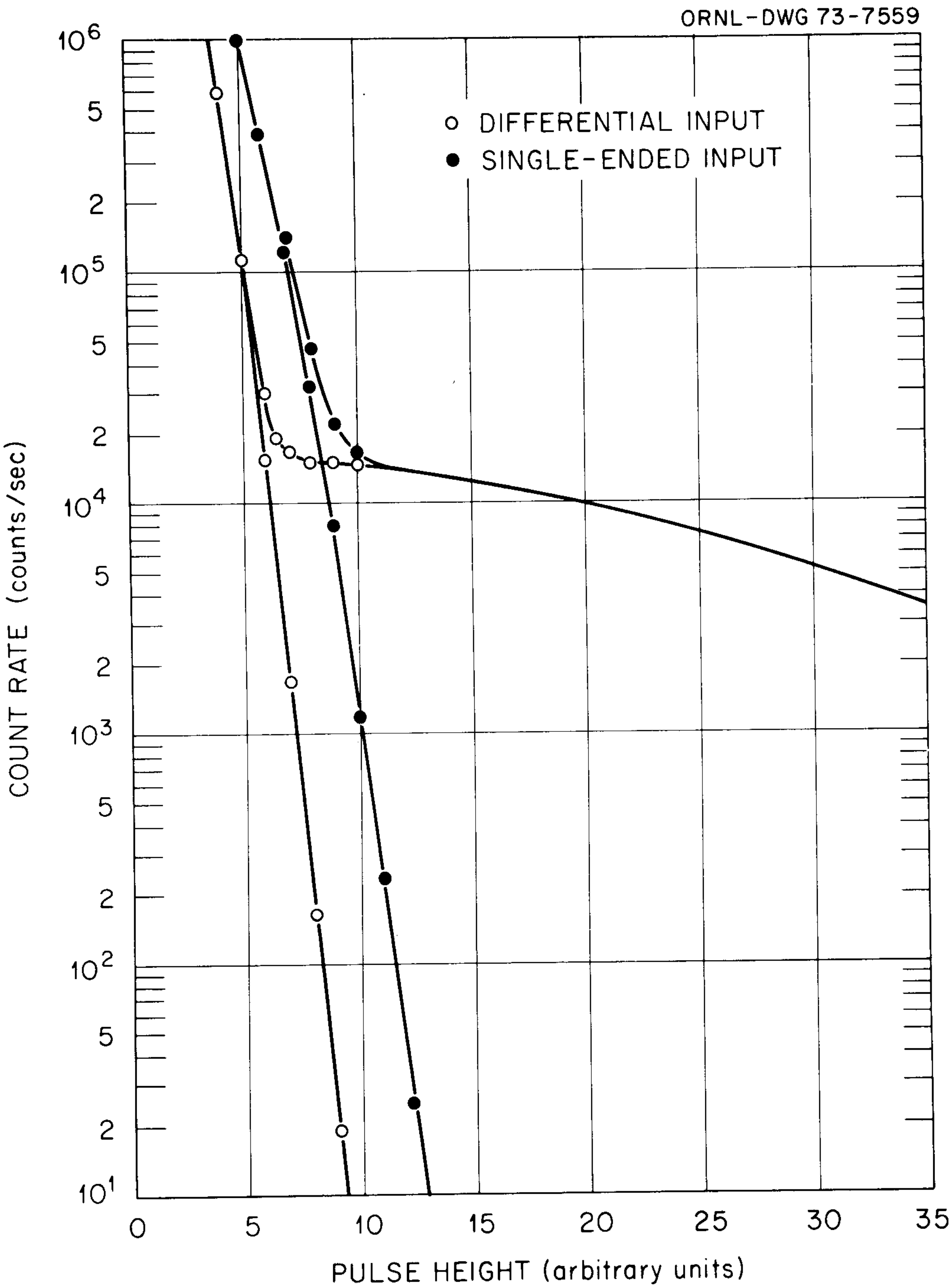

Fig. 4. Integral bias curve for differential and single-ended operation of fission counter.

is required to clarify this. Results of the common-mode tests imply that the shielding transfer impedance of a 10 m length of input cable should not exceed 2×10^{-3} Ω/m at the center frequency of the filter, in this case, 5.9 MHz. As a comparison, for single-ended operation this value of transfer impedance should not exceed 2×10^{-5} Ω/m for the same length of cable.

The integral bias curves for the differential and single-ended operation of the fission counter show a significant improvement for differential operation. The "electronic plus alpha" noise curves intercept the 10 count/sec level at 13.0 and 9.3 pulse height units for single-ended and differential operation, respectively. This improvement of nearly $\sqrt{2}$, however, is obtained at the risk of greater susceptibility of the high voltage cable to break-down noise.

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