A LINEAR LOW POWER REMOTE PREAMPLIFIER FOR THE ATLAS LIQUID ARGON EM CALORIMETER*

R. L. Chase
Laboratoire de l'Accélérateur Linéaire
91405 Orsay, France

S. Rescia
Brookhaven National Laboratory
Upton, NY 11973-5000

ABSTRACT

In a previous paper [1], it was shown that, for shaping times of the order of the transmission line delay, a remote, external preamplifier could perform as well as one connected directly to a liquid argon calorimeter. Here we describe an improved circuit configuration where, by attributing the functions of low noise and high dynamic range to two different transistors, the linearity can be improved and the noise can be decreased while reducing the power dissipation by a factor of three (to about 40 mW). The gain (i.e., the transresistance) and the input impedance can be chosen independently without changing the power supply voltages and power dissipation.

I. INTRODUCTION

In order to maximize the signal-to-noise ratio, it has been conventional wisdom to use very short connections between radiation detectors and their preamplifiers so as to minimize the total input capacitance. In a previous paper [1], it was shown that, under certain circumstances, as good, or even slightly better signal-to-noise ratios could be achieved with a transmission line connecting the detector to the preamplifier. This can be true, provided that:

1. pile-up considerations impose a shaping time that is of the order of, or shorter than the transmission line propagation time;
2. the reactance of the detector capacitance is of the order of the transmission line characteristic impedance at the center frequency of the shaping filter;
3. the input time constant, determined by the detector capacitance and the transmission line impedance is not long compared to the shaping time.

To prevent multiple reflections, the transmission line must be terminated in its characteristic impedance at the preamplifier. A physical resistance should not be used as it would normally be the dominant noise source. Conventionally [2], an "electronically cooled" termination is used, created by an operational amplifier with capacitive feedback, whose input resistance is, approximately:

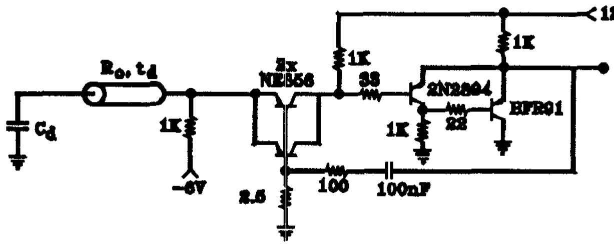

FIG. 1. Circuit schematic of the line terminating preamplifier described in [1]. It has a power dissipation of about 140 mW.

$$\frac{C_p}{g_m \cdot C_f} \tag{1}$$

where C_p is the dominant pole capacitance of the operational amplifier, C_f is the feedback capacitance and g_m is the input element transconductance.

This solution works well, provided that the input signal amplitude is not large enough to produce significant changes in the input amplifier transconductance. In the case of liquid argon calorimeters on high energy accelerators, this may not be the case, since signal currents may approach 10 mA or more and the corresponding voltage signal at the preamplifier input can substantially change the transconductance.

The preamplifier configuration presented in [1], and reproduced here as figure 1, is better adapted to these high dynamic range applications. Here, the equivalent "cooled" input resistance is:

$$\frac{1}{g_m} + R_c \cdot \frac{R_1}{R_1 + R_2} \tag{2}$$

where R_c is the collector load resistance, R_1 and R_2 are the feedback resistances and g_m is the transconductance of the pair of input transistors. The input transistor current is chosen to be high (about 4 mA) for low noise and to render the first term in expression (2), which varies with signal amplitude, small compared to the second term.

* This research was supported by the U. S. Department of Energy: Contract No. DE-AC02-76CH00016.

0-7803-3534-1/97 10.00©1997IEEE

Although this circuit works relatively well, it has a few drawbacks:

1. in the case of low impedance transmission lines (25 Ω), a very large input current would be necessary to make the first term in expression (2) small enough to achieve 1% non-linearity;
2. a high power supply voltage is required to prevent the input transistors from saturating with a large signal current, particularly if the dc current is also large. This leads to high power dissipation, limits the choice of input transistors and excludes the use of most integration technologies;
3. great care is required to prevent the input stage from oscillating at a high frequency (1 GHz) since transistors with high f_t are required for a low value of the base spreading resistance $R_{bb'}$ and stopper resistors would add too much noise.

II. HIGH LINEARITY, REDUCED POWER LINE TERMINATING PREAMPLIFIER

To circumvent these drawbacks, we propose the solution of figure 2. Here, the functions of providing low noise and high dynamic range are separated and assigned to different transistors. The pair of input transistors operates at high current (4 mA) for low noise, but has a low power supply voltage (3 V) and, therefore, modest dissipation. The transistor that absorbs the input current has low dc current (~1 mA). Even with high collector voltage, its dissipation is moderately low.

In this configuration, the first term in expression (2) is reduced by the gain of the input transistor pair (~40). This allows the inclusion of a large resistor (100 Ω) in series with the emitter, which eliminates all tendency towards high frequency oscillations, without significantly increasing the input resistance. Variations of the input resistance with signal current

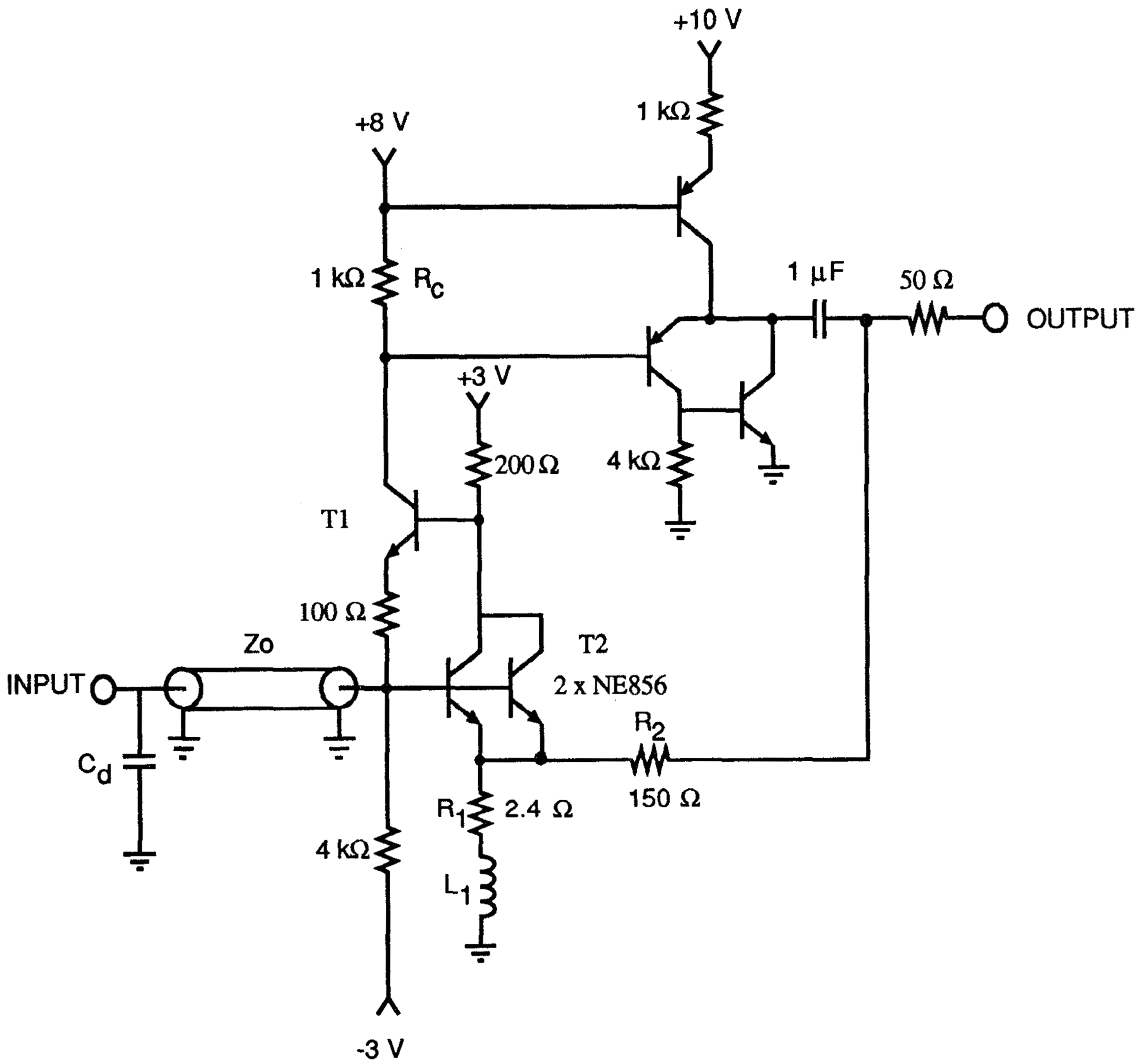

FIG. 2. Circuit configuration of the line terminating preamplifier for the ATLAS EM calorimeter.

are now reduced to about 0.5 Ω because of the gain factor of 40, providing excellent linearity. In the previous configuration the resistance change with signal was about 6 Ω. The same factor of 40 applies to the noise generated by the 100 Ω resistor.

The noise improvement with respect to the previous circuit is slight, but real. This is partly due to the fact that the resistor defining the current in the input common base stage is now larger (4 kΩ, because of the lower dc current). Since integration is now possible because of the reduced transistor voltages, the number of input transistors in parallel can be increased, thus decreasing the net value of $R_{bb'}$. A current source transistor has been added to the output White follower. This allows various values of resistor R_c to be chosen, to adapt to different dynamic range requirements in various parts of the detector, without changing the operating conditions of the follower. The input resistance is made to match the line impedance by appropriate choice of the feedback divider ratio, for each value of R_c.

III. AKNOWLEDGMENTS

We wish to thank V. Radeka for his support and many stimulating discussions.

IV. REFERENCES

1. R.L. Chase, C. de La Taille, S. Rescia and N. Seguin; Transmission Line Connections Between Detector and Front End Electronics in Liquid Argon Calorimetry; Nucl. Instrum. & Meth. A330 (1993) 228-242.
2. V. Radeka, Signal, Noise and Resolution in Position Sensitive Detectors; IEEE Trans. Nucl. Sci., NS-21, 51 (1974)