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Boster pick up electrode signal processing

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U.S. Department of Energy

USDOE Office of Science (SC)

DISCLAIMER

BOOSTER PICK UP ELECTRODE SIGNAL PROCESSING

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INTRODUCTION

Processing the beam-induced signal for transverse position data requires circuits which can function throughout three orders of magnitude in beam intensity and over several octaves in frequency, while maintaining accuracy of 0.5mm in the measurements. In addition, the equipment must be compatible with mechanical, alignment, radiation and cost requirements.

This note outlines some important evaluations of circuits which impact the overall design of the BPM system.

GENERAL

Prior efforts have investigated the beam sensor for the transverse measurements. These studies have concluded that a capacitive (*split cylinder) device is best from the standpoints of space, utilization, sensitivity, mechanical outline and many of the electronic requirements. One difficulty, however, with the capacitive element as a sensor is that an efficient means must be found to convey the induced charge collected by the electrode to the point where the signal is processed for sum-and-difference computation or for ratio computation. In a radiation environment such as near the beam line, semiconductor electronic devices, the usual means of processing signals, cannot be used because of their susceptibility to subsequent degradation in their characteristics. As shown in Figure-1, a matching network is proposed as a means to convey the electrode signal to an area (estimated to be 10 feet away from the beam line) where the effects of radiation on semiconductor components is negligible. In this way it is believed that most of the signal processing problems with component reliability can be resolved. During the last few days a network was constructed (see Figure-2) and tested in laboratory for its transfer parameters. The general results are illustrated in Figure-3, where the response to a simulated rectangular beam pulse applied via a coaxial test arrangement and model of the capacitive sensor is shown. The test illustrates that the response is preserved very well over the range of anticipated beam pulse widths and a measurement of the transfer signal loss indicated only about a factor of 2.5 from electrode to the load (terminal network of Figure-2). As a consequence, the beam sensor electrode signal can easily be transferred to a load point 10 feet away without serious loss in amplitude or frequency content.

A second very important circuit, having impact on the entire concept, is the CLAMP/RESTORER shown in the Figure-1 functional diagram. This circuit must restore the signals dc component so as to be able to measure the true energy components of the electrode potentials. The peak measure of the signal would not be adequate as the Boosters temporal beam profile changes markably during the machines cycle and as a result this easily measured quantity does not contain the needed information to obtain normalized position data. A measure of the electrodes signal which is adequate is the average of a dc restored peak-to-peak signal. An electronic circuit configured to do this is shown in Figure-4. In this figure the follower buffers the electrode signal and permits the operational amplifier and diode/capactior (D_2 and C_c) circuit to create the unipolar dc-restored signal from the beam electrode. The diode D_1 and 1K resistor prevent latch-up of the operational amplifier, a common problem with high bandwidth restorer circuits. The integrator and associated BUS INTERFACE control the amount of time (# turns) the beam signal is integrated to secure a measure of the average transverse beam displacement. With an operational amplifier having 400 MHz gain-bandwidth and with an ordinary (signal) diode D_2, an error of about 5% was noticed in correcting small signals for their dc component. It is proposed to utilize a wider bandwidth product amplifier (Harris or Com-Linear) together with a ZERO BIAS diode to improve accuracy. Tests using this circuit over a 40:1 input signal range were very encouraging and confirmed that the BPM outline shown in Figure-1 is a practical one.

In addition to the two circuits described, the gain switch alternator circuit in Figure-5 was constructed and tested for rectangular response. It was suspected that at the desired impedance of 200K ohms, that some loss in rise-time and flatness woul be be inherent in a design with such a large impedance. The test results of the circuit of Figure-5 was again very encouraging. It was a routine matter to compensate each alternator setting for frequency independence (make time constants for each upper network section equal to that of the lower section) and to realize rise time values of less than 7ns and droop value less than a few percent @ the 200 k ohm impedance level. It was also found that the attenuation ratio values were not very sensitive to the input capacity of the follower (variation to ± 2pf about the 5pf assumed value, and ± 500KΩ about the assumed 1.8Megohm value of the input resistance).

CONCLUSION

The important circuits which are vital in determining the feasibility of the Booster BPM system have been tested with 3 excellent results. The overall functional diagram for one channel takes on the form shown in Figure-1. The protection concept, and important aspect of the overall design and the digital control and optical circuits for transmission without ground loop complications appears to be the next most important investigations relative to overall system success.

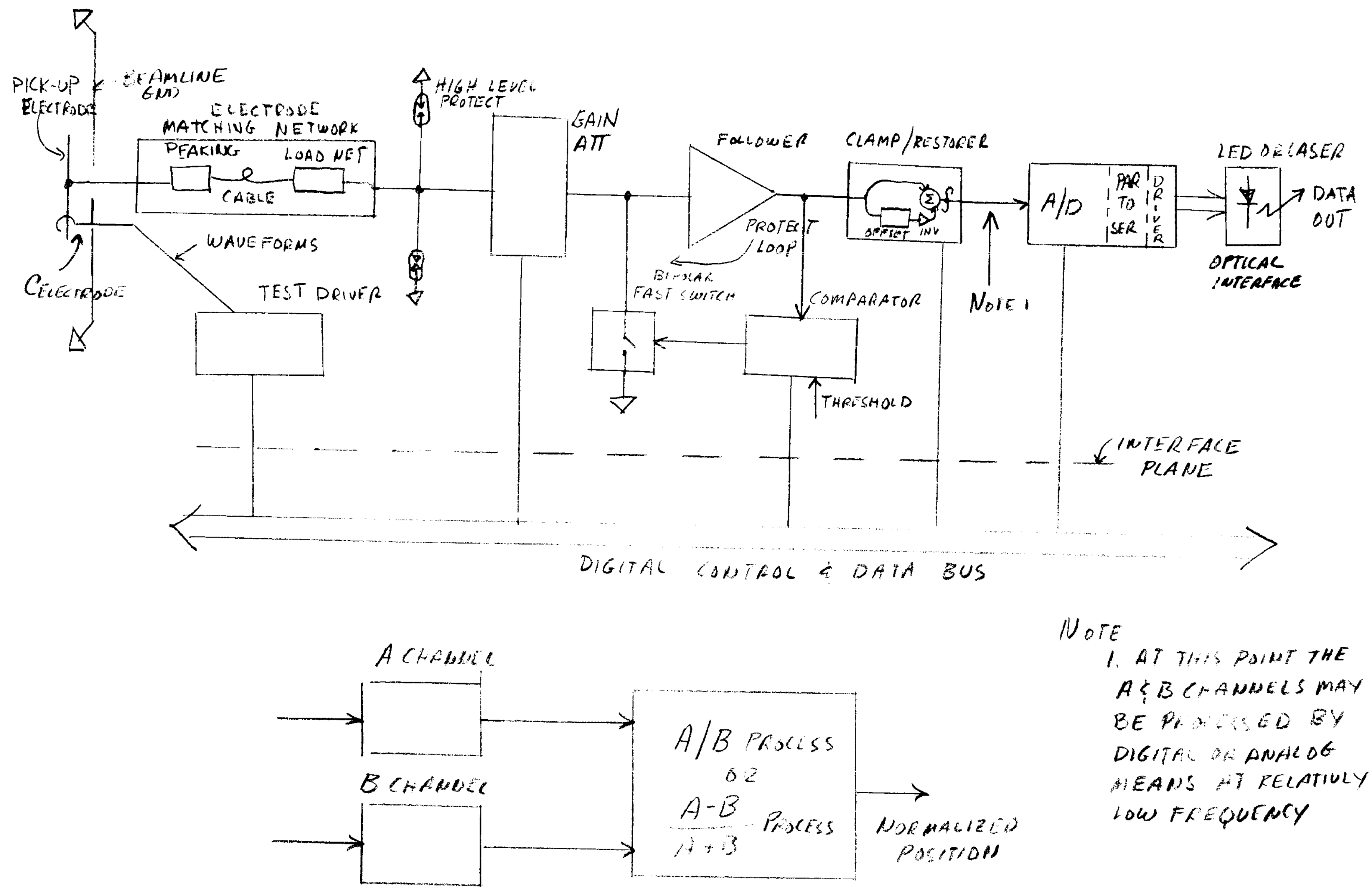

FIGURE - 1 FUNCTIONAL OUTLINE, BOOSTER BPM

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JOB: NETWORK FOR COUPLING A CAPACTIVE BEAM ELECTRODE TO A SIGNAL PROCESSING ELEMENT

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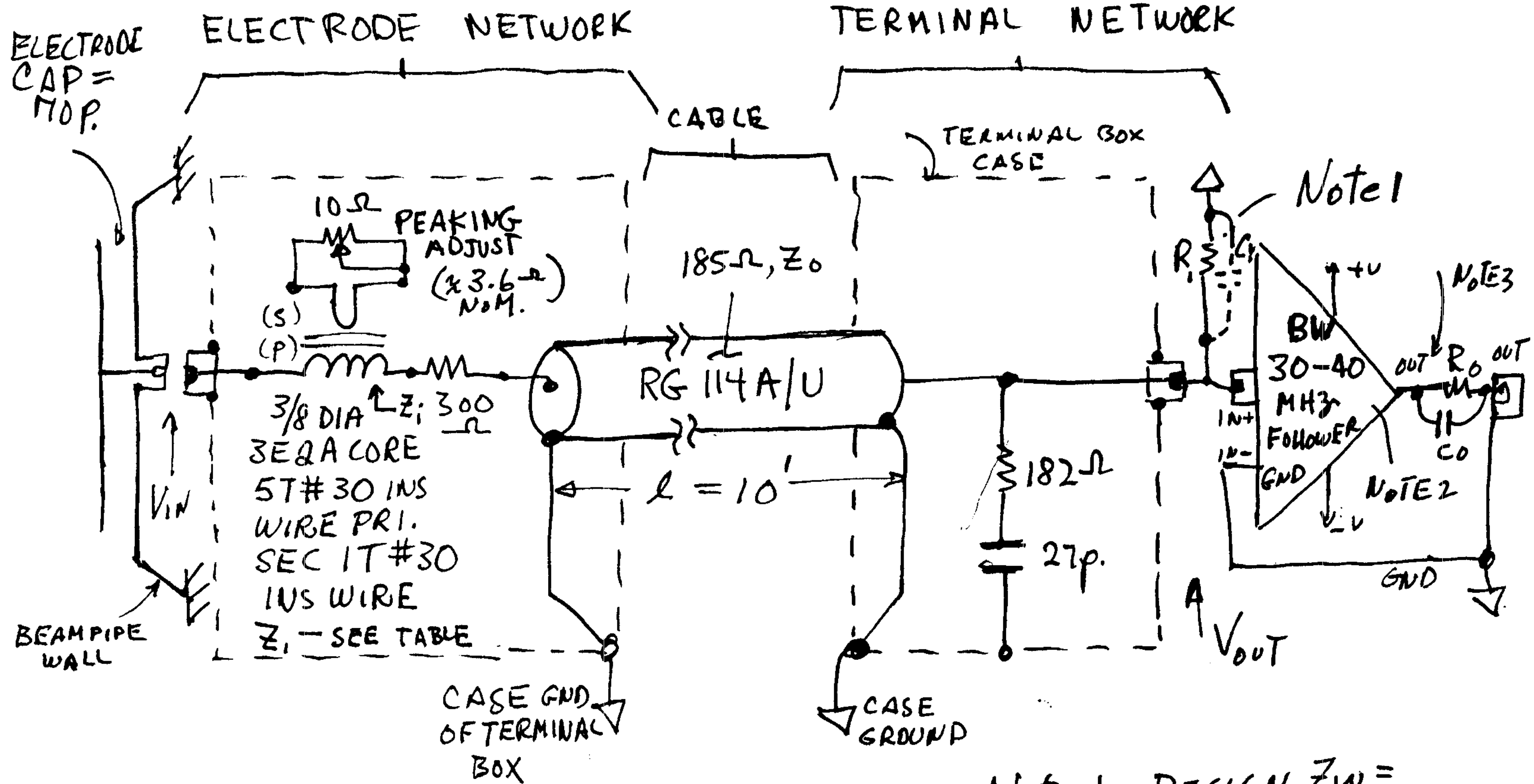
Date 3/8/88
By E. J. Higgins AT-5

FIGURE - 2 ELECTRODE NETWORK



$\frac{V_o}{V_{in}} \approx \frac{1}{2}$ ie Transfer Voltage loss ≈ 6 dB

Range of operation ≈ 200KC - to - 30 MHz

RISETIME with 30 MHz Follower ≈ 12 ns

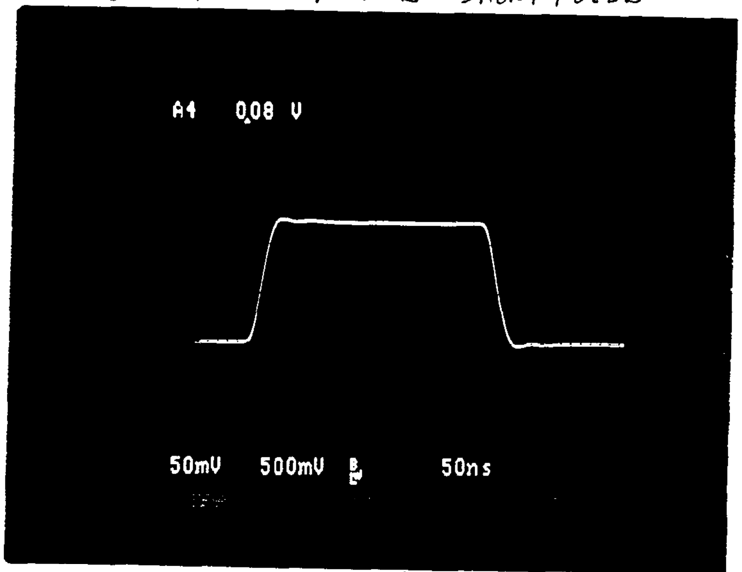
RISETIME WITH 150 MHz " ≈ 9.5 ns.

Note: 1 - DESIGN Z_{IN} = 0.2 - 1 Meg = R
10 - 20 pf Max = C

2. Design BW is DC - to - 30/40 MHz GRADUAL ROLL-OFF

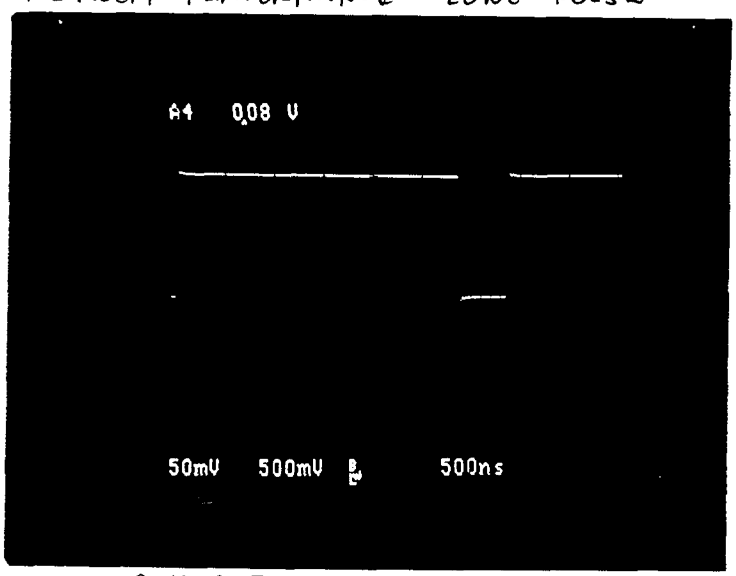
3. R_o-C_o CAN BE ADJUSTED FOR BW IF FOLLOWER IS NATIONAL LHK0063 R_o = 10-30 Ω TYP.

NETWORK PERFORMANCE SHORT PULSE



OUTPUT OF NET /W BW=20MHz

NETWORK PERFORMANCE LONG PULSE



OUTPUT OF NET WITH BW=20MHz

FIGURE - 3 NETWORK RESPONSE

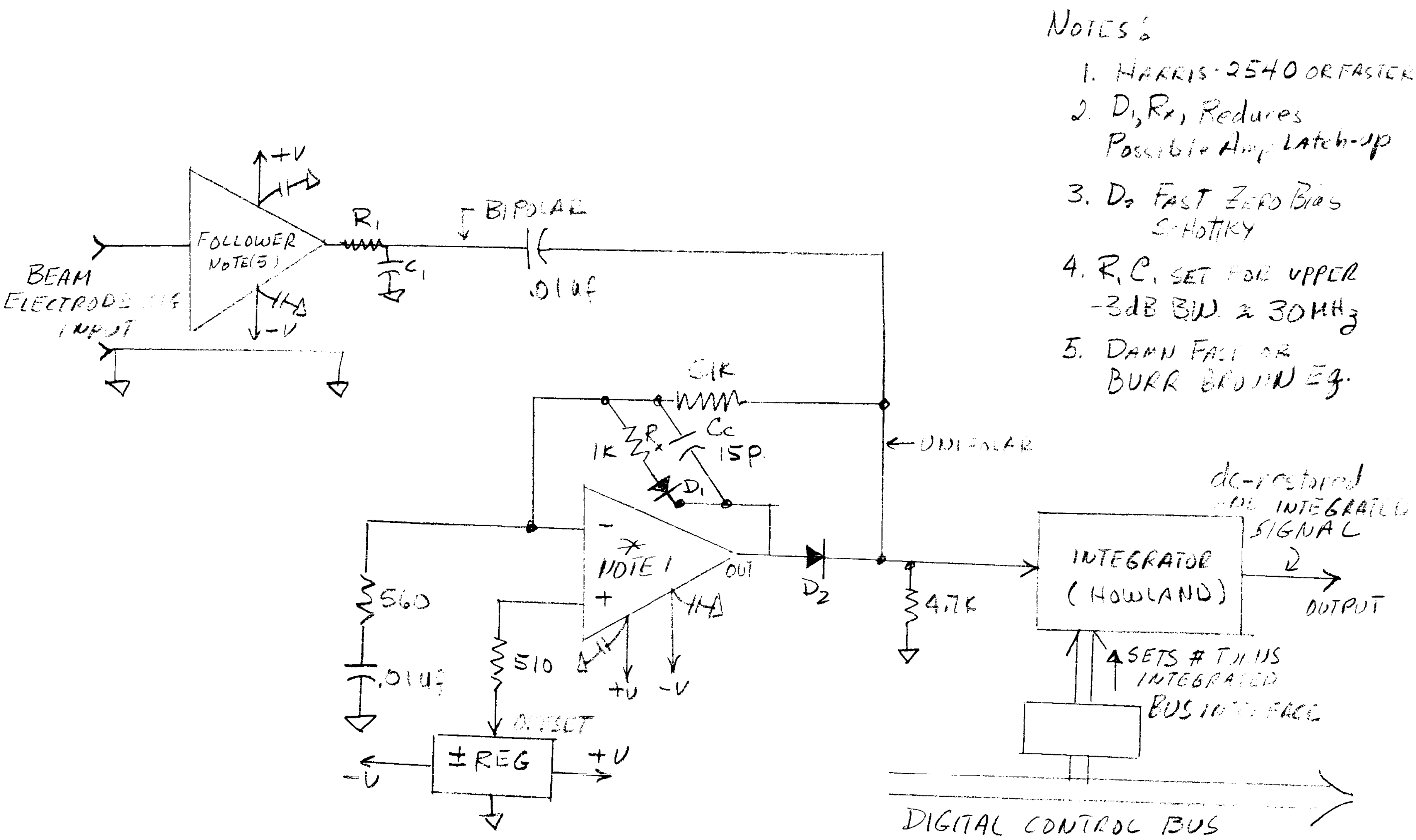


FIGURE - 4 CLAMP/RESTORER

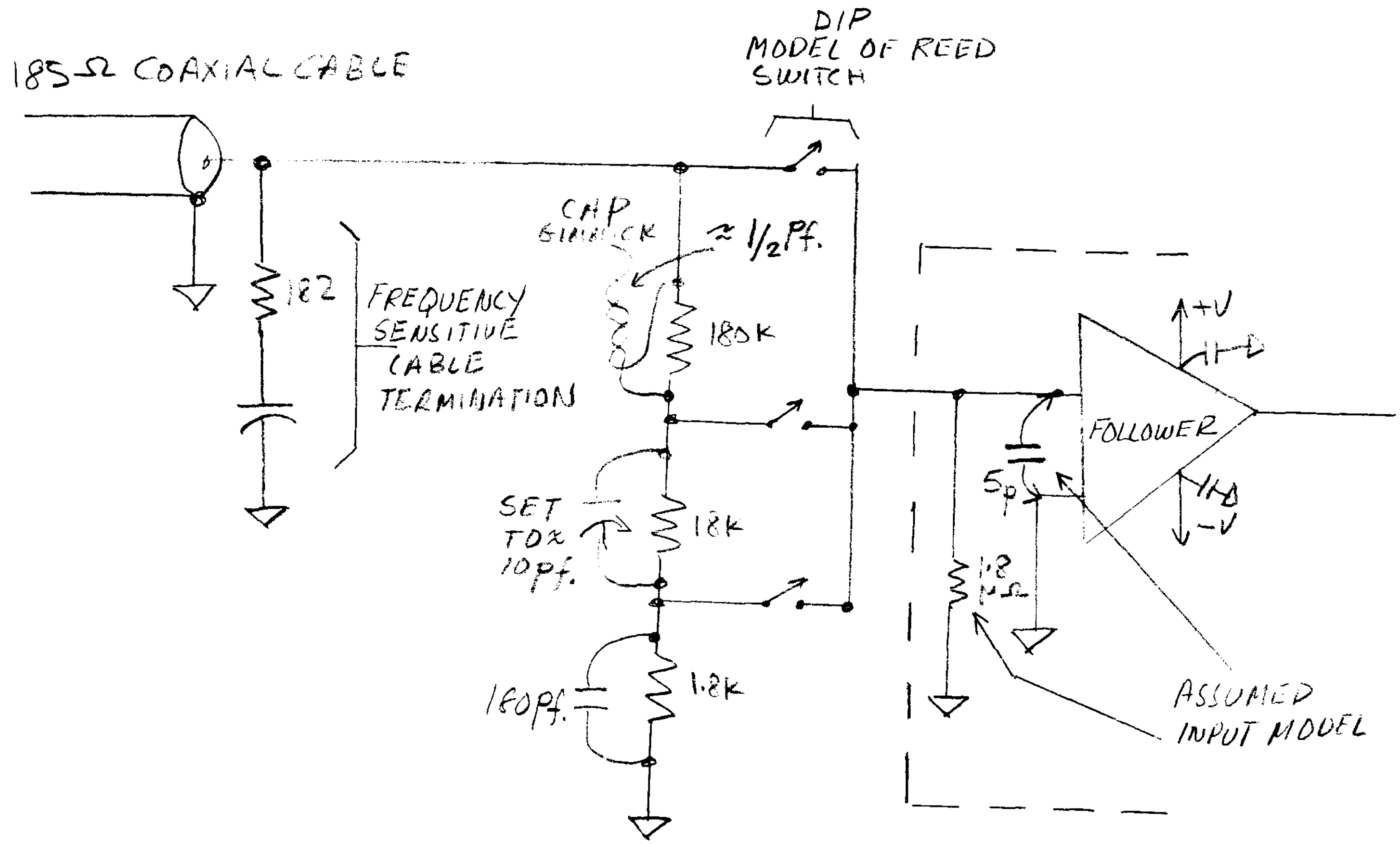


FIGURE-5 COMPENSATED ATTENUATOR