PMT Anode Current Measuring Considerations For The DUMAND Prototype Module

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This is in response to A. Roberts' proposed alternative circuit for measuring the prototype module's PMT anode current. I will briefly review the problem, and compare the two proposed solutions.

The Problem

This originates in the fact that we are constrained to using a positive HV at the anode with the photocathode at ground potential. This means that any component which is DC coupled to the anode circuitry must have a DC common-mode rejection of as much as 3 kV--which rules out most standard components such as op-amps, voltage comparators, transistors. Of course we could let such components float at this high potential, but this is only possible for non-active components which reqire no independent power supply, unless we can power them from the PMT dynode resistor chain. This is the method followed by Dr. Roberts.

First solution: the Isolation Amplifier

For the review of those who have forgotten the discussions concerning this method, I present it again. The heart of this method is a specialized operational amplifier which has a 3 kV common mode rejection and is designed for such applications. The circuit using it is shown in figure 1.

A Brief Description

A voltage drop proportional to the anode current develops across the measuring resistor Rm. The fast anode pulses are filtered through a pi-type RC filter across the inputs to the isolation amp. The resulting DC potential is amplified to give a 0-10 V output which is then digitized at the ADC. The gain of this amp. is set by external low-side resistors. Careful shielding of the input is used to eliminate ground loops, stray capacitances, and RF pickup.

Solution number 2: Dr. Roberts' Circuit

As I understand it, the cicuit is drawn as shown in fig. 2 (with particular transistors, diodes, etc. as yet unspecified):

A Brief Description

The potential across Rm is filtered to give pure DC at the collectors of the two transistors. This is modulated to a square wave with a peak- to-peak potential equal to that across Rm, with a frequency of 1-5 kHz. This is done by controlling the transistor bases with a multivibrator, presumably using the normal and inverted outputs to switch the transistors 180 deg. out of phase. This square wave goes through an HV bypass capacitor which gives the necessary isolation to the circuit's low side, and it is then rectified to give a DC potential proportional to the original drop across Rm. This potential is then digitized at the ADC. Power for the active component(s) is derived from the dynode resistor chain.

Comparison of the Two Solutions

First, I note the similarities of the two techniques.

-Both use initial RC filtering to smooth fast pulses to a DC potential taken from an I-R drop.

-Both use a DC-AC stage to isolate the output from the HV upstream from it. The isolation amplifier does this internally via a 30 kHz oscillator.

-Both then rectify the output to give the required DC output potential; the isolation amp again doing this internally.

Thus, since there is very little difference in the content between the two methods, further comparison will focus on how each circuit deals with the specific problems of the HV environment, and also the limitations in space and cost for the module.

RF Noise Problems

Whereas the isolation amplifier is shielded to prevent its internal oscillator from producing RF noise, the Roberts' circuit will require careful shielding to prevent external RF. Since the peak to peak potential of the square wave could be 10 V or more, inductive pickup by other components within the very small space of the Benthos sphere could be a serious problem, and the oscillator portion of this circuit would certainly require a metal box. The problems which then arise are: how to construct this box as small as possible without causing HV breakdown problems if the box is held at ground potential; or, if it remains at HV as a local ground shield, how to minimize the field effects on nearby components, including the PMT itself.

Power Requirements

The isolation amplifier has an internal supply for the HV side of its internal circuitry. Its passive current requirements are + 15 mA, -3 mA, and since the ADC input impedance is high (> 20 k ohms) these can be regarded as its active requirements also.

The Roberts' circuit will require at least a 5 V potential difference from the HV ambient ground to run the multivibrator. However, unless a regulator is used, this potential will vary with individual HV settings and with dynode chain current, since a passive divider must be used. If a voltage regulator is then employed, there is the problem of powering the regulator itself, and we have introduced one more component with additional power consumption and possible failure.

Power consumption in this circuit will probably exceed that of the isolation amplifier because of the limitations of the rectifier and switching transistors' efficiency. However, using a CMOS multivibrator, and with a careful choice of components, power use may not be much higher. However, this current must be supplied by the PMT HV supply, and may well exceed the current used by the dynode chain itself (since this is in the microamp range), and could interfere with its operation.

Impedance questions

The isolation amplifier has a high input impedance (> 100 megaohms) and small input capacitance (< 3 pf) as it is used here. The input impedance of the signal discriminator is effectively 50 ohms. The Roberts' circuit with large resistors after the input filter also has a high input impedance and niether circuit should affect the signal adversely on that account. However, I question the direct coupling of the collectors of the switching transistors to the anode; albeit through R and Rm, this still seems to invite possible interference.

Size

The isolation amplifier measures .89" x 2.5" x 3.5". If we consider the size of HV capacitors (.01 - 1 microfarad), transistors, multivbrator, possible voltage regulator, resistors, and a bridge rectifier needed in the Roberts' circuit, I think there is unlikely to be a great reduction in size, especially when precautions must be taken, if the case is at ground potential, to keep the interior components well clear of it. Or, if the case is kept at HV, its effective size will be larger than its apparent size since exterior components must be kept clear of it. Further, the safety hazard of a HV shield such as this must be considered.

Conclusions

I do not see a significant advantage in the Roberts' circuit for measuring PMT anode current. Even though its apparent cost is less, problems in construction presented by the high voltage environment the circuit must dwell in will increase the effort needed to build and troubleshoot it and probably offset the cheaper cost. The isolation amplifier seems at this point still a more viable solution.

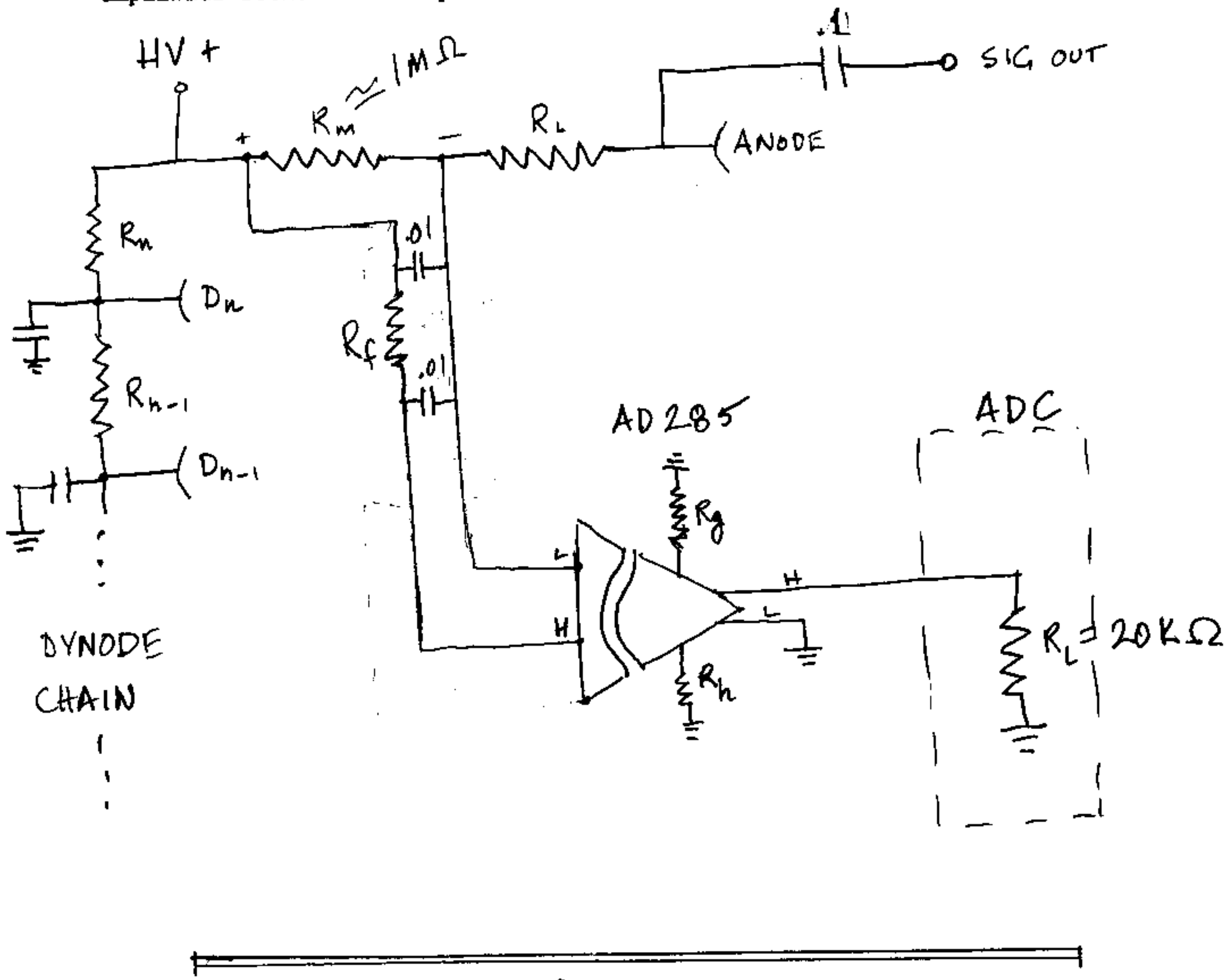
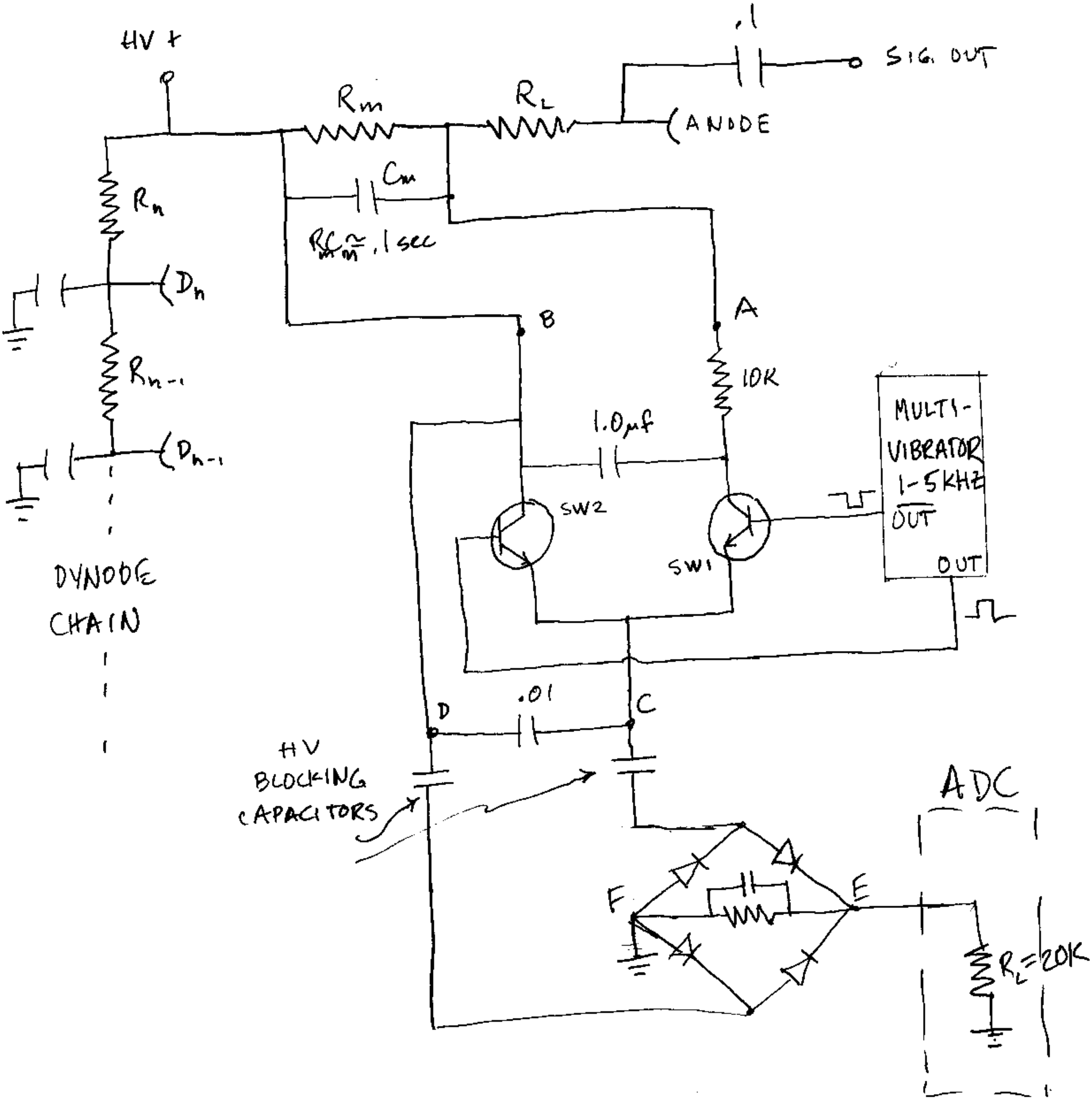


fig. 1


HV +
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SIG. OUT
Rm
RL
ANODE
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Cm
RC ≈ .1 sec
Dn
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1-5KHZ
OUT
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SW1
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D
C
HV
BLOCKING
CAPACITORS
ADC
F
E
RL=20K

fig. 2