Summary of Shower XP3461+base Modelling

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Legacy pmt-base assemblies from Hermes are in use in the Hall C SHMS calorimeter. These are XP3461 pmts with base cookies directly welded to the pins. I can find no substantive information about this pmt but it appears to be an early version of the Photonis XP3462 tube for which datasheets do exist. The base was even more of a mystery since we didn't have a circuit diagram.

The main point here was to measure the base resistances, make a circuit diagram, then predict how a nominal XP3462 tube should behave with these bases. Compared to Hermes, our beam energy in Hall C is lower and our luminosity is higher, so there might be some surprises. Current high priority questions which I answer below are:

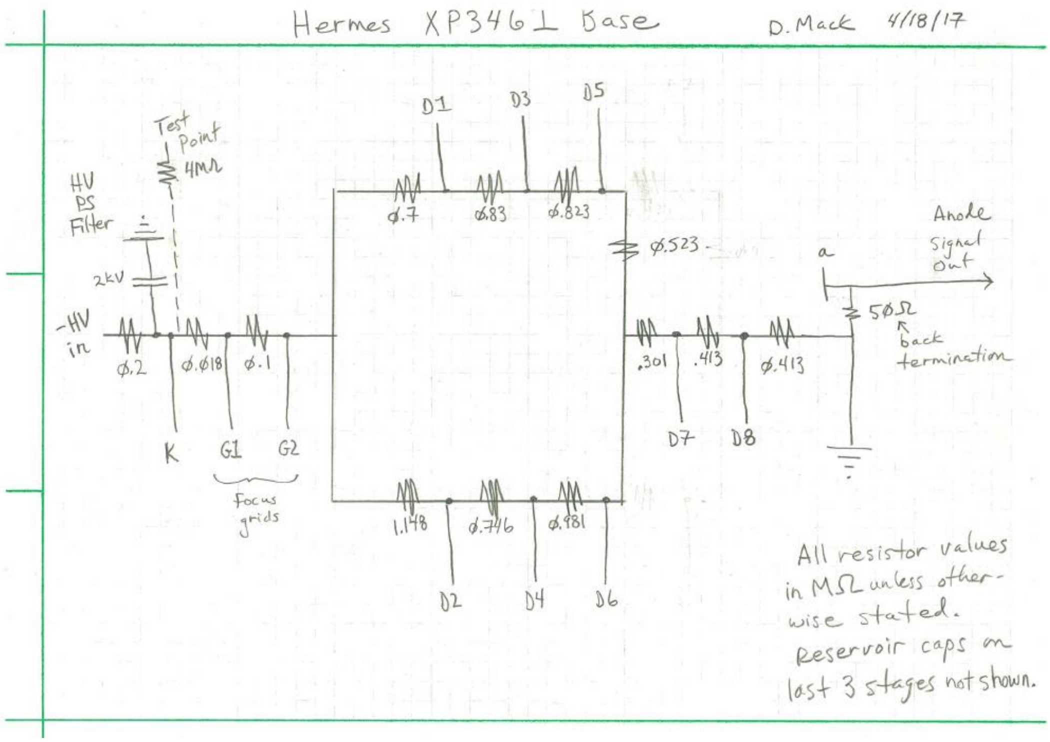
- *Can we understand why one of the bases failed shortly after installation and avoid such a problem in the future?* and
- *How high in voltage can we go without damaging the tube or base?*

The resistance measurements were a pain. I tried not to ruin Hamlet's base, but that didn't work out. Instabilities led me to snip off the large filter capacitor. Measurements still weren't making sense, so I then cut the entire cookie off the pmt revealing an unexpected parallel circuit on the underside. I was then able to measure the resistor values within 20%, but I had to cut a trace on the board to break the parallel circuit to get the final resistor values.

Although it's not obvious from the circuit diagram (below) this resistive base is equivalent to Divider B, a good choice for linear operation. In addition, it has the following bells and whistles:

- an RC filter in the front end to suppress high frequency noise on the HV supply,
- a test point to check the noise on the HV after filtering,
- a parallel circuit central section which sets the odd and even dynode voltages.

The base is also back-terminated in 50 Ohms. That means is the base will nicely gobble up any reflections from patch panels, etc, but the signal sent to our FADC will be a factor of 2 smaller.



This base was too unusual to model with my standard program. To get the power dissipations, I first wrote a fortran program to calculate the voltage drops, currents, and power dissipation in this base, HermesXP3461CustomModelv2.f . As the following table indicates, since the resistors appear to have ¼ Watt ratings, there should be no problem operating this base up to 2000V.

Resistor ID	Resistance (MOhms)	Watts at 1400V	Watts at 2000V
K	**0.200**	**0.05**	**0.10**
G1	0.018	0.004	0.009
G2	0.100	0.02	0.05
R1	0.700	0.04	0.08
R2	1.148	0.07	0.14
R3	0.830	0.05	0.10
R4	0.746	0.04	0.09
R5	0.823	0.05	0.10
R5prime	0.523	0.03	0.06
R6	0.981	0.06	0.12
R7	0.301	0.07	0.14
R8	0.413	0.10	**0.20**
Ra	0.413	0.10	**0.20**

Can we understand why one of the bases failed shortly after installation …: The most damaged component was a 200 kOhm resistor at the input of the base, part of an RC filter to reduce HV power supply noise. From the above table, this resistor should *not* be the first point of failure; even with an extreme excursion to 2000V, the power dissipation in that resistor would be less than half the rated value. Failure of this "K" resistor requires some short of short circuit, such as the HV arcing a few mm from a point of high potential on the board (the test point, cathode, G1, G2, …) to a nearby conductor. The most likely suspect for that conductor is an overly long ground braid which got pushed close to the board when the cables were tucked in while sealing the can. A less likely suspect is the conducting, spring-loaded tripod which may have helped to keep the ground braids away from the board. In the Hermes pmt assembly Hamlet loaned me, there is a safe 7mm separation between the metal tripod posts and the highest point on the cookie, so it would probably take a conspiracy of length variations in the pmt, the wires connecting the board to the pins, and the tripod posts to reduce the clearance to ~2mm needed for a spark. Again, I suspect the ground braid on the HV input cable.

… and avoid such a problem in the future?: If the ground braid or metal tripod was the offender, it seems like a problem that won't be systematic but will only appear in a few channels that slipped thru QC. The inside of the cans are unfortunately inaccessible so repairing a sparking base *in situ* is not possible. Hamlet has already set the Imax to 600muA on all channels, with a time over threshold trip setting of 1 second. Now if a tube sparks or even arcs, calculations suggest none of the resistors will be damaged. Of course, if this happens too frequently the channel will be noisy. *My only suggestion is that, during the humid summer down, the time over threshold trip setting could be reduced to a minimum value and the Shower counter operated for weeks. By looking for channels that trip off, we could better quantify how many bases are sparking.*

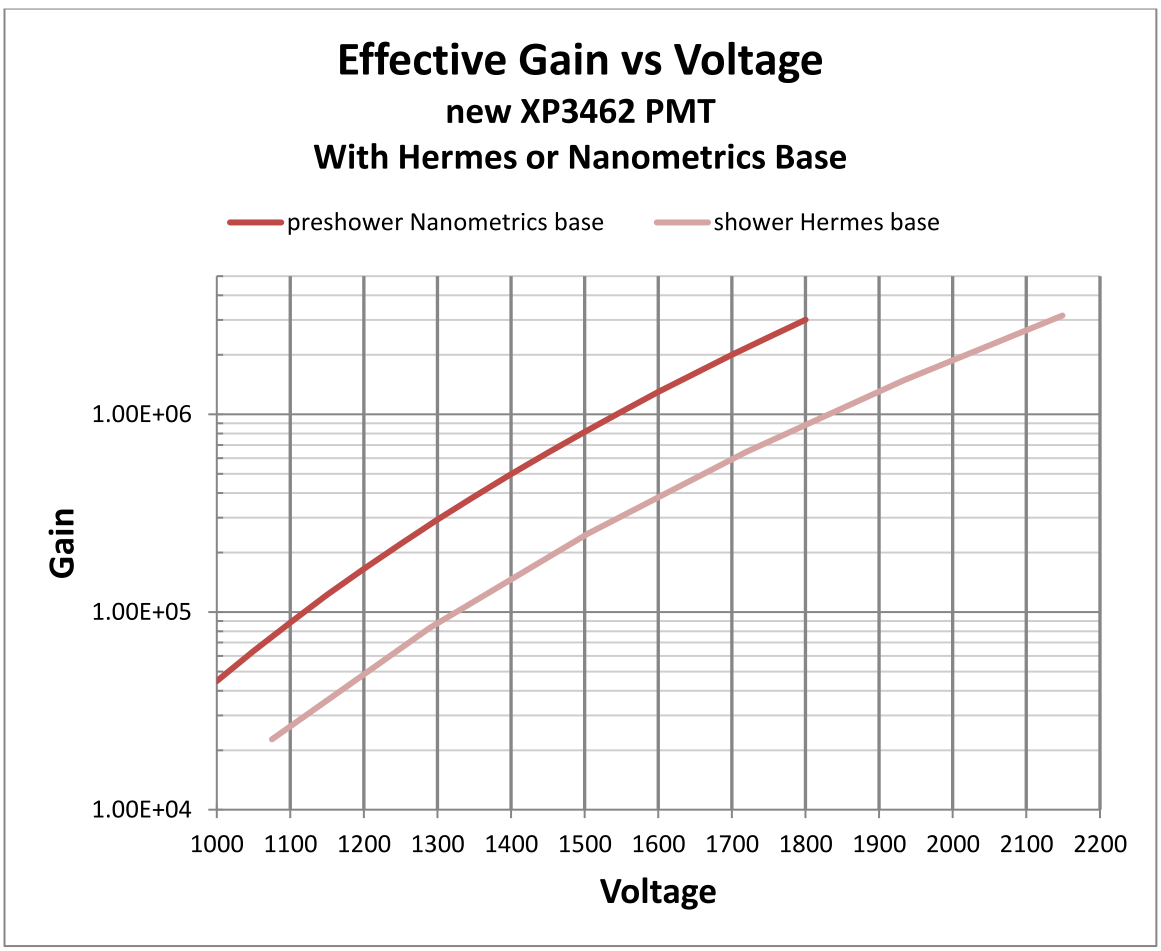
How high in voltage can we go without damaging the tube or base?: There is a soft limit of 1800V above which the internal gain may exceed the maximum rating of 3E6 in new pmts and begin to feed back. However, there should be no hard limit up to 2000V. Above that voltage some of the final resistors may be damaged.

Other discussion:

How does the gain compare for the shower blocks with Hermes bases versus the preshower blocks with the Nanometrics bases? Once the above custom fortran program provided me with the exact voltages and power dissipations, I was able to map the Hermes base to an equivalent series circuit so that I could use my program GvsV_version6.f to model the gain. Despite the complexity of the Hermes base, if one neglects the HV filter on the input, then in terms of gain it is very close to Divider B as one can see from the following table.

	k-d1	d1-d2	d2-d3	d3-d4	d4-d5	d5-d6	d6-d7	d7-d8	d8-anode
Hermes base	3.1R	1.5R	1.27R	1.21R	1.53R	1.74R	2.0R	2.75R	2.75 R
Divider B	3.1R	1.5R	1.25R	1.25R	1.5R	1.75R	2.0R	2.75R	2.75R

I didn't want to hack GvsV to accommodate the filter section, so my gain vs voltage calculations neglect the 0.2MOhm filter resistor (only ~7% of the total resistance). This means the GvsV results underpredict the voltage needed for a given gain by 50-150V. However, I corrected for this model deficiency with a hand calculator when making the following figure. The most important result is that at a given supply voltage, the *effective* signal gain from the Hermes divider is a factor of ~3 smaller than from the Nanometrics base. Part of this is due to the back-termination (x2) while the rest is due to losing 50-150V across the 0.2MOhm filter resistor.



The relevant output files contained in this same Hall C docDB entry are

- HermesXP3461BaseCircuitDiagram.pdf : circuit diagram for the Hermes base.
- HermesXP3461CustomModelv2.f : a program to exactly calculate the voltage drops, currents, and power dissipations in the Hermes base.
- ShowerXP3461GainvsVoltageModel_longoutput.dat, and ShowerXP3461GainvsVoltageModel_shortoutput.dat : approximate gain vs voltage performance from my program GvsV neglecting the initial 0.2MOhm resistor. Note that I corrected for this approximation when making the gain vs voltage curve for the Hermes base in the above figure.
- ShowerXP3461GainvsVoltage.xlsx : Excel file to generate the gain vs voltage plot.