Summary of HMS Hodoscope XP2262 Modelling

D. Mack (July 28, 2015)

The main purpose of the modelling was to estimate how much gain we have in reserve. As the gain of the pmt's drops over years of use, we'll want to increase the HV.

So the first question was, "What is the maximum HV?" We start exceeding the ¼W rating of one resistor near 2350V, so I'm taking ~2300V as a nominal max HV. Note that at this HV, we are far from running into limits from the CAEN HV channels or the PMTs themselves.

(See **HMSHodoXP2262GainvsVoltageModel_longoutput.dat** in this Hall C docDB entry.)

The next question was, "What gain might we expect at this maximum HV?" Gain vs Voltage plots are found below, with the present nominal operating point circled in red (~5E6 gain near 1800V). The same model and data are plotted twice on different scales. These plots are also found in this Hall C docDB folder as .pdfs, along with the Excel file that created them.

Dave Mack's program GvsV_version6.f was used to model the gain. Agreement between model and data is at the level of ~√2 which is excellent given the fact that these pmt's are not new, and the model is doing a lot of extrapolating from the manufacturer's resistive divider B to the actual zenerized base design.

(See **HMSHodoXP2262GainvsVoltageModel_shortoutput.dat**, **HMShodoGainVsVoltage.xlsx, HMShodoGainVsVoltage.pdf,** and **HMShodoGainVsVoltageZoomed.pdf** in this Hall C docDB entry.**)**

Comments:

* Near 1800V, every additional 100V gets us a factor of 2 more gain. That matches the 30 year old rule-of-thumb for 12-stage tubes my supervisor Phil Roos told me when I was a grad student. (For pmt's with fewer stages, one needs more than an extra 100V to get a factor of 2 increase in gain.)

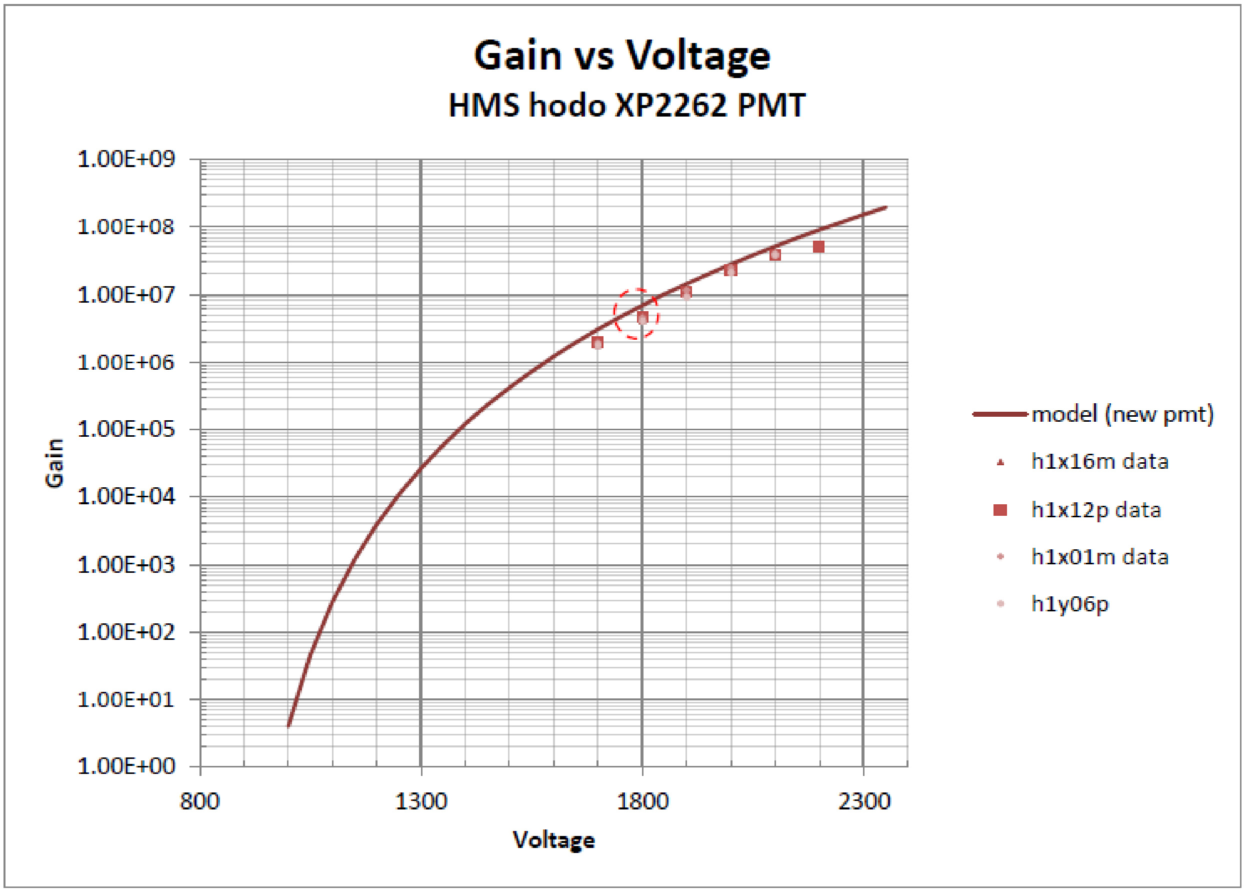
* Since we can run these bases at 2300V, the model suggests we have a factor of 2**5 = 32 gain in reserve. The data are from Simona Malace and her team of students. They used the single photoelectron peak to measure the gain. They didn't go lower in voltage because the signal got too small, and they didn't go higher because they didn't know at that time the maximum rating of the base. The highest two data points may indicate some sort of saturation that is missing in the model, but we still have at LEAST a factor of 2**3 = 8 gain in reserve. So if we can avoid helium poisoning, these tubes may last the lifetime of the HMS.

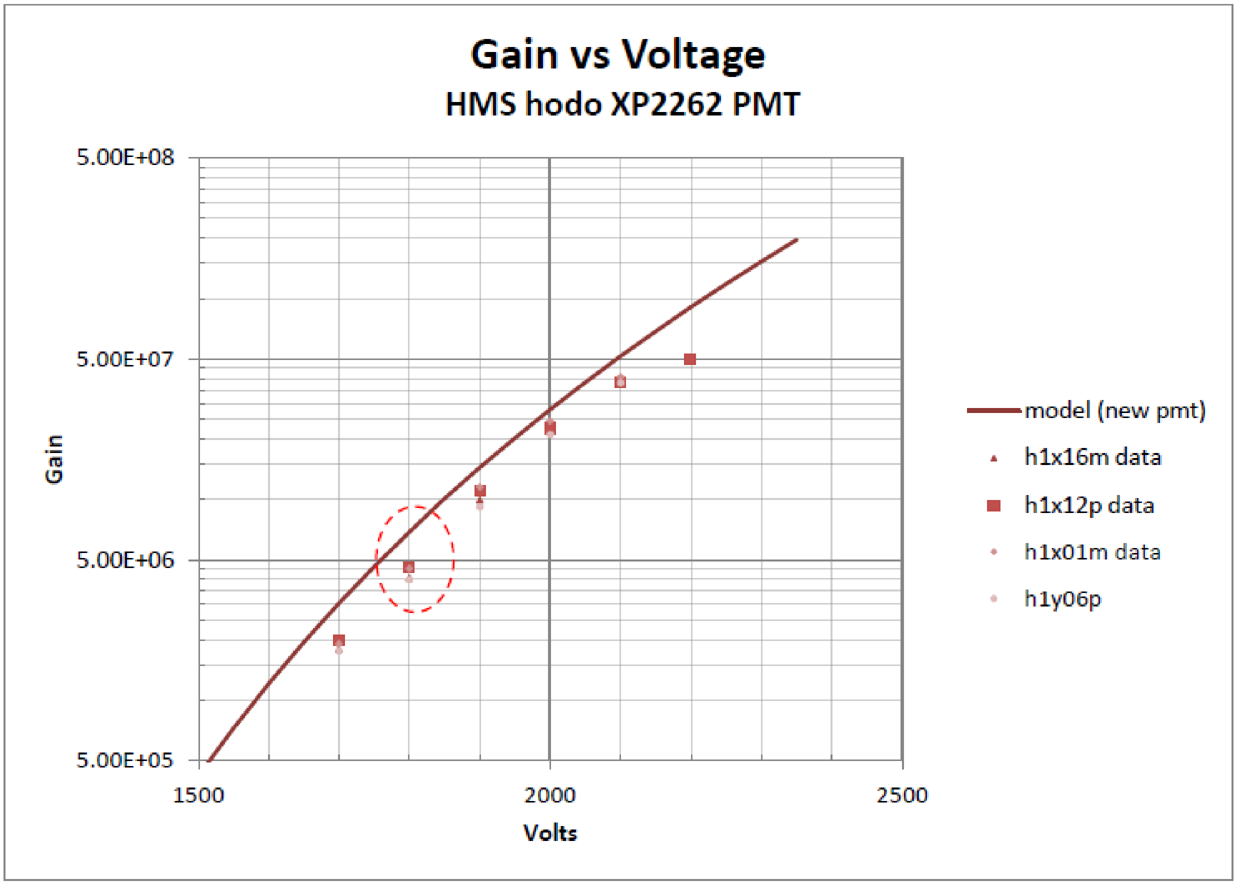
* Finally, the curvature in the log(Gain) vs HV plot is due to the zeners. This base has ~900V worth of zeners. Below 1500V the gain starts diving for 0 faster and faster. But that hardly matters for us since the nominal operating voltage is something like 1800V at the time of writing.

Methods:

My model assumes the gain for each active stage is given by $g_i = \beta V_i^{\alpha}$. With some tedious algebra, I extract the two parameters α and β from the manufacturer's purely resistive, divider B curve. The base we are actually using is what I would call a "zenerized implementation of a type B-ish divider with one inconsequential mistake". (See table below with differences highlighted in red. There are more differences than there are similarities.) I think the inter-stage voltages delivered by this base are quite reasonable near our nominal 1800V, and the mechanical and electrical layout is superb. However, the actual divider and divider B are apples and oranges, so my model is doing a lot of extrapolating and the simple $g_i = \beta V_i^{\alpha}$ ansatz is being thoroughly tested.

Our base	307V	1.00R	1.33R	1.00R	1.00R	1.00R	1.00R	1.00R	1.00R	1.25R	151V	200V	248V
Divider B	4.0R	1.10R	0.90R	1.00R	1.00R	1.00R	1.25R	1.25R	1.50R	2.25R	1.75R	2.75R	2.5R


Gain vs Voltage
HMS hodo XP2262 PMT
1.00E+09
1.00E+08
1.00E+07
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
Gain
800
1300
1800
2300
Voltage
model (new pmt)
h1x16m data
h1x12p data
h1x01m data
h1y06p


Gain vs Voltage
HMS hodo XP2262 PMT
5.00E+08
5.00E+07
5.00E+06
5.00E+05
Gain
1500
2000
2500
Volts
model (new pmt)
h1x16m data
h1x12p data
h1x01m data
h1y06p