High Voltage Generator and Voltage Divider for 8-stage PMT

TwinBase NG20-08

The TwinBase NG20-08 is a combined negative high voltage generator and voltage divider for 8-stage photomultiplier tubes (PMT). The NG20 has been designed to operate with a supply voltage of nominal 3.3 V, but will operate with supply voltages between 3.1 V and 5.5 V.

Highlights

- **Single supply voltage: 3.1 V to 5.5 V**
- **Power consumption: 120 mW at HV = 1000 V**
- **Standby mode: 0.5 mA at HV = 0 V**
- **PMT gain control via analog or digital input**
- **Digital temperature sensor**
- **For small-diameter PMTs (<2-inch)**
- **Transistorized high voltage divider supports high PMT anode currents in excess of 50 µA**

Features

- The NG20 is intended for high-gain or high count rate spectroscopy applications where the average PMT current may reach 50 µA.
- The power base incorporates a transistorized voltage divider chain, which presents a small load to the high voltage generator (71 MΩ to ground). At the same time it can support high average anode currents causing only minimal gain drifts in the photomultiplier.
- With a 3.3 V power supply and a high voltage of 1000 V the device consumes only 120 mW.
- The supply current is very nearly proportional to the PMT high voltage and reduces to only 0.5 mA when the high voltage is set to zero.
- The NG20 is mounted in-line with small-diameter PMT
- Related devices are NP10 and NQ10 series plug-on HV modules.

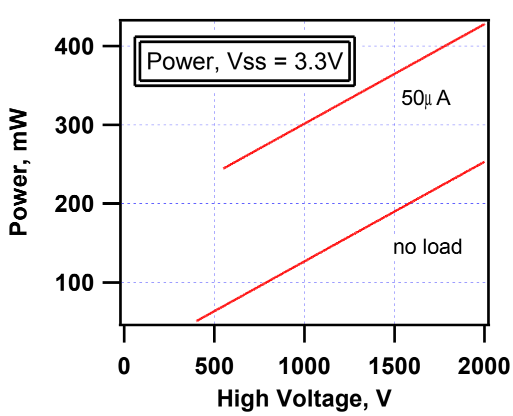


Figure 1: Power draw vs. high voltage for small and large PMT anode currents (no load and 50 µA, respectively). At low count rates and moderate PMT gains (R < 1 kcps and G < 0.2 M) the no-load curve is a fair estimate of the power draw when used with NaI(Tl). Hence, at HV = 1.0k V the supply current is only 37 mA at Vss = 3.3V. For a 24-hour period that is a charge of only 0.89 Ah.

Three AA NiMH rechargeables (1.8 Ah) will power this system for 2 days.

Specifications Vss = 3.3V unless otherwise noted

Parameter	***Symbol***	***Min***	***Typ.***	***Max***	***Comment***
General					
Supply voltage	VSS	3.1V	3.3V	5.5V	cf fig.
Ripple voltage	VRR			0.05%	at max HV and max load
HV temperature drift	ΔHV / ΔT		-130ppm/K	200ppm/K	TBD
Sensitivity to supply voltage	ΔHV / ΔVSS		0.5 mV/mV	1mV/mV	
HV range	HV_out	500V		1800V	
Max. HV output current	I_{HV}		180μA		HV = 2000V
Quiescent current	Iq		0.48 mA	0.70 mA	HV = 0V
Supply current, no load	Iss		37mA		HV = 1000V
Supply current, high load	Iss		90mA		HV = 1000 V, I_anode = 50μA
HV-generator					VSS = 3.3V
HV-load		47 MΩ	50 MΩ	53 MΩ	Total load, generator and divider
HV-capacitance	CHV	16nF	17nF	18nF	
HV output impedance	ZHVO		2.7 MΩ		Open loop
HV output impedance	ZHV		20 kΩ		Closed loop
HV-drop vs pulse charge	ΔHV / ΔQ		59mV / nC		
Control interface					
HV / V_set	M	980	1000	1020	at max HV
V_set input impedance		0.99 MΩ	1.00 MΩ	1.01 MΩ	

Specifications – continued Vss = 3.3V unless otherwise noted

Parameter	***Symbol***	***Min***	***Typ.***	***Max***	***Comment***
HV-divider					
DC-impedance at cathode	ZC	47 MΩ	52 MΩ	57 MΩ	
DC-impedance at dynode 8	ZD10		20 kΩ		
Anode impedance to ground	ZA	99 kΩ	100 kΩ	101 kΩ	

Absolute maximum ratings

Exceeding the absolute limits will most likely damage the device. Correct operation is not guaranteed at these limits. Operational limits are shown next to the absolute limits.

Parameter	***Limits***	
	Absolute	***Operation***
V_supply	-0.5 V – 14 V	3.1V – 5.5V
V_set	-0.5V – +2.0V	0V – 1.8V
HV out	2000V	500V – 1800V

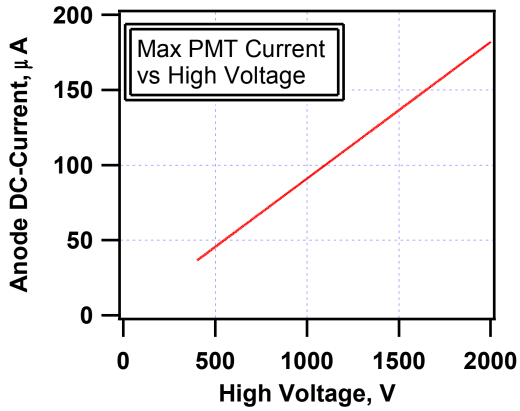


Figure 2: The maximum average PMT anode current is nearly proportional to the high voltage.

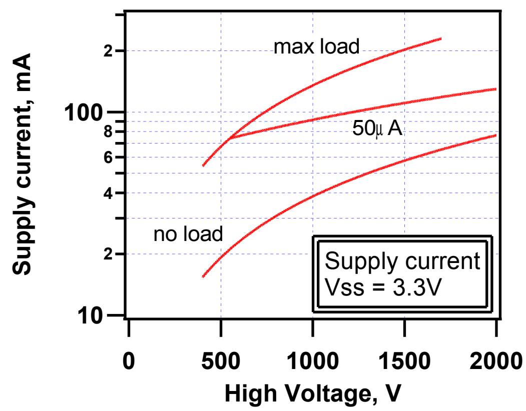


Figure 3: Supply current vs. output high voltage for PMT currents of 0, 50 µA and maximum value.

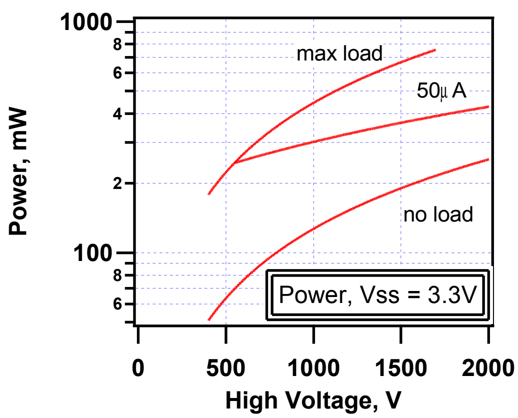


Figure 4: Power draw at fixed Vss vs. high voltage.

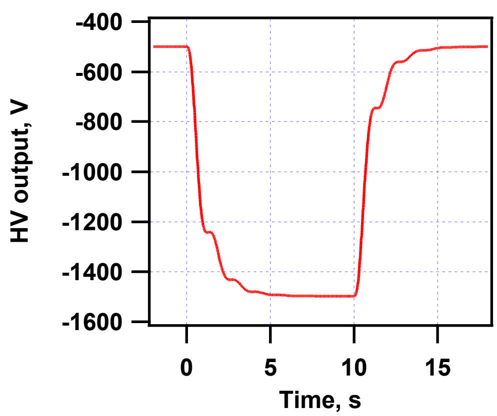


Figure 5: Response to switching the high voltage. Input is a 10 s wide pulse at V_ctrl from 0.5V to 1.5V

Theory of operation – HV generator

The NG20-08 consists of transformer-based high voltage generator and a separate transistorized high voltage divider that feeds the photomultiplier dynodes and the cathode.

The high-voltage generator core is a proportional module that creates an output voltage 800 times higher than its input voltage. Linear control circuitry compares the actual high voltage with the required high voltage.

Users can set the high voltage through a 14-pin connector on the back of the power base. The pin out is shown in the table below.

Pin	*Function*	*Pin*	*Function*
1	DAC_CLK	2	DAC_SYNC#
3	GND	4	DAC_DATA
5	V_CTRL	6	V_DAC
7	VA3	8	VSS
9	Anode	10	GND
11	GD	12	T_DATA
13	T_CS#	14	T_CLK

Table 1: Pinout of connector J1 on the PCB.

In the most simple case, an analog voltage will be applied to V_ctrl. The V_ctrl input connects to a buffer amplifier with a very high input impedance via a 1 kΩ, 1 µF RC-filter. The same amplifier input is connected to a DAC via a 1 MΩ resistor. The DAC powers up with a zero output voltage and remains at that setting if not externally programmed. Hence, a voltage applied at the V_ctrl input will override any DAC voltage, and the resulting nominal high voltage will be -1000 times the value of V_ctrl.

Ripple reduction and immunity to large scintillator / PMT pulses are dramatically improved by the huge 17 nF / 2500 V capacitance added to the embedded HV-generator.

Theory of operation – HV-divider

The divider consists of two chains of 14 bipolar PNP transistors in Darlington configuration. Each PNP ladder is biased in proportion to the applied high voltage, with I = 4.5 µA at HV = 1000 V. A resistive ladder controls the voltage at the base-emitter junctions of the PNP-transistors. It has an impedance of 98 MΩ in parallel with 17 nF of capacitance to ground.

The divider represents a passive, linear load to the high-voltage generator of about 52 MΩ || 17 nF.

The divider has a very low output impedance at the dynode taps and can therefore support high PMT signal currents with minimal gain shifts. At I_anode = 50 µA the gain of a typical 8-stage PMT will shift by less than 1% with this divider.

In proportional HV-dividers, active and passive, the PMT gain will increase with the anode current because the voltage between anode and dynode 10 reduces. In the NG20 this effect is partially compensated for by the effective DC output impedance of 10 kΩ to 20 kΩ of the high-voltage generator. Hence, gain drifts are expected to be less than 1% at 100 µA anode current.

Theory of operation – The DAC

Alternatively to using the analog V_ctrl input to control the HV, there is an on-board 12-bit serial DAC (DAC7512 from Texas Instruments). It's interface is SPI™ and Microwire™ compatible. The DAC pins are accessible through pins 1 – 4 on connector J1. The DAC reference voltage is 3.0V±0.2%. Hence, a digital value of 4095 corresponds to V_DAC = 3.000V. Since V_ctrl overrides V_DAC , be sure to disconnect V_ctrl when using the DAC.

The temperature sensor

The NG20 series devices include a digital temperature sensor, TC77, from Microchip (www.microchip.com) with an interface that is SPI™ and Microwire™ compatible. It is accessible through the pins 11 – 14 on connector J1. The sensor measures the power base temperature once per second with a resolution of 0.0625ºK and an accuracy of 1K.

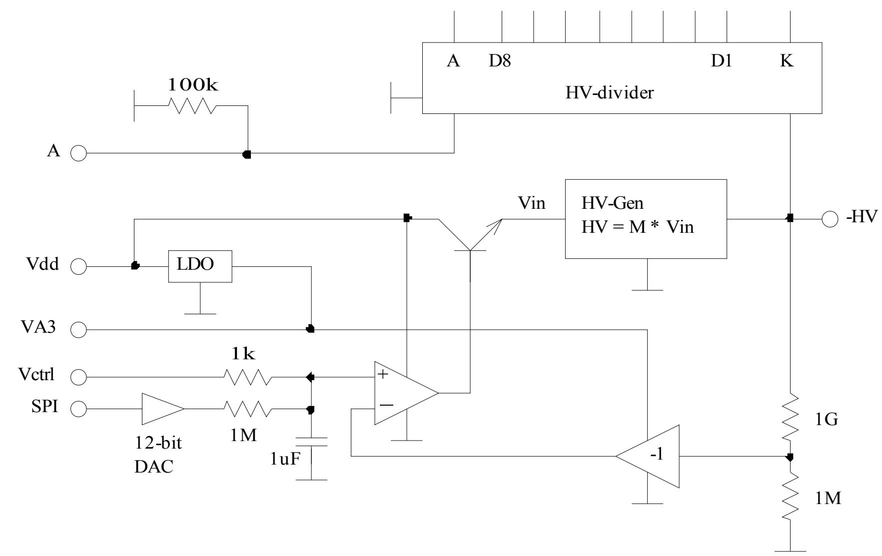
Divider ratio

For HV = 1000 V the cathode and dynode voltages are, in volt:

K	***D1***	***D2***	***D3***	***D4***	***D5***	***D6***	***D7***	***D8***
1000	900	800	700	600	500	400	300	200
R	R	R	R	R	R	R	R	2 R

One resistor unit R equals 22 MΩ.

Functional Block Diagram



Drawing 1: Block diagram of the power base. The error amplifier compares an attenuated version (1000:1) of the high voltage with the input voltage at its positive input. Hence the output voltage is 1000 times the input voltage. Note that a positive input voltage is used to create a negative high voltage. The input voltage is provided through the V_CTRL input or by the DAC. Disconnect V_ctrl when using the DAC.

A single supply, Vdd, powers the entire circuitry including all amplifiers. The high voltage generator core receives power via a shunt transistor whose conductance is controlled by the error amplifier.

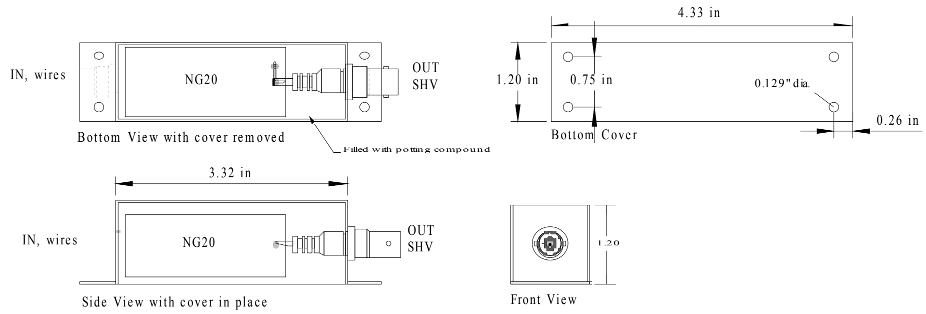
The high voltage divider is fed the negative high voltage. Voltage taps are provided to power the cathode (K) and the 8 dynodes of the PMT. The anode is DC-coupled and there is a safety resistor of 100 kΩ to ground.

Dimensions and connectors

The NG20 series units of PMT HV-supplies have been designed to be embedded inline with a small-diameter PMT. Hence, packaging depends very much on the application and can be specified by the user.

Most often the flying leads from the PMT are soldered directly to the TwinBase PC board and the whole unit is encapsulated in a protective HV sealant. Electrical connection to the TwinBase is made via a wire harness. After encapsulation, the unit measures about 2.5 inch by 1.2 inch by 1.2 inch (L x W x H).

The NG20 can be used as a HV-generator for proportional wire chambers. In this case it is fitted with a 22 MΩ output resistance to avoid chamber break down. The unit is mounted in a metal housing measuring about 3.3 inch by 1.2 inch by 1.2 inch (L x W x H), as shown below.



Revision history:

R1	Oct. 2007	Production release; initial document