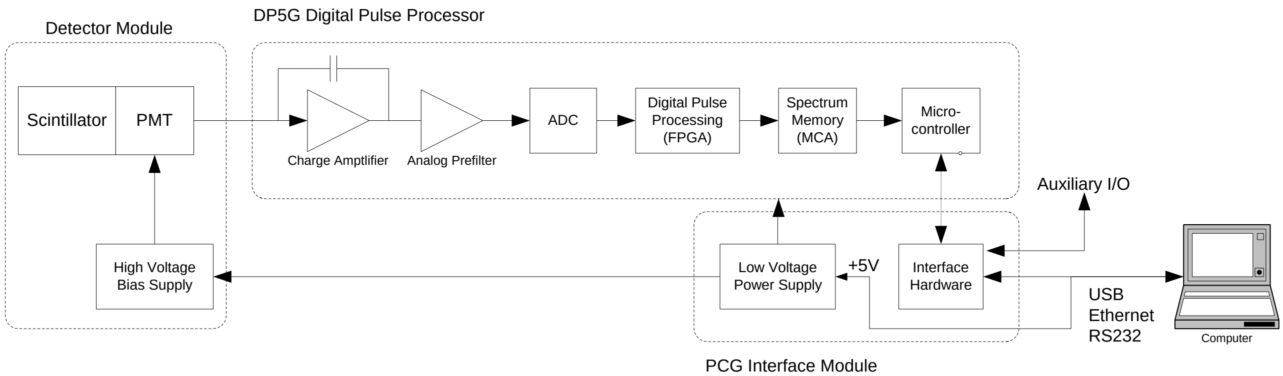
DP5G USER MANUAL ADDENDUM

Overview

The DP5G is a member of Amptek's DP5 signal processing family. It is a component in a complete γ-ray spectrometer, sketched below. The DP5G includes only the core signal processing functions. A complete system must also include a detector module (scintillator, PMT, HV supply, tube base) and interface circuitry with power supplies and connectors for the serial connection. Amptek can provide an OEM user with the DP5G alone, or can provide it with a PCG interface module, or can provide a complete system, including the detector module. The complete system is a separate Amptek product, the Gamma-Rad5.



This "addendum" will define the interfaces for the DP5G and the PCG (even if a customer chooses to implement a different interface module, the PCG design provides an application example). The DP5G, although a custom printed circuit board, is a variant of the basic DP5 digital signal processor. There exists a rather extensive set of documentation for the DP5, including specific sheet, user manual, and programmer's guide. The user should refer to the standard DP5 documentation for the core signal processing and software. This "addendum" defines the interface portion of the DP5 which have been changed.

At the top level, there are two major changes in going from the DP5 to the DP5G.

1) The analog prefilter on the DP5 (which is designed for use with a separate low noise charge amplifier) is replaced, in the DP5G, with a charge amplifier optimized for use with scintillator/PMT sensors.

2) There is a 50 pin connector which separates the signal processing circuitry on the DP5 (microcontroller and FPGA) from the external interfaces on the DP5G (USB connector, Ethernet connector, power regulators, buffers for auxiliary signals, etc). On the standard DP5, this is all on a signal board. The hardware and control software are the same but the division onto circuit boards is different.

This addendum describes (1) the analog interface of the DP5G, (2) the 50 pin connector and the hardware to which it interfaces, (3) the PCG output connectors, and (4) the mechanical interfaces.

DP5G ANALOG INTERFACE

The analog input of the DP5G is significantly different from that of the DP5. Some key changes include (1) the fact that the first stage is a charge amplifier, optimized for signals from a scintillator/combination, (2) the coarse gain range is smaller, from 1.6 to 6.5, because one can adjust the PMT bias for a larger range, and (3) the input connector is a threaded coaxial connector, more suitable for a PMT output.

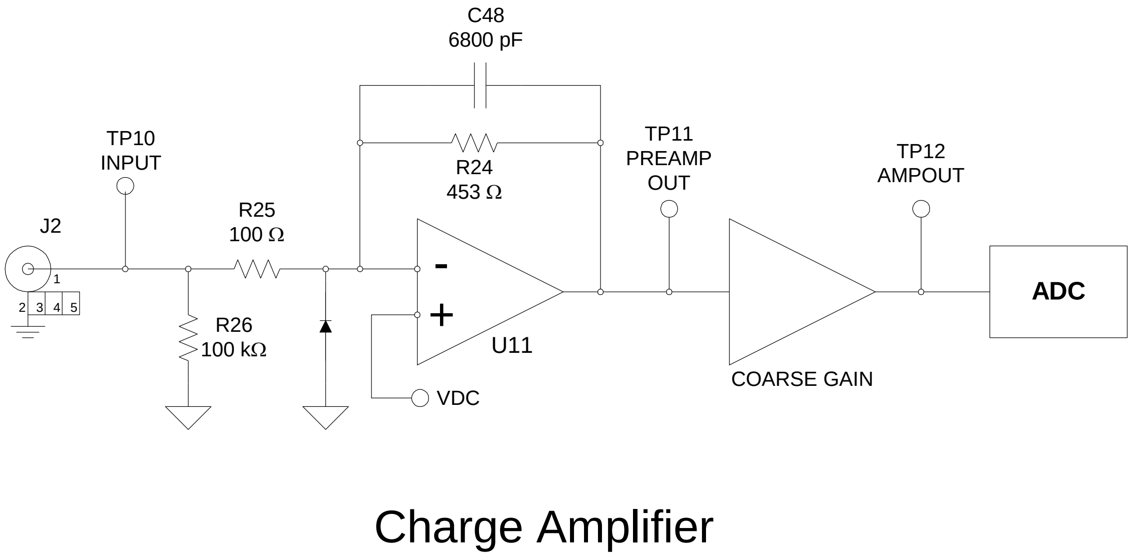


Figure 1. Schematic of charge amplifier at DP5G input

- **Input signal:** The input to the DP5G is the AC coupled anode output of a PMT, a current pulse, not a voltage pulse. The current into U11 is integrated on the 6800 pF feedback capacitor.

  NOTE: This has been a source of confusion for many customers. The current pulse from the PMT must be connected directly to the DP5G. If the PMT is first connected to an external preamplifier or transimpedance amplifier, and the preamp output connected to the DP5G, it will not work. These preamplifiers produce a voltage pulse while the DP5G requires a current input. The circuitry around U11 must be modified if the DP5G is preceded by any amplifier. Contact Amptek, Inc. for details.

  The DP5G can be used with either a positive or negative bias on the PMT. In either case, the signal is a pulse of electrons into the DP5G, as illustrated in Figure 3.

- **Input connector**: The DP5G uses a threading coaxial connector, RG174. The board has the female end, Samtec MMCX-J-P-H-RH-TH1. An example mate would be an MMCX to BNC cable, Samtec RF174-Q3SP1-Q4SP3-0300.

- **Charge amplifier conversion gain**: The input to the charge amplifier is a current pulse with total charge Q_{IN}. The charge amplifier has C_F=6800 pF, with a conversion gain of $1/C_F$, meaning that at TP11 one measures a voltage pulse with magnitude

  $$\Delta V_{TP11} = \frac{Q_{IN}}{C_F}$$

  In a typical application, $Q_{IN} = 10^{-9}$ C, so ΔV=150 mV. For example, if one measures a gamma ray spectrum with a scintillator and a photomultiplier, the charge can be written

  $$Q_{IN} = E_\gamma N_{phot} \varepsilon G_{PMT}$$

  where E_γ is the energy of the gamma-ray (in MeV), N_{phot} is the light yield of the scintillator, in photons/MeV, ε is the quantum efficiency (the product of the light collection efficiency of the system and the quantum efficiency of the photocathode), and G_{PMT} is the gain of the photomultiplier tube. For a 662 keV gamma-ray measured by a NaI(Tl) scintillator (3.8×10^4 photons/MeV) with a bialkali photocathode (ε=0.3) and 900V bias on a typical 9 stage PMT (G=10^5), Q_{IN}=1.2x10^{-10}C and ΔV=18 mV. Note that the system conversion gain depends strongly on the PMT gain.

- **Coarse gain**: There are four coarse gain settings: 1.6, 2.6, 4.1, and 6.5. This permits the system gain to be changed by a factor of four, with overlapping fine gains. One can adjust the HV bias on the PMT to obtain a larger gain range.

- **Pulse Shape**: The input signal, the current pulse into J2 from the preamplifier, typically has a very fast rising edge and then an exponential decay determined by the properties of the scintillator. The amplifier integrates this current to measure the charge but with a 3.2 μs time constant. The figure below shows the pulse shapes measured for a specific example, ^{60}Co gamma-rays measured using a NaI(Tl) scintillator with a PMT. For more information, refer to page 10.

  The light blue trace represents the AC coupled anode output of the PMT. It was measured at TP10. The current pulse across the 100 kΩ resistor produces a voltage pulse which can be measured. The 0.23 μs decay time of the NaI(Tl) can clearly be seen.

  The green trace was measured at TP12, the input to the ADC. There is a DC offset of about 300 mV, determined by VDC. The risetime of this pulse is determined by the time constant of the scintillator. The decay time of this pulse is due to the 3.2 μs time constant of the U11 feedback components.

  The dark blue trace is the shaped pulse, measured at the DAC output. The peaking time was 2.4 μs, the flat top 1 μs. The scintillator time constant shifts the pulse shape from the true trapezoidal shape, which is the impulse response of the pulse shaping.

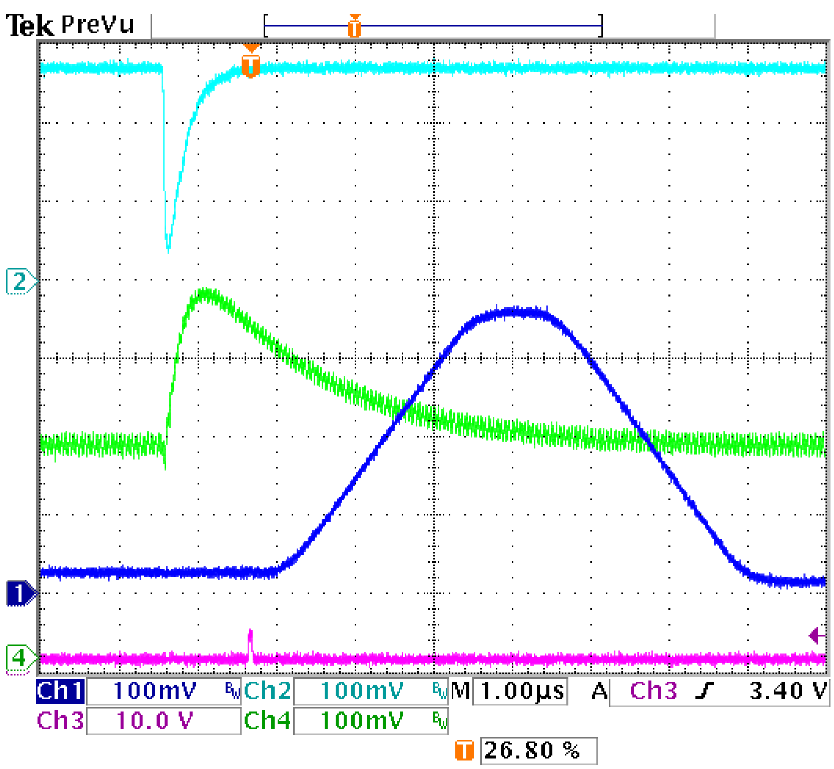


Figure 2. Oscilloscope traces measured using a NaI(Tl) scintillator and a PMT. Light blue: PMT output measured at TP10. Green: TP12 (ADC INPUT) Dark blue: Shaped pulse

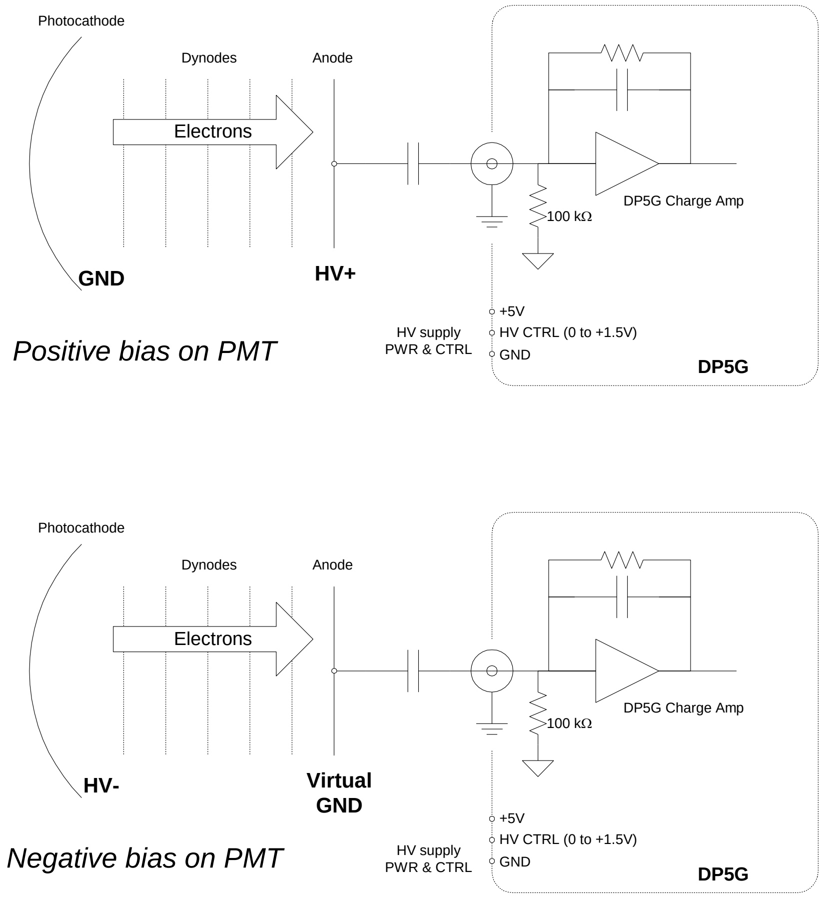


Figure 3. Figures showing operation with both positive and negative PMT bias voltages. In both cases, the signal is a pulse of electrons across the coupling capacitor and into the DP5G charge amp.

DP5G TO DPG CONNECTOR

J1 on the DP5G is the main connector to the PCG (J4 on the PCG). This is the 50 pin connector which separates the microcontroller, FPGA, and similar circuits on the DP5G from the Ethernet connector, USB connector, power regulators, and similar circuits on the PCG. The user may develop a custom interface board but will utilize the 50 pin connector. The DP5G interface is defined by the table, schematic, and discussion below.

Pin	Name	Description	Pin	Name	Description
1	3.3V	Pins 1-4 are connected in parallel and are the input power for the DP5G. This must be regulated 3.3VDC.	26	Reserved	Do Not Connect
2	3.3V		27	GND	
3	3.3V		28	GND	
4	3.3V		29	A_IO1	SCA 1
5	GND		30	A_IO2	SCA 2
6	GND		31	A_IO3	SCA 3
7	LED_GRN	Ethernet LED	32	A_IO4	SCA 4
8	RDN	Ethernet RX-	33	GND	
9	LED_YEL	Ethernet LED	34	GND	
10	RDP	Ethernet RX+	35	A_IO5	SCA 5
11	GND		36	A_IO6	SCA 6
12	TDP	Ethernet TX+	37	A_IO7	SCA 7
13	SDA	I2C SDA	38	A_IO8	SCA 8
14	TDN	Ethernet TX+	39	GND	
15	SCL	I2C SCL	40	GND	
16	GND		41	AUX1	Digital auxiliary I/O
17	TX0	Logic level RS232 TX0	42	AUX2	Digital auxiliary I/O
18	VBUS	USB VBUS	43	AUX3	Digital auxiliary I/O
19	RX0	Logic level RS232 RX0	44	AUX4	Digital auxiliary I/O
20	USB-	USB D-	45	GND	
21	/RS232_INV		46	GND	
22	USB+	USB D+	47	Reserved	Do Not Connect
23	GND		48	Reserved	Do Not Connect
24	Reserved	Do Not Connect	49	DACOUT	Used to display processed pulses
25	Reserved	Do Not Connect	50	Reserved	Do Not Connect

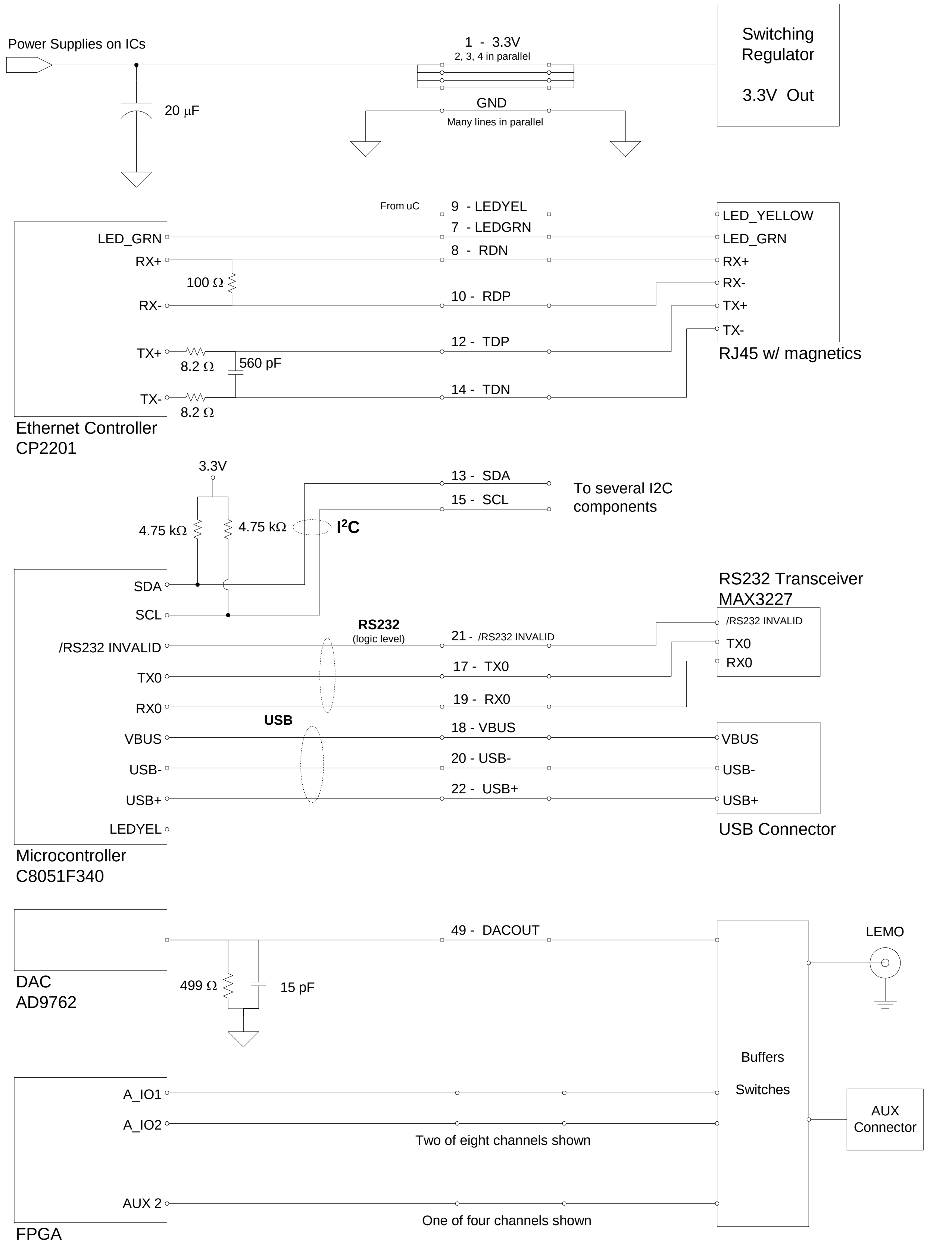


Figure 4. Schematic of DP5G power and communication interface.

Discussion

- **Power input:** The DP5G requires a regulated 3.3V input. The DP5G does not regulate this input and has no protection circuitry. It directly powers the digital circuits, and through a filter powers the analog circuitry. Input current is typically 160 mA. Pins 1-4 are in parallel for redundancy.
- **Ethernet:** The CP2201 Ethernet controller connects via J1 to an Ethernet connector with magnetics on the PCG (P/N Tyco 660572-1). Refer to the CP2201 data sheet for details. Note that the "Ethernet Yellow" LED line is driven by the μC on the DP5G.
- **I^2C**: There are several I^2C devices used on the PCG, including a DAC used to control the HV supply in the Gamma-Rad5 (discussed below). A customer may use additional I^2C devices and command them through the DP5G. See the DP5 programmer's guide for details.
- **RS232**: The DP5G μC produces logic level RS232 signals, which are sent via J1 to the PCG. An RS232 transceiver is located on the PCG.
- **USB**: The DP5G μC produces the USB signals, which go to a standard USB connector on the PCG. The VBUS line is only used by the DP5G as an indicator to the μC. On the PCG, the USB VBUS line can be used to power the system (discussed below).
- **Auxiliary**: There are several auxiliary output available on the DP5G. These same lines are available on the DP5 and their use is documented in the DP5 User Manual. The analog output (used to display shaped pulses for diagnostic purposes) is generated by a DAC on the DP5G. The remaining auxiliary signals are digital inputs and outputs which connect directly to the FPGA on the DP5G. The PCG contains buffer and protection circuitry.

  The AUX1 and AUX2 lines on the DP5G correspond to the AUX_IN_1 and AUX_IN_2 lines on the DP5. The AUX3 and AUX4 lines on the DP5G correspond to the AUX_OUT_1 and AUX_OUT_2 lines on the DP5.
- **Reserved**: There are several lines on J1 which are reserved. No connection should be made to these.

PCG DESCRIPTION

The DP5G contains the core signal processing functions but does not contain signal connectors or any power supplies. Amptek can provide an optional additional board, the PCG, which provides these functions. This section shows the architecture of the low voltage power supply, which takes a loosely regulated 5V input and produces the voltage used on the DP5G. It also shows the circuit used to control a HVPS. Note that the PCG does not include the PMT HVPS.

PCG Connectors

Power (J1)

Provides power to the PCG. Switching regulators on the PCG (discussed below) provide power to PCG circuitry as well as to the DP5G and to the HV supply.

Power Jack on PCG: P/N Molex 39-30-1020.

Mating Plug: Housing P/N Molex 39-01-2020. Terminal P/N could be Molex 44476-1112 (18-24 ga) or Molex 44476-3112 (16 ga).

Pin #	Name
1	VIN (+5 V DC)
2	GND

PMT (J2)

Provides power and a DC voltage which can control a PMT high voltage power supply. Note that the DP5G does not include a HV power supply, but these signals can interface to and control many suitable HVPS modules. The control circuit is discussed below.

Power Jack on PCG: Molex 53014-0310

Mating Plug: Housing Molex 51004-0300, Terminal Molex 50011-8100

Pin #	Name
1	HV CONTROL
2	PWR (5VDC)
3	GND

Ethernet (J3)

Standard Ethernet connector (RJ-45)

USB (J5)

Standard USB Type B jack. The DP5G can be powered from the USB bus (see discussion below).

Auxiliary LEMO (J6)

P/N Lemo EPK 00.250.NTN

This is the only coaxial auxiliary I/O line available. For maximum flexibility, the DP5G includes an analog switch which permits one to connect either AUX1 or DACOUT to the LEMO. Since AUX1 is AUX_IN_1, one can use the LEMO with the DP5G general purpose counter, e.g. to count pulses from a ^{3}He neutron monitor. We recommend connecting DACOUT to the LEMO for diagnostic purposes, to view the shaped pulses, as discussed in the DP5 User Manual.

Auxiliary (J7)

18-pin 2 mm spacing. For orientation, refer to DP5G/PCG assembly drawing.

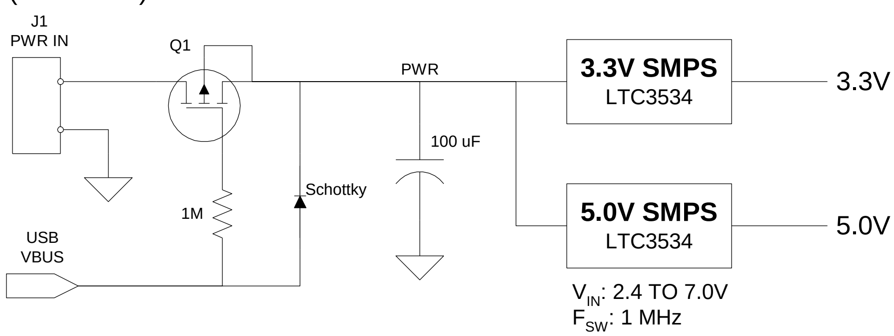
Connector on PCG: Samtec SMM-109-2-L-D-LC.

Mates with P/N Samtec TCMD-09-D-XX.XX-01.

Pin #	Name	Pin #	Name
1	GND	2	SCA 1
3	SCA 2	4	SCA 3
5	SCA 4	6	GND
7	SCA 5	8	SCA 6
9	SCA 7	10	SCA 8
11	GND	12	AUX 2
13	AUX 3	14	AUX 4
15	EXT	16	GND
17	RS232-RX	18	RS232-TX

PCG LOW VOLTAGE POWER SUPPLY

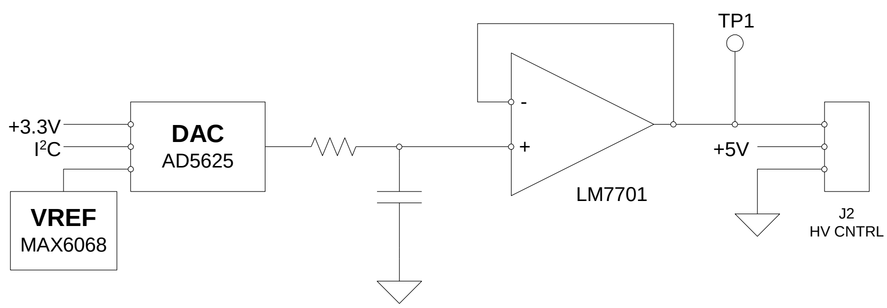
A schematic of the power supply on the PCG is shown below. It takes as input either (a) the 5V VBUS from the USB or (b) a voltage from 2.4V to 7V on the J1 connector. There are two switch mode power supplies on the PCG, one which produces 5V to power the PMT HVPS and one which produces 3.3V to power the DP5G and circuitry on the PCG. Q1 switches the power sources, drawing power from which ever source is higher (J1 or USB).



The DP5G typically draws 165 mA on the 3.3V line. The current into J1 is typically 155 mA at 5V.

PCG HV Bias Control

The circuit below is used to generate a control voltage to the PMT HVPS in the Gamma-Rad5 and can be used with other detector modules. Via software, a command is sent to the DP5G which sets the DAC output voltage. Using the standard DP5G configuration packets, the value is divided by 1000. That is, setting the “HV” to 900V in the DP5G software results in 900 mV at the output of the DAC and hence at pin 1 of J2. The LM7701 simply buffers this DAC output.



PMT TO DP5G INTERFACE

The following plots show how to debug the connection between the PMT and the DP5G front end. Please refer to the schematic in Figure 1.

First measure the input signal directly, at TP10 (or equivalently at the R25 resistor, which is easier to probe). The PMT's AC-coupled current pulse across the 100 kΩ R26 yields a voltage pulse which can be seen. Figure 5 (left) shows a typical result. The DC level is about 0.3V, from VDC (the U11 feedback ensures that the two inputs to U11 will be at the same DC level). The shape of this pulse arises from the scintillator's time constant.

Second, measure the charge amplifier output, at TP11. The input current is integrated by C48, then the result is differentiated by the 3.2 µs pole formed by C48 and R24. Note that even a fast time constant in the scintillator will yield a valid pulse here, because the current is integrated on C48. The signal at TP11 should have a DC offset of about 0.3V, a step of a few hundred mV, a risetime determined by the scintillator time constant, and a 3.2 µs fall time. If a different pulse shape is being produced at TP11, then the DP5G cannot function properly.

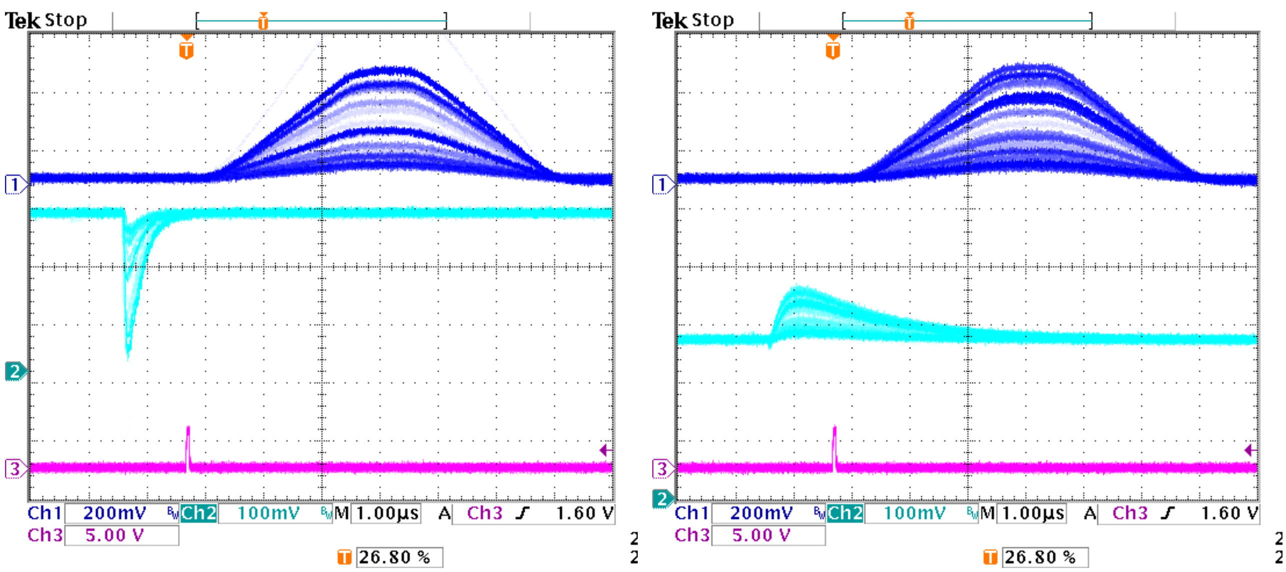


Figure 5. Left: Light blue trace shows TP10, the DP5G input. Right: Light blue trace shows TP11, the charge amplifier output.

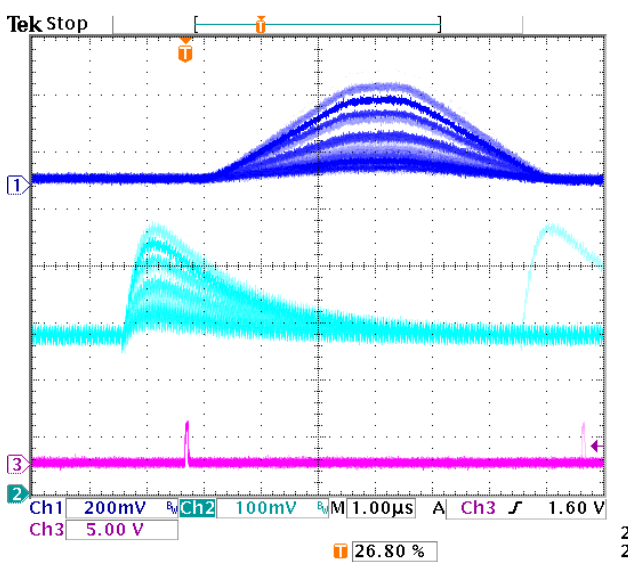


Figure 6. Light blue trace shows TP12, the input to the ADC.

Scintillator Time Constant

Some users are concerned that the ADC, at 20 or 80 MHz (12.5 or 50 ns clock) is not fast enough to catch the signal from a fast scintillator. But U11 integrates the current to produce a signal proportional to the charge, and this is slow enough to be accurately digitized. The plot below shows a PSPICE simulation of the TP11 signal for three different scintillator time constants. The dots are spaced at 50 ns, showing how the waveforms are digitized, and showing that the waveforms are captured quite well even for a fast current pulse, because the output of U11 is the time integral of the input current pulse (with a 3.2 μs pole).

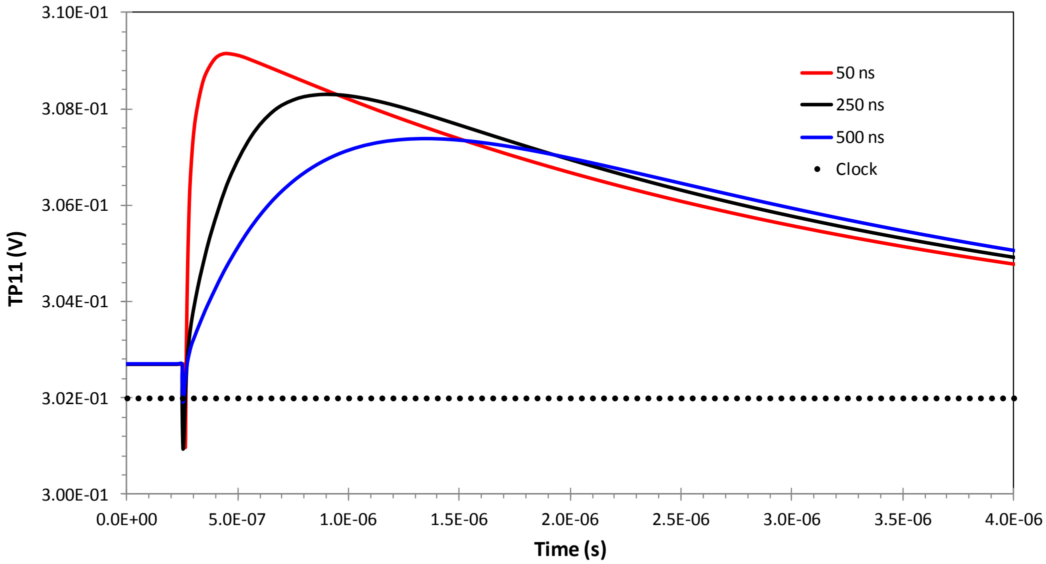


Figure 7. PSPICE simulation of TP11 (charge amplifier output) for various scintillator time constants