



DCC-100

Detector Control Module

PCI compatible detector control module for single photon counting experiments

- Power supply and gain control for Hamamatsu H7422, H5783 or H5773 modules
- Gain control for Hamamatsu R3809U MCP via FuG power supplies
- Overload shutdown of detectors in conjunction with bh HFAC-26 preamps
- Power supply for thermoelectric coolers, particularly for H7422
- Short circuit protected +12V, +5V and -5V power supply for preamps and detectors
- Software switched +12V, +5V and -5V power supply outputs for detector on/off control
- High current digital outputs for shutter and filter control
- PCI card, software for Windows 95, 98, 2000 and NT



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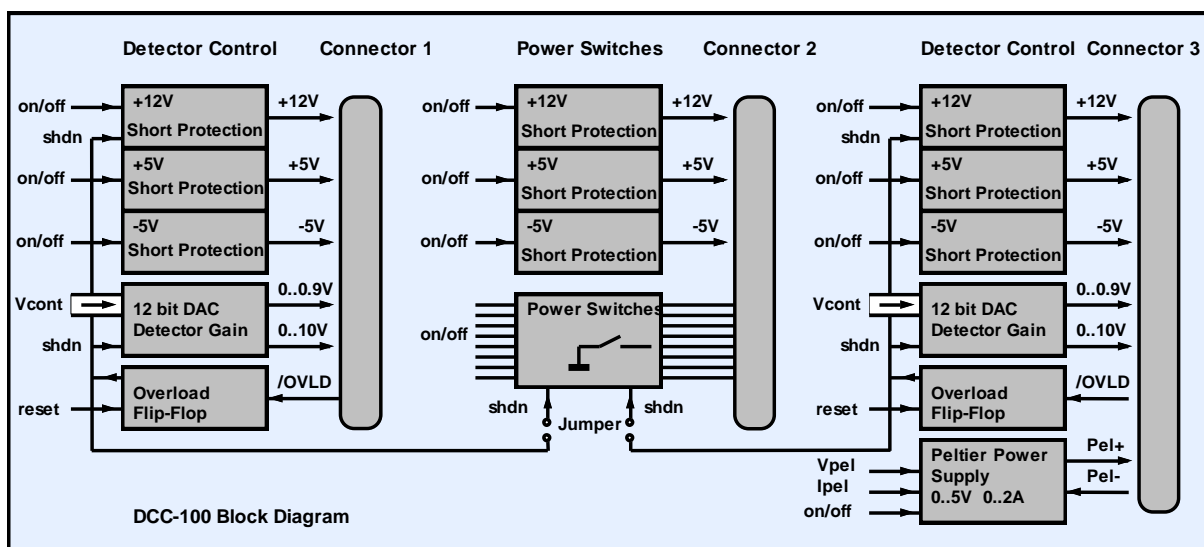
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Introduction

The DCC-100 module is used to control detectors in conjunction with **bh** photon counters. It can be used to control the gain of the Hamamatsu H7422, H5783, H6783 or similar photosensor modules by software. The gain of MCPs and PMTs can be controlled via the FuG HCN-14 high voltage power supply. In conjunction with **bh** preamplifiers, overload shutdown of the detectors can be achieved. Furthermore, the DCC-100 delivers the current for thermoelectric coolers, e.g. for the Hamamatsu H7422. High current digital outputs are available for shutter or filter control. The DCC-100 is a PCI module for IBM compatible computers. It works under Windows 95, 98, 2000 and NT.

Structure of the DCC-100

The block diagram of the DCC-100 is shown in the figure below.



The DCC-100 contains two detector control blocks and one general purpose power switch block.

Detector control blocks

The detector control blocks contain power supply outputs for detectors, a digital-to-analog converter (DAC) for detector gain control, and an overload shutdown circuit.

The power supply outputs are short-circuit-protected and deliver +12 V, +5 V and -5 V. The outputs can be switched on an off by software.

A 12 bit DAC is used to control the gain of the detector. It delivers the 0 to +1.0 V control voltage required for Hamamatsu photosensor modules (H7422, H5783, H5773 etc.) and a 0 to +10 V control voltage for FuG high voltage power supplies.

Both detector control blocks have a detector overload shutdown function. The shutdown function works in conjunction with **bh** HFAC-26 preamplifiers. If the preamplifier detects an overload condition it sends an active low overload signal (/ovld) to the DCC-100. This signal sets the overload flip-flop which shuts down the detector control voltage and the +12 V detector power supply. Furthermore, it can be used to deactivate the switches in the power switch block (see below).

One of the detector control blocks contains a power supply for thermoelectric coolers.

High Current Switch Block

The high current switch block contains power supply outputs for detectors and preamplifiers and eight high-current MOSFET switches to operate shutters, motors or magnetic actuators.

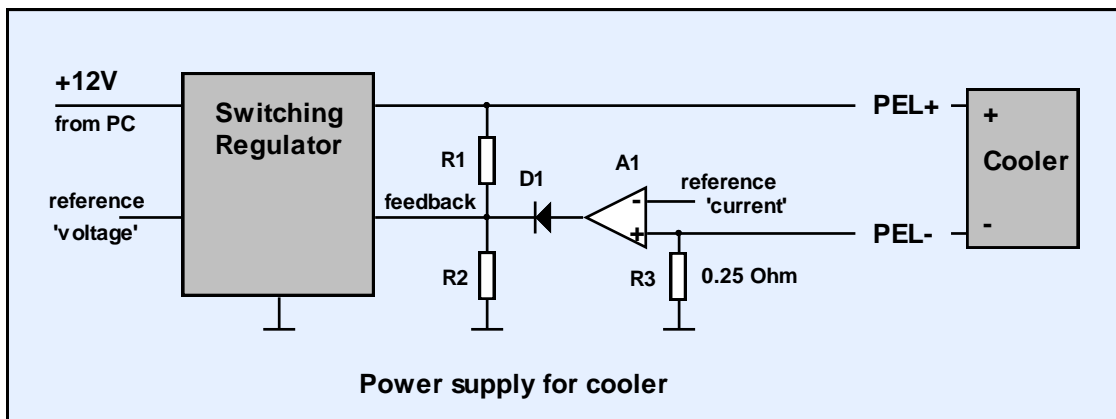
The power supply outputs are short-circuit-protected and deliver +12 V, +5 V and -5 V. The outputs can be switched on an off by software.

The MOSFET switches are able to switch currents up to 2A and voltages up to 20V. One side of each switch is connected to ground, the other side is available at the output connector. The switches are **not** short circuit protected.

The high current switches can be shut down (i.e. set into the non-conducting state) by one or both overload signals from the detector control blocks. The configuration is set by jumpers on the DCC-100 board, see 'Configuration of Power Switch Shutdown'.

Power supply for thermoelectric cooler

Power supply for thermoelectric coolers is available at connector 3. The output delivers up to 5 V and 2 A. Both voltage and current can be selected by software. The device automatically controls either the output voltage or the output current. Voltage control is active as long as the current through the load is smaller than the current limit set by the software. When the current through the load reaches the current limit the device automatically switches to current control. A block diagram is shown in the figure below.



A switching regulator is used to generate the supply current for the cooler. The cooling current flows through the sensing resistor R3. As long as the voltage at R3 is smaller than the reference voltage at A1 ('current' reference) A1 is inactive and the switching regulator works as a normal voltage stabiliser. If the voltage at R3 exceeds the reference voltage at A1, the amplifier becomes active, and, via D1, overwrites the feedback voltage of the switching regulator. This causes the regulator to reduce the output voltage until the voltage at R3 equals the reference of A1.

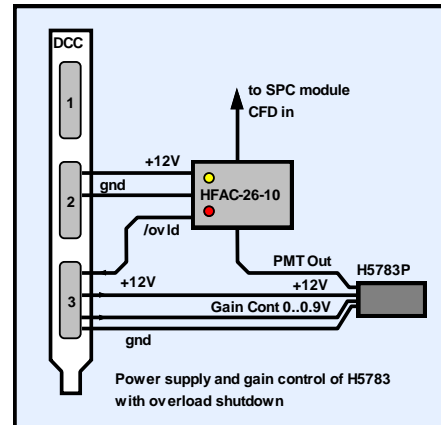
Please note that the current control can work only if the cooling current flows back into the 'PEL-' pin of the DCC-100. Therefore make sure that the '-' side of the cooler is not connected to ground. Moreover, make sure that you don't reverse the 'PEL+' and 'PEL-' lines. This would heat the detector instead of cooling it and probably result in severe damage of the detector assembly.

Applications

Some applications of the DCC-100 are described below.

Controlling H5783 and H5773 photosensor modules

The H5783 and the H5773 are high speed miniature PMT modules of Hamamatsu. The modules contain a small photomultiplier along with high voltage generator. The resolution in the TCSPC (time-correlated single photon counting) mode is typically 150 to 200 ps. The H5783 comes in various cathode versions for the wavelength range up to 820 nm. The H5783 can be controlled in a similar way as the H7422. The connections are shown in the figure right. A HFAC-26-10 preamplifier with a 10 μ A overload threshold is used to amplify the single photon pulses and to send an overload signal to the DCC-100.



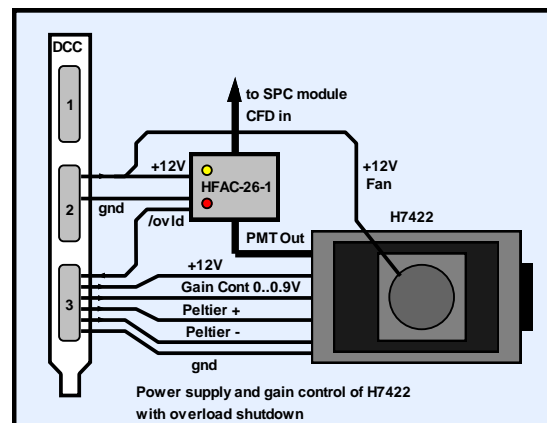
A second H5783 can be controlled separately via connector 1. In this case the power supply for both HFAC amplifiers should be taken from connector 2.

Don't connect or disconnect the signal cable from the detector to the preamplifier when the detector is switched on. This can destroy the amplifier. Make sure that the +12 V at connector 2 is switched on. Otherwise the HFAC does not work, and the overload protection is inactive.

Controlling the H7422 and H8632

The H7422 is a high speed, high sensitivity PMT module of Hamamatsu. It contains a GaAs photomultiplier along with a thermoelectric cooler and a high voltage generator. The resolution in the TCSPC (time-correlated single photon counting) mode is typically 250 ps. The H7422 comes in different cathode versions for the wavelength range up to 900 nm. The H8632 is available for the wavelength range up to 1100nm.

The recommended connection to the DCC-100 is shown in the figure right. The detector is connected to 'Connector 3' of the DCC-100. The DCC-100 delivers the +12 V operating voltage, the 0 to 1.0 V gain control voltage, and the current for the thermoelectric cooler.



The DCC-100 delivers the +12 V operating voltage, the 0 to 1.0 V gain control voltage, and the current for the thermoelectric cooler.

The output signal of the PMT is amplified by the HFAC-26-1 preamplifier. The single photon pulses at the output of the amplifier have a few 100 mV amplitude and are used to trigger the CFD input of a **bh** TCSPC module (SPC-300 through SPC-730, see manual at www.becker-hickl.de).

The HFAC-26-1 amplifier monitors the output current of the H7422. If an average current of 1 μ A is exceeded the /ovld signal of the HFAC-26 goes to 'low'. This sets the overload flip-flop in the DCC, and the gain control voltage and the +12 V at connector 3 are shut down.

Notice: The H7422 has its own overload shutdown. The H7422 may shut down if the gain control voltage changes at a rate faster than 10 V/s. The changing rate of the gain control

voltage in the DCC-100 is kept below the critical value. If the H7422 shuts down internally for whatever reason, it can only be re-activated by cycling the +12 V operating voltage.

Don't connect or disconnect the signal cable from the detector to the preamplifier when the detector is switched on. This can destroy the amplifier. Make sure that the +12 V at connector 2 is switched on. Otherwise the HFAC does not work, and the overload protection is inactive.

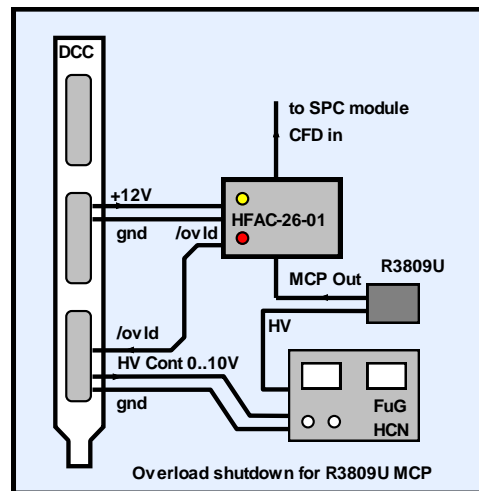
Controlling an R3809U MCP PMT

The Hamamatsu R3809U is the fastest photon counting detector currently available. It uses a microchannel plate for electron multiplication. In the TCSPC mode a time resolution of less than 30 ps (fwhm) can be achieved. MCP PMTs are extremely sensitive to overload. Because the microchannels are continuously destroyed by sputtering the lifetime of the detector is limited. The degradation effect is not noticeable under normal operating conditions. However, overloading the detector can rapidly exhaust the residual lifetime. Therefore, MCP PMTs should always be operated with overload protection, or at least with an overload indicator.

The figure right shows how an R3809U MCP can be operated with overload protection. An FuG HCN-14-3500 is used as an high voltage power supply for the R3809U. The HCN-14 is available with a 0 to 10 V control input. The high voltage is proportional to the control voltage. Therefore, the detector operating voltage can be controlled by the DCC-100 and be shut down on overload.

For overload detection, the HFAC-26-01 preamplifier - with an overload threshold of 0.1 μ A - is used.

Notice: Please observe the usual safety rules when working with high voltage. Make sure that there is a reliable ground connection between the detector and the HV power supply. Don't use broken cables, loose connectors or cables with insufficient insulation.



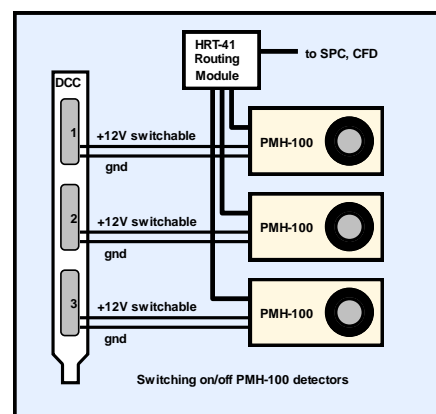
Don't connect or disconnect the signal cable from the detector to the preamplifier when the detector is switched on. This can destroy the amplifier. Make sure that you connected all ground connections. Missing ground connections can result in high voltage instability or unreliable overload shutdown.

Make sure that the +12 V at connector 2 is switched on. Otherwise the HFAC does not work, and the overload protection is inactive.

Controlling PMH-100 detectors

The PMH-100 of **bh** is an easy to use detector head that contains a Hamamatsu photosensor module, a preamplifier, and an optical and acoustical overload indicator. due to its compact design it has an excellent noise immunity and a TCSPC time resolution of 140ps to 200ps (fwhm of system response).

Since there is no overload signal available from the PMH-100 it cannot be automatically shut down on overload. Up to three detectors can, however, switched on and off via the DCC-100. By connecting the detectors to a **bh** SPC module via a HRT-41 or HRT-81 router the signals of all

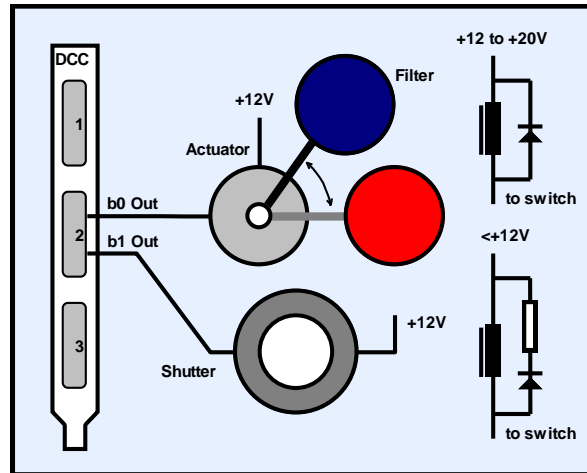


detectors can be recorded simultaneously. Or, by switching only one detector on, the desired detector can be selected for measurement. The configuration is exceptionally useful for laser scanning microscopes which normally use several detectors in different light paths.

Controlling Shutters

Shutters or other actuators can be controlled via the high current switches of connector 2. The switches can operate a voltage up to 20 V and up to 2 A. The power supply for the external load can be taken from connector 2 if a current of 100 mA at +12 V or 200 mA at +5 V is not exceeded. For higher currents an external power supply must be used.

Since shutters and other magnetic devices are inductive loads a flyback diode must be connected across the load. For supply voltage up to 12 V a resistor can be connected in series with the flyback diode to achieve a faster turn-off time. The value of the resistor should be about the DC resistance of the actuator or shutter coil.



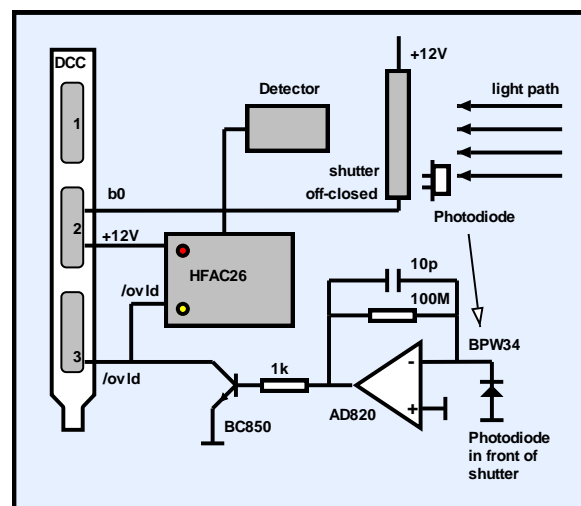
Controlling shutters and filters

The switches can automatically be shut down (i.e. set into the non-conducting state) when an overload condition occurs at connector 1 or connector 3. Which of the overload inputs is used for shutdown can be selected by jumpers on the DCC-100 board, see 'Shutdown of High Current Switches'.

Sometimes it is required to lock a shutter in the 'closed' state as long as a potential overload condition persists. An example is a microscope with a mercury or halogen lamp. When the lamp is on, opening the shutter must be inhibited. A solution is shown in the figure right. The photodiode detects the light from the lamp, and the amplifier sends an '/ovld' to the DCC-100. The signal can be connected parallel to the /ovld from the amplifier.

As long as the lamp is on, /ovld remains 'low' and the shutter cannot be opened. This gives additional safety against detector damage.

It must, however, be pointed out that an absolute safety against detector damage cannot be achieved in this way. If the lamp is switched on when the shutter is open it takes a few milliseconds until the overload is detected and the shutter closes. This can be enough to cause severe detector damage. Therefore, the best way is always an mechanical interlock so that the lamp path is closed when the detection path is opened.



Locking a shutter in a potential overload situation

Installation

Requirements to the Computer

The computer must be a Pentium PC with a graphics card of 1024 by 628 resolution or more. There must be enough free PCI slots to insert the required number of DCC-100 modules. Although computer speed is usually not an issue for the DCC-100 we recommend a computer with a speed of at least 300 MHz.

Installation of the DCC-100 Software

The installation of the DCC-100 Standard Software is simple - start setup.exe from the installation disk.

You can install the software also from the Becker & Hickl web site, e.g. if you want to upgrade your system with a new computer and a new DCC software version has been released in the meantime. In this case proceed as described under 'Update from the Web'.

The DCC software is based on 'LabWindows/CVI' of National Instruments. Therefore the so-called 'CVI Run-Time Engine' is required to run the DCC software. The 'Run-Time Engine' contains the library functions of LabWindows CVI and is loaded together with the DCC software. The installation routine suggests a special directory to install the Run-Time Engine. If the required version of the Run-Time Engine is already installed for another application, it is detected by the installation program and shared with the existing LabWindows CVI applications.

Software Update

If you install a new DCC software version over an older one only the files are copied which have a newer date. This, to a certain extend, avoids overwriting setup files such as auto.set (the last system settings). Consequently, you cannot install an older software version in place of a newer one. If you want to do this (normally there is no reason why you should), run the 'Uninstall' program before installing.

Update from the Web

The latest software versions are available from the Becker & Hickl web site. Open www.becker-hickl.de, and click on 'Software'.

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Click on 'Download', 'Windows 95/98/NT/2000'. Choose the DCC-100 software and get a ZIP file containing the complete installation. Unpack this file into a directory of your choice and start setup.exe. The installation will run as usual.

For a new software version we recommend also to download the corresponding manual. Click on 'Literature', 'Manuals' and download the PDF file. Please see also under 'Applications' to find notes about typical applications of the DCC in conjunction with **bh** photon counters.

Installation of the DCC-100 Module

To install the DCC-100, switch off the computer and insert the DCC module(s). To avoid damage due to electrostatic discharge we recommend to touch the module at the metallic back shield. Then touch a metallic part of the computer with the other hand. Then insert the module into a free slot of the computer.

The DCC-100 has a PCI interface. Windows has a list of PCI devices, and on the start of the system it automatically assigns the required hardware resources to the components of this list. When the computer is started first time with the DCC inserted Windows detects the DCC and updates the list of hardware components. Therefore it may ask for driver information from a disk. Although this information is not actually required for the DCC you should select the driver information file from the driver disk delivered with the module.

If you don't have the driver disk, please download the driver file from www.becker-hickl.com or www.becker-hickl.de, 'Software', 'Windows 95/98/NT/2000' 'Device drivers for **bh** modules'.

Shutdown of High Current Switches

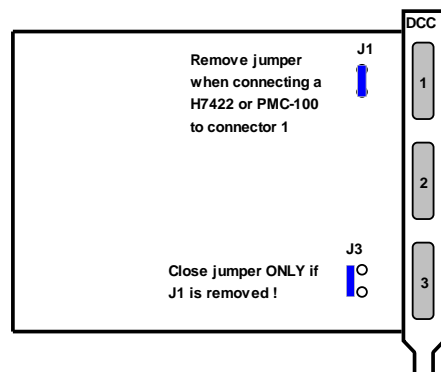
The high current switches can be shut down (i.e. set into the non-conducting state) by one or both overload signals from the detector control blocks. The configuration is set by jumpers on the DCC-100 board. The location of the jumpers is shown in the figure below.

If the jumpers 'SHDN1' or 'SHDN3' are set the high current switches are deactivated when an active '/overload' signal is detected at connector 1 or connector 3, respectively. If both jumpers are set the switches are deactivated by both '/overload' signals.



To operate the peltier cooling unit of an H7422 or PMC-100 detector the jumper next to the output connector must be removed (opened). Please make sure that the jumper at the connector which is NOT attached to an H7422 (PMC-100) is closed if only one detector is used. NEVER CLOSE BOTH JUMPERS SIMULTANEOUSLY.

Please note: If two H7422 (PMC-100) detectors are operated simultaneously the cooling units of both detectors are supplied in a series connection. As a consequence the sliders to control the coolers are used in common.



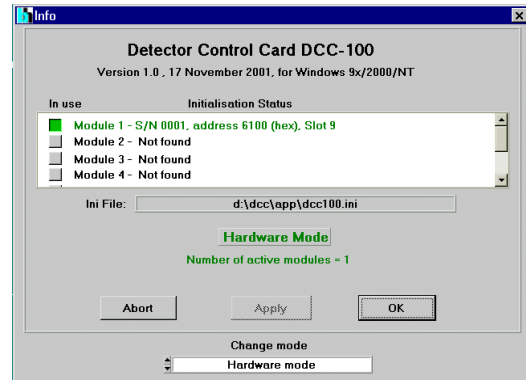
Software

Startup Panel

The DCC standard software is able to control up to four DCC-100 modules. The startup window is shown in the figure below.

The installed modules are marked as 'In use' and shown with their serial number, PCI address and slot number. When the startup window appears, click on 'OK' to open the main window of the DCC software.

The software runs a simple hardware test when it initialises the modules. If an error is found, a message 'Hardware Errors Found' is given and the corresponding module is marked red. In case of non-fatal hardware errors you can start the main window by selecting 'Hardware Mode' in the 'Change Mode' panel. Please note that this feature is intended for trouble shooting and repair rather than for normal use.



Startup Panel

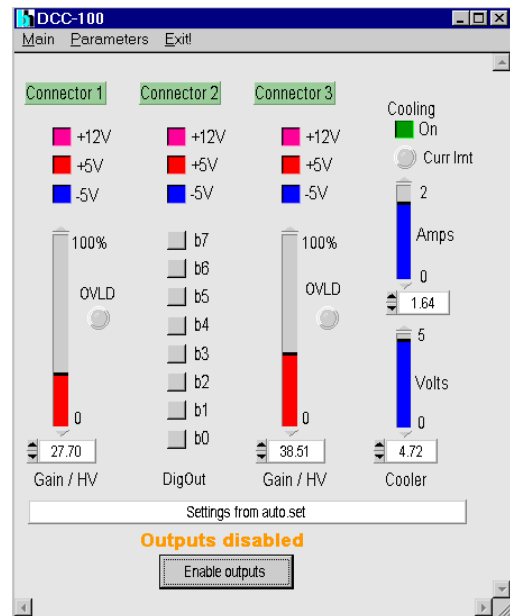
Main Panel

The main panel is shown in the figure right. The panel contains the controls for the power supply outputs, the high current switches, and for the peltier cooling.

Power-On State

Before the software takes control over the DCC the DCC control registers are in an undefined state. To avoid that the detectors are activated and possibly operated at a too high gain, after power-on the detector overload flip-flops are in the 'Overload Shutdown' state. That means, the +12V and the detector control voltages at connector 1 and 3 are shut down. If the jumpers for the shutdown of the high current switches are set also the switches are in the 'off' state.

When the DCC software starts, it loads the previously used parameters into the DCC registers.

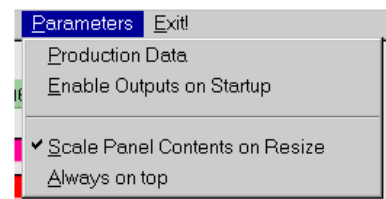


DCC main panel after power-on. 'Enable Outputs on Startup' is switched off.

State after Software Start

When the DCC software starts, it automatically reloads the settings of the last use. These settings are saved in a file 'auto.set' which is updated every time when you exit the DCC software.

After a software start, the DCC outputs are activated only if the 'Enable Outputs on Startup' option is switched on. 'Enable Outputs on Startup' can be switched on and off under 'Parameters', see figure right. We recommend to use the



'Enable Outputs on Startup' option

automatic enable only if detector damage or any hazard due to high voltage is reliably excluded.

If the outputs are disabled they can be enabled via the ‘Enable Outputs’ button at the bottom of the main panel.

Controls for Power Outputs and Detector Gain

The main panel is structured into ‘Connector 1’, ‘Connector 2’, ‘Connector 3’, and ‘Cooling’. To switch on or off one of the output signals click on the corresponding button. The detector gain control signals are changed by dragging the vertical bars or by typing in a value between 0 and 100%. Please note, that the Gain / HV signals control the high voltage of the detectors. Therefore, the detector gain is not proportional to the control signal. For PMTs and MCPs the relation is approximately

$$\text{GAIN} = V_{\text{control}}^n$$

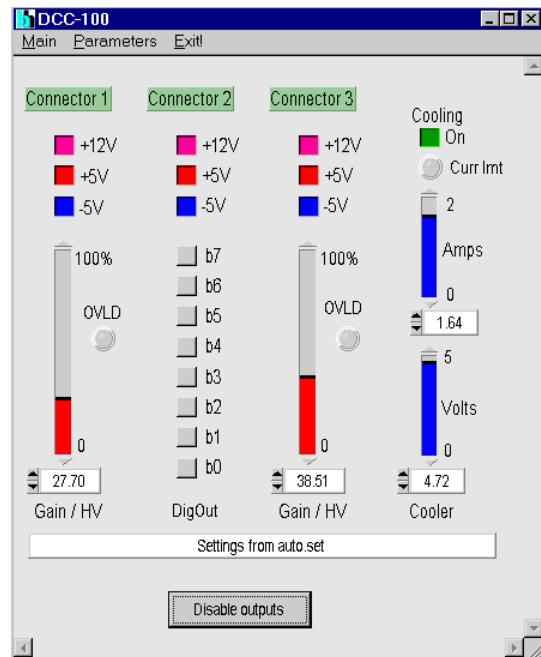
with n ranging from 2.5 to 5. Therefore, the relation is highly nonlinear, and the PMT gain varies over several orders of magnitude. Don’t be surprised that photon counting works only at a HV setting close to the maximum.

Detector Overload

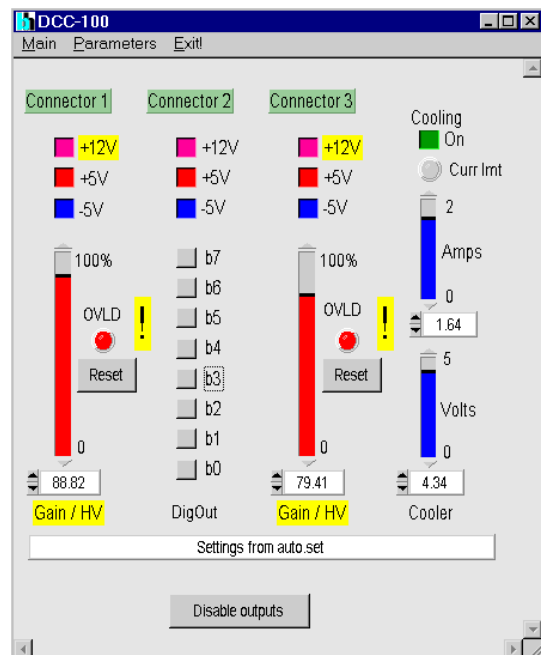
If a PMT overload is detected the ‘OVLD’ light of the corresponding connector turns on and a warning (flashing ‘!’) is issued. At the same time the detector control signal and the +12 V at the corresponding connector are shut down. You can also disable the high current switches on overload, e.g. to close shutters. To disable the switches from the overload flip-flops of connector 1 or 2 jumpers on the DCC board have to be set.

To switch on the detector(s) after an overload shutdown, click on the ‘RESET OVLD’ button. Make sure that the overload has been removed before you reset the detectors.

Safety note: Please make sure that you don’t exceed the maximum values for your detector(s). Particularly, if you control a HV power supply, make sure that it is safe to turn on or increase the voltage. Although the DCC-100 contains some safety features, such as detector shutdown at power-on or overload, it cannot be made safe in terms of operator errors, such as turning on HV power supplies with open or wrong connected output cables, or exceeding the maximum operating voltage for a given detector. bh will not take responsibility for accidents or detector damage resulting from setting or loading values exceeding maximum values for a given experiment setup.



DCC main panel, detectors activated



DCC main panel, after overload

High Current Switches

The high current switches can be switched on and off independently by the control buttons under 'Connector 2'. All switches can be disabled (i.e. switched into the non-conducting state) by the 'Disable Outputs' button.

The high current switches can be shut down (i.e. set into the non-conducting state) by one or both overload signals from the detector control blocks. The configuration is set by jumpers on the DCC-100 board, see 'Installation', 'Shutdown of High Current Switches'.

If the high current switches have been deactivated by detector overload they must be explicitly switched on after the overload condition is removed.

Disable Output Function

The power supply outputs, the detector gain signals and the high current switches can be disabled and enabled by the 'Disable Output' or 'Enable Output' button. You can automatically disable all outputs at the start of the software to bring the system in a safe state before you switch on the detectors. The 'Disable on Start' function can be switched on and off under 'Parameters'.

Cooler Control

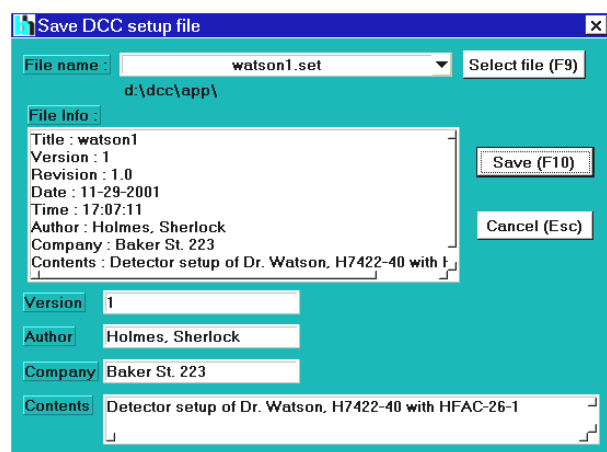
The cooling current can be switched on and off by clicking on the 'ON' button. To control the cooling power, you can set an output voltage and an output current. Of course, setting voltage and current in an electrical circuit simultaneously is impossible. The cooling power supply works in a way that the voltage at the output is controlled as long as the specified current is not reached. When the specified current is reached current control takes over and the current is controlled. In other words, the cooling is controlled in way that neither the selected voltage nor the selected current is exceeded. Current control is indicated by the 'Curr Lmt' light.

Saving and Loading the Setup

To load or to save the DCC setup, click on 'Main' in the menu bar and select 'Save' or 'Load'. The 'Save' and 'Load' menus are shown below.

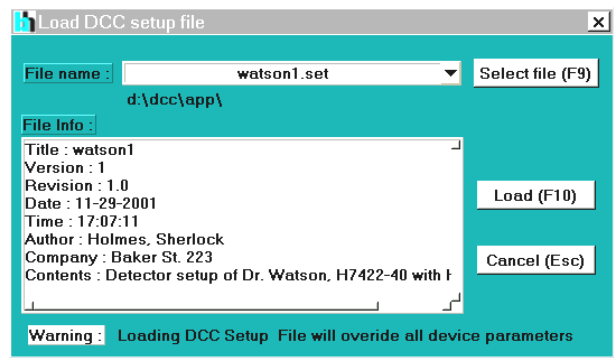
When you save a setup you first have to enter a file name or to select a file name by clicking into the 'file name' field. There you can also change to other directories or drives. A history of file names is available via the 'V' button right of the file name.

Then you can - but need not - type in the operator name, a company name, and a description for what your setup is.



Loading a setup file works in a similar way. Click on the 'file name' field and select the correct setup file. In the 'File Info' field you will see the information typed in when the file was saved. If it is the right file, click on 'Load'.

Note: Please make sure that you load the right file for your experiment setup. Although the DCC-100 contains some safety



features, such as detector shutdown at power-on or overload, it cannot be made safe in terms of operator errors, such as turning on HV power supplies with open or wrong connected output cables, or exceeding the maximum operating voltage for a given detector. bh will not take responsibility for accidents or detector damage resulting from setting or loading values exceeding maximum values for a given experiment setup.

Pin Assignment

Connector 1

15pin HD-SubD

Pin Signal

1	+5V out switchable
2	
3	
4	
5	GND
6	-5V out switchable
7	
8	
9	
10	+12V out switchable, ovld sdwn
11	-12V out
12	0...+10V HV cont., ovld sdwn
13	0...+1.0V gain cont., ovld sdwn
14	/OVLD1 input
15	GND

Connector 2

15pin HD-SubD

Pin Signal

1	+5V out switchable
2	Bit0 open drain out
3	Bit1 open drain out
4	Bit2 open drain out
5	GND
6	-5V out switchable
7	Bit3 open drain out
8	Bit4 open drain out
9	Bit5 open drain out
10	+12V out switchable
11	-12V out
12	Bit6 open drain out
13	Bit7 open drain out
14	
15	GND

Connector 3

15pin HD-SubD

Pin Signal

1	+5V out switchable
2	Peltier +
3	Peltier +
4	Peltier +
5	GND
6	-5V out switchable
7	Peltier -
8	Peltier -
9	Peltier -
10	+12V out, switchable, ovld sdwn
11	-12V out
12	0...+10V HV cont., ovld sdwn
13	0...+1.0V gain cont., ovld sdwn
14	/OVLD3 input
15	GND

Specification

Power Supply Outputs (Connectors 1 to 3)

Max. Current at +12 V	100 mA
Short Circuit Current +12 V	50 mA ¹⁾
Time from /OVLD to disable +12V	10 ms ²⁾
Output current in disabled state, +12 V	< 0.5 mA
Max. Current at +5 V	200 mA
Short Circuit Current +5 V	60 mA ¹⁾
Output current in disabled state, +5 V	< 0.5 mA
Max. Current at -5 V	200 mA
Short Circuit Current -5 V	60 mA ¹⁾
Output current in disabled state, -5 V	< 0.5 mA
Max. Current at -12 V	total 120 mA, single output 60 mA
Short Circuit Current -12 V	No short protection. Don't short longer than 1s

¹⁾ Foldback Characteristics, don't short several outputs simultaneously for more than 20s

²⁾ Connectors 1 and 3 only. 250 Ω load, time from +12V to +6V output voltage.

Detector Gain Control (Connectors 1 and 3)

Resolution	12 bit
Voltage Range Pin 12	0 to +10 V
Load at Pin 12	min. 1 k Ω
Output Resistance at Pin 12	100 Ω
Voltage Range Pin 13	0 to +1.0 V
Load at Pin 13	min. 1 k Ω
Output Resistance at Pin 13	100 Ω
Output Time Constant	100 ms

Overload Shutdown

Overload inputs at connector 1 and 3	TTL, active Low, Pull-up resistor 10 k Ω
Overload Reset	By Software and at Power-ON

High Current Switches (Connector 2)

Typical 'On' Resistance, 25°C	70 m Ω
Max. Switch Current, Single Switch	2 A
Max. Switch Current, Sum of all Switches	5 A ³⁾
Max. turn-off Voltage at Switch	20 V
Turn-on and turn-off transition time, Load 10 Ω	100 ns
Disable on /OVLD	if configured by jumpers
Disable Transition Time	< 1 us
Time from /OVLD to Disable	< 2 us

³⁾ Both GND pins used

Supply for Thermoelectric Coolers (Connector 3)

Output Voltage	0 to 5 V
Output Current	0 to 2 A
Resolution of Output Voltage and Current	12 bit
Output Resistance	0.4 Ω ⁴⁾
Output Capacitance	300 uF
Output Ripple	< 5 mV

⁴⁾ All pins parallel

PC Interface

Dimensions	160 mm x 106 mm x 15 mm
Interface / Connector	PCI
Register Access	I/O only
Supply Current, +5V, No Load, typ. value	0.6 A
Supply Current, +5V, Maximum Load, typ. value	1.2 A
Supply Current, +12V, No Load, typ. value	0.2 A
Supply Current, +12V, Maximum Load, typ. value	1.6 A

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