# High-Voltage System for CLAS Time-of-Flight Counters

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The purpose of this note is to describe the high voltage requirements for operation of the time-of-flight (TOF) counters. There are 684 photomultiplier tubes (pmts) in the TOF system which need to have separately adjustable voltages.

## 1.0 Configuration

The counters are divided into six sectors and will be mounted on four support assemblies:

- Forward Carriage
  23 scintillators (46 pmts) in each of six sectors
  138 scintillators [ 6 x (1-23) ]
  276 phototubes, EMI 9954A (2") except for Philips XP2262 on #23
- Clam Shell North
  19 scintillators (44 pmts) in each of three sectors
  66 scintillators [ 3 x (24-39) + 3 x (40-42 a,b) ]
  132 phototubes, Philips XP4312B (3")
- Clam Shell South
  19 scintillators (44 pmts) in each of three sectors
  66 scintillators [ 3 x (24-39) + 3 x (40-42 a,b) ]
  132 phototubes, Philips XP4312B (3")
- Space Frame
  6 scintillators (24 pmts) in each of six sectors
  72 scintillators [ 6 x (43-48 a,b) ]
  144 phototubes, Philips XP4312B (3") except for XP2262 on 47 a,b and 48 a,b

Counters 40 to 48 have two pmts on each end. These pmt's will have separate voltage supplies, but the signals for the two pmts on each end will be added to give one signal for that end of the counter to the electronics.

### 1.1 Diagram and naming convention

Figure 1 shows the counter arrangement for one sector of the CLAS detector. The counters are numbered beginning with 1 at the downstream (small angle) end. In sector 2, the phototube on the left end of a counter is designated as L and the tube on the right as R when

looking down the beam line. For other sectors the R and L designation depends on the position of the sector, as shown in Figure 2. Each end of counters 40 thru 48 have two phototubes labelled "a" and "b". The phototube at the smallest angle is designated "a".

## 1.2 Photomultiplier Tubes

There are three different kinds of photomultiplier tubes used on the TOF counters. The manufacturers specifications are given below.

### 1.2.1 EMI 9954A

- Active diameter: 46 mm
- 12 stage tube
- Photocathode: bialkali
- Spectral range: 310-650 nm
- Quantum efficiency at 400 nm: 26% (typ), 24% (min)
- Voltage for $1x10^7$ gain: 1900 V (typ)
- Dark current at $1x10^7$ gain: 0.2 nA (typ); 20 nA (max)
- Rise time: 2 ns
- Transit time: 41 ns
- Transit time spread FWHM (typ): 1.75 ns
- Ratings:

  Supply voltage, 2800 V

  Voltage D-D, 450 V

  Voltage K-D1, 500 V

  Continuous anode current, 200 μA (mean)

### 1.2.2 Philips XP2262

- Active diameter: 44 mm
- 12 stage tube
- Photocathode: bialkali
- Spectral range: 290 - 630 nm
- Quantum efficiency at 400 nm: 25%
- Voltage for $3x10^7$ gain for voltage divider A (see man. spec): 1850 V (typ)
- Rise time: 2.3 ns at 1900 V
- Transit time: 31 ns at 1900 V

- Limiting values (absolute maximum rating system)

  Supply voltage max 2500 V

  Voltage D1-K, 800 V max, 300 V min

  Voltage D-D, 400 V max

  Continuous anode current, 200 μA max

### 1.2.3 Philips XP4312B

- Diameter: 76 mm, 3"
- 12 stage tube
- Photocathode: bialkali
- Spectral range: 290-630 nm
- Quantum efficiency at 400 nm: 28%
- Gain at 2500 volts (depends on voltage divider): $8 \times 10^6$ min; $1.5 \times 10^7$ max
- Dark current at 2700 V: about 75 nA, depends on voltage divider
- Rise time at 2500 V: 2.1 to 2.5 ns depending on voltage divider
- Transit time at 2500 V: 30 ns
- Limiting values:

  Supply voltage < 3000 V

  Voltage K-G1 < 300 V

  Voltage K-D1 min 400 V, max 1300 V

  Voltage D-D < 500 V

  Continuous anode current < 200 μA

The phototube's voltage dividers, designed at the University of New Hampshire, incorporate FET stabilization/overload protection in the last four dynode stages of the tube as well as a current-limiting resistor connected to the charged μ-metal shield for safety.[1]

## 1.3 LeCroy Power Supply

The photomultipliers for the TOF counters typically operate at about 2000 volts with a negative polarity, and draw a current of about 0.5 ma. The voltage will be supplied by LeCroy 1458 mainframes. The mainframe holds sixteen LeCroy 1461N cards each supplying 12 independent channels giving a maximum of 192 channels per mainframe. The mainframes will be located in the experimental hall. Two HV mainframes will placed on the forward carriage, one on each CLAM shell, and one on the space frame.

1. K. MacArthur and J. Distelbrink, "CEBAF Large Angle TOF Prototype Photomultiplier Circuits" CLAS Note 94-021, October, 1994.

The LeCroy 1458 Mainframe can be controlled by either a RS-232 port or a local area network. The RS-232 port allows control and display of voltage settings by a standard terminal. This interface is always available for reviewing information in the mainframe, but changes can be locked out remotely or via a front-panel key switch. Control over a local area network is achieved via ARCNET, a high speed (2.5 Mbaud) token-passing network protocol. The network can extend up to distances of 4 miles.

The LeCroy 1461 HV card stores information, such as voltage ranges and limits, for each of it's twelve channels. The output is programmable from 0 to 3 kV with an output current limit that supports a 1.2 MΩ load at 3 kV. The limiting output current as a function of output voltage is shown in Fig. 3. The card includes voltage measurement, current measurement, programmable current trip, hardware voltage limit (one per card), and separate programmable ramp-up and ramp-down rates.

A device driver has been written to allow communication between the LeCroy system and EPICS (Experimental Physics and Industrial Control System),[1] and a high voltage record for the system has been written for creation of the database in EPICS. [2]

The following properties can be obtained for each channel:

- Channel enabled or disabled
- Demand voltage (the desired output voltage)
- Hardware voltage limit, adjusted via a frontpanel screw on the HV module
- Channel status, describes the state of each HV channel. The status is read as a bit wise word, with each bit defined as in Table 1:

**TABLE 1. Bit definition of channel status word**

| Bit | Description |
|---|---|
| 0 | Channel is enabled |
| 1 | Output is ramping to a higher absolute value. |
| 2 | Output is ramping to a lower absolute value or zero |
| 3 | (reserved) |
| 4 | Trip for violation of supply limits |
| 5 | Trip for violation of user's current limit |
| 6 | Trip for voltage error |
| 7 | Trip for violation of voltage limit |

- Measured current
- Measured current dead zone

1. T. Auger, "Elements of EPICS and the High Voltage Control System for the CLAS Detector", Master Thesis submitted to the University of South Carolina, 1996.
2. M. Swynghedauw, "EPICS Development: High Voltage Slow Controls for the CLAS Detector at CEBAF", Master Thesis submitted to the University of South Carolina, 1996.

- Measured voltage
- Measured voltage dead zone
- Ramp-up rate and ramp-down rate, separately programmable, nominally from 50 to 1000 V/sec in 50 V steps
- Trip current, programmable from 50 to 2550 μA.

Typical initial settings for these properties are shown in the table below.

**TABLE 2. Typical high voltage parameters**

| Property | Value |
|---|---|
| Demand voltage | ~2000 V[a] |
| Hardware voltage limit | 2500 V |
| Measured current dead zone | 0.2 mA |
| Measured voltage dead zone | 15 V |
| Ramp-up rate | 1000 V/s |
| Ramp-down rate | 1000 V/s |
| Trip current | 1 mA |

a. Determined by gain matching

In addition, system information can be obtained such as the model number, hardware revision, ECO level, test date, firmware version, serial number and operational hours.

# 2.0 HV Control

The system for controlling the high voltages should incorporate the following features:

- The voltage on each pmt must be capable of a fine setting so that amplitudes can be adjusted in 1 volt increments. Gain matching is done with minimum ionizing particles.
- Means must be provided for separately enabling or disabling each high-voltage channel so that voltage will not be applied to every channel when power is applied to the system.
- Power for the whole system should be applied with one command. And power for the system should be removed when the voltage or current exceed operator-selected limits.

A person working with the TOF counters will require

- Status of the system (HV on or off) and each channel (enabled or disabled)
- Voltage settings for each channel
- Current drawn by each channel

In addition, the following parameters must be available:

- Measured voltage
- Demand voltage
- Channel status (status of channels when ramping up or down and information about channels that have tripped off)
- Measured voltage dead zone
- Measured current dead zone

The following parameters are useful for monitoring the system

- Ramp-rate up
- Ramp-rate down
- High-voltage limit
- Trip current

In order to keep track of system components, the software must be able to display the identification and property name of each card in the mainframe as well as the mainframe itself. This information includes:

- Serial number of each module
- Revision number
- ECO number
- Firmware revision

# 3.0 Graphical User Interface (GUI)

A preliminary screen for the GUI is shown in Fig. 4. Three different screens are used to control the high voltages.

- The top screen, Fig. 4a, has a diagram of the counters and gives a summary of the status of the counters in each sector on the four support assemblies. A button on this screen can be selected to display a second screen for control of a subset of counters.
- The second screen, Fig. 4b, allows the user to read and set voltages on each of the phototubes in a subset of counters. A button on this screen can be selected to display more information about the high voltages system for the phototubes on one counter.
- The third screen, Fig. 4c, gives detailed information about the high voltage system such as ramp-up rate, trip current, voltage dead zone and current dead zone. These parameters can be changed on this screen.

## 4.0 Alarm Handling

The operator must be alerted when a change in the system occurs such as the loss of power to a pmt or a change in voltage or current outside the programmed dead zone.

## 5.0 System Backup

The operator must be able to backup all voltage settings, restore them and obtain a printed listing of all parameters.

## 6.0 System maintenance

Means must be provided for continuous monitoring of the EPICS software and the LeCroy mainframes. Both systems are complicated and can be expected to fail during initial operation. To minimize downtime, each failure must be identified and traced to find its cause so that a correction can be made. In order to monitor failures of the system, the EPICS system must maintain a history of the most recent commands sent to the mainframe before a failure occurs. When the failure occurs, there should be easy access to this information.

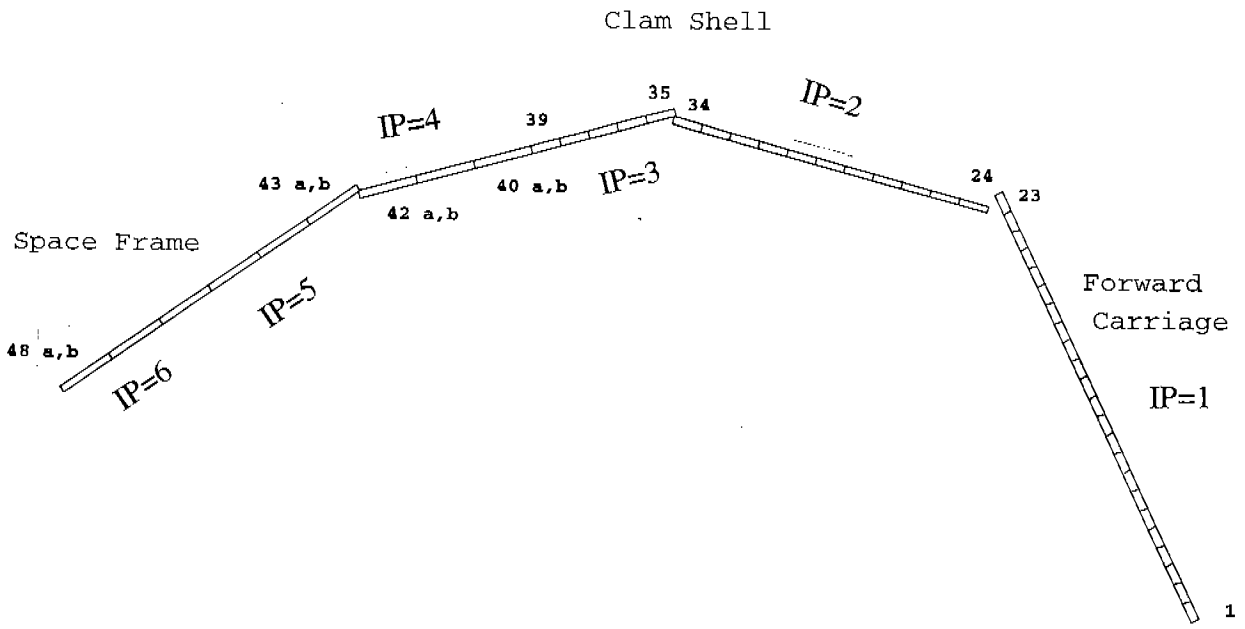
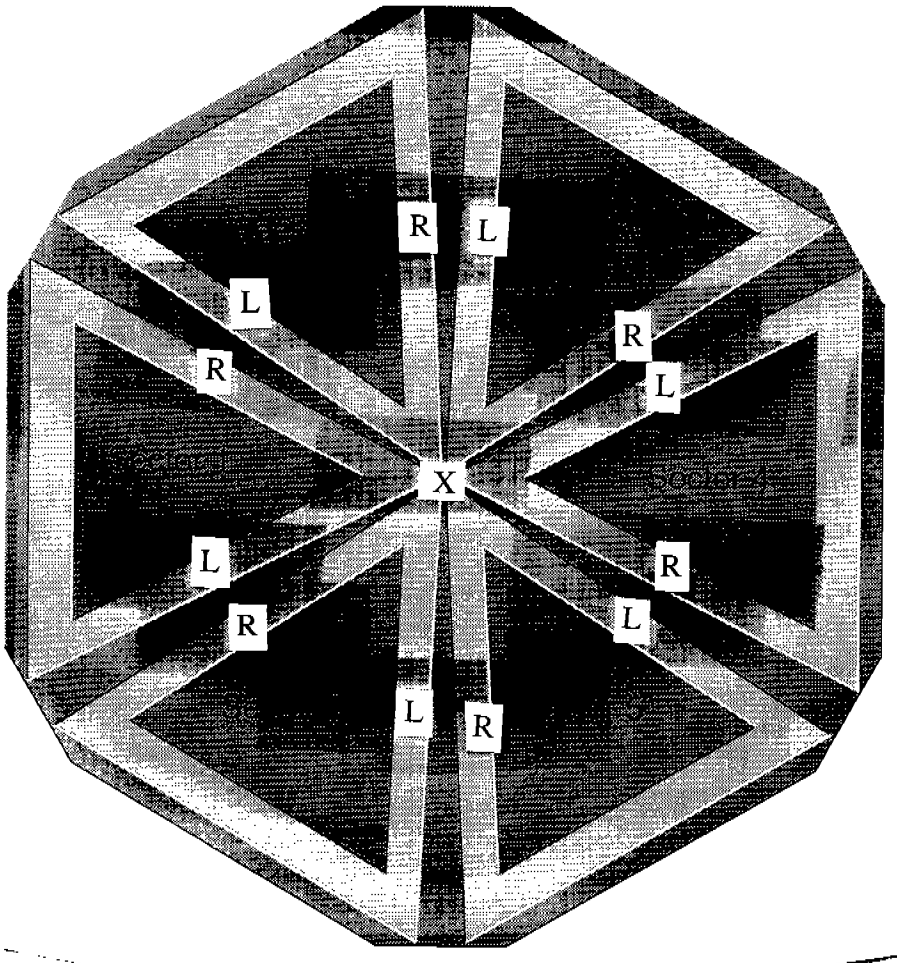



Figure 1. Counter arrangement for one sector of CLAS. With the same "plane" IP=1-6, the construction and geometry of scintillators are identical.




Beam into paper

Figure 2. The six sectors of the CLAS detector. The convention for labelling the right and left ends of TOF scintillators is shown.

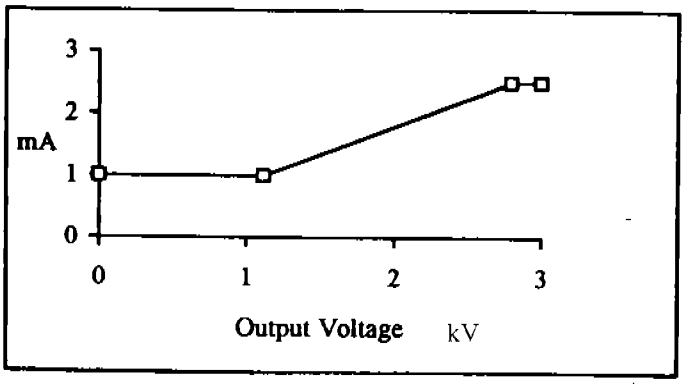



Figure 3. Limiting output current as a function of output voltage for the LeCroy 1461 HV card.

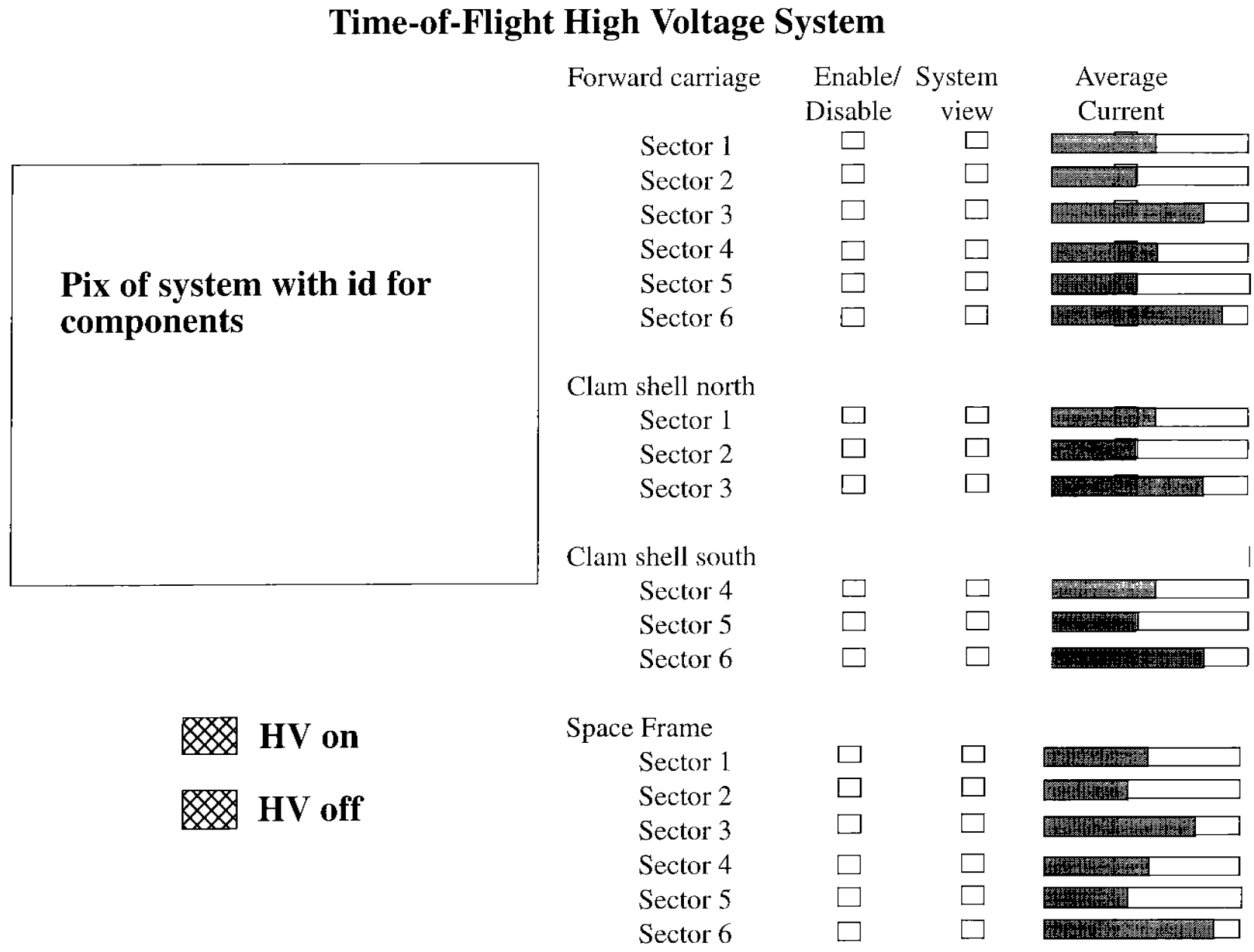



Fig. 4a. Top screen of the graphical user interface.

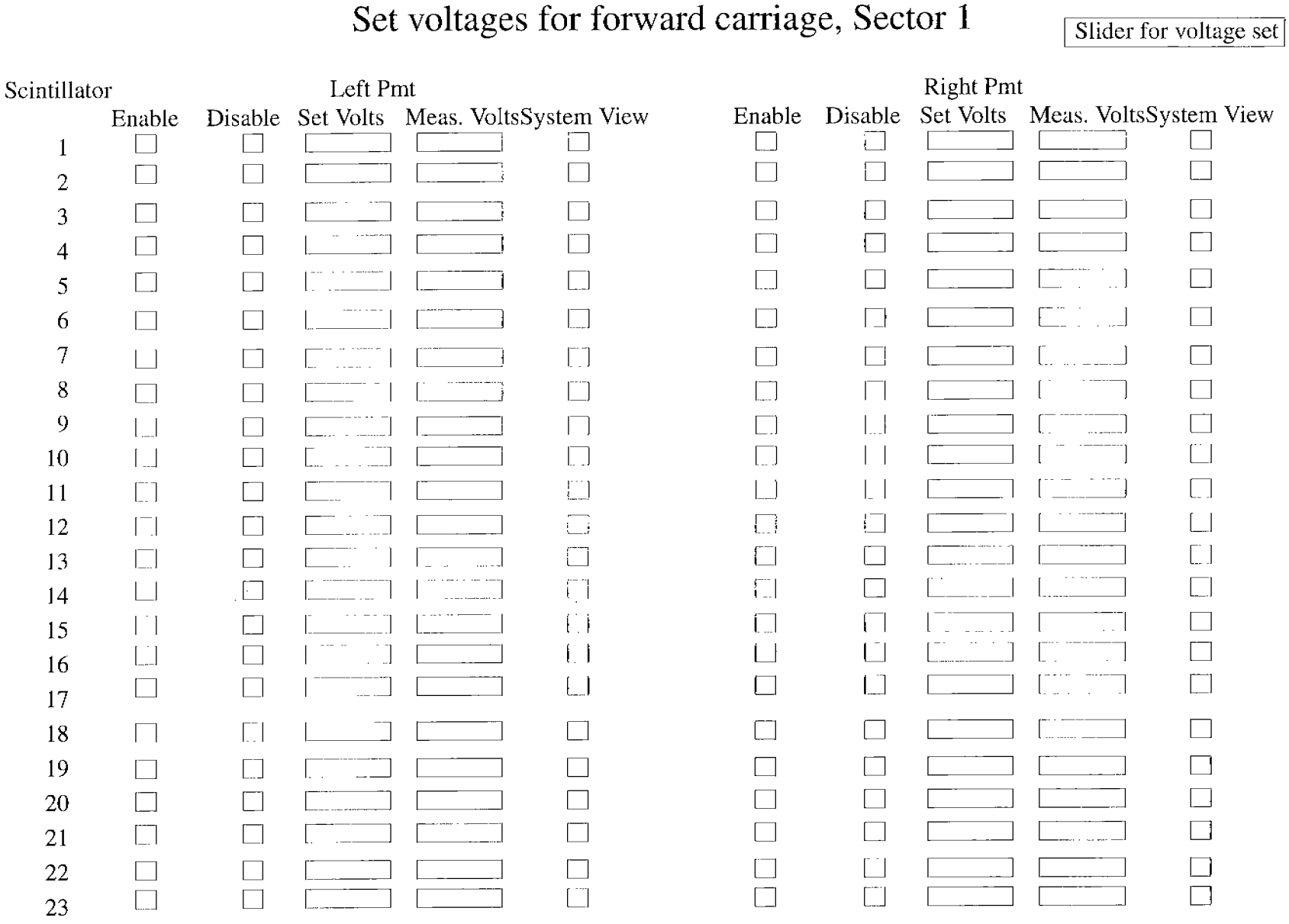



Fig. 4b. Second screen of the graphical user interface. This screen is called by selecting a system view button on the top screen.

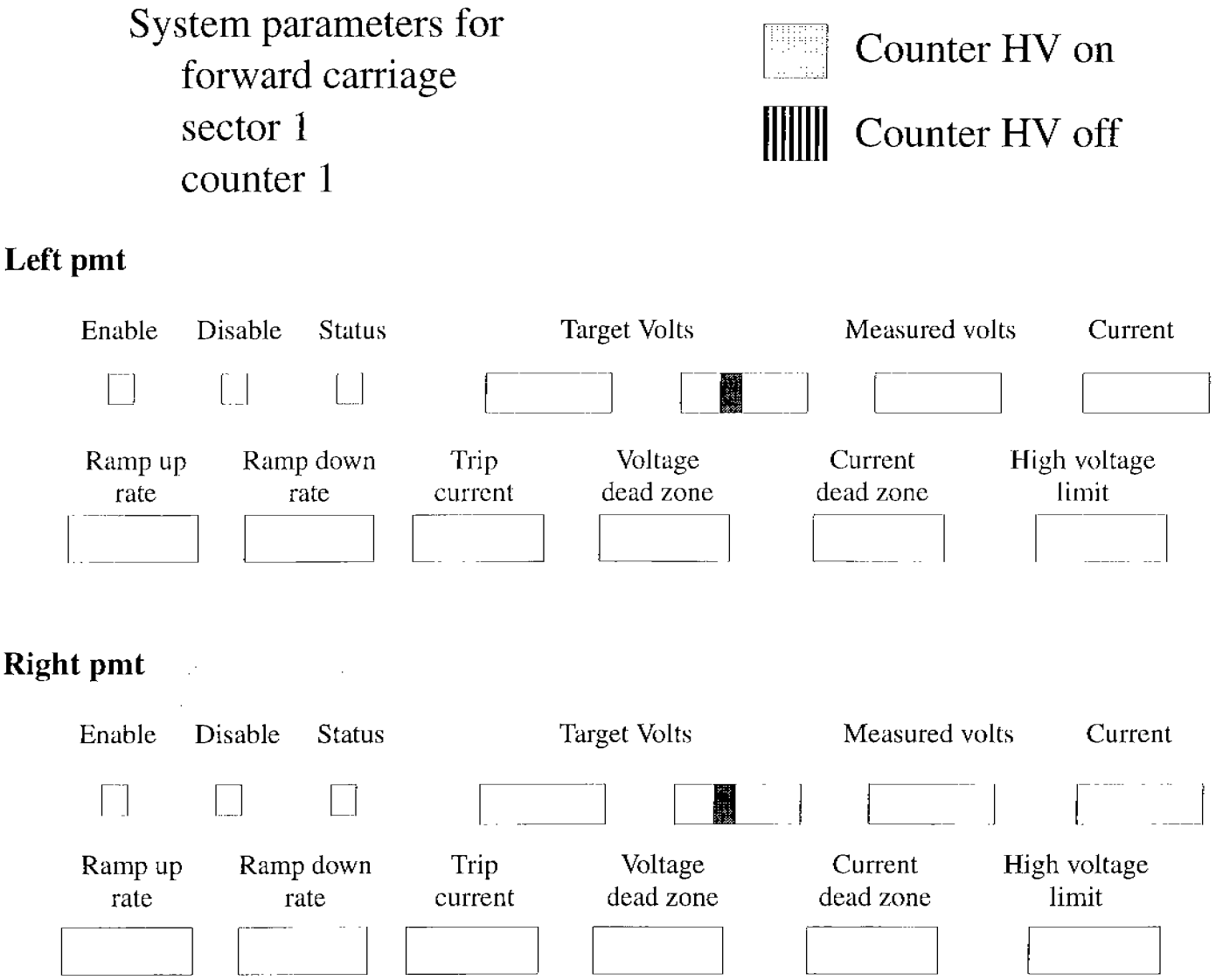



Fig. 4c. Third screen of the graphical user interface. This screen is called by selecting a view button on the second screen shown in Fig. 4b.