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Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

CHRPR Operations Manual

B Windsor
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August 2012

Pacific Northwest
NATIONAL LABORATORY

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Contents

Figures and Tables

1 Overview

The TSA Systems VM-250AGN portal monitor is a set of two pillars made to detect nuclear material in a vehicle. Each pillar contains two polyvinyl toluene (PVT) plastic gamma ray detectors and four ^{3}He neutron detectors, as well as a power supply and electronics to process the output from these detectors. Pacific Northwest National Laboratory (PNNL) has designed and built a continuous high-resolution PVT readout (CHRPR) for the TSA portal to allow spectral readout from the gamma and neutron detectors. The CHRPR helps differentiate between different types of radioactive material through increased spectroscopic capability and associated developments.

The TSA VM-250AGN continually monitors the levels of gamma ray and neutron radiation that occur around the pillars. A presence sensor records the passage of vehicles between the two pillars. An alarm is generated when radiation levels exceed a preset alarm threshold. The outputs of the radiation detectors inside each pillar are amplified and shaped by the SCA-775 single channel analyzer unit. Information from both SCA-775 units is passed to the SC-770 detector interface module and processor in the master pillar. This module analyzers count readings, triggers any appropriate alarms, and can output time-stamped measurements to a serial connection.

The CHRPR allows radiation readings from the TSA portal monitor to be recorded at a higher level of precision. The system captures electrical signals from the SCA-775 units. These signals are digitized by custom electronics and transmitted over Ethernet to a data acquisition computer. The CHRPR records the magnitude of each pulse to a continuous event mode file on or each detector and occupancy sensor. The TSA portal monitor otherwise operates normally, and still issues the same alarm indications.

This manual begins with CHRPR installation instructions, and then describes the CHRPR readout software. Afterward is a brief overview of how the TSA system works, then an explanation of the CHRPR. This manual is meant as a supplement to the TSA VM-250AGN manual, located at the following link:

http://tsasystems.com/library/manuals/pm700agn-vm250agn_manual.pdf

2 Installation

Follow the steps below to install the CHRPR system.

Step 1: Test the power supplies

Open the middle panel of the slave pillar and locate the lower terminal block shown in Figure 2.1. (The slave pillar is the one not displaying a numeric keypad on the center box.) Find the ports labeled **23** and **25**. These should initially be empty. Using a voltmeter, make sure that the potential difference between these two points is roughly 13 to 15 V.

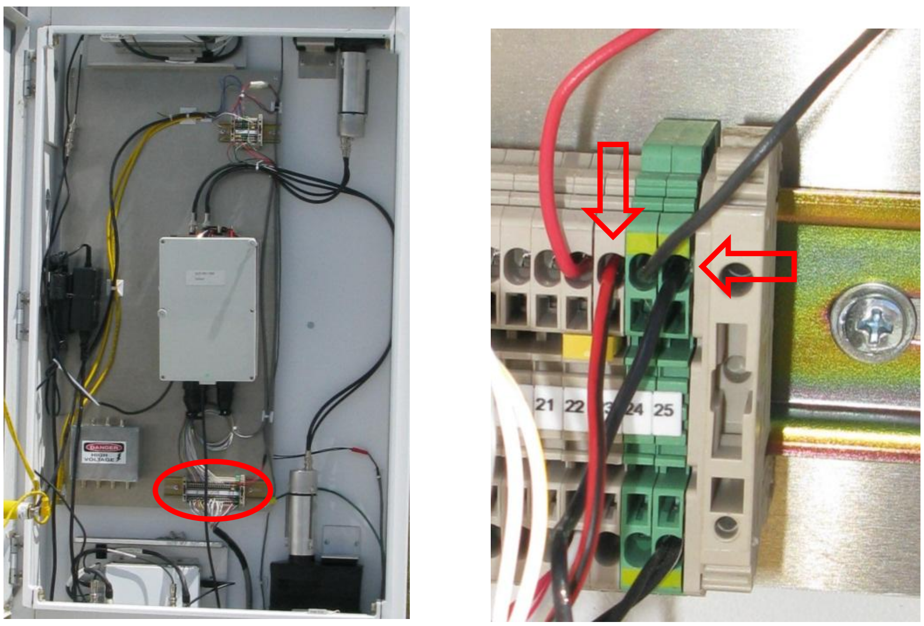


Figure 2.1: Location and detail of lower terminal block inside slave pillar.

Repeat the above process with the middle panel of the master pillar. Locate the lower terminal block shown in Figure 2.2 and test the voltage between the ports labeled **23** and **25**.

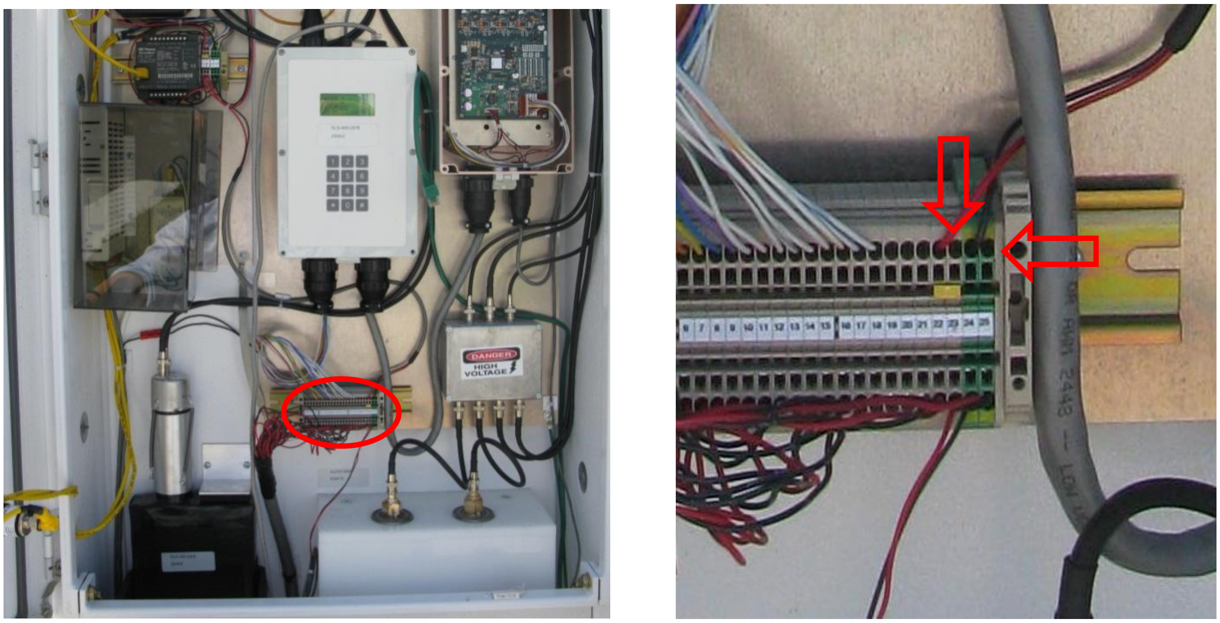


Figure 2.2: Location and detail of lower terminal block inside master pillar.

Step 2: Install the CHRPR box and cables in the slave pillar

Unplug the slave and master columns from the 110 VAC outlets. Unplug the battery from the gray wire connected to it in the master column. See Figure 2.3. This makes the system safe to work with.

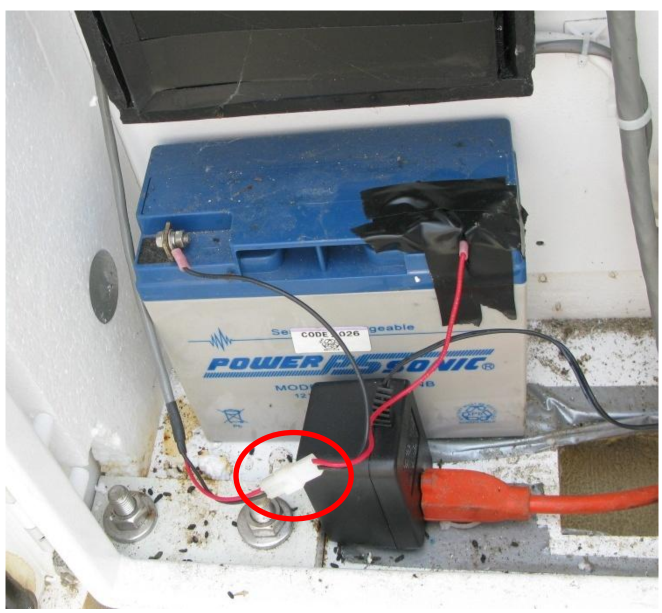


Figure 2.3: Battery disconnect wire.

Locate the SCA-775 in the middle panel of the slave pillar, shown in Figure 2.4. Unscrew the lid and set it aside. Provided in the CHRPR kit is a replacement lid with connectors and cable feeds. This lid is labeled "Slave Pillar." Five clip-on leads are attached to the back of this lid. Four of the wires are numbered, and the fifth is the ground. Attach the clip-on leads to the circuit board at the locations shown in the figure. Place the lid on the box, and screw the lid back on carefully to avoid compressing or crimping the connection wires.

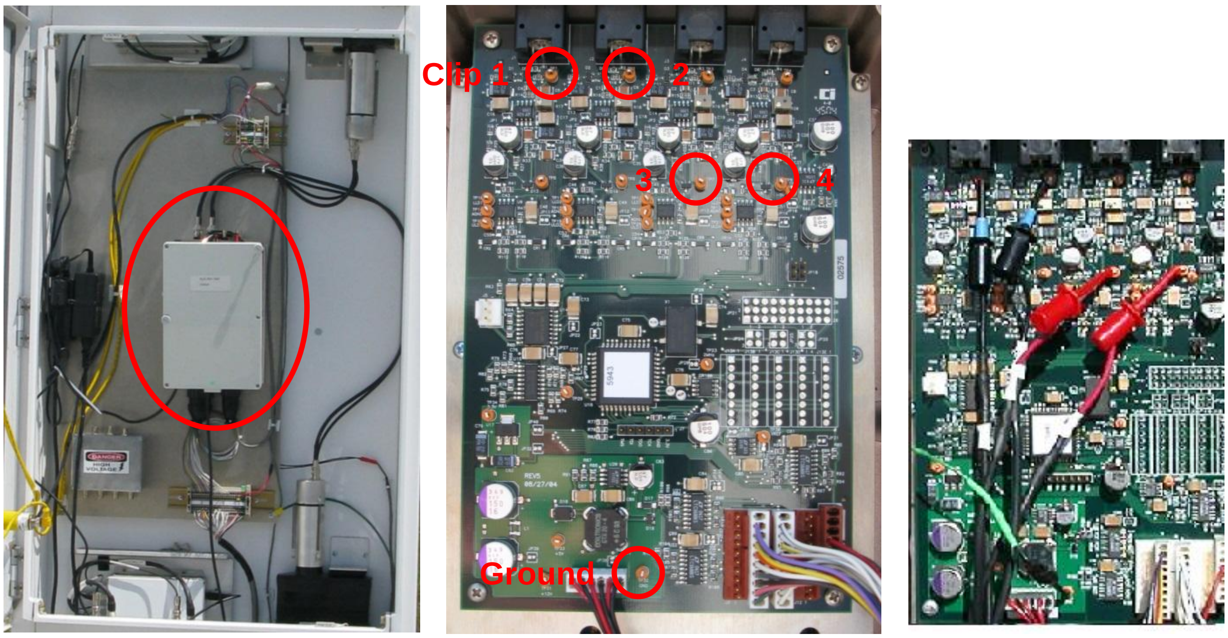


Figure 2.4: Location of SCA-775 inside slave pillar, and placement of clip-on leads.

Next, locate the black CHRPR box with **five (5)** silver BNC connections mounted on the outside. Place the box as shown in Figure 2.5 using the sticky Velcro strips provided.

Obtain the red and black power cable included in the kit. Strip the two ends of the wires. Plug the black cable (ground) into port **25**, and the red cable (power) into port **23** of the lower terminal block. These are the ports which were previously tested with the voltmeter. To plug cables in, insert a small screwdriver into the square above the number, insert the cable into the oval, then remove the screwdriver. Pull on the wire gently to make sure it is secure. The result should look like Figure 2.6.

Figure 2.5: Placement of CHRPR box inside slave pillar.

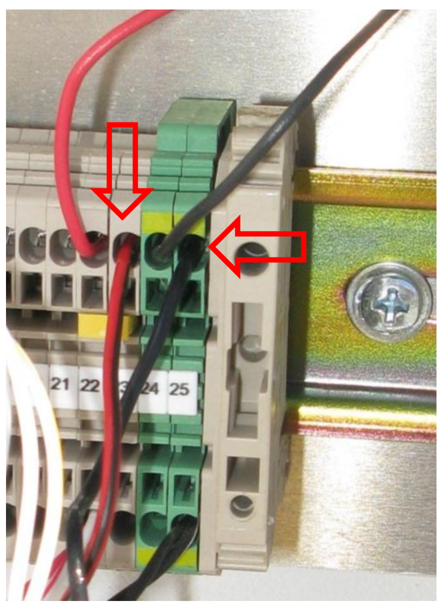


Figure 2.6: Power connections inside slave pillar.

Now attach the CHRPR box to the power and SCA-775. Plug the red and black power cable to the corresponding connector on the CHRPR box. Attach the four coaxial cables labeled 1-4 which were included in the kit. Cable 1 should go from output 1 on the SCA-775 to input 1 on the CHRPR box, and so forth. Figure 2.7 shows the result.

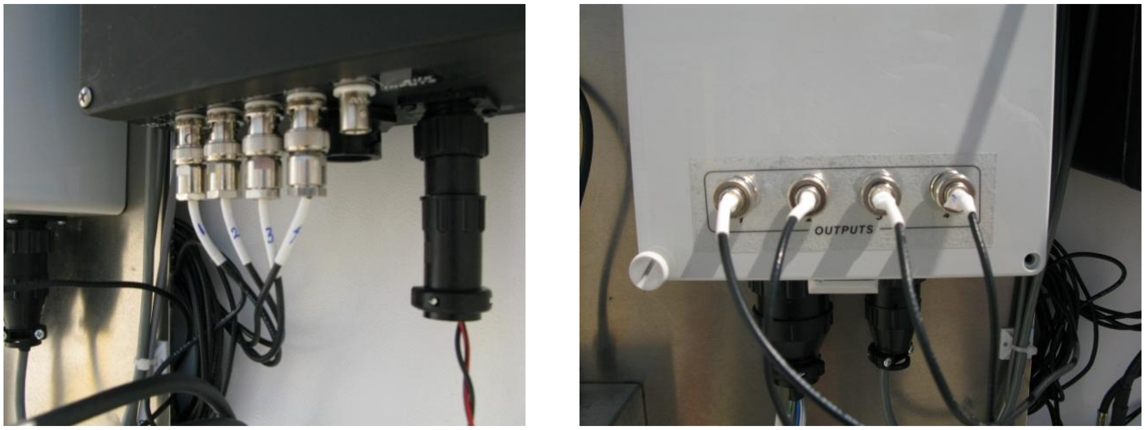


Figure 2.7: Connections to CHRPR box inside slave pillar.

Finally, connect the occupancy sensor. Plug the coaxial cable into the port labeled “Aux 1”, and run the cable to the upper terminal block shown in Figure 2.8. Connect the coaxial signal wire to port **8**, and then run the ground wire (~10 cm lead) into the bottom of port **5**. See Figure 2.8.

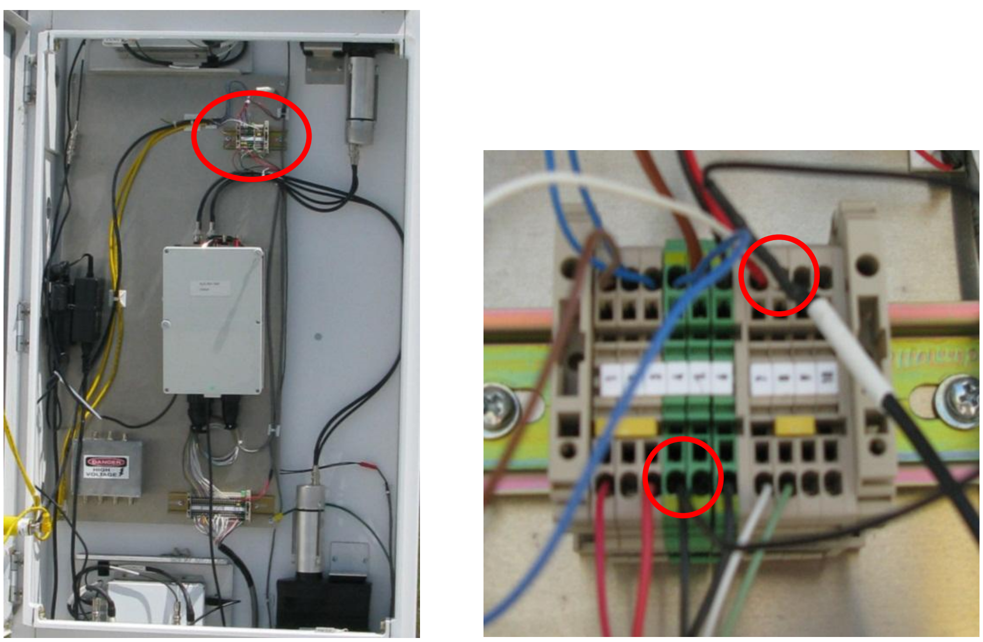


Figure 2.8: Placement of occupancy sensor cable inside slave pillar.

If necessary, use zip ties or coiling to tidy the wires inside the panel.

Step 3: Install the CHRPR box and cables in the master pillar

This process is nearly identical to the slave pillar. To start, unscrew the lid of the SCA-775, shown in Figure 2.9. Take the second replacement lid from the CHRPR kit, and attach the clip-on leads to the circuit board as shown in Figure 2.4. Carefully screw the lid back on.

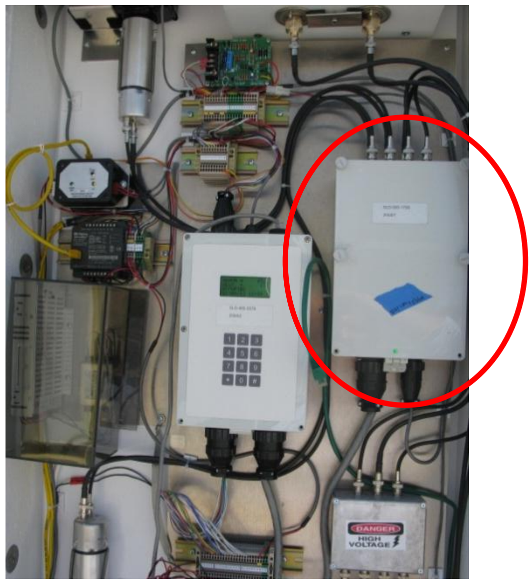


Figure 2.9: Location of SCA-775 inside master pillar.

Next, locate the black CHRPR box with **six (6)** silver BNC connections mounted on the outside. Place the CHRPR box against the door as in Figure 2.10. Before peeling off the Velcro sticky backing, try closing the door partway to ensure that the box clears the other components inside the master pillar.

Figure 2.10: Placement of CHRPR box inside master pillar.

Obtain the second red and black power cable and strip the two ends of the wires. As before, plug the black cable (ground) into port **25**, and the red cable (power) into port **23** of the lower terminal block. The result should be identical to Figure 2.11.

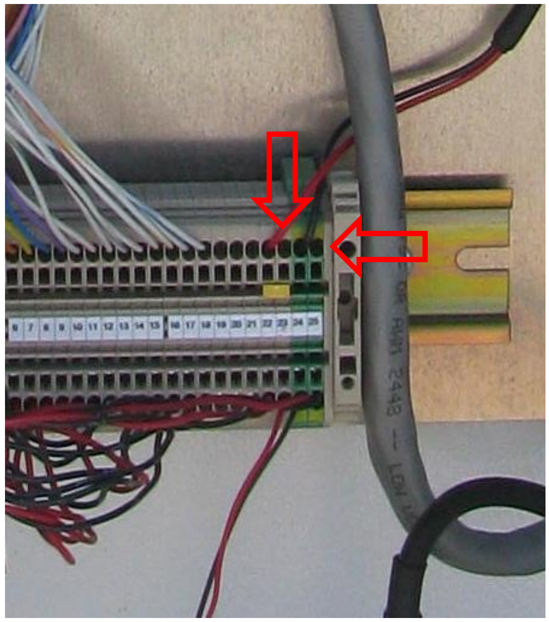


Figure 2.11: Power connections inside master pillar.

Attach the SCA-775 outputs to the CHRPR box, again using cable 1 to connect output 1 to TSA input 1, and so forth.

For the occupancy sensors, find the two coaxial cables labeled “A1” and “A2”. Plug these into Aux inputs 1 and 2 on the bottom of the CHRPR box. Now, locate the Nano controller shown in Figure 2.12. Attach the coaxial signal lead of A1 to pin **I1**, and A2 to pin **I2**. Locate the two ground leads on these cables. These are the small, ~10 cm wires attached to the end. Twist the ends of the two ground leads together, and plug them into hole **5** on the terminal block.

As before, use zip ties and coiling to tidy the inside of the panel.

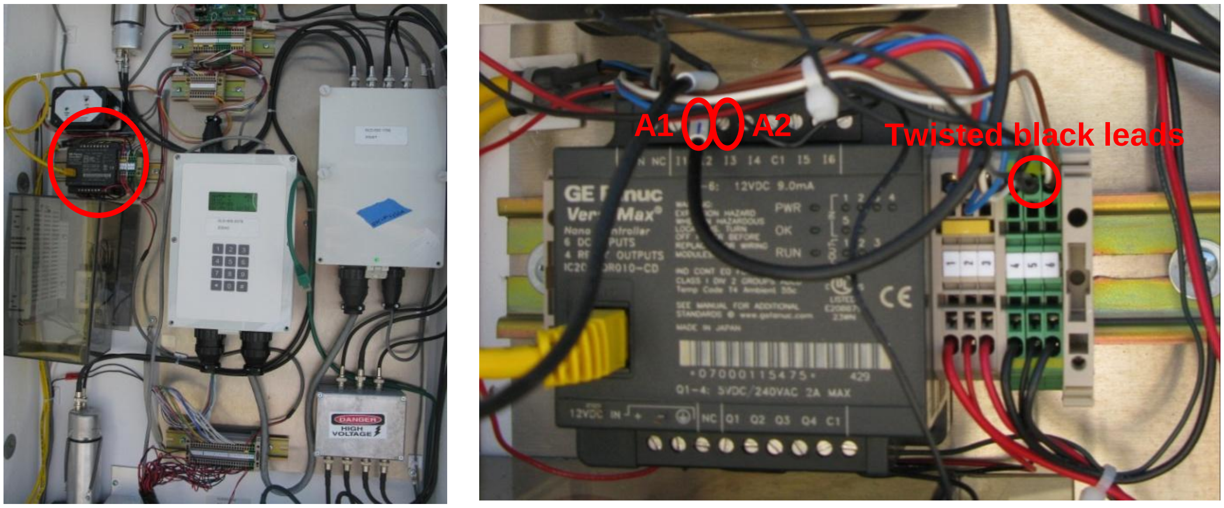


Figure 2.12: Placement of occupancy sensor cables inside master pillar.

Step 4: Attach the Ethernet connections

Run a 110 VAC extension cord from an outlet into the bottom of the master column. Attach the power converter for the Netgear fast Ethernet switch to this cord. Plug the small end of the power converter into the port in the back of the Ethernet switch. The switch can be mounted between the SC-770 and the SCA-775, as in Figure 2.13. Any other convenient mounting approach may also be used.

Figure 2.13: Placement of Ethernet switch inside master pillar.

Plug an Ethernet cable into the CHRPR box in the master pillar, and then attach this cable to any port of the Ethernet switch. Attach a second Ethernet cable to the bottom of the CHRPR box in the slave pillar. Run this cable to the master pillar and plug it into any other port of the Ethernet switch.

Finally, plug an additional Ethernet cable into any unused port of the Ethernet switch and run the cable to the location where the data collection computer will reside.

Step 5: Power on the TSA system

Reattach the battery to the grey cord in Figure 2.3, and plug in all system 110 VAC cords. Ensure the green light is illuminated on the load disconnect, circled in Figure 2.14. If not, check the power supply.

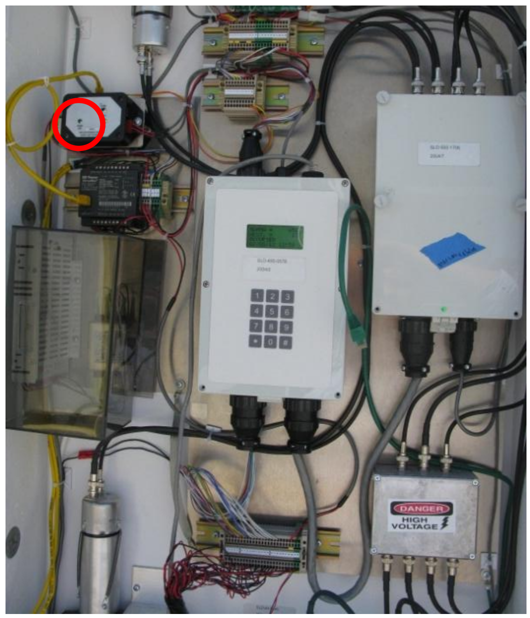


Figure 2.14: Location of green light inside master pillar.

Also examine the window of the SC-770. The screen should say “Gamma,” followed by a changing number, then “Neutron,” followed by another number. Don’t worry about the “Tamper” indication this displays when the door is open. If this screen is not displayed, check the connections to the SC-770, or refer to pages 14 and onward in the TSA manual for adjusting settings.

Finally, look on the fast Ethernet switch to see if the lights are on for the two ports connected to the CHRPR boxes. Use the troubleshooting guide in this manual to solve any problems.

Once everything checks out, close the center panels on the master and slave pillars. However, do not reopen the lane to vehicle traffic until the data acquisition is tested.

Step 6: Configure the data acquisition computer

Obtain a computer running Windows XP or Windows 7. Either a laptop or desktop computer is acceptable. Install the Microsoft .NET Framework version 4 on the computer if it does not already exist. These components may be obtained from the following link:

http://www.microsoft.com/en-us/download/details.aspx?id=17851

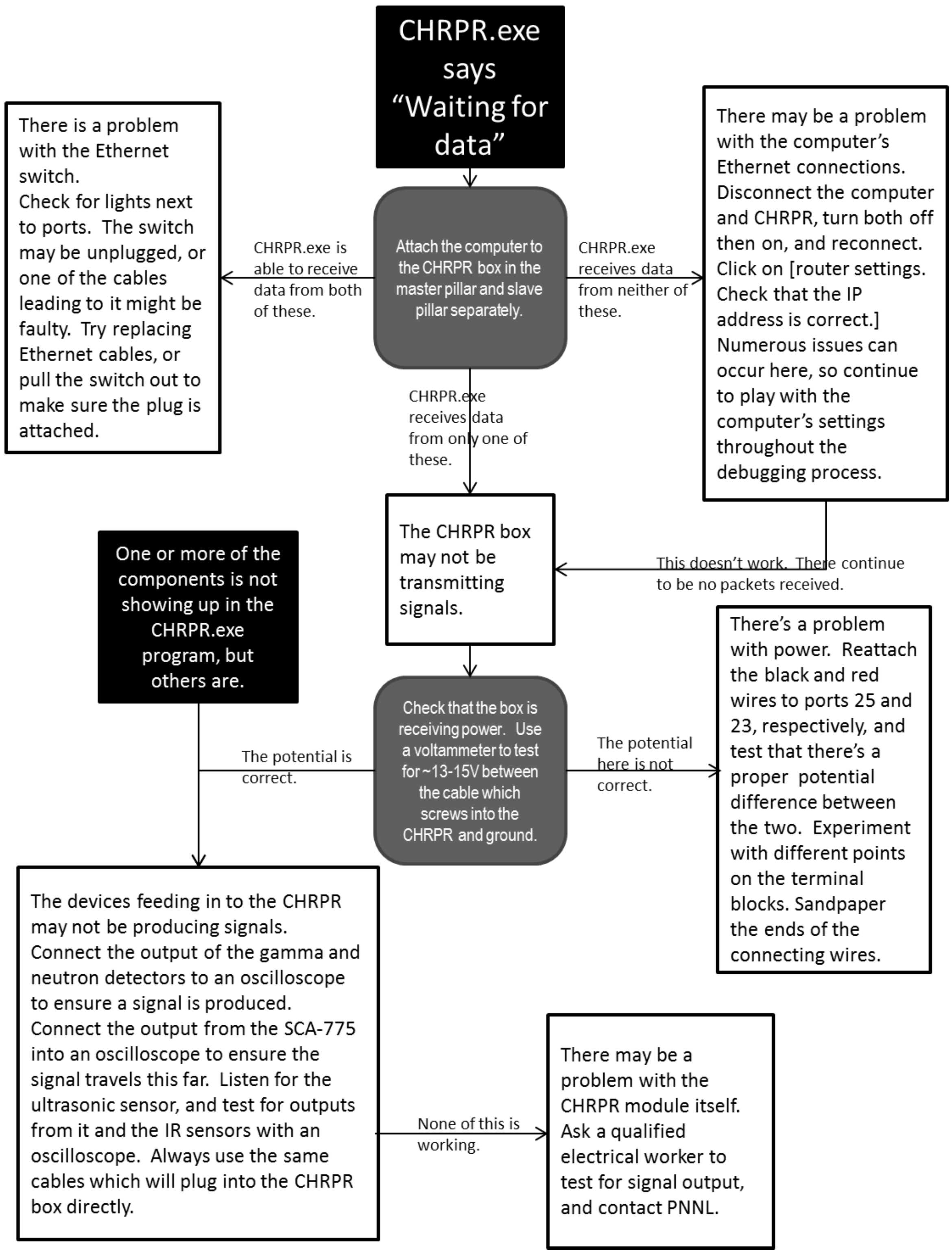
Copy the software provided onto the computer. The software consists of two executable files:

- CHRPR.exe: saves raw binary data from the CHRPR
- Analysis.exe: converts the binary data into text and displays histograms

Set the IP address of the computer to 192.168.0.100 with a subnet mask of 255.255.255.0. Disable any firewall settings on the computer that block UDP traffic, as these may interfere with system operation.

Plug the computer to the Ethernet cable that connects to the Ethernet switch. A window should pop up near the system tray indicating that the computer is connected.

3 Troubleshooting



4 Readout Software

To start data collection, open CHRPR.exe. The screen shown in Figure 4.1 should appear. Select an output directory using the "…" button next to the directory field. Press "Record" to start recording data. If the system is functioning properly, the program should indicate the count rates received on the gamma and neutron detectors, as well as the status of the infrared and ultrasonic occupancy sensors. See the troubleshooting section in this manual to resolve any problems.

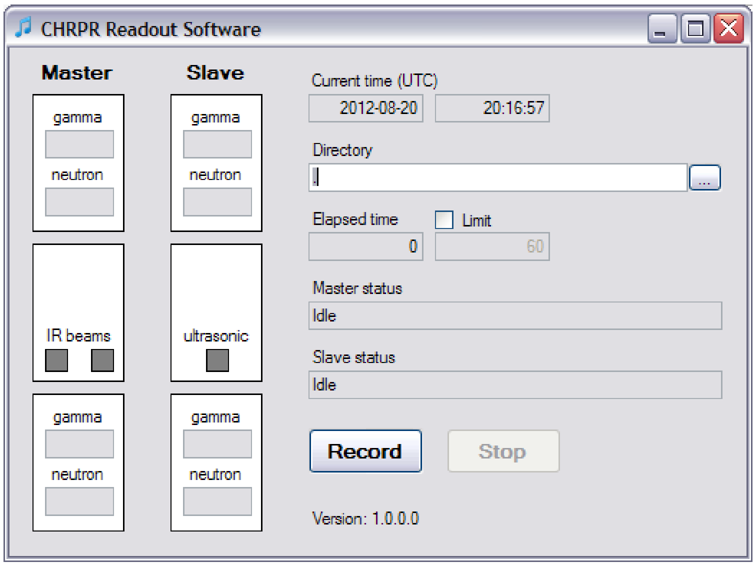


Figure 4.1: Screenshot of readout software.

To stop recording data, press "Stop". The software can be configured to stop after a fixed time using the "Limit" checkbox and associated text field. This field accepts values in seconds, minutes:seconds, and hours:minutes:seconds.

The readout software saves data from the CHRPR in binary format. These files contain data in list mode from the gamma detectors, neutron detectors, and occupancy sensors. One file is created for each detector; the file name specifies the detector number and start time in UTC:

- M0-20120820-173000.bin: Breakbeam sensors in master panel
- M1-20120820-173000.bin: Bottom gamma detector in master panel
- M2-20120820-173000.bin: Top gamma detector in master panel
- M3-20120820-173000.bin: Bottom neutron detector in master panel
- M4-20120820-173000.bin: Top neutron detector in master panel
- S0-20120820-173000.bin: Ultrasonic sensor in slave panel
- S1-20120820-173000.bin: Bottom gamma detector in slave panel
- S2-20120820-173000.bin: Top gamma detector in slave panel
- S3-20120820-173000.bin: Bottom neutron detector in slave panel
- S4-20120820-173000.bin: Top neutron detector in slave panel

The software creates a subdirectory underneath the specified output directory to store all data for a particular day. In the case above, the subdirectory would be named 20120820. If a measurement takes longer than 25 minutes, the software begins to save new sets of files on each hour change. This mechanism ensures that the binary files do not become too large.

The supplied analysis software converts the binary files to text format. However, the remainder of this section describes the binary format should the user desire to perform more detailed analysis.

The binary files begin with the following 16-byte header:

byte	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
value	00	00	00	02	00	00	MS	DN	start time							

MS (byte 6) is 01 for the master column and 02 for the slave column. DN (byte 7) is 00 for occupancy data (M0 or S0), 01 for detector #1 data (M1 or S1), and so forth.

The last field specifies the creation time of the file as a Unix timestamp. This 8-byte value specifies the time in GMT as the number of milliseconds elapsed since January 1, 1970. The Unix timestamp can be processed as a date by C and Java libraries. Other software packages (including Excel and MATLAB) require a simple translation. The value should match up with the start time encoded in the filename. The timestamp is given in **big endian** format, with the most significant byte at byte 8.

Following the 16-byte header, the format for the rest of the file contains data in list mode:

byte	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
value	x1	t1			x2	t2			x3	t3			x4	t4		

byte	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
value	x5	t5			x6	t6			x7	t7			x8	t8		

Each event is specified by a 1-byte channel number xn and a 3-byte timestamp tn. All fields are in big-endian format, as before. For detector data, the byte xn represents the energy channel which an incident gamma ray fell into at time tn. The value of xn ranges from 0 to 255. Placing all of the xn values into a histogram will produce a spectrum for the detector.

The timestamp t contains only the least significant three bytes of the full 8-byte Unix timestamp. This technique reduces the overall size of the data file by over 50%, but means that the value rolls over every 224 milliseconds (about 4 hours, 40 minutes). The start time in the header can be used to extend the value to the full 8 bytes using binary arithmetic. The following pseudocode illustrates how to perform this operation:

```
int64 start = [start time from header]
int32 low = (int32) start

while (not end of file)
     int32 data = [next 4 bytes of file]
     int32 x = (data >> 24) & 0xFF;
     int32 difference = ((data - low) << 8) >> 8;
     int64 time = start + (int64) difference
loop
```

Occupancy sensor files have the same overall format as detector files, except that the value xn encodes the status of a break beam sensor. For an M0 file, representing the two infrared sensors, xn has the following format:

- 00: neither beam broken
- 01: left beam broken
- 02: right beam broken
- 03: both beams broken

In S0 files, which record the ultrasonic sensor, xn has the following format:

- 02: no vehicle present
- 00: vehicle present

5 Analysis Software

Open Analysis.exe to start the analysis software. A screen similar to Figure 5.1 should appear.

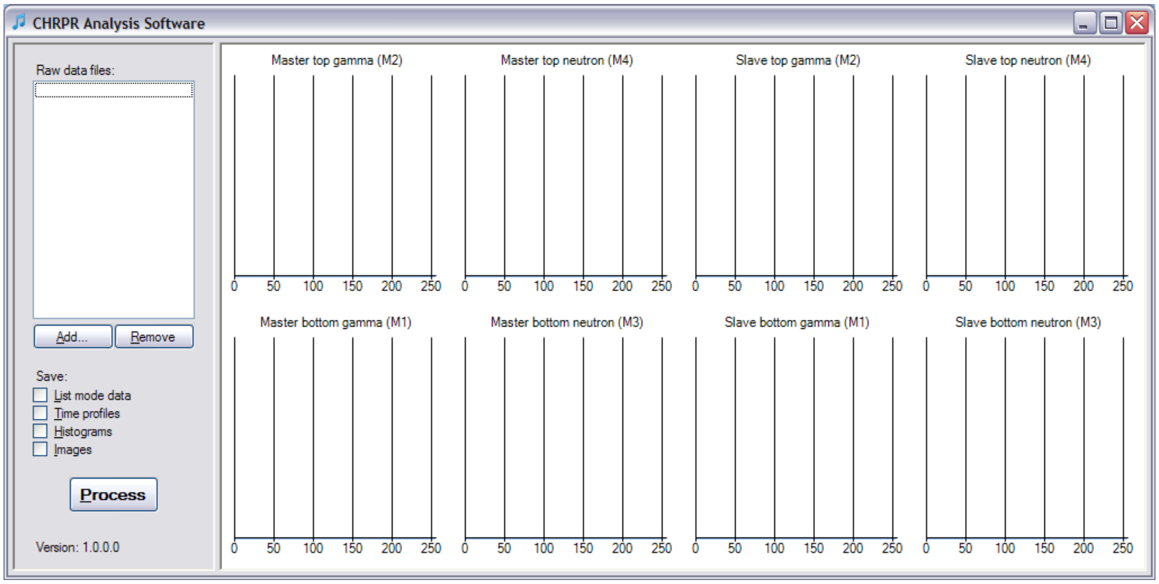


Figure 5.1: Screenshot of analysis software.

First click Add and select one or more binary files. Use the Shift and Ctrl keys to select multiple files. Files may be deleted from the list later using Remove. Next, use the four checkboxes to specify which files to save. Finally, click Process to analyze the data. Note that the data files cannot be processed if the readout software is currently accessing them.

The eight plots on the screen are updated with time-integrated histograms from each detector. The horizontal axis of each plot is the channel number from 0 to 255. The vertical axis is the total number of counts per channel. Data files from the same detector are combined together in the histograms.

Checking “List mode data” generates a text file in .csv format for each input data file. The text file contains two columns: a timestamp and a channel number. Open the .csv file in Excel and change the timestamps to “Date” or “Time” format to display the actual date and time.

Checking “Time profiles” produces a single text file in .csv format with a “P” prefix. This text file bins the counts from each detector into 100-ms intervals to create a time series. The status of the occupancy sensors is also listed. If no data is present during a 100-ms interval, the interval is omitted.

Checking “Histograms” produces a single text file in .csv format with an “H” prefix. This text file contains a 256-channel histogram of each detector.

Checking “Images” saves images of the eight plots in .png format.

6 TSA System

Figure 6.1 gives a block diagram of the master pillar.

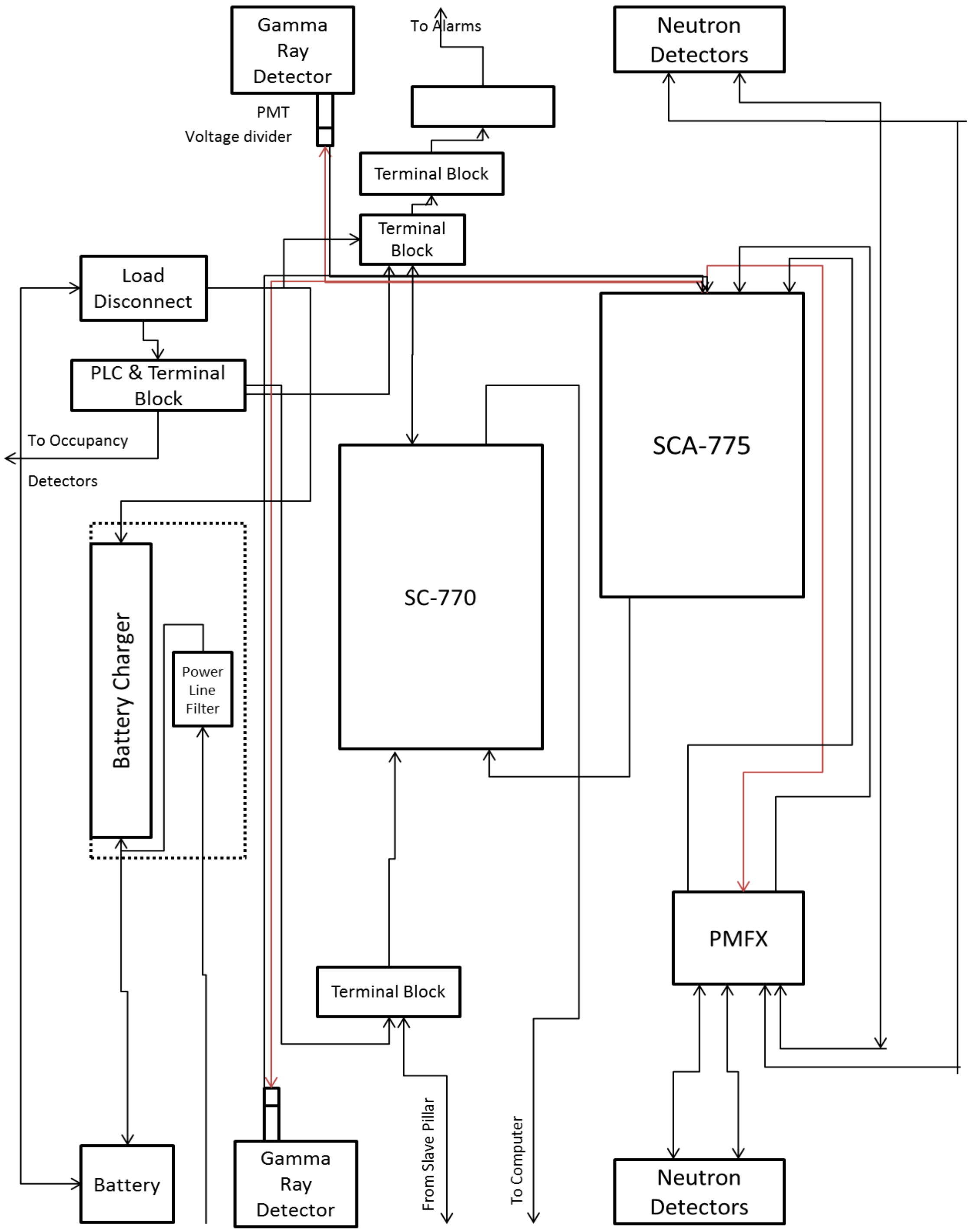


Figure 6.1: Diagram of master pillar.

Figure 6.2 shows a picture of the interior of the master pillar, with major components labeled. The components are briefly described in the following pages.

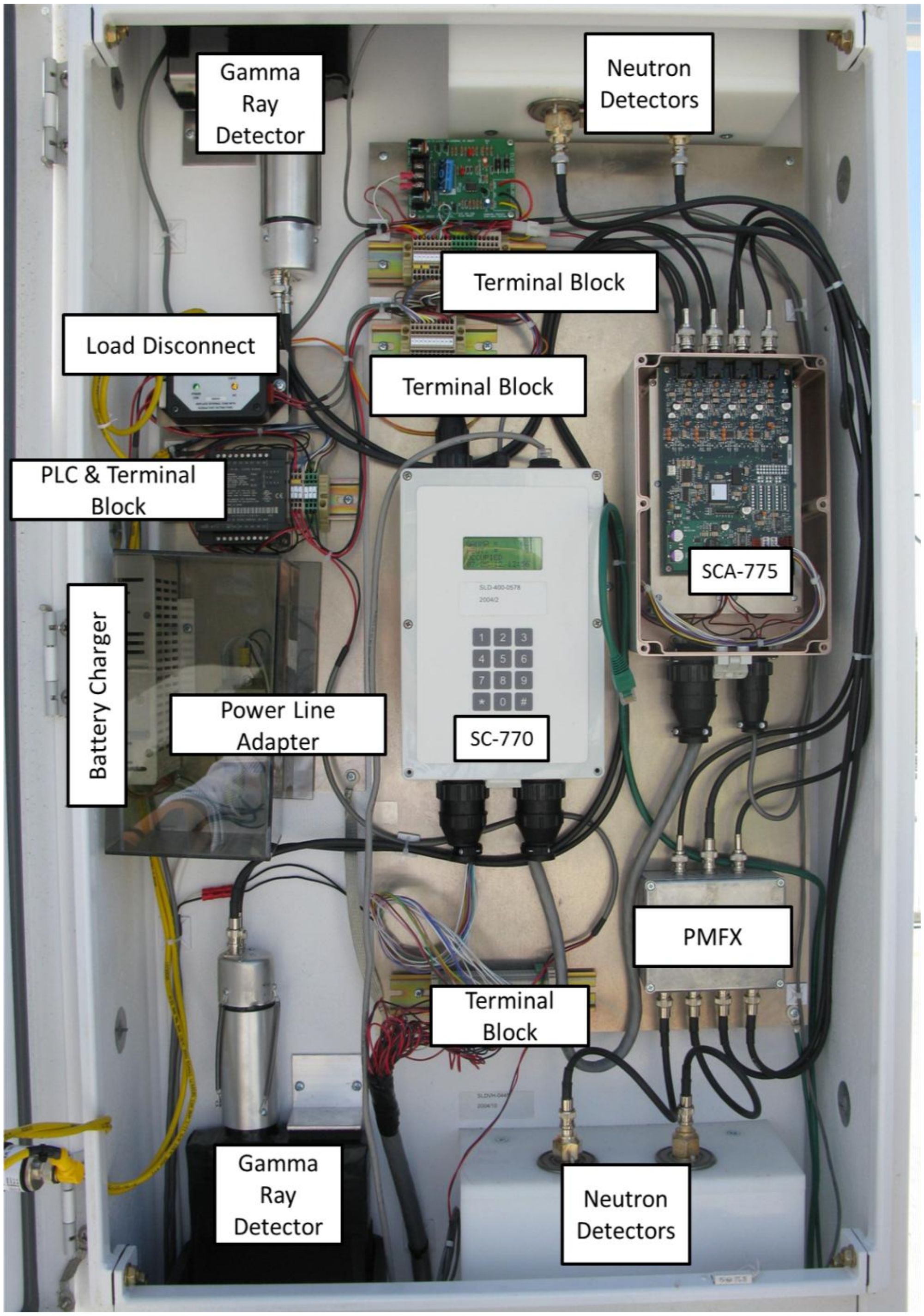


Figure 6.2: Annotated picture of master pillar.

Load Disconnect

The TSA LD-260a controls the supply of power to the rest of the system. It cuts off power if voltage drops below 10.5Vdc, and has a 5x20mm fast acting fuse. The yellow light indicates that power is being delivered to the unit, while the green light indicates that power is turned on.

Battery

The lead-acid battery receives power from the battery charger and sends power to the load disconnect. It is a 26 amp-our battery, and operates at 12 or more volts. It is designed to run for at least12 hours if power shuts off.

Battery Charger

The battery charger sends power to the battery. The output is 90-250 VAC, 47-63 Hz.

PLC (Programmable Logic Controller)

The General Electric VersaMax Nano PLC IC200NDD010 processes information from the vehicle presence sensors. It determines occupancy based on signal from the ultrasonic detector. It also compares the time between when the two infrared photo beam sensors to determine vehicle speed. The output is in ASCII text.

PMFX

This TSA unit takes high voltage from the SCA-775 and applies it across four wires which go to the neutron tubes. The output signal from the bottom two neutron tubes is combined into the leftmost wire on top of the box. The top two neutron tubes have their signal combined in the rightmost wire.

Power Line Filter

The Corcom 3VDK1 is an RFI power line filer. It is meant to filter conducted and radiated interference to protect the equipment from noise in the power supply lines. Essentially, the unit is a low-pass filter designed to attenuate frequencies outside that of the power line frequency. It operates at 50-60 hertz, with a 3A, 120/250V output. This unit leaks .4 mA / .7 mA in a line to ground at 120VAC 60 Hz / 250VAC 50 Hz.

SC-770

The SC-770 is the main processing center for the pillars. It collects data from the SCA-775, sends data to a computer in ASCII format, executes firmware and software, relays alarm triggers, and sends information about current settings to the computer. Pages 14-35 in the TSA manual detail how to program this unit with the keypad.

Gamma Ray Detector, PMT, Voltage Divider

This detector is filled with a plastic designed to emit several lower-energy photons when struck with a gamma ray. These photons are transformed into a wave of electrons by a photocathode. This wave of electrons is amplified into a larger electrical pulse with a photomultiplier tube (PMT), and this pulse is passed to the output wire. The voltage divider takes the input voltage from the SCA-775 and applies it to the PMT.

Occupancy Detectors

There are two types of occupancy detectors. The ultrasonic detector emits ultrasonic sound waves, then listens for a reflection to test for the presence of a vehicle. This is the single, silver-colored detector in the bottom panel. For information on programming the ultrasonic detector, see page 62 in the manual.

The two yellow detectors in each panel are IR Photo beam detectors. These output infrared light from one pillar which is picked up in the other pillar. The difference in time between when the two beams is broken is used to calculate the vehicle speed.

Information from the occupancy sensors is sent to the PLC in the master pillar.

SCA-775

The SCA-775 collects pulses from each individual detector, times them with a 2MHz clock, and passes them along to the SC-770 in the master column. The SCA-775 also applies the discriminator settings from the SC-770 to determine which pulses should be passed along.

For a detailed diagram of voltage test points, refer to page 69 in the TSA manual.

Terminal Block

The terminal block serves as a point for wires to be connected. It is not designed to modify the signals in each wire in any way. For more information about the setup of a terminal block, see page 13 in the TSA manual.

Slave Pillar

The slave pillar contains similar elements to the master pillar, although, notably it does not contain a control box and some of the power circuitry.

7 CHRPR System Description

Figure 7.1 gives a block diagram of the CHRPR system. The CHRPR box reads analog signals from the test amplifier outputs in the SCA-775. Each box contains custom analog and digital electronics to digitize the height of each pulse, record the binary values in memory, and transmit the values across an Ethernet link. The readout software on the computer controls the two CHRPR boxes and ensures they remained time synchronized.

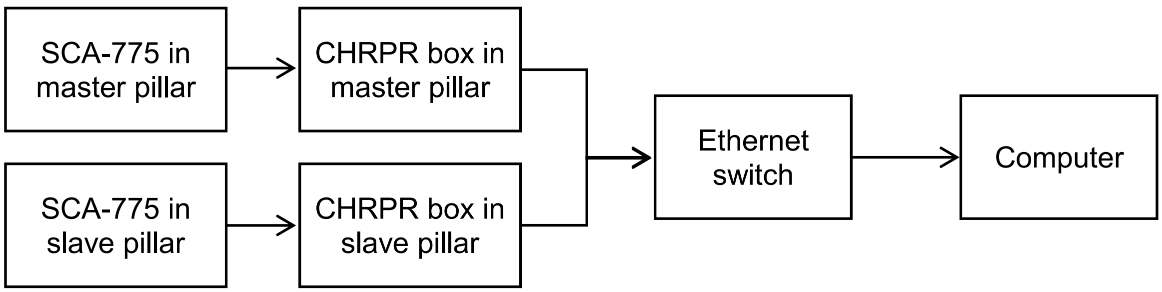


Figure 7.1: Block diagram of CHRPR system.

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