Raydec

MT5 Multi-Tracer
Operating Manual

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Doc Version 2.04

Jan 2022

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1. Contents

2. Introduction

The Multi-Tracer 5 System (MT5) provides a complete, self-contained, electrical load and data acquisition system for collecting performance data of photovoltaic modules. The MT5 collects two types of data; continuous performance under load, and IV curves.

When not taking IV curves, the MT5 operates the PV modules under load conditions defined by the user. While under load, the MT5 samples module voltage and current. Additionally, the system samples temperatures and a set of auxiliary (Aux) inputs (e.g., pyranometers). The MT5 samples all values once per second and averages these values over a period defined by the user.

The MT5 also takes periodic IV curves of each module. The period is set by the user. For example, the system can be setup to take curves once each hour.

An MT5 System consists of one MT5 Controller and one to four load units. An MT5 Controller operates the load units and also samples data from the temperature and auxiliary input connections. A standard MT5 Controller has 24 temperature (thermocouple) inputs and 8 Aux inputs. An MT5 Load Unit provides an electrical load and data acquisition for up to 16 photovoltaic (PV) modules. The actual load configurations are defined by the user when their MT5 is ordered.

The MT5 system is self-contained and once setup, the MT5 will collect and store data internally without any other external equipment. The MT5 is a network device. This means that it connects to an existing computer network via common Ethernet cables and uses standard TCP/IP protocols.

A web browser provides the primary user interface for configuring and monitoring the MT5 system. Currently, the MT5 system only supports the Mozilla Firefox browser. The MT5 runs an internal web server. No special software is needed to interact with the MT.

3. Setup

Basic setup of the MT5 System is straight forward and requires a few key steps:

1) Hardware Installation.
2) Establish a network connection.
3) Configure operating parameters.

Each of these is discussed, in detail, in the following sections

3.1. Hardware Installation

Follow these basic steps for proper installation:

1) Mount the MT5 Controller and Load Unit(s).
2) Connect AC power (but leave units turned off).
3) Connect MT5 Load unit(s) to MT5 Control Unit using provided cable.
4) Connect PV modules, temperature sensors, and other signals.
5) Power up the MT5 Load and Control units.
6) Allow approximately 2 minutes for the MT5 System to boot.
7) Test Network Connection.

3.1.1. Mounting

Mount the MT5 Controller and Load units in standard 19-inch equipment rack or on a stable surface. Each controller and load requires AC power and each load must connect to the controller with a load control cable. See Appendix E - Specifications, for detailed power requirements.

The load unit dissipates energy as warm air. Fans are mounted on the bottom of the load unit. Make sure the airflow is not blocked. See the discussion of ventilation below for more details. The cooling fans are relatively noisy when running at full power (up to 86 dB). Therefore, consider fan noise when locating the system.

3.1.2. AC Power

Both the MT5 Controller and Load units require AC power. Raydec strongly recommends powering the MT5 Controller and Load units through an uninterruptible power supply (UPS). The MT5 System includes an internal computer and, as with any computer, clean and stable power helps to ensure trouble-free operation. In addition to helping to prevent system damage, a UPS also reduces the possibility of losing data.

Each load unit requires an external electrical ground. Although the AC power cord connects the Load unit chassis to AC power ground, this ground connection cannot handle the potential worst-case ground-fault currents from the connected PV modules. Therefore, additional grounding is used to ensure safe operation of the unit under worst-case conditions. Figure 1, shows the grounding lug mounted on the MT5 Load units. This lug accommodates wires from #4 to 1/0 AWG.

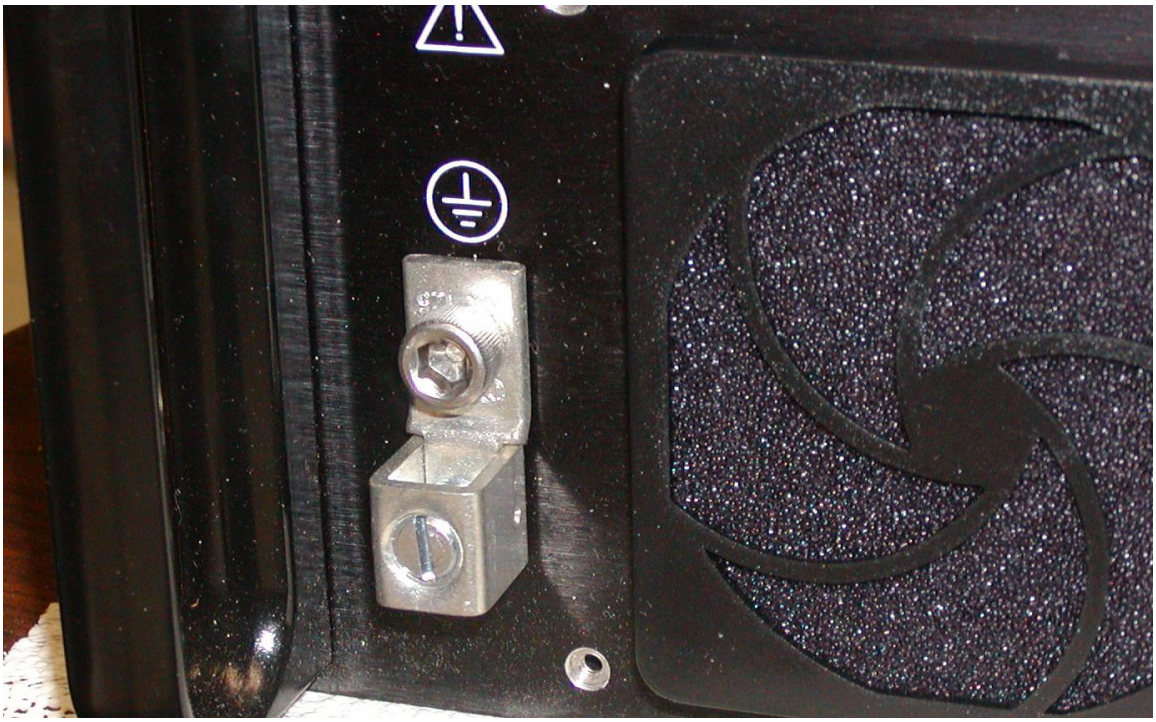


Figure 1. Grounding lug.

Raydec recommends connecting the largest gauge wire possible in your installation from this external ground point to earth ground. Note: That this external ground is not needed for proper operation, nor is the unit unsafe without this connection. However, this connection provides additional safety if the MT5 Load Unit experiences a catastrophic failure requiring that all module currents be shunted to ground.

3.1.3. Ventilation

The MT5 Load Units dissipate the electrical energy from the modules as heat in the form of warm air. It is critical that the MT5 Load unit have adequate ventilation that allows cool ambient air to enter the front and exit the back of the load unit with minimal airflow restriction. Raydec recommends a minimum of 1 foot (12 “or 30 cm) of clearance between the load fan intakes and exhaust, and surrounding surfaces.

Take care to avoid allowing the warm exhaust air to re-circulate to the fan intake. This will cause the MT5 Load Unit to overheat requiring that it shutdown, and possibly damage the unit.

Note: If operating the MT5 System inside an air conditioned area, the heat from the MT5 will add to the load on the air conditioning system. This will require the cooling system work harder to remove this heat from the room. Or conversely, this heat will help warm a room in winter months. The MT5 load dissipates all of the PV module power as warm air, plus some small additional power from the load unit circuitry.

The MT5 Control unit dissipates little power and no special precautions or ventilation is needed.

3.1.4. Connections

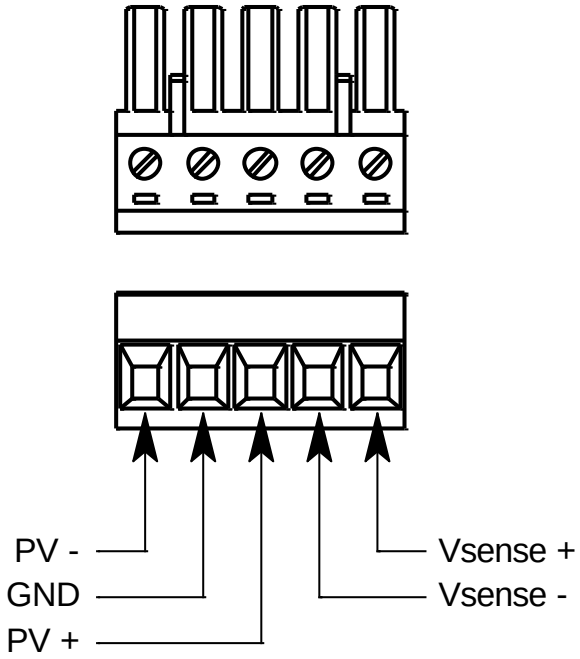
The MT5 has several specific connections and each is described below. The MT5 system comes with all the connectors needed. The manufacturer and part numbers of each connector are listed in Appendix A.

Load Control

Each MT5 Control unit can control up to four MT5 Load Units. For a typical system with one controller and one load, connect the load unit to the Load 1 port of the controller. Use the 1-meter load control cable provided. Longer cables may be used if necessary. Contact Raydec if you need a longer load control cable.

PV Module Connections

The Multi-Tracer uses a 5-pin connector for each PV module input. The connector and each pin function is shown in Figure 2.



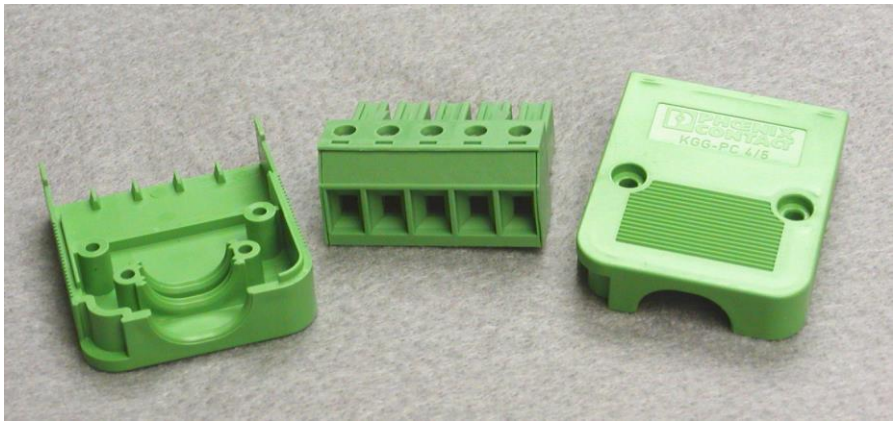


Figure 2. Multi-Tracer PV module input connector.

Depending on the size of the wires used, the module connector strain relief may be attached in one of two positions as shown in Figure 3.

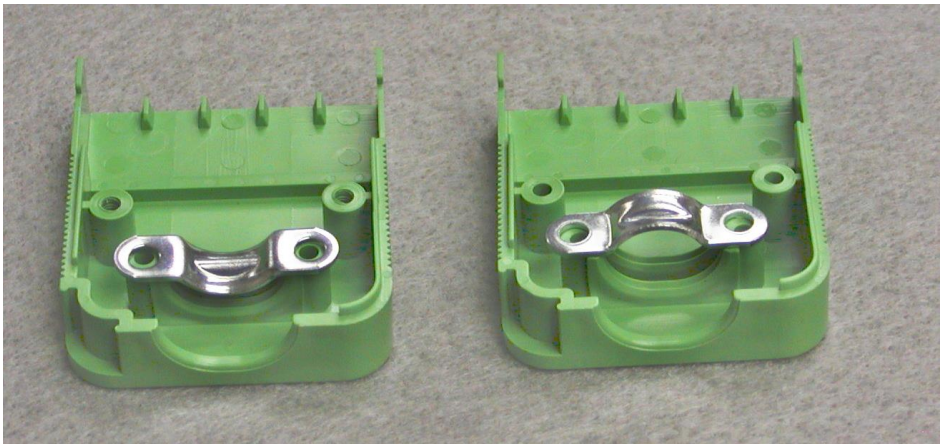


Figure 3. Module connector strain relief options.

The Multi-Tracer supports grounding either the module negative or module positive terminal. Therefore, each channel must be wired as a positive or negative ground channel. Most modules are connected using negative grounding, and, by default, all Multi-Tracer channels are configured this way unless positive grounding is specified by the customer when the unit is ordered. Note: A simple wiring modification is required inside the Multi-Tracer to convert the given channel from positive to negative grounding. Please see the section 8 “Changing Module Grounding” for details.

The module connects to the Multi-Tracer in one of two ways, either the positive input (PV+) and ground (GND) or to the negative input (PV-) and ground (GND). Never connect a module to PV+ and PV- at the same time. No damage should result, but the unit will not function properly.

The voltage sense lead is connected the same regardless of the grounding scheme. While the diagrams below show the shield of the voltage sense cable connected to ground at the Multi-Tracer, other shielding connections may perform better depending on the specifics of the installation. Generally, it is better to connect a shield at one end only.

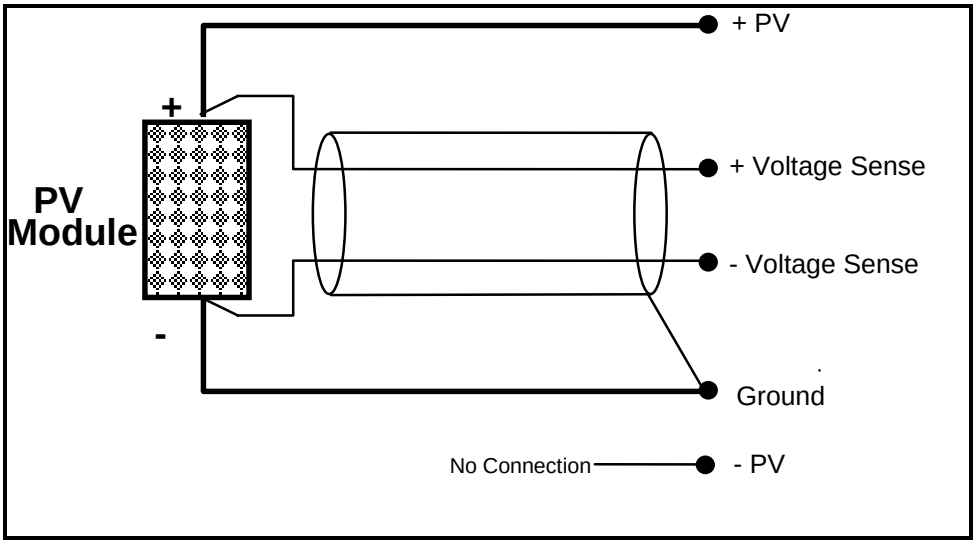


Figure 4. Multi-Tracer PV module wiring for negative grounding.

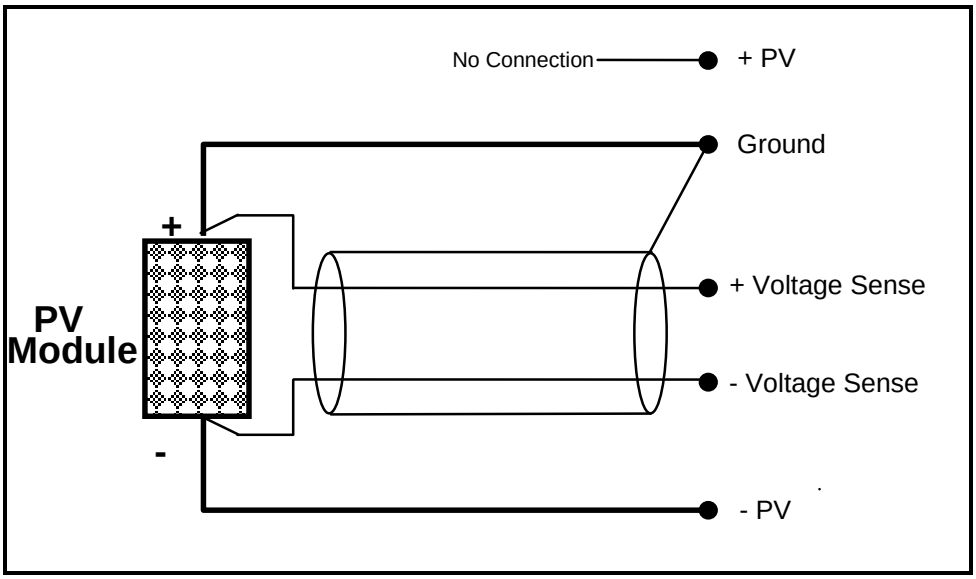


Figure 5. Multi-Tracer PV module wiring for positive grounding.

Four wires connect the PV module to the Multi-Tracer:

- Positive PV Power Lead (Large Gauge).
- Negative PV Power Lead (Large Gauge).
- Positive Voltage Sense Lead
- Negative Voltage Sense Lead

Use a shielded-pair wire with a voltage rating greater than Voc of the PV module for the voltage sense lead. Connect the shield of this cable to the GND pin of the Multi-Tracer module connector or other suitable ground point. Connect the shield at one end only. Keep the power leads as short as possible and use #10 AWG wire. This is the largest wire that can be used with the Multi-Tracer connectors.

Wire Size and Voltage Drop

The MT Multi-Tracer loads operate in the first quadrant. This means that they only dissipate power and only operate where the voltage is positive and the current is flowing from the PV module into the Multi-Tracer. While the 4-wire module connection, with separate voltage sense, eliminates any measurement error due to voltage drop along the power wires, this voltage drop still exists.

Table 1 shows the approximate wire resistance for several gauges of wire. Note: The largest wire the MT5 module connectors accommodate is #10 AWG. This is highlighted in the wire table. The total wire length is the combined (or round-trip) distance of the positive and negative module power leads.

As an example, the voltage drop at 10 A is shown. The significance of this voltage drop is that it limits how close to a true short-circuit the PV module can operate.

For most applications, these voltages drops are insignificant as far as any discrepancy between true short-circuit current and the minimum or near short-circuit current measured by the Multi-Tracer.

Table 1. Module Wiring Resistance Chart.

Wire Gauge (AWG)	Res. (mOhms/ Ft)	Resistance for 50 ft (100 ft round trip) (Ohms)	Voltage Drop @ 10 A	Res. (mOhms/m)	Resistance for 15 m (30 m round trip) (Ohms)	Voltage Drop @ 10 A
#14	2.61	0.261	2.61	8.56	0.257	2.57
#12	1.64	0.164	1.64	5.38	0.161	1.61
#10	**1.03**	**0.103**	**1.03**	**3.38**	**0.101**	**1.01**
#8	0.65	0.065	0.65	2.13	0.064	0.64
#6	0.41	0.041	0.41	1.35	0.041	0.41
#4	0.26	0.026	0.26	0.85	0.026	0.26

Table 1 shows wire sizes larger than #10 (the maximum that fits the MT5 Module connectors). If #10 AWG wire is too small to avoid excessive voltages drops, larger wire can be used by transitioning from the larger wire to a #10 wire near the Multi-Tracer load unit. For example, by mounting a terminal block near the load unit.

Aux Input Connections

The Multi-Tracer uses a 3-pin connector for each auxiliary (Aux) input. These are typically used for pyranometers but may be used for any DC voltage signal within the input range of +/- 5V.

The connector and each pin function is shown in Figure 6.

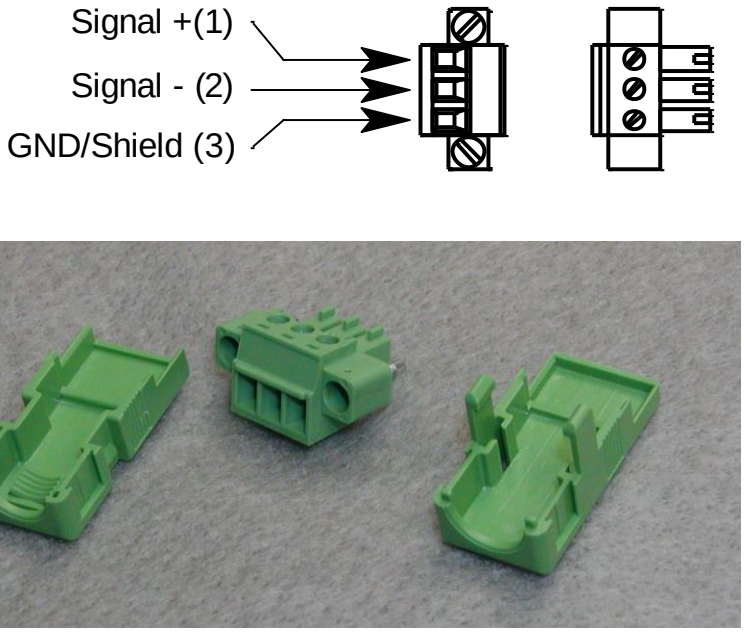


Figure 6. Multi-Tracer Aux input connector.

Note: The Multi-Tracer makes a differential measurement between the signal positive and negative inputs. However, this signal must be referenced to the Multi-Tracer ground (GND). If the signal source (pyranometer) does not reference to ground, then add a reference to ground at this connector. For example, place a jumper from signal negative to the GND connection.

Other referencing techniques may be more appropriate. For example, a resistance rather than a direct shorting jumper. Different grounding schemes may have significant impact on signal noise. If noise appears to be a problem, try alternate methods of referencing the signal and alternate connections for the signal cable shield.

Thermocouple Connections

The MT5 Controller accepts standard mini-thermocouple plugs as shown in Figure 7.

Figure 7. Type T Mini-thermocouple plug.

Keyboard and Video Monitor

The MT5 control unit supports a keyboard and video monitor. A common USB type computer keyboard can be connected to either of the two USB host ports on the front panel of the MT5 control unit. A computer monitor can be connected to the video port. This video port is a standard VGA analog video connector.

Figure 8. Video and USB Connections.

Use of the keyboard and monitor is optional and is only necessary for reconfiguring the system as described in section 10 “System Expansion and Configuration” or as an alternate user interface when changing network settings as described in section 6.1.1 “Network Change via Keyboard and Monitor.”

3.1.5. Power Up

Once all AC power, control, module, and signal connection have been made, turn on the AC power switches of both the load and control unit. The system takes approximately 2 minutes to completely power up and boot. The Multi-Tracer will automatically begin collecting data as soon as it completes its startup process.

3.1.6. Network

Interaction with the Multi-Tracer system requires a functioning network connection to the unit. This network connection is the primary user interface to the unit. Please refer to the section 6 “Network Connection” for details on setting up and testing the network connection to the Multi-Tracer.

3.1.7. Setting the Time

The first thing to do after getting the MT5 system running and establishing a network connection is to set the system date and time. This is done using the “Systems” menu in the software as described in section 4.4.1 “Date & Time”. There are numerous other user settings that affect how the data are collected. Refer to the following section “MT5 Configuration and Use” for details on all of the available settings.

4. MT5 System Configuration and Use

The MT5 system automatically collects data any time it is turned on. However there are parameters and settings that can be customized. The MT5 collects two forms of data; performance data under load, and IV curves (see section 5 “Multi-Tracer Data”).

A web browser provides the Multi-Tracer user interface. Currently, Mozilla Firefox is the only browser fully compatible with the MT5 system. All interface pages have a common layout with menu selection tabs, as shown in Figure 9 and Figure 10. Each of these tab menu items are discussed in the following sections.

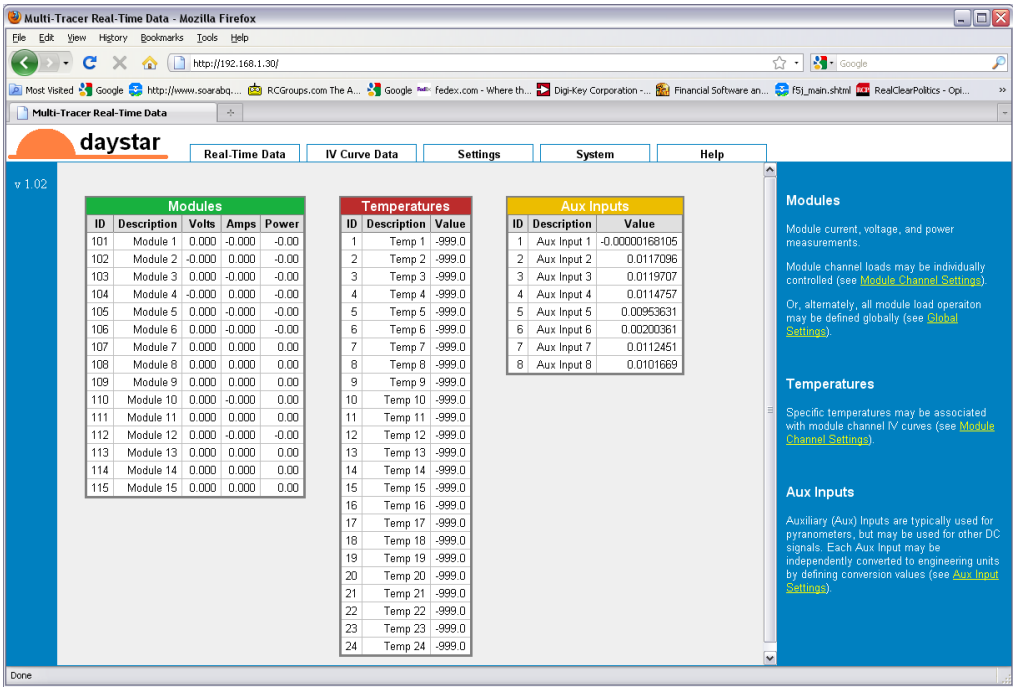


Figure 9. Multi-Tracer real-time data page.

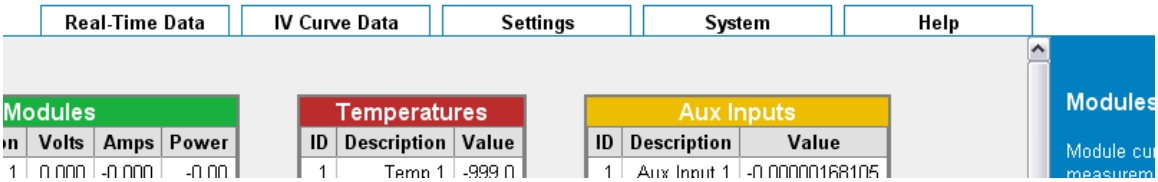


Figure 10. Menu selection tabs.

The system supports two levels of access control “user” and “administrator”. Use the “Admin” link, shown below, to go to the administrator .

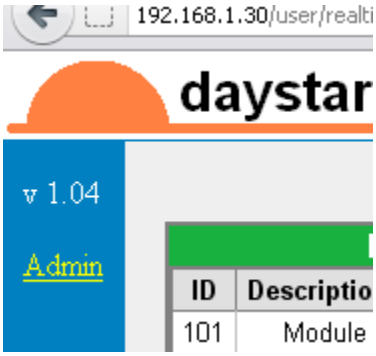
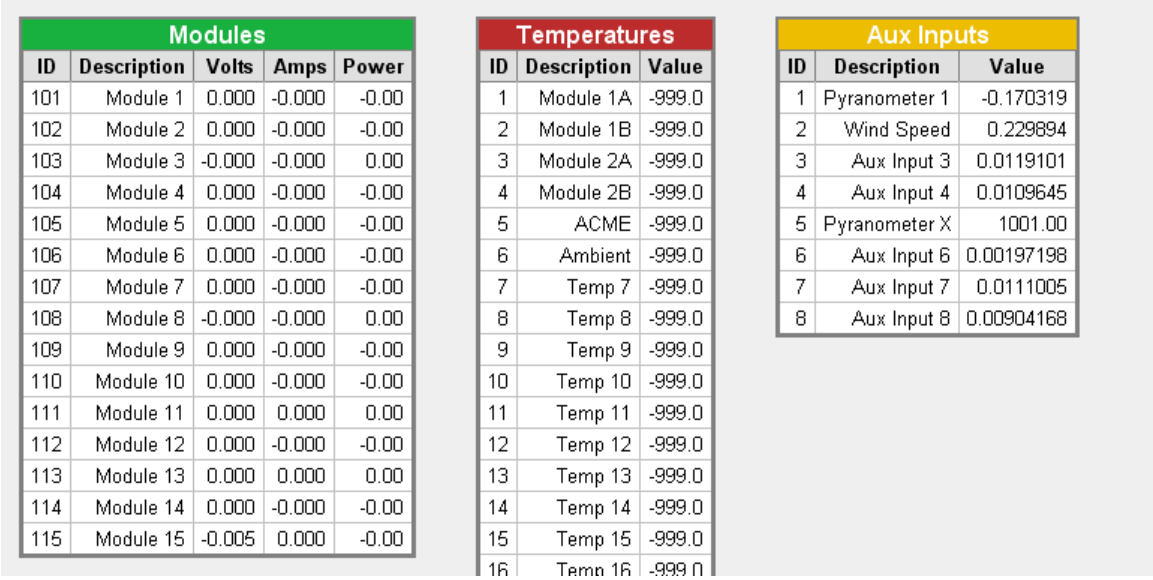


Figure 11. Administrator Link.

See section 6.4 “Network Security, Usernames and Passwords” for details on users and access control. The following descriptions assume no security access limits (the default for new MT5 systems) or that administrator access is in use.

4.1. Real-Time Data Tab

The “Real-Time Data” tab is the main MT5 data page. It shows the latest measurements updated once per second. This page only displays data and provides no other features.



Modules

ID	Description	Volts	Amps	Power
101	Module 1	0.000	-0.000	-0.00
102	Module 2	0.000	-0.000	-0.00
103	Module 3	-0.000	-0.000	0.00
104	Module 4	0.000	-0.000	-0.00
105	Module 5	0.000	-0.000	-0.00
106	Module 6	0.000	-0.000	-0.00
107	Module 7	0.000	-0.000	-0.00
108	Module 8	-0.000	-0.000	0.00
109	Module 9	0.000	-0.000	-0.00
110	Module 10	0.000	-0.000	-0.00
111	Module 11	0.000	0.000	0.00
112	Module 12	0.000	-0.000	-0.00
113	Module 13	0.000	0.000	0.00
114	Module 14	0.000	-0.000	-0.00
115	Module 15	-0.005	0.000	-0.00

Temperatures

ID	Description	Value
1	Module 1A	-999.0
2	Module 1B	-999.0
3	Module 2A	-999.0
4	Module 2B	-999.0
5	ACME	-999.0
6	Ambient	-999.0
7	Temp 7	-999.0
8	Temp 8	-999.0
9	Temp 9	-999.0
10	Temp 10	-999.0
11	Temp 11	-999.0
12	Temp 12	-999.0
13	Temp 13	-999.0
14	Temp 14	-999.0
15	Temp 15	-999.0
16	Temp 16	-999.0

Aux Inputs

ID	Description	Value
1	Pyranometer 1	-0.170319
2	Wind Speed	0.229894
3	Aux Input 3	0.0119101
4	Aux Input 4	0.0109645
5	Pyranometer X	1001.00
6	Aux Input 6	0.00197198
7	Aux Input 7	0.0111005
8	Aux Input 8	0.00904168

Figure 12. Real-time data tables.

4.2. IV Curve Data Tab

The “IV Curve Data” tab displays information on the last IV curve taken for each module channel. This page displays key information such as peak-power, Voc and Isc values. In addition to displaying the last IV curve taken, this screen is used to manually take IV curves.

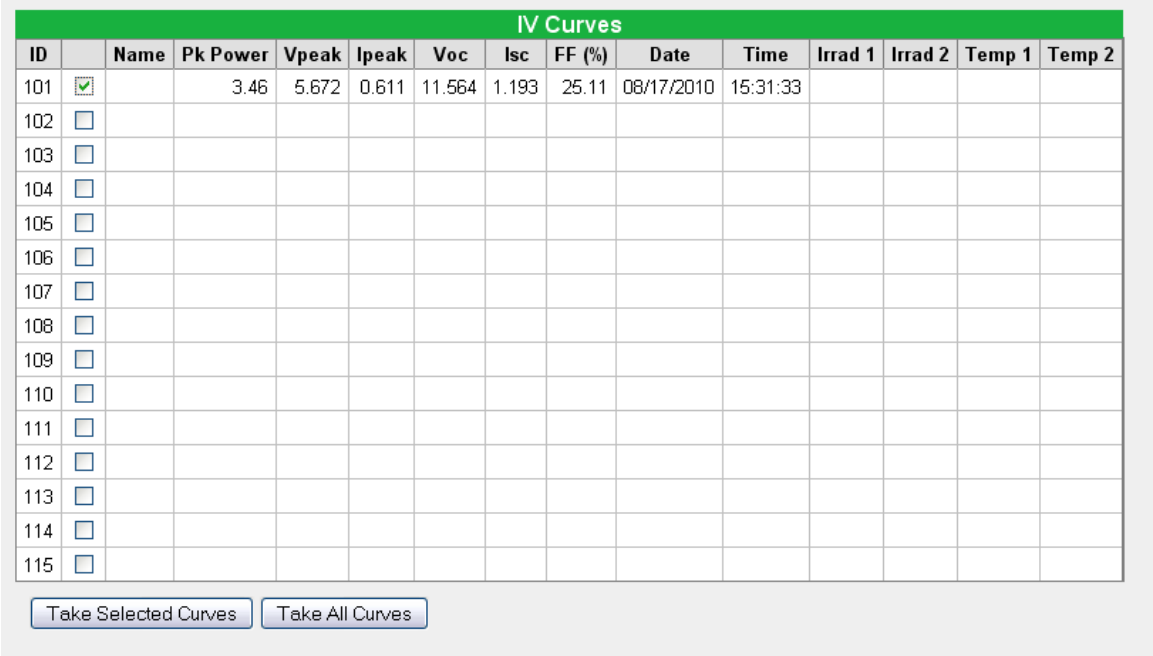


Figure 13. IV curve data table.

To take an IV curve of all modules, press the “Take All Curves” button. To take selected curves, use the check boxes to enable a subset of curves and then press the “Take Selected Curves” button.

These settings have no effect on automatic IV curves and are only used to manually take IV curves. The Multi-Tracer takes manual curves independent of any settings that affect automatic IV curves.

Note: IV curves take a significant amount of time. Commonly 2-3 seconds per module.

4.3. Settings Tab

4.3.1. Global Load & IV Curve Control

The load control mode (peak-power, voltage tracking, or off) can be set individually for each module or globally for all modules (see Figure 12). Refer to section 4.3.2 “Module Channel Settings” for individual module channel settings. Global control settings override the individual settings. There are separate settings for continuous load operation and IV curves.

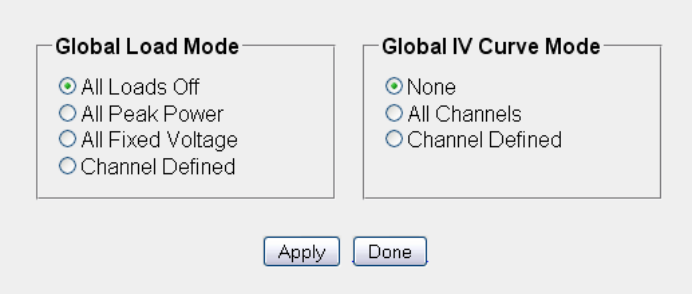


Figure 14. Global load & IV curve modes.

Global Load Mode

This setting controls how all the module loads operate while collecting performance data.

- All Loads Off – Turns all loads off (open circuit) regardless of individual module channel setting.
- All Peak Power – Sets all modules to peak power track, regardless of module channel setting.
- All Fixed Voltage – Sets all modules to operate at a fixed voltage. The fixed voltage is separately set for each module in the module channel settings.
- Channel Defined – Operate the module load as defined for that individual module channel.

Global IV Curve Mode

This mode controls what module curves are taken automatically. This setting has no effect when taking manual IV curves.

- None – No automatic IV curves are taken at any time, regardless of IV curve or module channel settings.
- All Channels – Automatic IV curves are taken on all channels, even if these channels are not individually enabled for IV curves.
- Channel Defined – IV Curves are taken on modules that have been enabled for IV curves within that module’s channel settings.

4.3.2. Module Channel Settings

The MT5 Multi-Tracer operates each module separately and these module channel settings are used to define values specific to a given module channel. By default, the page opens to the first module in the system. Use the “Module Channel” drop-down list to select the specific module to work with.

Note: These settings are optional, though important to get the full benefit of the MT5. Figure 15, shows all of the module channel settings. Each area of this screen is described below.

WARNING: Press the “Apply” button to save these settings before moving to another page.

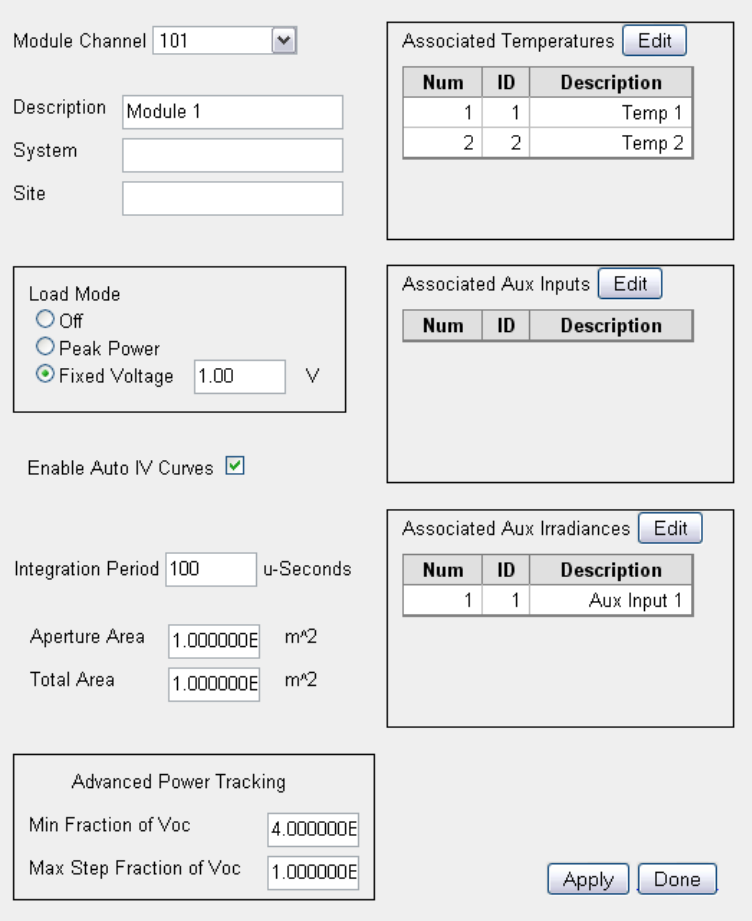
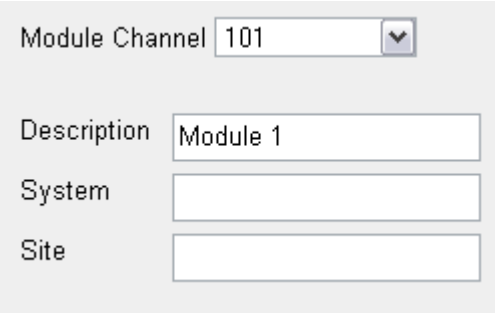


Figure 15. Module channel setup dialog.

Module Channel & Description Fields

The first section contains the “Module Channel” drop-down list. Use this to select the specific module settings to work with. The three fields (Description, System, and Site) are simply text fields that you can enter identifying information. The Description-field is shown on many of the other interfaces pages and in the MTD performance data file header (refer to section 5.1 “Performance Data”).

The primary module identifier is the module channel number, for example, “101” as shown below. This number uniquely defines the module data. But the Description-field is recorded in both the MTD performance data files and the IV curves files.

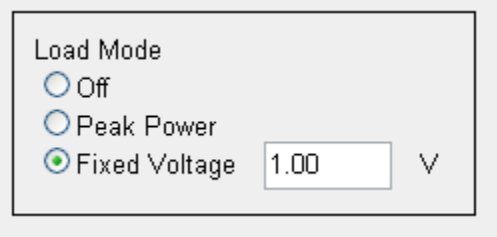


The “System” and “Site” fields are additional description fields. These fields are only recorded in the IV curve files and are not recorded in the MTD files.

Because these fields become part of the data sets, avoid using punctuation that could confuse subsequent data processing. The MT5 System records whatever is placed in these fields.

Load Mode

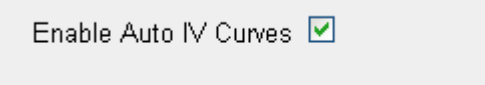
The “Load Mode” section defines how the module is electrically loaded while collecting performance data (MTD file data). This setting has no effect on IV curves.



- Off – Keep this module's load turned off. Therefore the module will operate in an open-circuit condition.
- Peak Power – Operate the module in a peak-power tracking mode (see Appendix B - "Peak-Power" tracking for details).
- Fixed Voltage – This mode operates the module at the fixed voltage given. Enter the voltage in the associated box.

Enable Auto IV Curves

This check box enables this module for automatic IV curves. See the section 4.3.5 "IV Curves Setup" for additional details. This setting determines if an IV curve is taken automatically for this module when the "Global IV Curve Mode" is set to "Channel Defined". See the section 4.3.1 "Global Load & IV Curve Control" for details on overriding this setting.



Integration Period

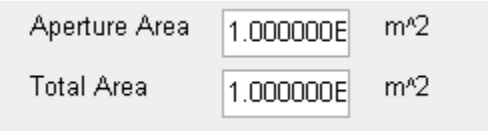
The "Integration Period" setting defines the number of microseconds used for module voltage and current data sampling. The default 100 uS is recommended and should not be changed unless necessary. Larger values will help reduce signal noise by averaging the signal over a longer period.

For example, if there were a large amount of 60 Hz, power-line noise being picked up by the module wiring, setting this value to 16,667 uS would virtually eliminate all 60 Hz noise. However, all data sampling on this channel will be much slower. Larger values could prevent the system from sampling at the nominal 1 second interval and will certainly greatly increase the time required to take IV curves.

Larger integration periods can be helpful if illuminating the module with an artificial light source powered with an AC power source. For example, some artificial light sources use AC power with frequencies that cause the light to fluctuate at a frequency of 400 Hz. In that case an integration period of 2,500 uS would ideally eliminate the noise at this frequency.

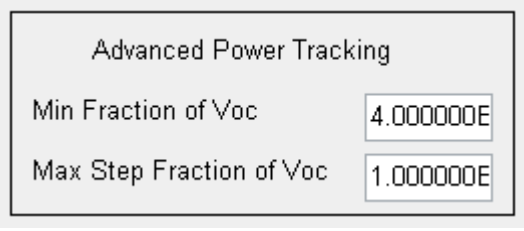
Aperture & Total Area

These values are for convenience and are used to calculate the modules electrical efficiency based on the irradiance 1 value associated with this module. The efficiency values are only recorded with IV curve data. These values have no effect on any data recorded other than the associated efficiency values. These values are often not used and therefore these settings may be left at their default values.



Advanced Power Tracking

Refer to Appendix B - “Peak Power Tracking” for details.

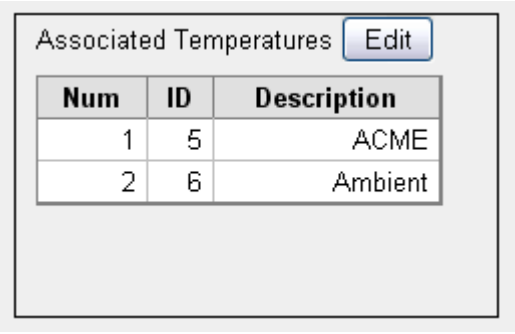


Associated Temperatures, Irradiance and Aux Data

Performance data recorded in the MTD data files contains all module, temperature, and auxiliary data. Therefore the Multi-Tracer makes no relationship between module channels and specific temperature or auxiliary inputs for data recorded to MTD files. Refer to section 5.1 “Performance Data” for more information on these files.

However, typically a subset of temperatures and auxiliary (irradiance) data measurements have a physical association with a given module, module temperature(s) for example. It is therefore unnecessary, potentially confusing, and a waste of storage space to store all temperature and auxiliary data measurements in every IV curve. The association feature defines which temperature, irradiance and auxiliary measurements are recorded in a given module’s IV curves data file.

For example, the following temperature associations show that system temperature ID 5 (labeled “ACME”) is defined (associated) as this module’s temperature number 1. Similarly, system temperature ID 6, “Ambient”, is this module’s temperature number 2. Therefore, for this module’s IV curve file, temperature number 1 and 2 will actually come from MT5 system temperature ID’s 5 and 6.



Press the “Edit” button to bring up the dialog, shown in Figure 16, and set these associations.

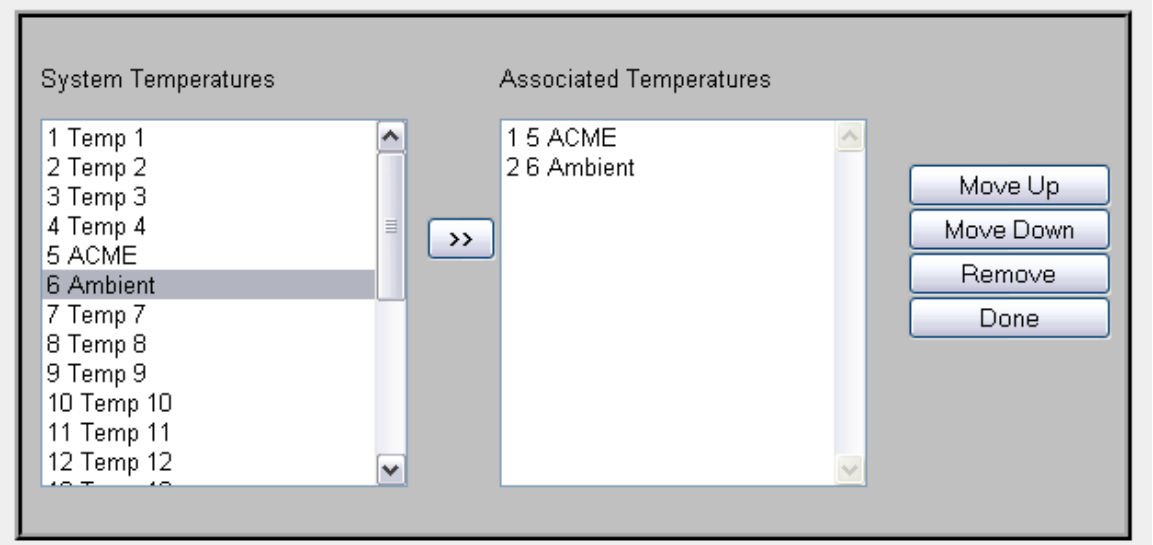


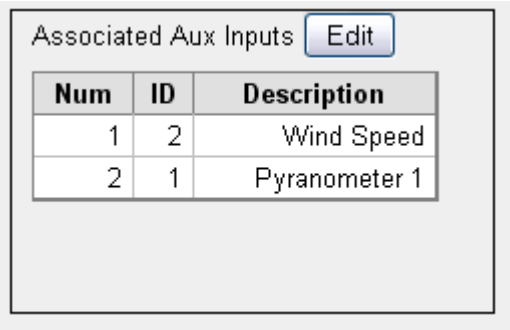
Figure 16. Temperature association edit dialog.

All temperatures of the MT5 system are shown in the left column and the associated temperatures for the given module are in the right-hand column. By default, the temperatures are associated as module temperature numbers 1, 2, 3 etc., in the order they are added using the “>>” button. However, the order can be changed by selecting the associated temperature, in the right-hand column, and using the “Move Up” or “Move Down” buttons to alter its association number. The “Remove” button will remove the selected associated temperature.

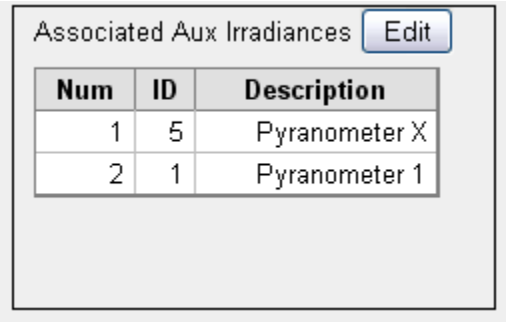
The “Done” button closes this edit box.

Note: These associations must be saved using the “Apply” button on the module channel setup page.

The auxiliary associations work the same as the temperature associations.



The MT5 Multi-Tracer system does not have specific inputs for measuring irradiance. However, it is common for some auxiliary inputs to be used for irradiance measurements. The “Associated Aux Irradiance” settings associate auxiliary inputs specifically as irradiance measurements. This means that these values will be stored as irradiance values in the module IV curve data files. This simply identifies the given auxiliary inputs as irradiances values.



4.3.3. Aux Input Scales

The “Aux Input Scales” page provides a method to label and define the scale of auxiliary data values. For example, as shown below, auxiliary input ID 1 has been labeled “Pyranometer 1”. It has been given a scale of 1000 to 0.0098362 V (9.8362 mV). This means that if the auxiliary input 1 signal were 9.87 mV, the auxiliary data value would scale such that the recorded value would be 1000.

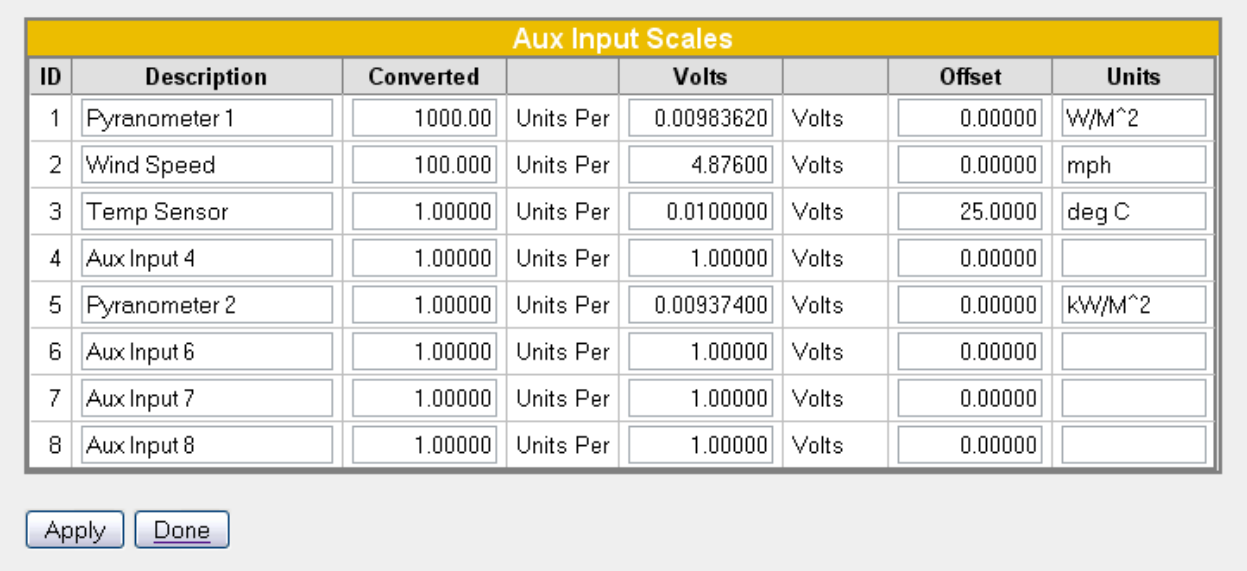


Figure 17. Auxiliary input scales.

In this case, the signal comes from a pyranometer and the units would typically be in watts per square-meter (W/M^2). However, the units field is only a text label and is only informational. The units label has no effect on the conversion.

Another example, auxiliary input 2, Wind Speed, has converted units of 100 per 4.876 V. This could be either 100 miles-per-hour or 100 m/s at 4.876. The converted units depend on the constant applied. In this example, the units have been labeled “mph”. The MT5 places no restriction on what the actual units are.

Do not be confused by that fact that there are two scaling values to enter; “Converted” and “Volts”. This is done for convenience. Often instruments are specified with an output for a given input. For example, a pyranometer might have an output given as

9.8362 mV at one sun (1000 W/m^2). In this case, the constants would be entered as shown.

On the other hand, if this constant were given as a single value, such as 9.8362 uV/W/m^2 (same effective value), the “Converted” value could be set to a value of 1.0 while the “Volts” values could be entered as 9.8362E-6 (9.8362 uV). Alternatively, the “Converted” value could be entered as shown, or as 1,000,000 (1E6) and the “Volts” value as 9.8362. In effect, the ratio of these two numbers, for example 1000/0.0098362, is the slope of the line of the linear conversion.

In addition to scaling, an offset value can also be set. Therefore the complete conversion equation is a standard linear conversion of the form:

y = m * x + b

In this case:

x = Measured voltage

m = Converted/Volts

b = Offset

Recorded Value = (Measured voltage x Converted/Volts) + Offset

For common inputs, like those from pyranometers, the offset would be 0. However, as shown above for the “Temp Sensor”, there is an offset of 25 °C. In this case, the output changes 1 unit (1 °C) for every 0.01 V (10 mV) of signal change. Therefore the signal changes 1 °C for every 10 mV of input change. But, with an offset of 25 °C. This means that if the input signal voltage were 0 mV, the resulting computed value would be 25 °C.

For this signal, the effective conversion equation is:

Recorded Value = (Measured voltage x 1.0/0.010) + 25

Note that the offset is in the converted units and applied after the scaling.

As with all settings pages, be sure to press the “Apply” button to save any changes.

4.3.4. Temperature Setup

The “Temperature setup” page allows the user to name temperature inputs. Temperature measurements are not physically associated with any module or temperature source. These labels are for convenience.

Be sure to press the “Apply” button to save any changes.

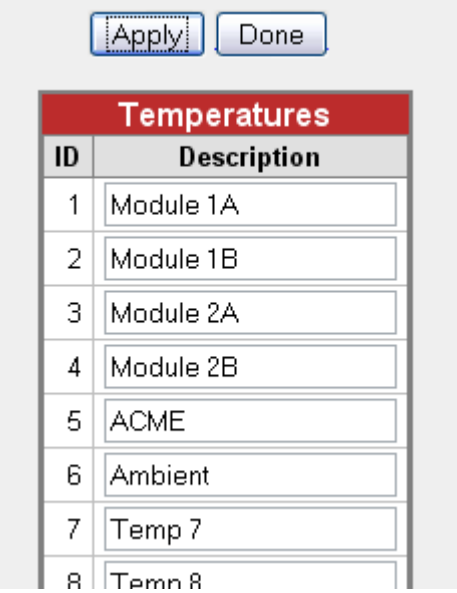


Figure 18. Temperature description setup.

4.3.5. IV Curve Setup

The “IV Curve Setup” page defines how often automatic IV curves are taken and during what time period during the day. Automatic IV Curves may be scheduled as often as once per minute or at intervals defined in hours and days. Furthermore, the start and stop times define the time period each day for limiting automatic IV curves. For example, it is common to limit IV curves to daylight hours.

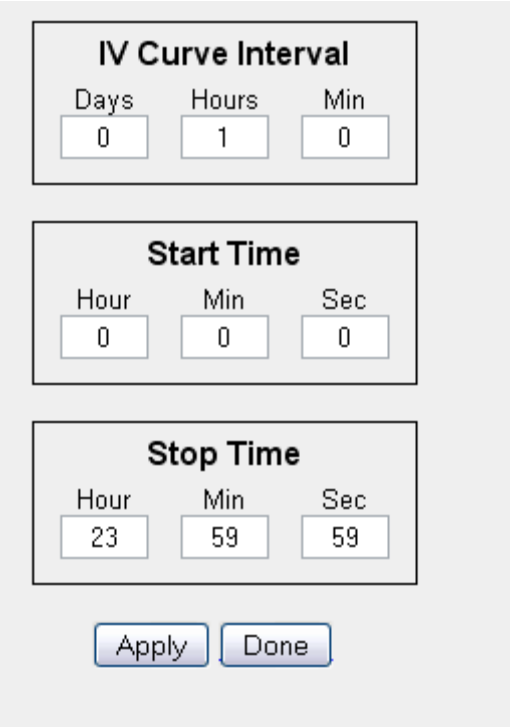


Figure 19. IV Curve setup dialog.

4.3.6. Data Logging

The “Data Logging” setup page defines the averaging period (interval) and time period within a day for recording performance data (MTD data). The interval represents the average period and time interval between data records recorded in the MTD data file. See the section 5.1 “Performance Data” for details on this data.

As with all setup pages, press the “Apply” button to save any changes made to these settings.

Figure 20. Data logging setup dialog.

4.4. System Tab

4.4.1. Date & Time

The MT5 Control unit clock may be operated in two modes; manual and time sync.

Manual Time & Date

In manual mode (“Automatic Set Time” not checked), enter the current time, date, and time zone, and press the “Apply” button. The MT5 will continue to keep time using its internal clock. This clock is similar to those found in a desktop PC.

The time zone is expressed in hours west of GMT. For example, in the United States, the eastern standard time (EST) is 5 hours west of GMT while Dubai is 4 hours east of GMT and you would enter (-4) for the time zone value. No provision is made for automatically handling daylight savings time, but the time zone offset can be adjusted by one hour if required. Figure 21 shows an example of a manual time and date setting.

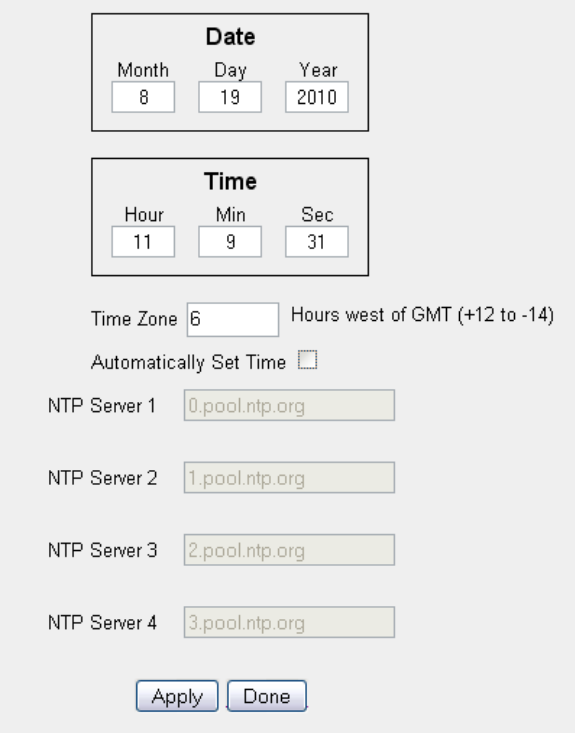


Figure 21. Manual time setting dialog.

Automatically Set Time

The MT5 system supports synching to NTP time servers. Time synching typically maintains the time to an accuracy well within 1 second. Enable this feature by checking the “Automatically Set Time” check box as shown below in Figure 22. The default NTP time servers are shown. However, any other NTP time servers may be specified. It is not uncommon for an organization to maintain its own NTP time server.

NTP time servers are network devices and therefore the MT5 must have appropriate network settings for this function to work properly. See section 4.4.2 “Network Setting” for details. Only one NTP time server is absolutely required, but up to 4 servers may be specified. These can also be given as IP addresses, for example, 123.145.167.189.

Set the MT5 clock manually prior to using the automatic time server. This shortens the sync time between time server time and the MT5 clock. When using time severs, be sure to verify that the MT5 is keeping accurate time. If the MT5 is unable to access the specified time servers, it will continue to keep time using its internal clock, but will not correct clock variations.

NTP time services use network UDP port 123. It may be necessary to open this port in network firewalls, routers, or network address translation (NAT) tables. Consult with your network administrator if this is necessary.

Be sure to press the “Apply” button to save these settings.

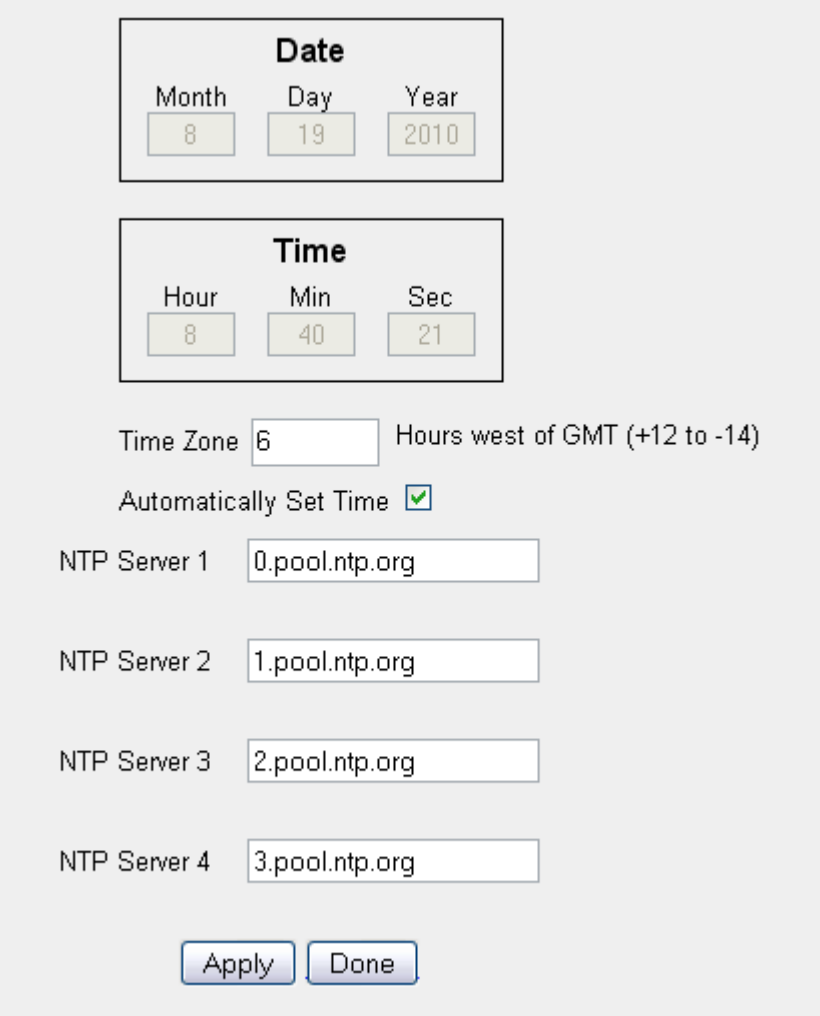


Figure 22. NTP time server setup dialog.

4.4.2. Network Settings

Use this “Network Settings” page to define the important MT5 network settings. Refer to section 6 “Network Connection” for additional details about network connections.

CAUTION – The MT5 is a network device, if you are accessing any Multi-Tracer page via a browser, then you have a functioning connection to the MT5 system. Depending on your network and whether you are accessing the MT5 from within or outside of the local network, changing one or more of these settings may disable your connection. Reestablishing a connection may require connecting a keyboard and monitor directly to the MT5 Controller to reset these network settings. Refer to the section 6 “Network Connection” for complete details on the MT5 network connection.

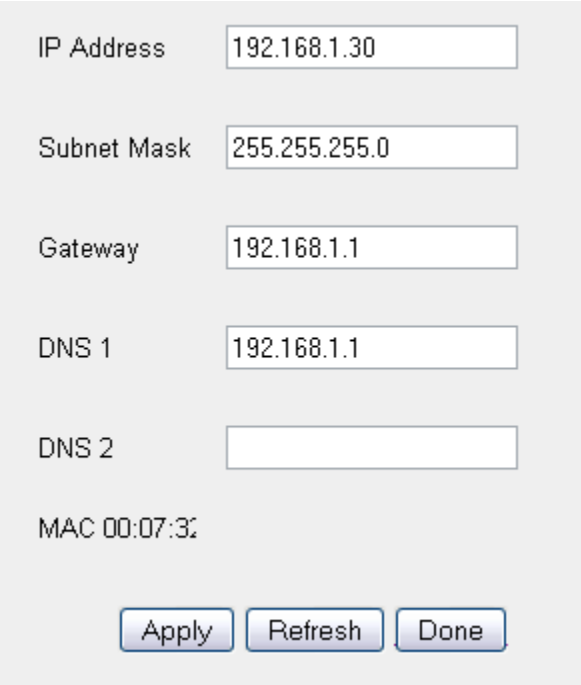


Figure 23. Network settings

- IP Address – Defines the IP address of the MT5 on the network. This is most typically a local area network (LAN) IP address and NOT a globally unique internet or wide area network (WAN) address. Consult your network administrator for a valid IP address.

- Subnet Mask – This is defined by the network. Consult your network administrator for this value.
- Gateway – This defines the address used for accessing network resources outside of the local network. This is needed if accessing NTP time servers and DNS servers outside of your local network. It is also needed is accessing the MT5 from outside your local network.
- DNS 1 & 2 – DNS, or domain name server provide the conversion from names such as “acme.com” to an IP address like “123.123.123.123”. This setting is needed when using NTP time servers defined by name. Only one DNS server is required, though a second may be listed.
- MAC Address – Every network device has a unique MAC address. The specific MAC address of the MT5 is shown on this page for convenience. Some networks require the MAC address for security reasons.

4.4.3. Users

Starting with version 5.09, of the MT5 controller software, the systems supports network access control. Use this “User” menu selection to open the usernames and passwords setting page. See section 6.4 “Network Security, Usernames and Passwords” for details.

4.4.4. Calibration

The calibration selection opens the main calibration page. Refer to section 7 “Calibration” for details.

4.5. Help Tab

The “Help” tab provides links to this manual, the Quick Start Guide, and links to the Raydec web site. In addition, the “About” item provides specific information about your MT5 system.

Figure 24, shows typical information displayed on the “About” page. The most important values are the software version numbers. The MT 5 Control unit runs two separate programs or processes; “Controller” and “Data Source”. The MT5 Load units only run the data source program. There may be specific requirements in matching the controller software version to the data source versions. Raydec periodically announces software updates and will provide update information as needed. These updates will be available from the Raydec website.

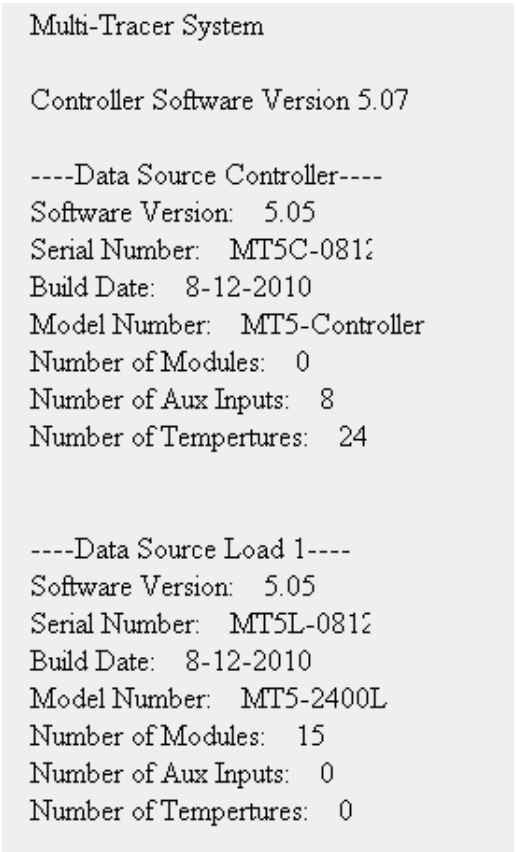


Figure 24. Example "About" display.

In addition to the software version, this page also displays the serial number of the controller and any loads units. This page includes basic information about the number and type of data sources on each device. As shown, it is common for the MT5 Control unit to have a data source with 0 modules, 8 auxiliary inputs, and 24 temperature inputs. While MT5 Load units will commonly have any number of modules from 1 to 16 and no auxiliary or temperature inputs.

Another key number shown on every page is the web page version number, I.E., v1.02 as shown below. Knowing this version number as well as the software version numbers will help resolve problems. Please provide these version numbers to Raydec when requesting support.

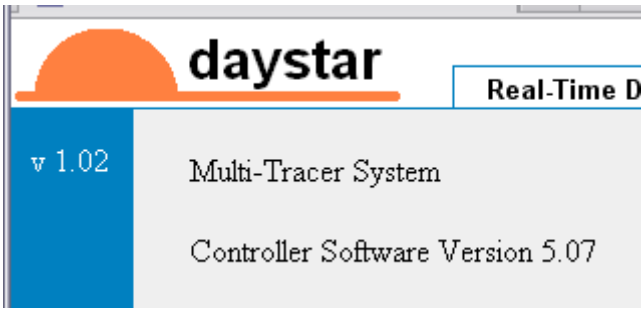


Figure 25. Web interface version number.

4.6. Direct Hardware Interface

In addition to the web interface, MT5 control units running software version 5.08, or newer, provide a simple user interface via a keyboard and video monitor directly connected to the MT5 control unit. In order to use this feature, connect a standard computer keyboard to either of the USB host ports on the front of the MT5 control unit. Connect a standard video monitor to the video port, also located on the MT5 control unit front panel. This is a VGA (or analog) type video connection.

You may immediately see the simple menu. If not, press the “enter” key on the keyboard and the menu should appear on the screen. The menu should look similar to the example shown below:

```
1) Network Setup
2) Learn System
3) Show System Configuration
4) Reset Passwords
```

Refer to section 6.1.1 “Network Change via Keyboard and Monitor” for details on the network settings. Refer to section 10 “System Expansion and Configuration” for details on the “Learn System” and “Show System Configuration” menu items. Refer to section 6.4 “Network Security, Usernames and Passwords” for details on system passwords.

Enter the appropriate number and press “enter” to make that menu selection.

> **Warning: DO NOT access these features unless necessary. Some of the options accessed by this interface affect the basic operation of the unit. Indiscriminant changes may disable the Multi-Tracer system causing a possible loss of data.**

5. Multi-Tracer Data

The MT5 system collects two types of data; performance data, stored in an MTD file, and IV curves. Module performance data are collected by electrically loading the module to simulate operation under real-world conditions. The MT5 system measures current and voltage of each module and stores this data in the MTD file. IV curve data are pairs of current and voltage values over the entire voltage range of the module. The following sections describe these data in greater detail.

5.1. Performance Data

When not taking IV curves, the Multi-Tracer collects continuous data on the PV modules while operating them under load. Unless IV curves are scheduled frequently, the modules operate most of the time in this loaded condition.

5.1.1. Data Logging Interval

The primary user setting affecting performance data is the data logging interval or average period for this data.

For example, if the data logging, averaging interval is set to 10 minutes (the default), the MT5 averages the 1-second sample data for 10 minutes before writing these average values to the data file as a data record. To change this value, refer to section 4.3.6 “Data Logging”. Change the value as required. The minimum value is 1 minute averaging.

These data are stored in Multi-Tracer Data files (MTD files). The Multi-Tracer creates a single MTD file for each day. These files are stored inside the Multi-Tracer itself. Refer to the section 5.3 “Accessing Data Files” for how to move the data from the MT5 to your computer.

Note: All module, temperature and aux input data are stored together in this file using a single, comma delineated line or record for each data logging interval (average). The

MT5 automatically creates a new file every day and automatically appends new data to this file throughout the day.

The MTD file is a comma delineated, text file that can be imported into programs such as Microsoft Excel for data viewing or additional processing.

5.1.2. Load Mode

Each PV module load operates independently from the other loads. There are three operating conditions for a load:

1) Off
2) Peak-Power Track
3) Fixed Voltage

The most common setting is to operate the module at its peak-power point. The MT5 continuously regulates the load to hold the module near its peak-power operating voltage. While it is possible to set each module's load mode separately, it is often simpler to set all loads to peak-power track using the "Global" settings. Refer to section 4.3.1 "Global Load & IV Curve Control" for details on global load settings.

Note: It can take some time for the power tracking algorithm to converge, but tracking typically begins within 30 seconds.

5.2. IV Curve Data

An IV curve represents a snapshot of module performance. Each module may be independently or globally set to enable or disable automatic IV curves. Refer to sections 4.3.2 “Module Channels Settings” and 4.3.1 “Global Load & IV Curve Control” for additional details.

It takes approximately 2 seconds to obtain data for one IV curve. IV curves are taken sequentially for all modules that are scheduled for automatic IV curves. Therefore, it takes more than a half minute if 16 module IV curves are taken. Note: the MT5 attempts to collect data from a channel even if no PV module is connected. Therefore, it is recommended that you only enable automatic IV curves on modules of interest, that you consider the time-of-day IV curve data are collected, and only enable automatic IV curves on channels that have a module connected. Refer to section 4.3.5 “IV Curve Setup” for details on setting the automatic IV curve interval.

Each module IV curve is stored in a separate IV curve data file in XML format. See section 5.3 “Accessing Data Files” for more details. The XML data file format is a text file format and very verbose. All data values are clearly defined with tags. XML data files use a strict, though flexible format. Many programs directly read XML data files.

Optionally, after transferring these files to your computer, you can import these XML files into the Raydec IVPC 3 program (supplied). IVPC 3 can display and print IV curves, and provides features for normalizing and examining the IV curve data. Refer to the IVPC 3 “Help Menu” documentation for details on importing XML data.

Caution: The MT5 Multi-Tracer IV curve, XML data files contain data fields that are not used within IVPC 3. As a result, the IVPC 3 worksheet data file or any files created using the IVPC 3 export function will not contain these fields. Therefore, always archive the original MT5 XML data files.

IVPC 3 can export IV curve data files in the old “IVA” file format. However, Raydec recommends working directly with the newer XML file format.

5.3. Accessing Data Files

The MT5 Controller has enough storage capacity to store months of data depending on the settings. However, Raydec strongly recommends copying data from the MT5 on a regular basis to provide a secure backup of operational data (for example, daily).

The MT5 system provides access to the data files using file transfer protocol (FTP). Any standard FTP client program should be able to access the MT5 data. You must setup your FTP client using three values: FTP host, username, and password. The MT5 system provides two levels of FTP access; “data user” and “data administrator”. The data user may read or transfer files, but cannot modify or delete files. The data administrator can delete files and perform other basic file system operations.

The FTP host setting is the IP address of the MT5. For example, if the MT5 IP address is 192.168.1.30, the FTP host should be:

ftp://192.168.1.30

The two access modes have the following username and default password values (do not include quotes):

Data User access:

User name (login): “data_user”

Default password: “du_rd3200”

Data Administrator:

User name (login): “data_admin”

Default password: “da_xrd3200”

See section 6.4 “Network Security, Usernames and Passwords“ for details on how to change and reset the FTP passwords.

FTP access defaults to the MT5 “data” directory. Within this directory are two folders “mtd” and “curves”. The “mtd” directory contains the daily performance data (MTD) files. The “curves” directory contains all of the IV curve data files.

Note: The Multi-tracer creates a new MTD file at midnight every day. Therefore, the current day’s MTD file will always represent a partial day. To avoid confusion, it is best NOT to copy this partial day. Or if you do, be sure to copy the complete daily file at a later date.

File management is not automatic. Files will stay on the MT5 until deleted by the data administrator. The MT5 can store months of data but you should never rely on the MT5 for data archiving. As with any computer data, you must make regular backups of the data to prevent possible data loss.

Again, Raydec recommends transferring data from the MT5 on a daily basis.

As for actual FTP access, a modern browser such as Firefox and Internet Explorer (IE) support FTP access. FTP functionality is built into IE and in fact, Internet Explorer can present FTP directories as standard Windows file system directories. This makes it as easy to work with these files as they would be if they were part of your desktop file system.

Firefox doesn’t have a built in FTP client, but there are plug-ins available such as “FireFTP” that add this functionality to Firefox.

6. Network Connection

6.1. Networking Basics

Basic network configuration involves just two network settings; IP address and subnet mask. The MT5 System, as do all network devices, requires a unique network IP address. Currently the MT5 only supports static IP addressing. Therefore the MT5 must be assigned a unique, static IP address within your network. Your network administrator can provide you with the appropriate IP address and subnet mask.

Note: The static IP address needed by the MT5 must be unique to your local area network (LAN). Do not confuse this with a wide area network (WAN) static address that is unique on the entire, worldwide, internet network.

If your MT5 IP address has been configured before shipping, all you need to do is connect the MT5 controller to your network via a standard Ethernet cable, then proceed to section 6.2 "Testing Network Connection."

If the MT5 IP address and subnet mask were not preconfigured, several steps are needed to change the MT5 network settings. There are two methods for changing networks settings. The easiest is to connect a keyboard and video monitor to the MT5 control unit. The second is to create a temporary network with the Multi-Tracer and a computer.

6.1.1. Network Change via Keyboard and Monitor

This is a new feature supported by MT5 controller software versions 5.08. Connect a computer keyboard with a USB connector to either of the USB host ports on the front of the MT5 control unit. Plug a standard computer video monitor into the VGA video connector on the front of the MT5 control unit.

Press the “enter” key, to have the monitor display a short menu. Enter the number ‘1’ and press enter. This selects menu item “1) Network Setup.”

The “Network Setup” sub-menu has a list of network settings options:

```
1) Set IP Address
2) Set subnet mask
3) set gateway address
4) Set DNS 1
5) Set DNS 2
6) Save Changes
7) Exit
```

For example, to change the IP address, enter the number ‘1’ and press enter. You are then prompted to enter the IP address in standard form such as “192.168.1.30” (without quotes). Note The Multi-Tracer accepts the data as entered and does not verify the format. Be sure to enter a properly formatted IP address as shown.

The other parameters are entered in a similar manner. Enter ‘6’ to save any changes and the number ‘7’ to exit this menu. Be sure to save any changes before exiting.

Refer to sections 4.4.2 “Network Settings” and 6.3 “Advanced Network Settings” for details on these parameters.

6.1.2. Network Change via Temporary Network

It is not possible to change the network settings via the network without a working network connection. This dilemma is overcome using the following steps:

1) Temporarily connect a computer (PC) to the MT5 directly using an Ethernet crossover cable (included).
2) Temporarily change the PC network setting to be compatible with the default MT5 network settings given below.
3) Establish a connection to the MT5.
4) Change the MT5 network settings.
5) Reset the PC settings back to their original values.
6) Re-establish MT5 connection using the new network settings.

The MT5 ships with default network settings of:

```
IP Address 192.168.1.30

Subnet: 255.255.255.0
```

These steps may not work properly if done with your computer and MT5 connected to your existing network. It is recommended that you connect the computer to the MT5 directly using an Ethernet crossover cable. An Ethernet crossover cable is a special Ethernet cable intended for directly connecting two network devices without the use of a router, hub or network switch.

An alternative, to using a crossover cable, is to connect the MT5 and computer to the same network switch or hub, yet keep this switch isolated from the main LAN. In either case, this setup creates a small network consisting of just the MT5 and a single computer.

Before continuing, record the existing IP address and sub-net mask of your computer. Or note the settings if configured for dynamic addressing. You will need to restore these settings.

Temporarily set the computer's IP address and subnet to values compatible with the default values of the MT5. Set the IP address of the computer to a value different than the Multi-Tracer and use the same subnet mask as shown below:

```
IP Address 192.168.1.31 (temporary computer address)

Subnet: 255.255.255.0
```

At this point, you should be able to establish a connection to the MT5 using these temporary network settings. See section 6.2 “Testing Network Connection” and then return here to complete the process of changing the network settings.

Once you have established a successful, temporary network connection, you should change the MT5 network settings to the permanent values provided by your network administrator. Assuming you have a working connection as described in the "Testing Network Connection" section, select the "Network Settings" item under the "System" menu tab. This will open the network settings page. See section 4.4.2 “Network Settings” for details.

> **Warning: It is critical that you know the MT5 IP address. If unknown, you will have to connect a keyboard and monitor to determine the network IP address.**

At a minimum, change the IP address and subnet mask and apply these changes. This immediately changes the MT5 settings to these new values. Since these values will no longer be compatible with the setting used to establish this temporary connection, you will immediately lose connection to the MT5. This indicates that the MT5 network settings have been changed.

Restore your computer to its original network settings, which must be compatible with the new Multi-Tracer network settings. Reconnect your computer and the MT5 to your network. Note: If you were using an Ethernet crossover cable, be sure to replace this

with a conventional Ethernet cable. You should now be able to connect to the MT5 through your network using the network IP address provided by your network administrator. Repeat the network test to confirm that the network connection is functioning properly.

6.2. Testing Network Connection

To test the network connection, follow these steps:

1) Connect the MT5 Controller to AC power and turn on the MT5 controller power switch.
2) Wait approximately 2 minutes to allow the MT5 Controller to complete its power up sequence. Note: It is not necessary to have the MT5 Load Unit power on or even connected.
3) Using a common web browser (Mozilla Firefox currently required), enter the following URL into the browser address line. The exact IP address to use depends on the current network settings of the MT5.

For example, if the MT5 IP address were 192.168.1.30 enter the following URL into your browser:

```
http://192.168.1.30
```

The web browser should immediately display the Multi-Tracer "Real-Time Data" page of the MT5 System as shown in Figure 26. There will be data tables for modules, temperatures, and aux inputs. Display of this page, confirms that you have a functioning network connection to the MT5 System.

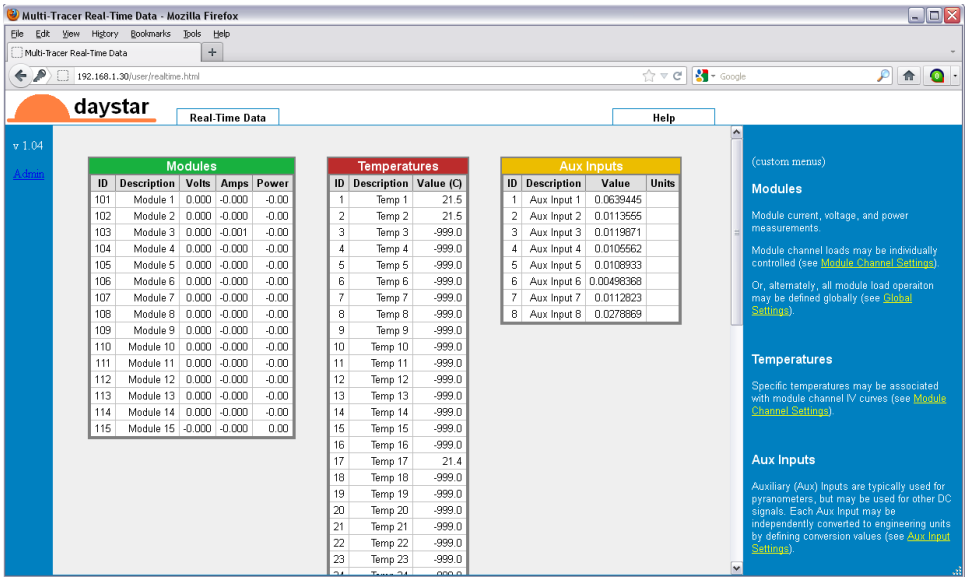


Figure 26. User main Multi-Tracer data page.

If the connection failed, you will get a standard 404 error, page not found.

Note: For convenience, be sure to use your browser's bookmark or favorites feature to provide quick access to the Multi-Tracer.

The Multi-Tracer has two user levels; "user" and "administrator". Most of the features involve settings that are only accessible by the administrator. See section 6.4 "Network Security, Usernames and Passwords" for details.

6.3. Advanced Network Settings

In addition to the IP address and subnet mask, there are several other optional network settings. Consult you network administrator for these values.

6.3.1. Gateway Address

This defines the local address of the gateway for your network. The gateway address must be properly set to access the Multi-Tracer from outside the local network (LAN) or to use the NTP timer server feature.

6.3.2. DNS 1 & 2

A domain name server (DNS) converts a named server value such as “acme.com” to an IP address. At least one DNS address is needed to use named server references. Currently, only the NTP time server feature would depend on this setting.

6.3.3. MAC Address

The MAC address is the globally unique machine address of the Multi-Tracer network port. This value is not a setting, but is displayed on the “Network Settings” page. Your network administrator may need to know this value.

6.4. Network Security, Usernames and Passwords

Beginning with MT5 Controller software version 5.09, the MT5 system supports username and password access control. The intent is to control access to the data and limit the ability to change the settings and operation of the MT5 system. There are two independent types of MT5 access; web interface and FTP.

6.4.1. Web Interface Access Control

The web interface functions as the primary user interface for the MT5 system. There are two levels of access control; “user” and “administrator”. The user level allows access to the main user level page which displays real-time data and provides access to system documentation and other information. Administrator access provides full access to all MT5 data and settings including system calibration.

Note the administrator link near the upper left of the main, user-level page. This will open the main administrator page, which adds the additional menus available to the administrator.

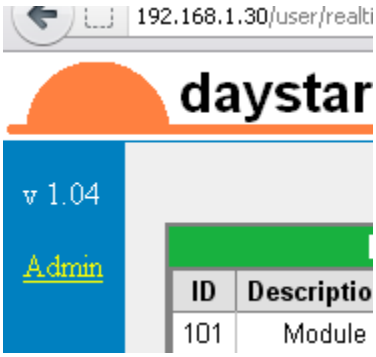


Figure 27. Administrator Link.

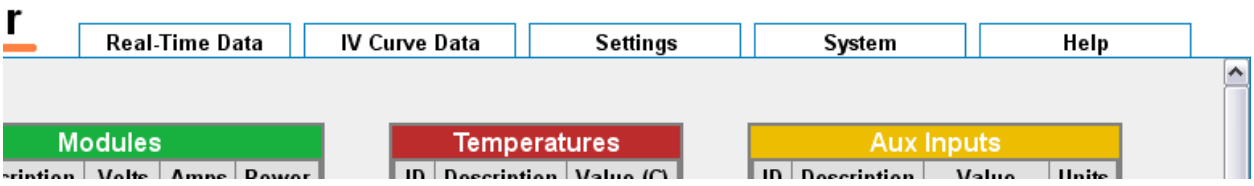


Figure 28. Administrator Menu Tabs

A new MT5 system has no administrator or users defined and therefore has no access restrictions. It is recommended to define administrator access to limit the possibility of unauthorized modification of systems settings and functions. This may be especially critical because administrator access provides access to system calibration.

Selecting “Users” from the “System” tab opens the usernames page. This page lists the web access usernames and the FTP access usernames, describe in a later section. This page only shows the currently defined names. Press the “edit” link next to each name to edit that name and password.

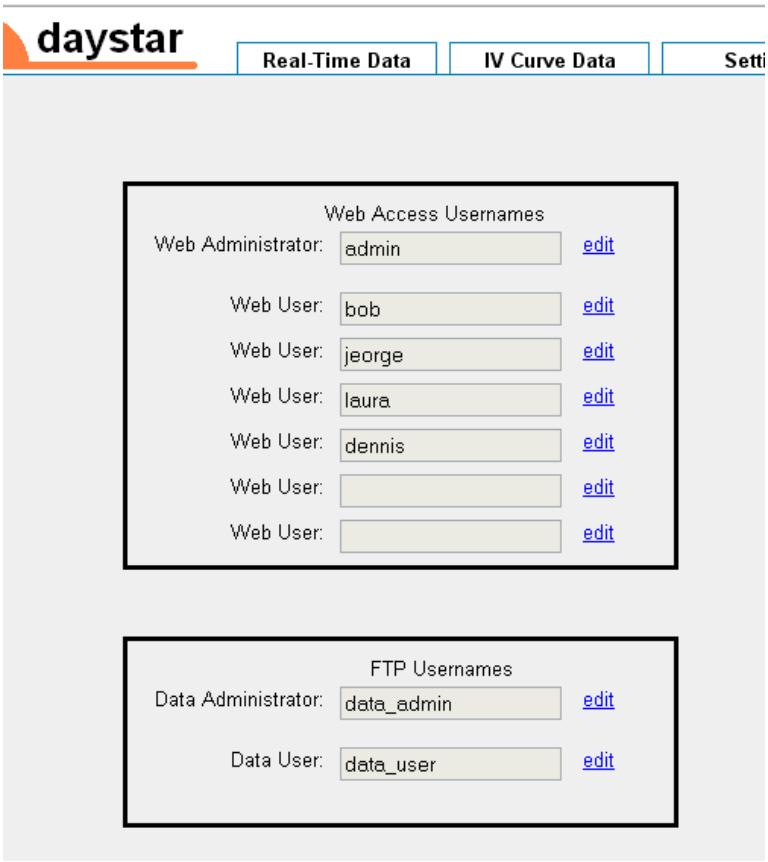


Figure 29. Web and FTP access usernames page.

As seen above, the system only supports one administrator and six users. It is possible to delete all users and to delete the administrator. Deleting the administrator necessarily deletes all users. In this state, there is no network access restriction.

Clicking on an “edit” link opens the username and password editing dialog. While the existing username is shown, the existing password is not shown. Therefore it is always necessary to enter a password, even if only changing the username. However, the existing password can be re-entered.

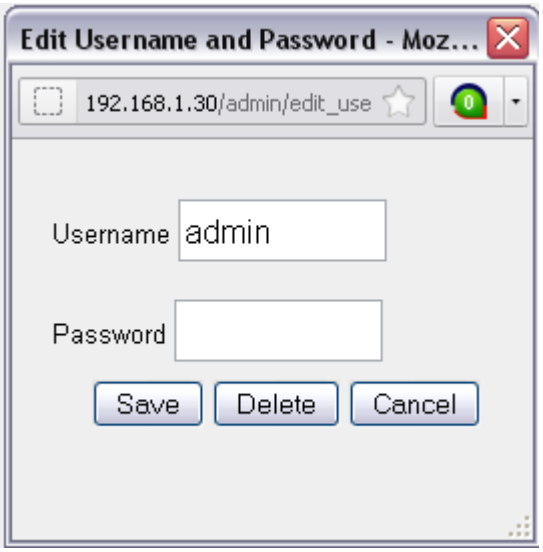


Figure 30. Username and password edit dialog.

Usernames do not have to be for one specific user. There is no reason they cannot be shared. However, using several different names and passwords allows for separate control of a single user or group user sharing the same username.

6.4.2. FTP Access

Similar to the web access described above, File Transfer Protocol (FTP) access also supports two levels of access; data user and data administrator. See section 5.3 “Accessing Data Files” for details.

Starting with MT5 Controller software version 5.09, it is now possible to change the default data user and data administrator passwords. However, it is not possible to change or delete these usernames.

Press the edit button near the respective FTP user to display the username and password editing dialog.

6.4.3. Resetting Passwords

As long as the web administrator username and password are known, it should not be necessary to force a reset of the passwords. However, when needed, this may be done using the direct hardware interface (see section 4.6 “Direct Hardware Interface”).

Resetting the web access passwords necessarily deletes the web administrator and all usernames and passwords. After deleting administrator and users, there will be no web access restriction and both the user and administrator access is open to anyone on the network. Be sure to redefine the administrator as soon as possible after resetting the web access usernames and passwords.

Resetting the FTP passwords, sets the FTP data user and data administrator to the default values. Refer to section 5.3 “Accessing Data Files” for these values.

6.4.4. Security Limitations

The MT5 system uses basic and common web page password protection which has known vulnerabilities to network hacking. Furthermore, MT5 data is not encoded. Similarly, the FTP access has known vulnerabilities. Although breaking this security would require a concerted effort, the potential does exist.

While MT5 operation and data would typically not be considered sensitive, users are encouraged to limit network access via other means when possible. For example, do not expose the MT5 system to the worldwide web unnecessarily. Consult with your network administrator about network access options.

7. Calibration

The MT5 system provides a software calibration feature for module-voltage, module-current, and auxiliary-input measurements. Calibration is accessible via the “Calibration” item under the “Systems” menu tab.

This page has buttons for selecting what to calibrate, as well as some basic control for the calibration report.

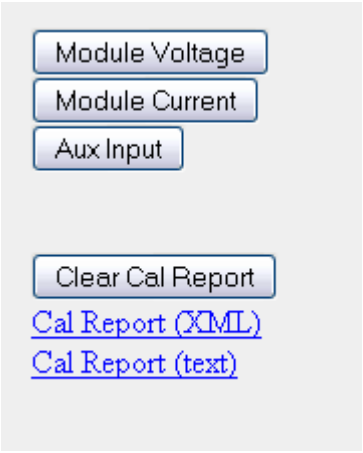


Figure 31. Main calibration dialog.

For module voltage and current calibration, it is best to fashion a calibration test cable using one of the module connectors supplied with the MT5 system. This should be wired as if it were being connected to a PV module (see the section 3.1.4 “Connections” for details), but connected, instead, to the appropriate voltage or current source.

The calibration report is a simple report that shows the measurement before and after calibration as well as the calibration constant. The “Clear Cal Report” button clears any data from previous calibration sessions. The report is available in both XML and text formats. These reports can be opened up with the browser, or more commonly saved as a text file on your computer.

7.1. Module Voltage Calibration

A source signal of known value is needed to calibrate module voltage. This voltage value should be nearly equal to but not exceed the rated voltage of the module channel. Take care when moving to different module channels. Special attention should be paid to avoid applying excess voltage to lower-voltage channels.

Any stable DC voltage source may be used. Even a module under test can be used as long as a separate voltmeter is used to determine the value of the applied voltage. This voltage should be applied as if it were a PV module under test. The actually voltage signal is measured by the voltage sense inputs, but this signal MUST be ground referenced. For the most accurate measurements, these sense signals should be referenced to the PV ground (GND) connection of the module connector in the same way the module would be connected.

For example, if the channel is wired as a negative grounded channel, then the negative sense lead should be referenced to this same ground. Similarly, if the module channel is configured as positive ground, then the positive sense lead should be connected to the MT5 Load unit ground on the module connector.

Note: This requires that the calibration voltage source have a floating output signal, or selectable grounding that can be switched to either the positive or negative output.

To begin voltage calibration, press the “Module Voltage” button on the main calibration page. The following dialog box opens:

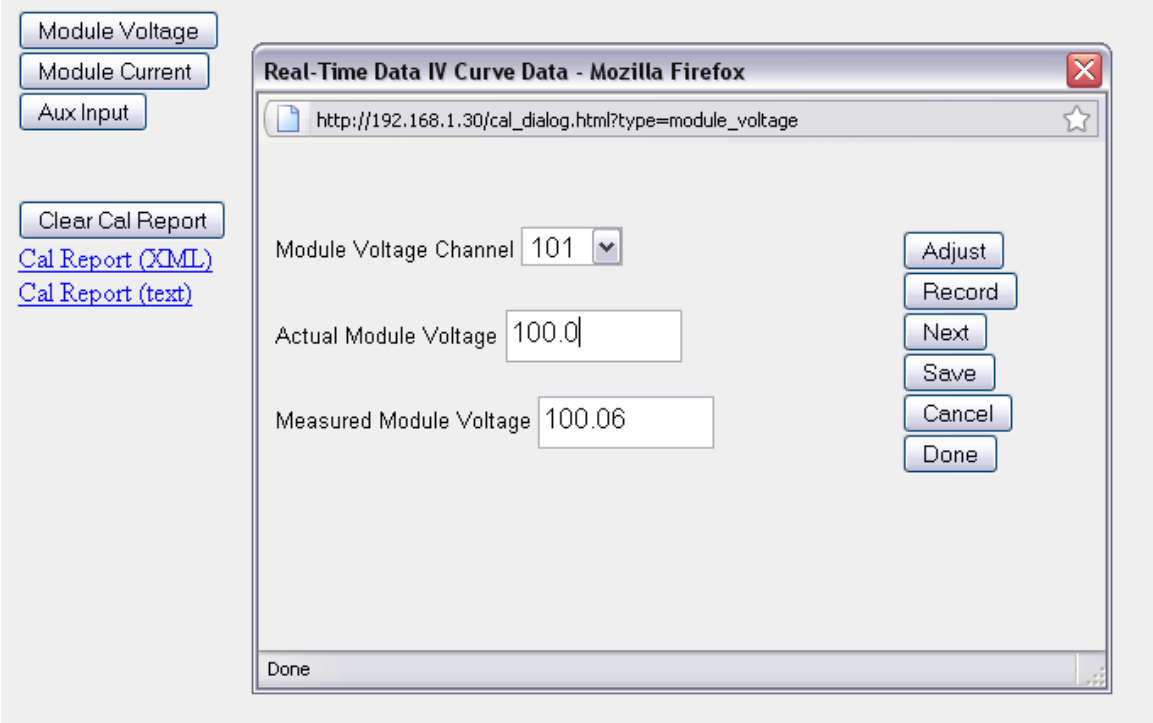


Figure 32. Voltage calibration dialog.

Use the drop-down list to select the specific “Module Voltage Channel” to calibrate. Enter the known module voltage from your calibration source in the “Actual Module Voltage” input box, for example, 100.0 as shown above.

The “Measured Module Voltage” box displays the module voltage as currently being measured by the Multi-Tracer. In the above example, this value is shown as 100.06 V. Assuming the Multi-Tracer is nominally calibrated, the measured value should be very close to the actual value. If there is a large discrepancy, this may indicate that the Multi-Tracer is not properly connected to the voltage source. Be sure to resolve any problem before continuing.

The “Adjust” button performs an adjustment to the calibration constant that scales the measured value to match the given actual value. The MT5 system automatically zeros all signals, so there is no need for a zero or other offset correction. In addition to adjusting the internal conversion constant, the adjustment process also makes an entry in the calibration report.

The “Report” button performs the same function as the “Adjust” button, except it doesn’t change the conversion constant. Its purpose is to make an entry in the calibration report. This may be useful if it is necessary to document the Multi-Tracer response over a range of measurement signals.

The “Next” button advances the “Module Voltage Channel” to the next module in the system. This is a more convenient method to advance to the next module as compared to using the drop-down list to change module channels. Either before or after changing to the next module channel, unplug the module connector and move it to the next channel. Note: Clipping the prongs off of this calibration plug makes it easier to unplug this connector.

The “Save” button saves all of the changes made to any module-channel, voltage calibration performed since this dialog was opened. It applies to all changed calibration, not just the one currently selected. Therefore, it is not necessary to save each module calibration separately. The normal procedure is to start at module 1, adjust it, use the “Next” button to advance to the next module, adjust that channel and so on. Once all module calibrations are completed, all changes can be saved with a single use of the “Save” button.

Because it is very easy to calibrate module voltages, it is reasonable to save one time at the completion of module calibration. However, if there is any confusion at any time, and you want to ensure saving the calibration to that point, use the “Save” button at any time to prevent inadvertent loss of the new calibration adjustments.

The “Cancel” button cancels all changes made since the dialog was opened or since the last save and then closes the dialog.

The “Done” button closes the dialog. If adjustments were made and not yet saved, you will be prompted to do so.

7.2. Module Current Calibration

The module current calibration is similar to the module voltage calibration. However, a stable, DC current source is required and a measurement of this current is needed. This source must provide no more than 95% of the rated channel current limit, for example, 9.5 A for a 10 A rated channel. This ensures that the current signal will not be inadvertently clipped causing a calibration error.

As with the voltage source, the current source must be floating and allow for the Multi-tracer to provide the ground reference. Or at least, the current source must have a similar ground. I.E., if the Multi-Tracer is configured for negative grounding, the current source must be floating or negatively grounded.

During current calibration, the Multi-Tracer load will switch between open-circuit and short-circuit conditions. Therefore, be sure the current source cannot output a voltage in excess of the rated voltage of the channel when the load is at open-circuit and no current is flowing.

After connecting the current source to the Multi-Tracer, turn the Multi-Tracer load on using the check box shown below in Figure 33. The Multi-Tracer will turn the load on to a near, short-circuit condition. At this time the current should begin flowing from the current source.

> **Caution: Be sure the current source has been set to an appropriate level before turning the load on. Or alternatively, that the source has been set to a minimal level and then increased to the needed value after the load is turned on.**

As with the voltage calibration, enter the actual value and then press the “Adjust” button to make the adjustment. Refer to the “Module Voltage Calibration” for details of using the buttons on this dialog

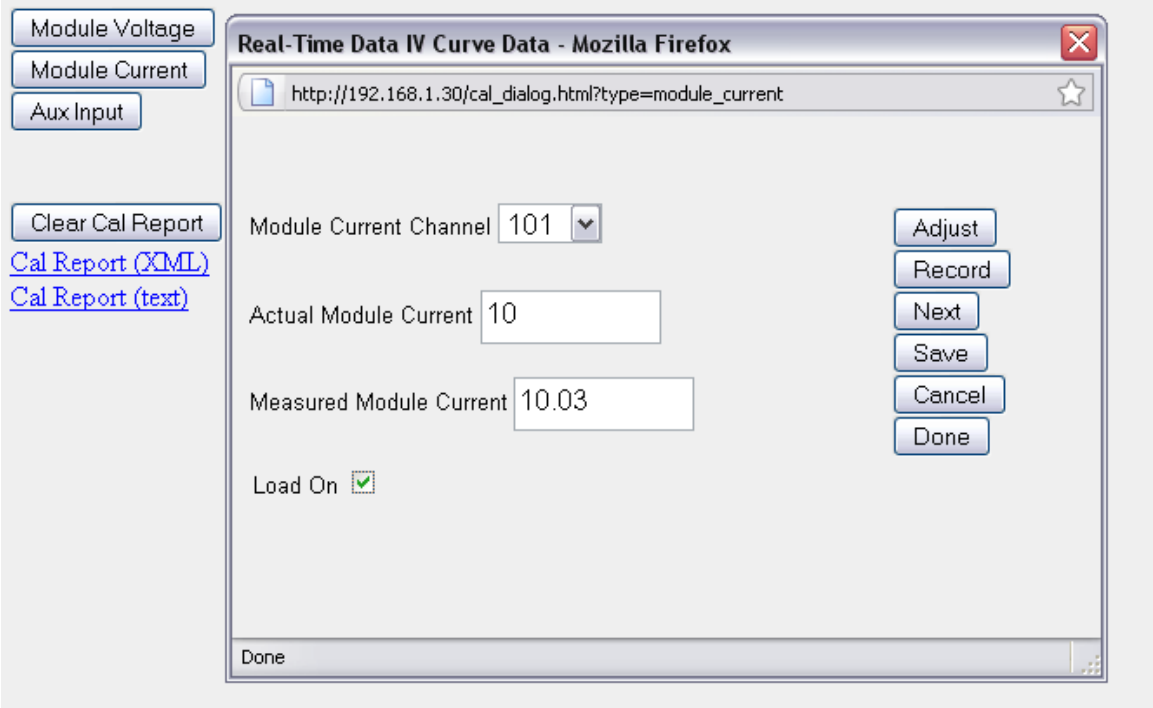


Figure 33. Current calibration dialog.

The load will automatically be turned off when switching to another module. Be careful to wait for the current to actually drop before removing the module connector. Unplugging the connector, while current is flowing, could generate an electrical arc and possibly damage the Multi-Tracer connectors.

7.3. Aux Input Calibration

Auxiliary (Aux) input calibration is identical to calibrating module voltage, with the signals being applied to the MT5 Controller auxiliary inputs. Of course, these are low-level signal inputs and the voltages must be limited to a safe level. See Appendix E - “Multi-Tracer Specifications” for these limits. +/- 5 V is the typical, maximum input range.

Refer to the “Module Voltage Calibration” for the specifics of each button on this dialog.

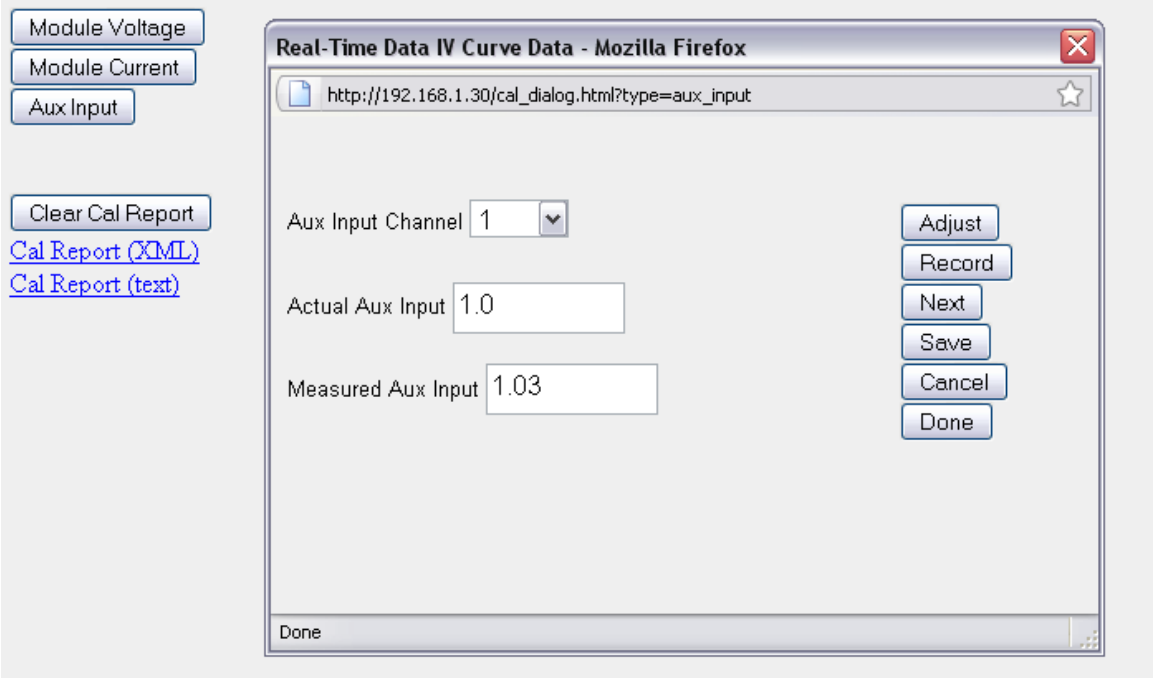


Figure 34. Auxiliary input calibration dialog.

8. Changing Module Grounding

Each MT5 module channel may be configured for either negative (most common) or positive grounding. The Multi-tracer load provides the ground reference to the modules. In order to switch the operation of the channel from one grounding reference to the other, the module connector must be wired differently, see section 3.1.4 “Connections”, and a simple change is required inside the Multi-Tracer load unit. This section describes how to make the change inside the Multi-Tracer.

Before opening the Multi-Tracer load unit to make this change, turn off the AC power switch, unplug all PV module connectors, and unplug the AC power cord.

> **This is important, both the AC power and PV modules present potentially dangerous voltages that can harm or cause death.**

To access the inside of the load unit, remove the top cover of the unit. There are four screws (one in each corner). After removing these screws, remove the cover and two trim strips, and set these aside.

On the inside, immediately opposite the module connector panel, there is a module input circuit board. The input board(s) have a section for each module. These sections are immediately behind the associated module connector.

Figure 35, show a typical module input board section configured for negative grounding. Note: The fuse is located in the top position and the lower fuse position is empty. Also, the internal load wire plug is in the topmost position. This plug has two positions, yet the board has a three position connector.

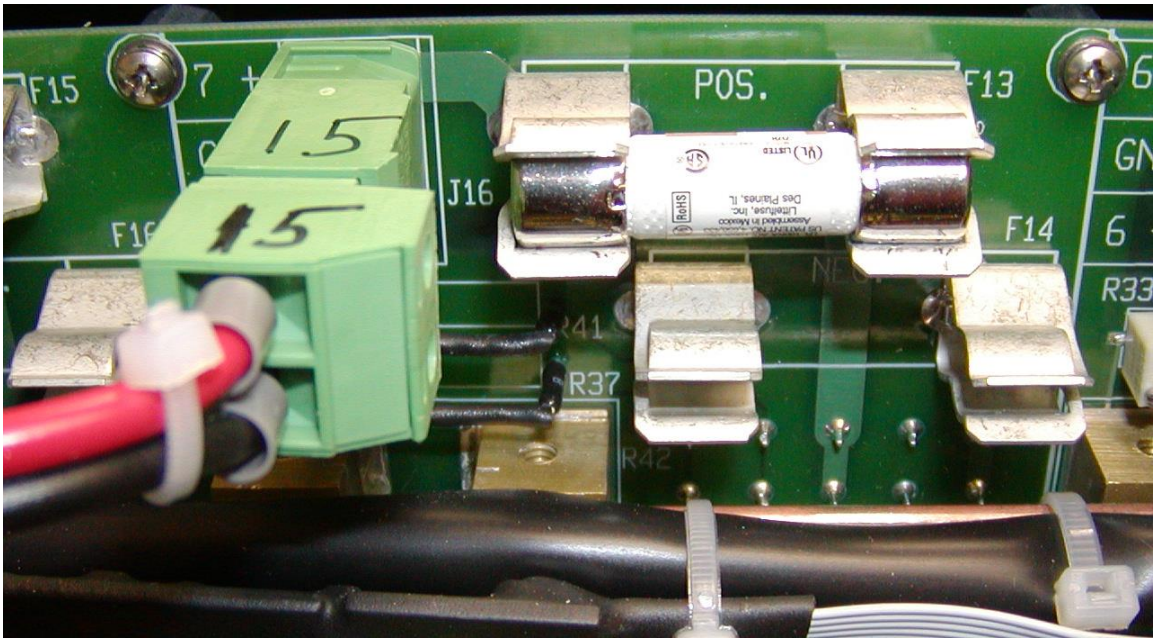


Figure 35. Negative grounding wiring and fuse placement.

Changing the grounding scheme from negative to positive grounding, requires moving the fuse from the upper to the lower position and relocating the load plug by one position lower. This is shown in Figure 36. When moving the module load connector, do not attempt to rotate this connector, just move it one connector position down. In this case, to go to positive grounding, locate it in the two lower positions, leaving the third position of the input board connector unused.

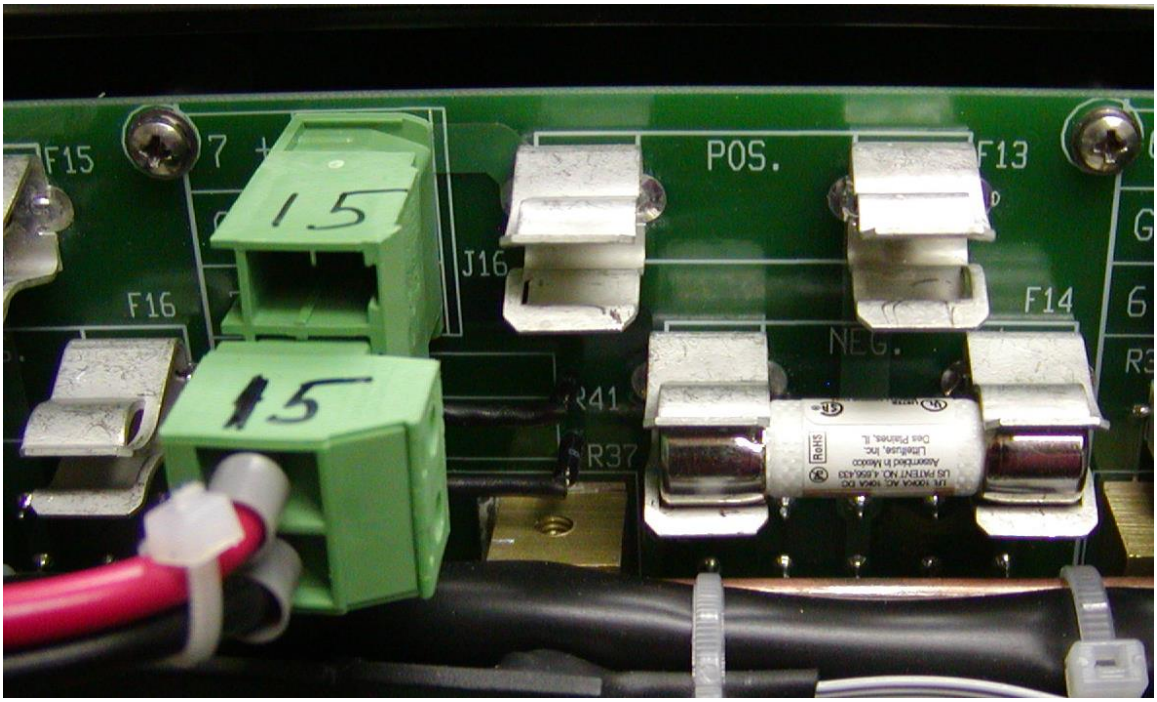


Figure 36. Positive grounding wiring and fuse placement.

Moving the fuse and connector are the only hardware changes needed inside the Multi-Tracer. However, recalibration of this channel is required. First, altering the ground reference makes an extreme change to the module-voltage, common mode signal. While the Multi-Tracer is designed to reject common mode voltage, it, as do all measurement systems, has some sensitivity to common mode voltage changes. Therefore for the best possible accuracy, the module voltage channel should be recalibrated.

Re-calibrating the module-current channel is not optional. Changing the grounding scheme has the effect of reversing current flow through the channel. Therefore currents will read negative after making this grounding change. The MT5 system will not function properly if currents are measured as negative values. Therefore, the current must be recalibrated. The effect of this recalibration is to reverse the polarity of the current calibration. Refer to section 7.2 “Module Current Calibration” for details on calibration.

9. Status Indicators

The MT5 Control and Load units have the following LED status indictors.

9.1. MT5 Controller Status LED's

The MT5 Controller has two sets of status LED's. The "STATUS ABCD" set is shown below.

- Status LED A = Pulses, indicating normal controller operation.
- Status LED B = On, indicating control data source active.
- Status LED C = Unused.
- Status LED D = Unused.

Figure 37. Controller ABCD status LEDs.

The MT5 controller also has a separate status LED for each of 4 load control connections. The given LED will be on when the controller has normal communication with the connected load unit. In addition, to these, there is also a power LED indicating that the primary system power is operating.

Figure 38. Controller Load and power status LEDs.

9.2. MT5 Load Unit Status LED's

The Load unit has two LED's.

- POWER =On to indicate primary system power is on.
- STATUS = Pulses to indicate nominal load operation.

Figure 39. Load unit status and power LEDs.

10. System Expansion and Configuration

The Multi-Tracer system supports up to 4 loads connected to a single MT5 control unit. Raydec supplies the Multi-Tracer system pre-configured for the number of load units, and load configuration ordered. However, in order to add more loads to system, in addition to connecting the new load, the system must “learn” about the new loads and their configuration.

10.1. Connecting a new load

The first step is to connect the new load to one of the unused load ports on the MT5 control unit. This is exactly the same operation as the original setup as described in section 3.1.4 “Connections”.

There is no preference for which load to connect to which load port. Though it will effect the identification labels associated with the data. Raydec strongly recommends leaving the existing loads connected to their original load ports and connecting any new loads to an unused port. Rearranging the loads will re-designate the data ID labels and likely cause confusion in the data sets. Furthermore, user settings specific to existing load channels will be lost.

After connecting the new load to the MT5 control unit and turning the new load unit on, the system configuration must be re-learned as described in the next section.

10.2. Learning The System Configuration

The MT5 system keeps a record of the system configuration. The system configuration defines how many loads and how many channels each load. This configuration determines which loads and which channels are used. It also controls the channels available for user settings and operations such as taking of IV curves.

Having the system “learn” the configuration also allows the system to detect when a load and its data are not available. Data files will contain placeholders for the missing data and the system will periodically attempt to reconnect to a missing load. For example, if a load were turned of temporarily, the MT5 controller will automatically restore a connection once the load is reconnected and turned on.

While it is technically possible for the system to automatically “learn” the configuration, for example, at power up, Raydec has chosen to require the user to initiate the “learn” mode to ensure recording of the proper system configuration.

Raydec delivers new MT5 systems already configured and it is not necessary to “learn” a new system. But it is common to add a load to an existing system. In that case, the system must “learn” the new configuration before this new load operate.

The “learn” mode requires that all of the loads be connected, turned on, and operation (load status LED blinking). This is a very important point. The “learn” mode scans each load port for a functional load and queries the load for basic information. When learning the system configuration after attaching a new load, the system will be re-learning the entire system, not just the new load. So it is critically important that the existing load(s) be connected and operating normally before re-learning the configuration.

> **Warning: Be sure ALL loads are connected and turned on and running before initiating the learn mode.**

The learn operation has a fundamental effect on the operation of the unit and should not be used unless necessary. Indiscriminate use of the learn operation could disrupt data collection and user settings.

Once all loads are connected, powered and operating (power on for at least 2 minutes and status LED blinking) the system can be “learned.”

As described above and in section 4.6 “Direct Hardware Interface”, connect a keyboard and video monitor. Press “enter” to display the menu. Select the menu item for “Learn System”

You will then be prompted to confirm your intention to “learn” the system. After confirmation the system will scan all the load ports for connected loads and query these loads for their configurations. This operation takes a few moments. Once completed, the system configuration is shown as described in the next section.

Look closely at the information displayed to make sure it agrees with the expected number of loads and module channels on each load. The learn mode immediately implements the learned configuration. If there is an error, there are no undo, save, or not-save options.. The hardware problem must be resolved (for example, connecting the load control cable) and the learn operation repeated.

10.3. Show System Configuration

The system configuration may be shown on the local interface (video monitor) as a result of using the “learn” mode or by user selection. In either case, the current system configuration is shown one page at a time. Press enter to advance to the next page. The pages display basic information about the MT5 control and load units. This information is similar to the information displayed in the “About” menu item available on the web interface.

11. Maintenance

11.1. MT5 Controller

The MT5 Controller is essentially maintenance free. However, a low velocity fan is internally located that functions to minimize thermal gradients and reduce measurement errors due to thermal-electric effects. Raydec recommends examining this fan once a year to confirm that it is still operating. Failure of this fan is not anticipated during the life of the equipment.

To examine this fan, remove the top cover of the control unit. It is not necessary to unplug the AC power or signal connections to perform this visual inspection. The unit must be kept powered to examine the operation of the fan. The fan is located to one side. Simply verify that the fan is rotating.

> **Warning: Do not stick hands, tools or any other objects inside the unit. The AC power supply has potentially harmful or fatal voltage levels. Take great care to avoid contact with ANY circuitry inside the controller while making this visual inspection.**

11.1.1. MT5 Load Unit

The MT5 Load Unit moves a large volume of air to dissipate the energy of the connected PV modules. Depending on the operating environment, the fan intake air filters may require periodic cleaning or replacement. These filters are on the outside of the load unit and may be removed by unsnapping the filter guard. The filter material may be cleaned with water.

These filters are inexpensive and readily available. See Appendix D - “Replaceable Parts” for the specific information on this filter. How frequently these filters need cleaning and replacing depends heavily on the air quality.

Raydec recommends examining these filters at least monthly to ensure that they are free of restrictions. If these filters become plugged, the MT5 Load Unit will not be able to cool properly. The load unit will likely overheat and turn off the module loads. Even if the loads do not overheat to the point of shutdown, they will operate at an elevated temperature which will reduce the functional life of the equipment.

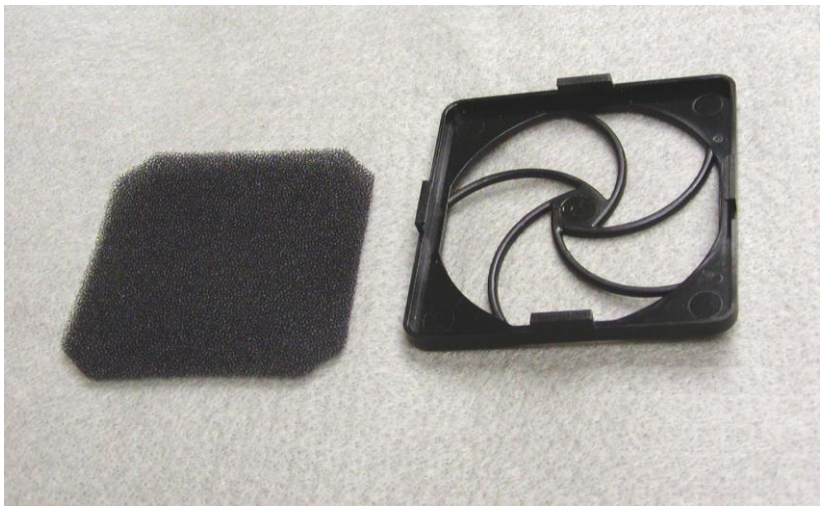


Figure 40. Load unit fan intake air filter and guard.

In addition to keeping the fan intake filters clean, the heat sink itself may require periodic cleaning. Raydec recommends examining the heat sink assembly at least once per year and cleaning if necessary. To clean the unit, unplug all connections and remove the unit from service. Set the unit on its back side (air exhaust side) and remove the bottom cover as shown below in Figure 41.

With the MT5 load oriented as shown, use a soft brush or compressed air to remove any dirt, dust or other debris in the heat sink. Air often contains grease and this will build up on the heat sink fins. In this case apply a degreasing solvent appropriate for electronic equipment. When oriented as shown below, the solvent should only come in contact with the heat sink fins and enclosure panels and represents low risk to internal components.

Figure 41. Load unit heat sink assembly.

With the cover removed, examine the cooling fans and, if required, blow clean with compressed air. Take care not to rotate the fans at excessive speed. If needed, hold the fans immobile to prevent possible damage from over-speeding with compressed air.

Appendix A - Multi-Tracer Connectors

MT5 Controller

Description	Manufacturer	Part #
Auxiliary Input Plug	Phoenix Contact	1827716
Aux. Input Plug Cover	Phoenix Contact	1834356
Type T Thermocouple Plug	Omega Engineering	SMP-T-M
Type K Thermocouple Plug	Omega Engineering	SMP-K-M

MT5 Load Unit

Description	Manufacturer	Part #
Module Input Plug	Phoenix Contact	1804933
Module Input Plug Cover	Phoenix Contact	1837243

MT5 Load Control Cable

Description	Manufacturer	Part #
Load Control Cable Twinax Plug	Amphenol	82-5589-RFX
Load Control Cable Twinax Cable	Belden	9207

Appendix B - Peak-Power Tracking

The MT5 Load Unit peak-power, tracks using a walking algorithm. The nature of peak-power tracking a PV module is that there is no way to detect that any given operating point is actually the peak-power point. All that can be done is to continually compare the operating point to near-by operating points by making small step changes. This can only be done by continually moving the operating point voltage.

The technique used by the Multi-Tracer is to increase or decrease the operating voltage and note the change in power. If the power increases, then the next step is taken in the same direction. I.E, the voltage is increased or decreased again. The operating voltage is continually changed in the same direction until the power drops relative to the last measurement. By doing this, the system “knows” that it has just crossed the peak-power point.

At this time, the unit reverses direction and steps back toward the peak-power point. After initially crossing the point, it will take a smaller step every time it changes direction. In this way, the system is said to be walking back and forth across the peak-power point. Ultimately the step size is reduced to very small values, with the ideal to make the changes in power so small as to be insignificant.

Unfortunately, there are several real-world issues that complicate this process. The first is signal measurement noise. Every measurement system has some level of noise. Given the resolution of the Multi-tracer measurements, noise is easily measured. As a result, when making small step variations in operating voltage, power may appear to change simply due to signal noise. Therefore the Multi-Tracer requires that the power change by an amount large enough to reject signal noise. Currently the limit is 1/1000 (0.1%) of the measured power. There is also a minimum limit defined by the power rating of the channel to prevent absurdly small fractions of power when the measured power is very small.

Another problem arises when false power peaks are created due to rapid changes in irradiance. This can confuse the power tracking. However, this is typically only an issue when initially acquiring the peak-power point. Because the power varies directly with irradiance levels, the operating voltage point is relatively immune to irradiance changes. Therefore once the Multi-Tracer has locked on to the peak-power point, irradiance changes have little effect.

Another potential issue is testing PV modules with unusual IV curves due to internal failures. Damaged or extremely poorly functioning PV modules may have IV curve characteristics with multiple, local peak-power points. It is possible for the Multi-Tracer to lock on and track one of these false peaks.

There are two advanced parameters affecting peak-power tracking defined on the module channel settings page, see section 4.3.2 “Module Channel Settings”. These are the “Advanced Power Tracking” settings of “Min. Fraction of Voc” and “Max Step Fraction of Voc”.

“Min. Fraction of Voc” defines the minimum possible peak-power, voltage as a fraction of Voc. The default is 0.40 (40%) which is actually very low for typical PV modules. During peak-power tracking, the Multi-Tracer will not attempt to power track at any voltage below 40% of the Voc value. If the tracking reaches this point, it will “turn around” and begin increasing the operating voltage. This lower limit avoids wasting time at unrealistically low values of operating voltage. Although 40% is very low, unless there is a reason to change this value, Raydec recommends leaving it at this value.

“Max Step Fraction of Voc” is the largest possible power-tracking step size as a fraction of Voc. The default is 0.1 (10%). The larger this value the more quickly the Multi-Tracer will find and begin power tracking. However, if this value is too large, there may be difficulty in locating the peak power point for modules with very high fill-factors. High fill-factor modules operate at levels approaching 90% of Voc. Therefore a 0.1 (10%) step size may be too large. If working with high fill-factor modules and experiencing difficulty with reliable peak-power tracking, reduce this value by half of its current setting.

Appendix C - Module Fuse Replacement

Because PV modules are inherently current limited it is unlikely that a module fuse will blow. However, a fuse may blow if a high-current module is mistakenly plugged into a channel with low current rating.

Refer to the section 8 “Changing Module Grounding” for details on opening the Multi-Tracer load case and accessing this fuse. As describe there, always unplug all PV modules, and turn AC power off and unplug the AC power cord before opening the unit.

The image below, shows the fuse as positioned for negative grounding. Note: When negative grounded, the fuse goes in the positive connection leg as shown.

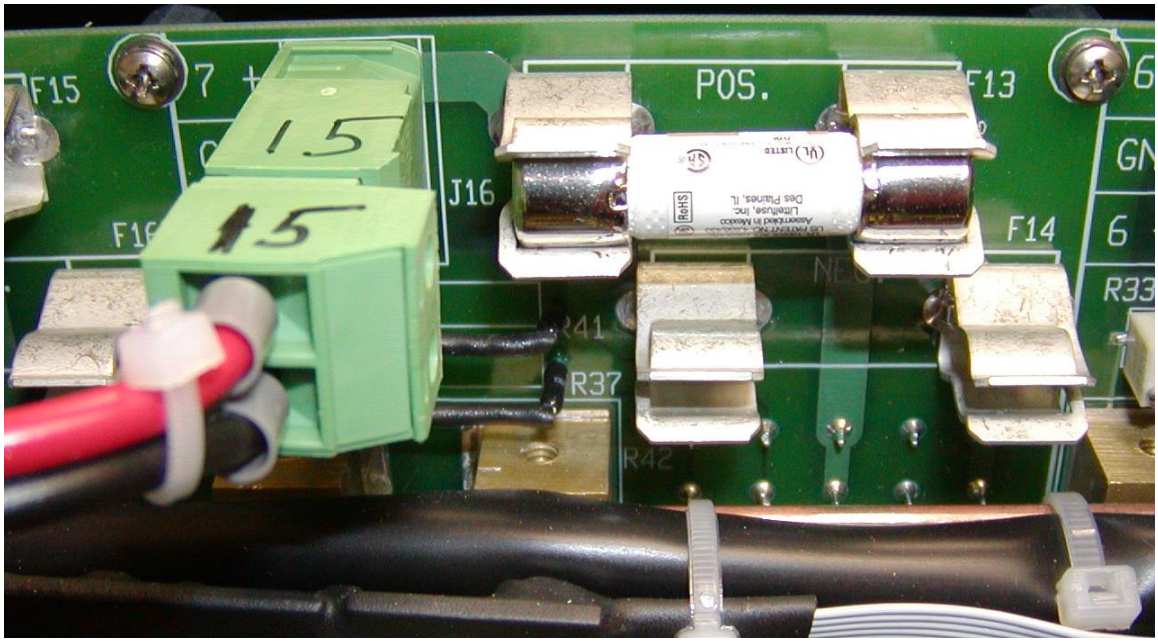


Table 2 shows the fuses to use for a given channel rating. Note: Because Multi-Tracer loads are built to order, the specific current rating of all possible rated currents may not be shown in the table below. If not shown, use a fuse rated approximately 20% to 25% above the current rating of that channel.

Also, the Multi-Tracer fuse must be rated appropriately for the channel voltage. While high-voltage fuses can be used for low-voltage channels, the reverse is not true. We do

not use high-voltage fuses in all channels because high-voltage fuses are much more expensive than low-voltage fuses.

Table 2. Module fuse specifications.

Channel Rated Current	Fuse Rating	Low-Voltage <= 250 V Littelfuse Part #	High Voltage > 250 V Littlefuse Part #
1 A	1.5 A	BLN 1-1/2	KLKD 1-1/2
2 A	3 A	BLN 3	KLKD 3
3 A	4 A	BLN 4	KLKD 4
4 A	5 A	BLN 5	KLKD 5
5 A	6 A	BLN 6	KLKD 6
6 A	8 A	BLN 8	KLKD 8
8 A	10 A	BLN 10	KLKD 10
10 A	12 A	BLN 12	KLKD 12
12 A	15 A	BLN 15	KLKD 15
15 A	20 A	BLN 20	KLKD 20
20 A	25 A	BLN 25	KLKD 25

Appendix D - Replaceable Parts

MT5 Controller

Description	Details	Manufacturer	Part #
AC power Fuse	1 ¼" , 1 A, 250 Vac Slow		
Internal Fan	80 mm Fan, 12V 24 CFM	NMB	FBA08A12L1A

MT5 Load Unit

Description	Details	Manufacturer	Part #
AC power Fuse	1 ¼" , 5 A, 250 Vac Slow		
Fan	80x38 mm 24 V 131 CFM	EBM Papst	8214J/2HP
Fan Filter	45 PPI (pores per inch)	Qualtek	09325-M/45
Module Fuses	See section "Module Fuse Replacement"		

Appendix E - Specifications

Dimensions

All enclosures are standard 19” rack mount. All cases are 17.5” wide (not including rack mounting ears). All units are 19” wide across mounting ears. Note: Rack mounting ears are integrated into the case and are NOT removable.

Units come with small rubber feet and can be set on a flat, level surface. Rack mounting is NOT required.

All units include front handles that add 1.5” to basic depth. Depth dimensions do NOT include any connectors or other minor protrusions.

MT5 Controller

Width	17.5” (445 mm) [19” (483 mm) including ears]
Depth	10.625” (270 mm) [12.125” (308 mm) including handles]
Height	8.75” (222 mm) [5 rack U]
Weight	15 lbs (6.8 kg)
Power	90 – 264 Vac, 50/60 Hz 40 W

MT5 3200W Load

Width	17.5” (445 mm) [19” (483 mm) including ears]
Depth	22.625” (575 mm) [24.125” (613 mm) including handles]
Height	14” (356 mm) [8 rack U]
Weight	82 lbs (37.2 kg)
Power	90 – 264 Vac, 50/60 Hz 200 W

Airflow Considerations

Load units require free air flow front and back. A minimum of 1 foot (12” or 30 cm) of clearance is recommended for both front and back to ensure no airflow restrictions.

Noise

The MT5 load units use forced air (fans) for cooling. At highest speed, fan noise is 86 dB. It is recommended that MT5 load units NOT be located in areas where personnel work on a regular basis, I.E., not in a laboratory or office environment.

Caution: Continuous exposure to high sound pressure levels, such as those produced by the Multi-Tracer, are known to cause permanent damage to hearing. Take appropriate steps to minimize exposure to these harmful sound levels.

Measurement Specifications

Voltage Measurements

Measurements	Range	Common Mode	Resolution	*Accuracy	Temp Co.
500 V Full Scale					
	500 V	±500 V	15 mV	0.1% + 0.02%	50 ppm/°C
	50 V	±500 V	1.5 mV	0.1% + 0.02%	50 ppm/°C
	5 V	±500 V	150 uV	0.2% + 0.04%	50 ppm/°C
250 V Full Scale					
	250 V	±250 V	7.6 mV	0.1% + 0.02%	50 ppm/°C
	25 V	±250 V	760 uV	0.1% + 0.02%	50 ppm/°C
	2.5 V	±250 V	76 uV	0.2% + 0.04%	50 ppm/°C
200 V Full Scale					
	200 V	±200 V	6 mV	0.1% + 0.02%	50 ppm/°C
	20 V	±200 V	600 uV	0.1% + 0.02%	50 ppm/°C
	2.0 V	±200 V	60 uV	0.2% + 0.04%	50 ppm/°C
150 V Full Scale					
	150 V	±150 V	4.6 mV	0.1% + 0.02%	50 ppm/°C
	15 V	±150 V	460 uV	0.1% + 0.02%	50 ppm/°C
	1.5 V	±150 V	46 uV	0.2% + 0.04%	50 ppm/°C
100 V Full Scale					
	100 V	±100 V	3 mV	0.1% + 0.02%	50 ppm/°C
	10 V	±100 V	300 uV	0.1% + 0.02%	50 ppm/°C
	1.0 V	±100 V	30 uV	0.2% + 0.04%	50 ppm/°C
80 V Full Scale	80 V	±80 V	2.5 mV	0.1% + 0.02%	50 ppm/°C
	8.0 V	±80 V	250 uV	0.1% + 0.02%	50 ppm/°C
	0.8 V	±80 V	25 uV	0.2% + 0.04%	50 ppm/°C
50 V Full Scale					
	50 V	±50 V	1.5 mV	0.1% + 0.02%	50 ppm/°C
	5 V	±50 V	150 uV	0.1% + 0.02%	50 ppm/°C
	0.5 V	±50 V	15 uV	0.2% + 0.04%	50 ppm/°C
5 V Full Scale					
	5 V	±5 V	150 uV	0.1% + 0.02%	50 ppm/°C
	0.5 V	±5 V	15 uV	0.1% + 0.02%	50 ppm/°C
	0.05 V	±5 V	1.5 uV	0.2% + 0.04%	50 ppm/°C

*** Percent of Reading + Percent of Range @ 25 °C**

Current Measurements

Measurements	Range	Resolution	*Accuracy	Temp Co.
20 A Full Scale	20.0 A	610 uA	0.1% + 0.02%	50 ppm/°C
	2.0 A	61 uA	0.2% + 0.04%	50 ppm/°C
15 A Full Scale	15.0 A	460 uA	0.1% + 0.02%	50 ppm/°C
	1.5 A	46 uA	0.2% + 0.04%	50 ppm/°C
12 A Full Scale	12.0 A	366 uA	0.1% + 0.02%	50 ppm/°C
	1.2 A	37 uA	0.2% + 0.04%	50 ppm/°C
10 A Full Scale	10.0 A	300 uA	0.1% + 0.02%	50 ppm/°C
	1.0 A	30 uA	0.2% + 0.04%	50 ppm/°C
8 A Full Scale	8.0 A	245 uA	0.1% + 0.02%	50 ppm/°C
	0.8 A	25 uA	0.2% + 0.04%	50 ppm/°C
5 A Full Scale	5.0 A	150 uA	0.1% + 0.02%	50 ppm/°C
	0.5 A	15 uA	0.2% + 0.04%	50 ppm/°C
2 A Full Scale	2.0 A	60 uA	0.1% + 0.02%	50 ppm/°C
	0.2 A	6 uA	0.2% + 0.04%	50 ppm/°C
1 A Full Scale	1.0 A	30 uA	0.1% + 0.02%	50 ppm/°C
	0.1 A	3 uA	0.2% + 0.04%	50 ppm/°C

*** Percent of Reading + Percent of Range @ 25 °C**

Auxiliary Inputs

Measurements	Range	Common Mode	Resolution	*Accuracy	Temp Co.
General Purpose DC	±5V	±5V	150 uV	0.1% + 0.02%	50 ppm/°C
	±500 mV	±5V	15 uV	0.1% + 0.02%	50 ppm/°C
	±50 mV	±5V	1.5 uV	0.2% + 0.04%	50 ppm/°C
	±5 mV	±5V	0.15 uV	0.3% + 0.06%	50 ppm/°C

*** Percent of Reading + Percent of Range @ 25 °C**

Temperature Inputs

Measurements	Range	*Resolution	Accuracy	Temp Co.
Type T Thermocouple	-40 to 200 C	0.06 C	+/- 1.5 C	50 ppm/°C
Type K Thermocouple	-40 to 200 C	0.08 C	+/- 2.0 C	50 ppm/°C

*** Worst case resolution**

Specifications subject to change without notice.

Appendix F - Network Access and Ports

Description	Use	Port
http access	Primary browser access	80 TCP, UDP
NTP	Time server access	123 UDP
FTP Access	Data file access	20-21 TCP
TTY	Remote system access	22 TCP, UDP