FORMULA SAE®

Energy Meter

User Guide and Specifications

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Energy Meter

Introduction
In order to comply with Rule EV.1.4 of the Formula SAE Rules an energy must be installed in each vehicle at competition. The energy meter will measure energy usage as well as monitor for power or voltage violations. The energy meter will be provided by the competition organizers at technical inspection and must be returned by the end of the competition.

Specification
GLV Supply
Supply Voltage: 6-60Vdc
Power Consumption: <1W

Voltage Sensing
Measuring Voltage Range: 0-600V
Maximum Voltage: +/-1000V
Resolution: 45mV

Current Sensing
Continuous Current: +/-600A
Shunt Resistance: 0.1mΩ
Resolution: 11mA

Communication
CAN Bus 500k

Wiring
Tractive System
The energy meter has three tractive system (TS) connections. The first two connections are bus bars on either side of the meter. This is a shunt for measuring current. These must be wired in series with the TS on the negative side such that all power supplying the tractive system passes through the energy meter. The third TS connection is a TS positive sense lead for measuring voltage. This is a flying lead (~6") coming out of the top of the energy meter. The team must supply the mating connector. All energy meter TS connections must be on the motor controller side of the AIRs. The team must fuse the positive sense connection.
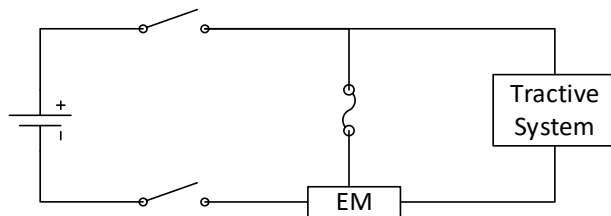

Figure 1 - Example Energy Meter Location

Description	Manufacturer & PN
Housing	Anderson Power Products 1327G17
Terminal	Anderson Power Products 262G1

Table 1 - TS Voltage Sense Mating Connector

GLV System

The energy meter has a 4 pin connector for GLV connections which will must be connected to the GLV system of the car. The power should be supplied directly from the switched side of the GLV Master Switch. To download, the energy meter will require GLV power with the TS off. A hard-wired connection will be used to download the energy meter. The team must provide a download connector outside of the TS enclosure to allow race officials to download the energy meter.

The energy meter has a CAN bus connection which is used for downloading the energy meter. The energy meter also broadcasts real-time data of its measurements on this CAN bus. Teams are free to connect to this CAN bus to monitor or use the data coming out of the energy meter during the competition. The CAN bus operates at 500k baud and the energy meter contains a 120Ω terminating resistor inside. A dbc file documenting the CAN messages for the energy meter is provided separately. Please note there are two reserved messages. These are used by the organizers to download data from the energy meter. These CAN IDs cannot be used by any other device on the CAN bus connected to the energy meter. Downloading the energy meter can create significant CAN bus traffic. In order to ensure a fast download teams should keep additional CAN traffic on the energy meter CAN bus to a minimum while the organizers are downloading.
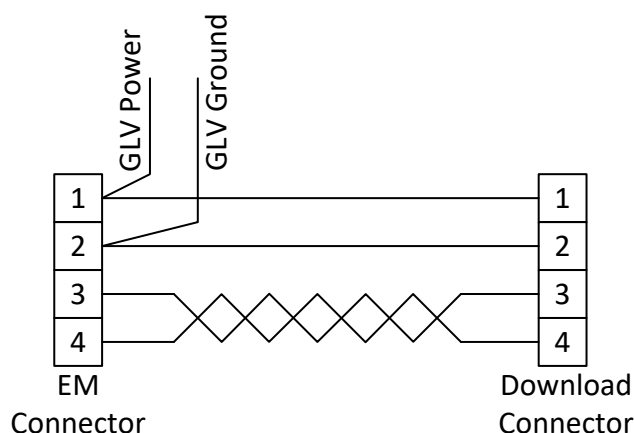
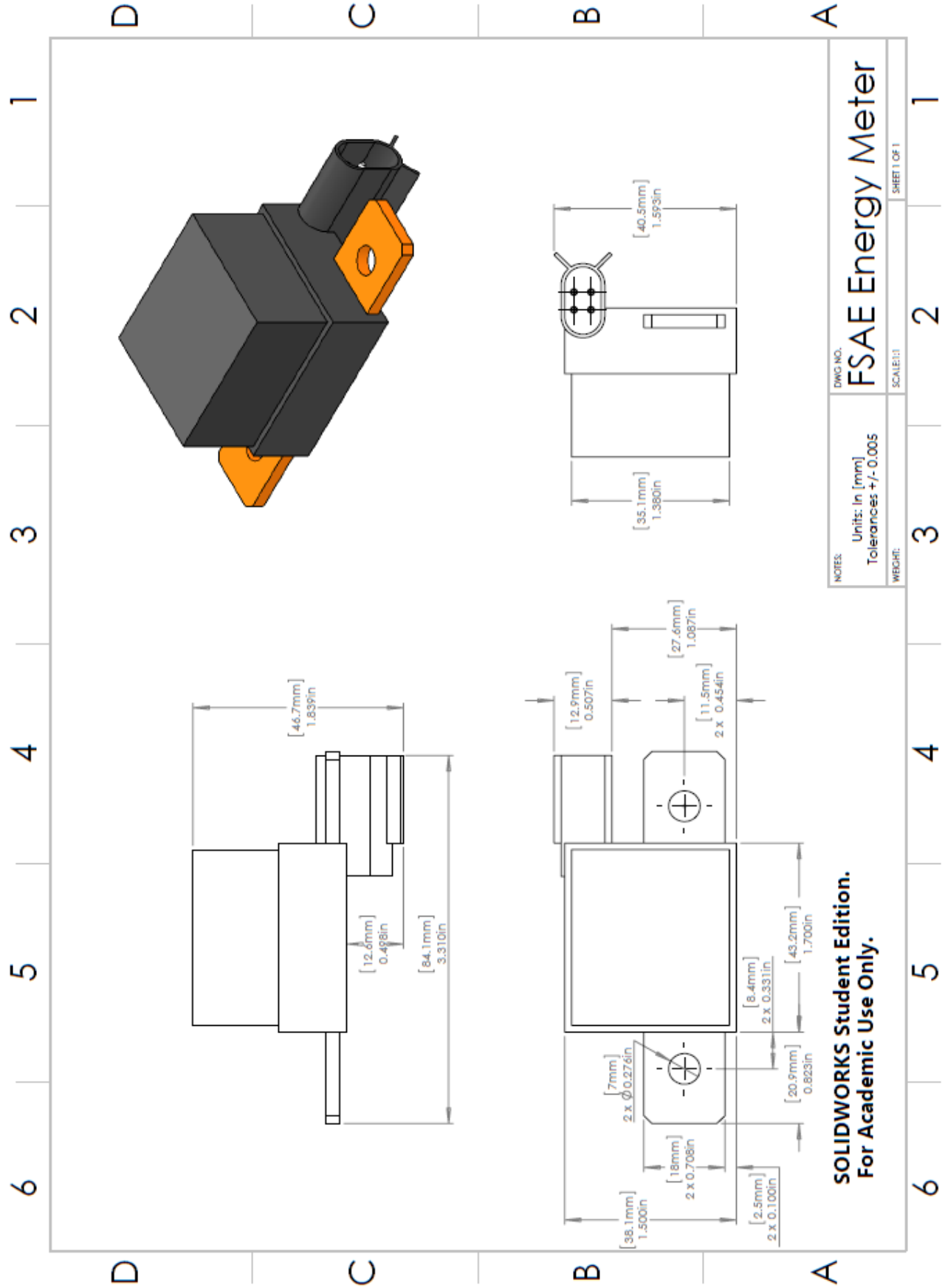

Figure 2- GLV Connections for energy meter

Pin	Function
1	GLV+ Supply
2	GLV Ground
3	CAN High
4	CAN Low

Table 2 - GLV Connector Pinout

Description	Manufacturer & PN
Mating connector for energy meter	Molex 33472-4001
Mating connector terminal	Molex 33012-2002
Download connector	Molex 33482-4001
Download connector terminal	Molex 33000-0002

Table 3 - GLV Mating Connector and Download Connector

Dimensions

Drawing title block:

NOTES:		
Units: In [mm]	DWG. NO.	FSAE Energy Meter
Tolerances +/- 0.005	SCALE:1:1	SHEET 1 OF 1
WEIGHT:		

Dimensions shown:
- [40.5mm] 1.593in
- [35.1mm] 1.380in
- [46.7mm] 1.839in
- [12.6mm] 0.498in
- [84.1mm] 3.310in
- [27.6mm] 1.087in
- [12.9mm] 0.507in
- [11.5mm] 0.454in — 2 x
- [8.4mm] 0.333in — 2 x
- [43.2mm] 1.700in
- [20.9mm] 0.823in
- [7mm] Ø0.276in — 2 x
- [18mm] 0.708in — 2 x
- [38.1mm] 1.500in
- [2.5mm] 0.100in — 2 x

Theory of Operation

The energy meter uses a 24bit delta sigma ADC with a 1 - 32x PGA to measure current and voltage. The ADC is operated with a data rate clock of ~500kHz and an oversample ratio of 4096 to produce a sample rate of ~120Hz. The energy meter internally processes every sample from the ADC. The energy meter uses fixed point 32bit math for calculations. The samples from the ADC are first scaled to physical units using calibration factors that are unique to each meter.

The energy meter then processes the scaled values to monitor for violations of the power or voltage limits as defined in the FSAE rules. It also monitors the values within the range of the ADC to dynamically adjust the PGA for maximum resolution.

Whenever the TS is energized, the energy meter logs the measured current and voltage at 10Hz. If a violation of the power or voltage limits is detected, a high-speed buffer of 120Hz data is stored containing 1 sec of data centered on the violation.

Order an Energy Meter

Contact Collegiate Design Series by emailing collegiatecompetition@sae.org. Include in your email subject line: Energy Meter Purchase. Include in your email a point of contact, university name and competition you are registered to attend.

Energy Meter Download Tool (EMD Tool)

THIS SECTION IS ONLY APPLICABLE TO THOSE WHO HAVE PURCHASED AN ENERGY METER FOR USE DURING TESTING PHASE AT UNIVERSITY.

Required Hardware

To connect to the energy meter to download data or recalibrate it the following is required:

1. A Windows PC running the Energy Meter Download Tool
2. A Kvaser HS CAN interface connected to the energy meter CAN bus.
3. Wiring harness to connect to energy meter.

Kvaser HS CAN Interface

Any Kvaser HS CAN interface that supports 500kbps CAN2.0A will work with the EMD tool. *This cable must be acquired separately and is not included with the energy meter*.

Wiring Harness

To connect the Kvaser cable to the energy meter a harness will need to be built. Below is the pinout for an example of what this cable would look like if the Kvaser cable being used has a standard DB9 connector. The energy meter will also need GLV power when connecting with the EMD tool. This could be integrated into this harness. ***This is not supplied with the energy meter.***

	Energy Meter (Molex 33472-4001)	Kvaser (DB9 female)
CAN High	Pin 3	Pin 7
CAN Low	Pin 4	Pin 2

Table 4 - Example pinout for Kvaser to energy meter harness

Settings

To access the settings for the EMD Tool click the gear icon in the lower left corner as seen in Figure 3. *Note: Not all settings are available in the student version of the tool.* Setting changes will take effect as soon as the new value is entered and will be automatically saved and loaded when the tool is relaunched.
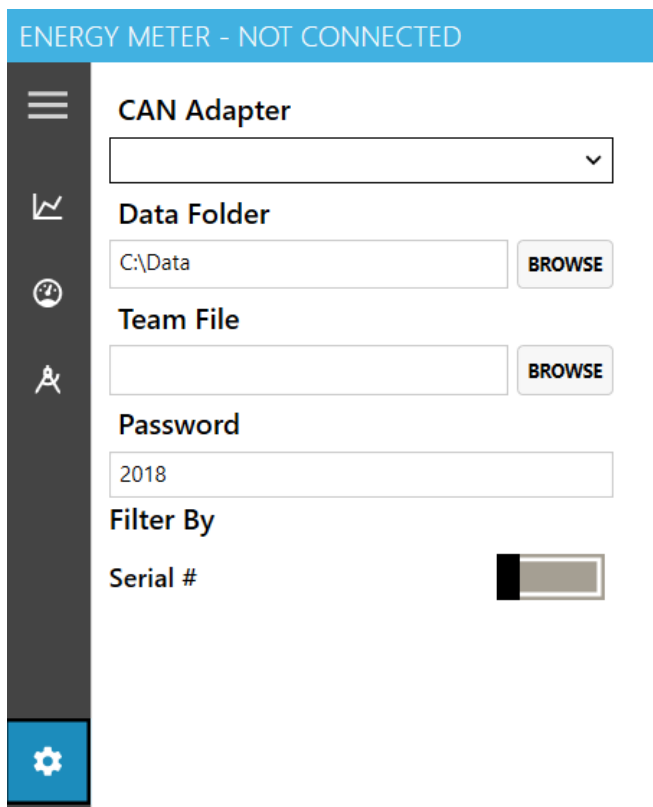
Figure 3- Setting Screen

- **CAN Adapter** – Used to select which CAN adapter to use to connect to the energy meter. Drop down will automatically populate with the adapters currently found on the computer.
- **Data Folder** – Root folder where data will be downloaded to and where data will be loaded from when reviewing logs.
- **Team File** – A tab delimited file listing energy meter serial numbers and team names. An example can be found in the installation folder.
- **Password** – Password used to connect to the energy meter. This must match the password programmed in the energy meter.
- **Filter By** – Selects the primary grouping method for data in the Review Data tab.

Live Data

The live data tab can be viewed by clicking the meter icon on the left side of the screen. This screen shows the real time data being measured by the connected energy meter as well as providing options to download stored data and erase stored data on the energy meter.
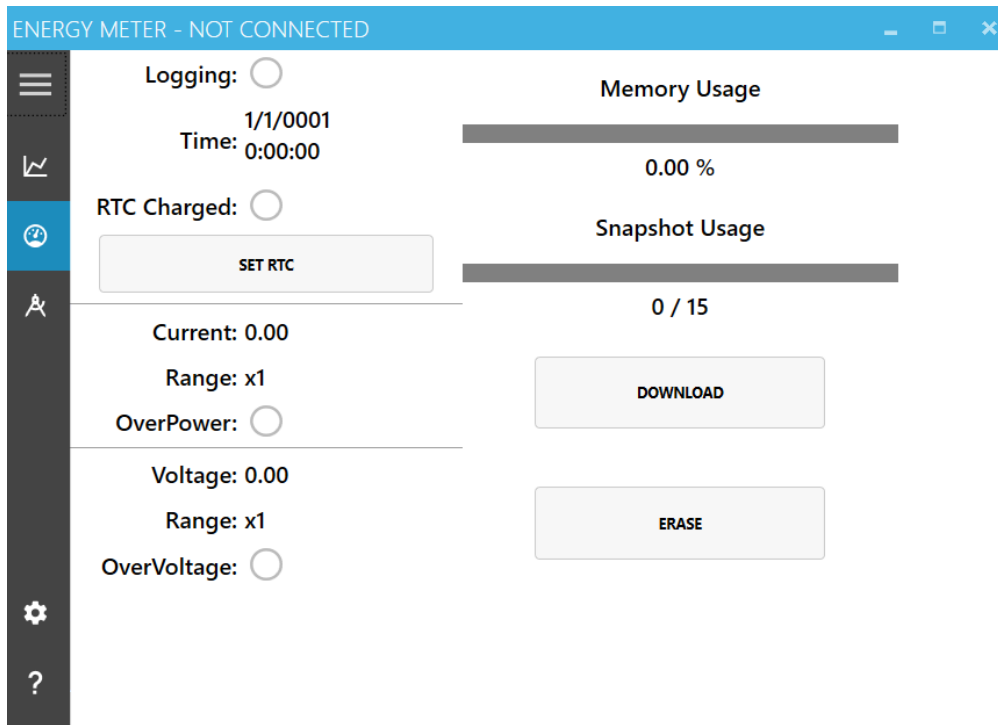

Figure 4 - Live Data Screen

Logging – Indicates if the energy meter is currently logging.

Time – Shows the current time according to the RTC in the energy meter.

RTC Charged – Indicates if ultracap in energy meter is charged enough to keep RTC running. *This does not mean the ultracap is fully charged.*

Current/Range – The TS current measured by the energy meter and the PGA range being used.

Voltage/Range – The TS voltage measured by the energy meter and the PGA range being used.

OverPower – Indicates that the power limit is currently being exceeded.

OverVoltage – Indicates that the voltage limit is currently being exceeded.

Memory Usage – Indicates how much of the flash memory used for logging is currently used. Once the energy meter is full, it will no longer log additional data.

Snapshot Usage – Indicates the number of high-speed snapshots that are filled. Once there are no more high-speed snapshots available, further violations will be flagged in the low speed data, but no snapshots will be taken.

Set RTC – Sets the energy meter RTC to the current PC time.

Download – Downloads all data currently in the energy meter.

Erase – Erases all data in the energy meter. Data previously downloaded to the PC will not be affected.

Review Data

This screen will allow the user to view data previously downloaded from the energy meter as well as export it in .csv file format. The screen can be accessed by clicking the graph icon on the upper left side of the screen.
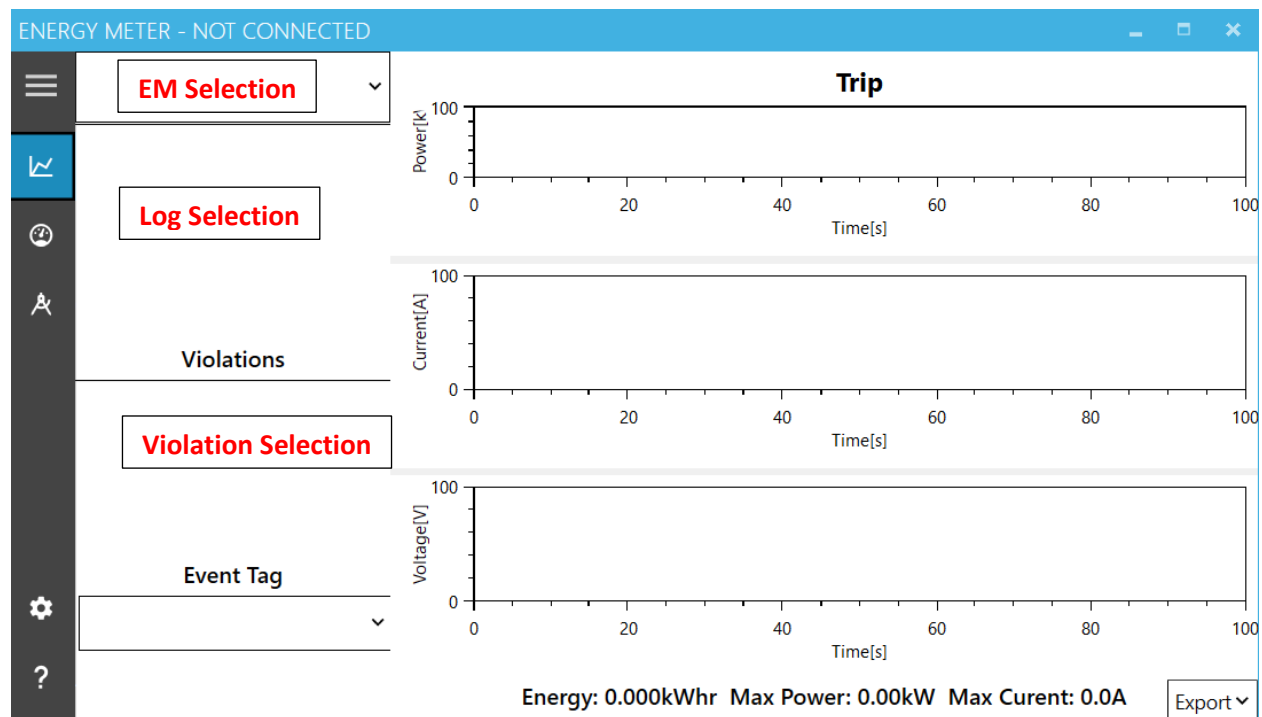
EM Selection – Drop down to select which energy meter or team to view data from.

Log Selection – This list is populated with all the available logs from the selected meter or team. Click one to view the log data. The date/time stamp is the based on the energy meter's time at the start of the log.

Violation Selection – This list is populated with all the violations in the selected log. Click one to view the violation data.

Event Tag – Use this to tag logs from a specific event (tag shows up in log selection window). This makes finding the log file for a particular event easier.

Trip – This area shows the power, current and voltage logged from the energy meter.

Use scroll wheel to zoom.
Left click to show cursor values of data at a point.
Right click to drag axis to new position.

Violation – This area appears to the right of the trip data when a violation log is selected. It will show the high-speed violation data.

Export – Exports the selected log as a .csv file.

Calibration

The calibration screen can be accessed by clicking the drafting tool icon on the left side of the screen. This screen allows viewing and modifying the calibration values in the energy meter. *Note: Not all settings are available in the student version of the tool.*

The typical workflow in this screen is:
1. Read current calibration from device.
2. Modify calibration as required.
3. Write calibration to device.
4. Store EEPROM.

Failure to read the current calibration from the device could result in overwriting calibrations which have not been changed with default values.
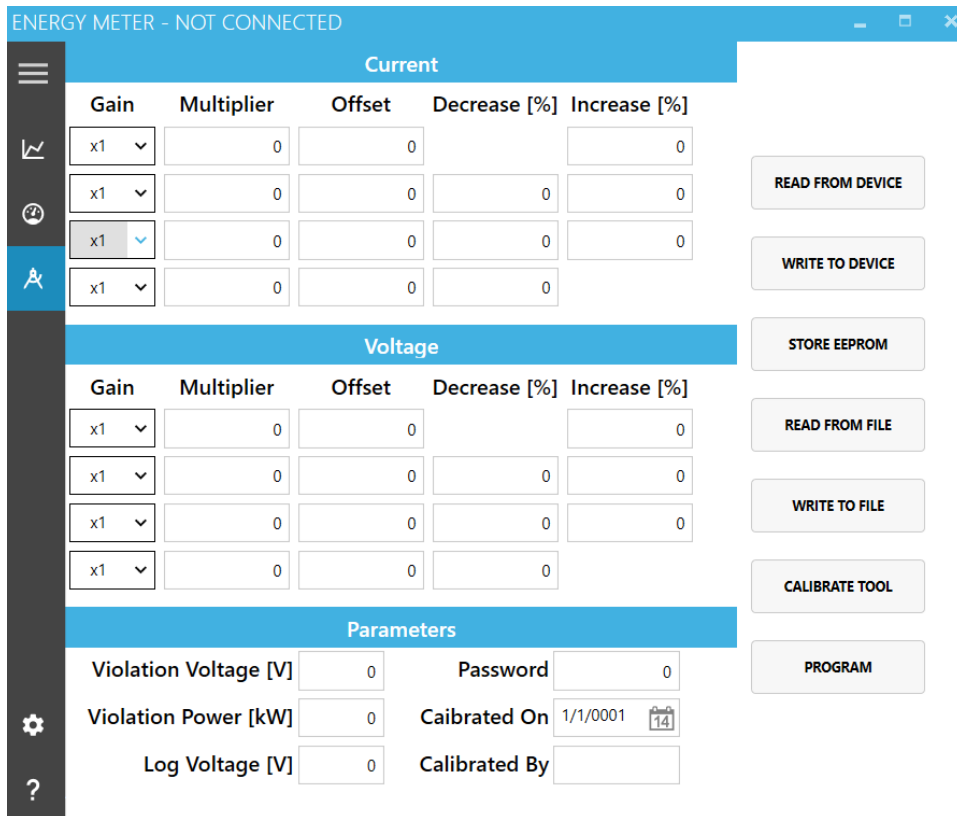

Figure 5 - Calibration Screen

Current / Voltage
Each input can use up to four different PGA gains which are dynamically selected as the signal reaches the upper/lower section of the range. It is not required to use all four ranges. Ranges must be defined in increasing order (ie highest resolution/smallest range to lowest resolution/highest range). All unused ranges should be set to a Gain of None.

- **Gain** – This sets the PGA gain for the range. Set to none if the range will not be used.
- **Multiplier** – The scaling factor in amps/bit or volts/bit to scale to physical units.
- **Offset** – The offset in amps or volts to scale to physical units.
- **Decrease [%]** – When the input signal is below this percentage of full scale the energy meter will switch to the next lower range.
- **Increase [%]** – When the input signal is above this percentage of full scale the energy meter will switch to the next higher range.

Parameters

- **Violation Voltage [V]** – Competition maximum TS voltage above which a violation will be flagged.
- **Violation Power [kW]** – Competition maximum TS power above which a violation will be flagged.
- **Log Voltage [V]** – TS voltage at which the energy meter will start or stop logging.
- **Password** – Password used to connect to energy meter. *CAUTION! If the password is changed/lost the energy meter would need to be sent back for recovery. There is NO field recovery method for lost passwords.*
- **Calibrated On** – Informational field with the date of last calibration
- **Calibrated By** – Informational field with the calibrator.

Actions

- **Read From Device** – Reads the calibration in the connected energy meter.
- **Write To Device** – Writes the current calibration to the connected energy meter. Does not save in energy meter.
- **Store EEPROM** – Saves the calibration currently in the energy meter so that it will be used the next time the energy meter is powered up. Does not write the current calibration to energy meter.
- **Read From File** – Reads a calibration from a file.
- **Write To File** – Writes a calibration to a file.
- **Calibrate Tool** – Some helper functions to aid in calibrating the energy meter.
- **Program** – Used to flash new software into the energy meter.

About

The about screen can be accessed by clicking the question mark in the lower left corner of the screen. This screen displays various information about the EMD tool and connected energy meter.
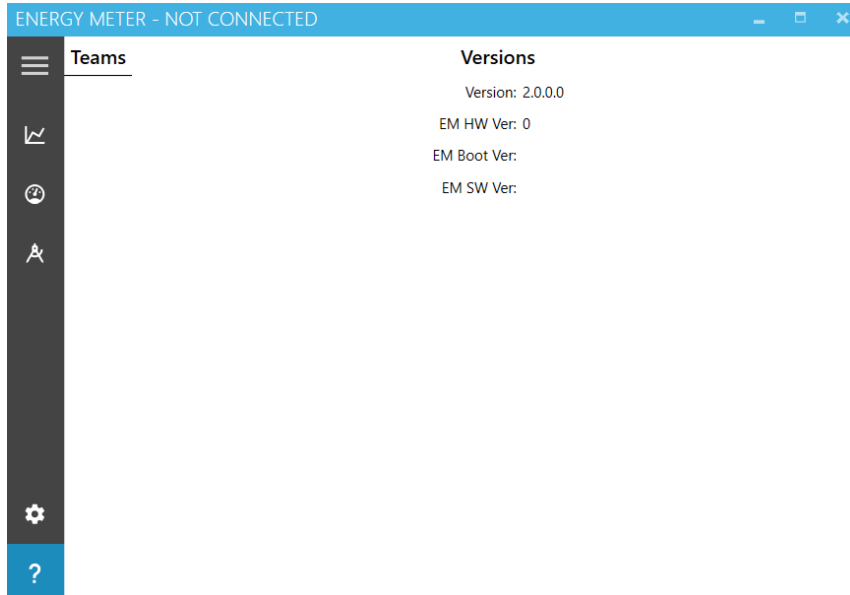

ENERGY METER - NOT CONNECTED
Teams	Versions
	Version: 2.0.0.0
	EM HW Ver: 0
	EM Boot Ver:
	EM SW Ver:

Figure 6 - About Screen

Teams – Lists the teams defined in the team file.
Version – The version of the EMD tool.
EM HW Ver – The hardware revision of the currently connected energy meter.
EM Boot Ver – The version of boot software in the currently connected energy meter.
EM SW Ver – The version of application software in the currently connected energy meter.

Connecting

To connect to an energy meter:
1. Connect the CAN adapter to PC and energy meter CAN bus.
2. Set the appropriate settings in the Settings tab.
3. Power on the energy meter with GLV power and no TS voltage present.
4. The title bar should change to – CONNECTED from – NOT CONNECTED.

Once connected to the energy meter you can view the live data, download data or calibrate the energy meter. The energy meter requires GLV power only in order to connect. The energy meter will not accept any new connections once it has started logging, however existing connections will remain active. There is a brief window when initially powering on the energy meter where it will accept new connections even if it is logging.

Symptom	Solution
The title bar shows –NOT CONNECTED but there is current, and voltage displayed on the live data page.	-The incorrect password may be configured in the settings. -The energy meter may be logging and not accepting any new connections.
The title bar shows –NOT CONNECTED and the current and voltage in the live data window are not changing.	-Check that energy meter has power. -Check that correct CAN adapter has been selected in settings. -Restart EMD tool. -Check CAN wiring.

Table 5 - Connection Troubleshooting

Downloading Data

To download data, connect to the energy meter then click Download in the live data screen. Downloading may take several minutes depending on how much data is on the energy meter. Data is stored in an xml file format in a per energy meter per download folder hierarchy. All data in the energy meter is downloaded and saved each time it is downloaded, regardless of if the data has been previously downloaded. When reviewing data only a single instance of the downloaded log will be shown in the log selection window.