

SAE INTERNATIONAL

# FORMULA SAE

## ENERGY METER USER MANUAL

Updated October 24, 2025



## Introduction

Formula SAE Electric requires the installation of the competition provided Energy Meter in every vehicle. The Energy Meter will monitor energy usage and peak power, voltage and battery temperature. This information is used to check for power, voltage and temperature violations during the competition as well as computing the efficiency score.

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# ENERGY METER REQUIREMENTS

## EM.1 USER MANUAL

### EM.1.1 Incorporated by Reference

The Energy Meter Requirements Section EM is **Incorporated by Reference** into the Formula SAE Rules **GR.4.2.3**

### EM.1.2 Formula SAE Rules

Refer to Formula SAE Rules 2026 Section **EV.3.2** for additional requirements

## EM.2 DESCRIPTION

### EM.2.1 Design

EM.2.1.1 The Energy Meter is designed as two components:

- a. **Receptacle** – modified Amphenol MSDXLF000F
- b. **Energy Meter** – modified Amphenol MSDXLM000

*The Energy Meter will not be available for purchase*

### EM.2.2 Implementation

EM.2.2.1 Prior to the Formula SAE Electric competition, each team must:

- a. Purchase the Receptacle from the given source
- b. Install the Receptacle per this User Manual

*An unmodified Amphenol MSDXLM000 may be purchased (from any source) to use as an Alternative to the Energy Meter and let the Tractive System operate*

EM.2.2.2 At the Formula SAE Electric competition, an Energy Meter is given to the team. This Energy Meter must be:

- a. Installed in the vehicle for the entire competition
- b. Removed and returned before the end of the competition

## EM.3 INSTALLATION

### EM.3.1 Physical

EM.3.1.1 The Energy Meter must be installed and removed from the Receptacle without opening any enclosures or disassembling the vehicle. Bodywork, the firewall, or a cover may be removed.

EM.3.1.2 The Energy Meter Download Connector must:

- a. Be accessible without removing the Energy Meter from the vehicle
- b. Not be extended

### EM.3.2 Electrical

The Energy Meter must be continuously supplied by GLV power on the specified pins before and when the Tractive System is Active

### EM.3.3 Temperature Sensors

EM.3.3.1 Each Module in the Tractive Battery Pack must contain minimum one Temperature Sensor

EM.3.3.2 Each Temperature Sensor must be:

- a. Analog Devices DS18B20

- b. Located in the hottest area of each Module and meet **EV.7.5.4**
- c. Connected to the Energy Meter
- d. Free from EMI that would cause the sensor to not work

## **EM.4 DRIVERLESS**

This section EM.4 only applies to vehicles with Driverless features

### **EM.4.1 CAN Connection**

EM.4.1.1 The Energy Meter CAN bus must be connected to the Remote Emergency Stop CAN bus

EM.4.1.2 The Energy Meter must receive the Driverless vehicle CAN messages

## **EM.5 OPERATIONS**

### **EM.5.1 Downloading Data**

EM.5.1.1 Each team must:

- a. Download their Energy Meter Data prior to the published deadline
- b. Associate their Energy Meter Data to each Dynamic event

EM.5.1.2 The results website will show Violations **EV.3.4**

EM.5.1.3 Data not downloaded or missing may:

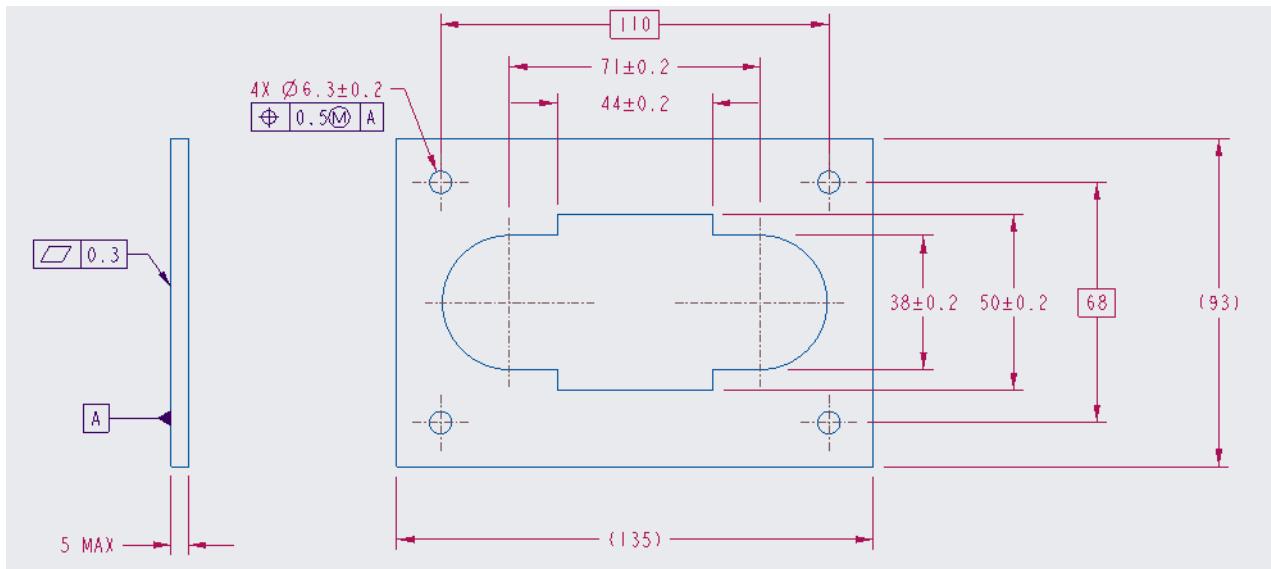
- a. Be treated as a violation **EV.3.4.2**
- b. Give no score **D.13.3.4**

## MECHANICAL

The receptacle cut-out is based off the Amphenol MSDXLF000F recommendations.

Additional clearance will be required to account for the Tractive System and GLV connectors.

Below provides a summary. Modification may be required to fit to teams' specific applications.



Receptacle mounting screws are M6 x 1.0, torque limit is 8 Nm.

The bolted connections for the series high current Tractive System connections are M8 x 1.25, torque limit is 13.4 Nm and must meet **EV.6.4.3**.

The receptacle is based on the front mount (MSDXLF000F) receptacle from Amphenol and is designed to be mounted on the outside side of an exterior panel of a Tractive System enclosure. Rear mount receptacles are not available.



**Picture of a SAE Energy Meter Base showing the added Molex blind mate connectors.**

The Molex connector are designed to move in their cavities to facilitate its blind mate feature.

**DO NOT OVER CONSTRAIN THE WIRES** on the back of the Molex connectors – the connector body should easily move to any position in its cavity.



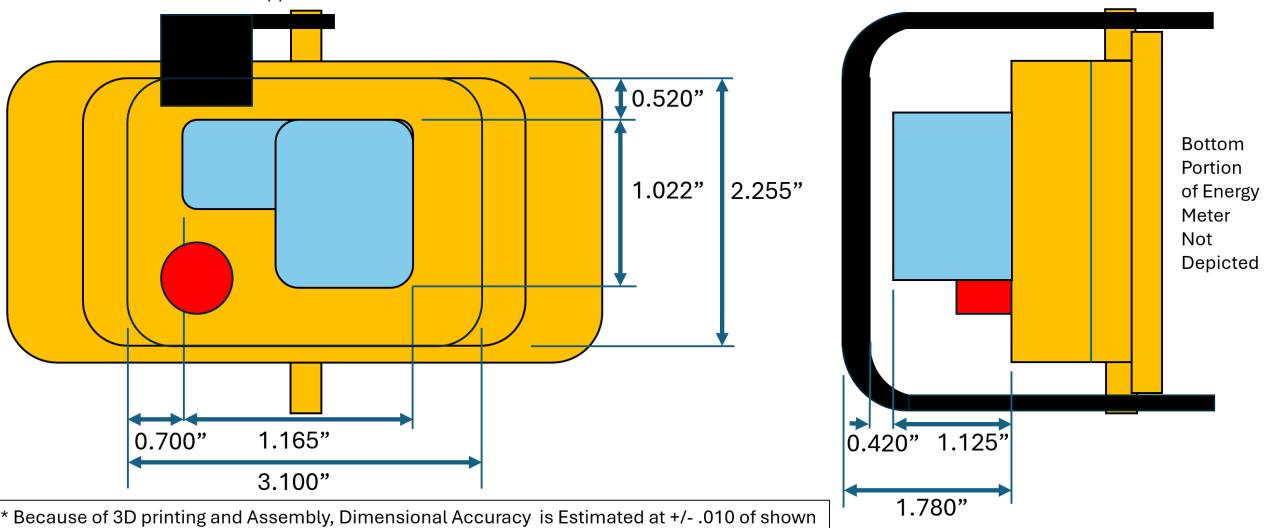
**Pictures of a SAE Energy Meter. The translucent cup extends 1.120" above the original disconnect surface (yellow arrow in left picture).**

## Energy Meter Dimensions

Orange – Unmodified Amphenol Disconnect  
Red – Ethernet Port (approx. position)

Blue – Cup Extension  
Black – Handle

Partial Handle Shown – Approx. Position



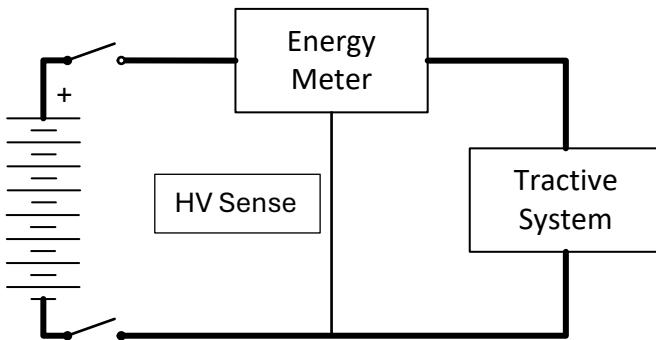
## TRACTIVE SYSTEM WIRING

The Energy Meter has three (3) Tractive System connections.

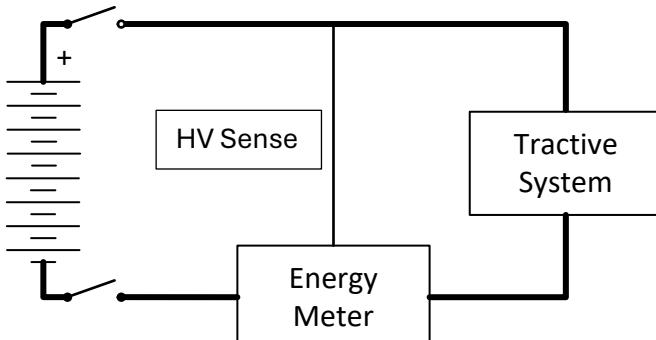
The first two connections must be wired in series with the high current path of the Tractive System such that all Tractive System power runs through the Energy Meter. This series connection must be in either the most positive or most negative side of the Tractive System. The Energy Meter cannot be wired midpack.

The third connection must be wired to the other pole of the Tractive System for sensing voltage (the wire lead in the #1 socket of the 2 pin connector).

The Energy Meter must be connected on the Tractive System (not always energized) side of the isolation relays.



Option A: Energy Meter in HV+ Path

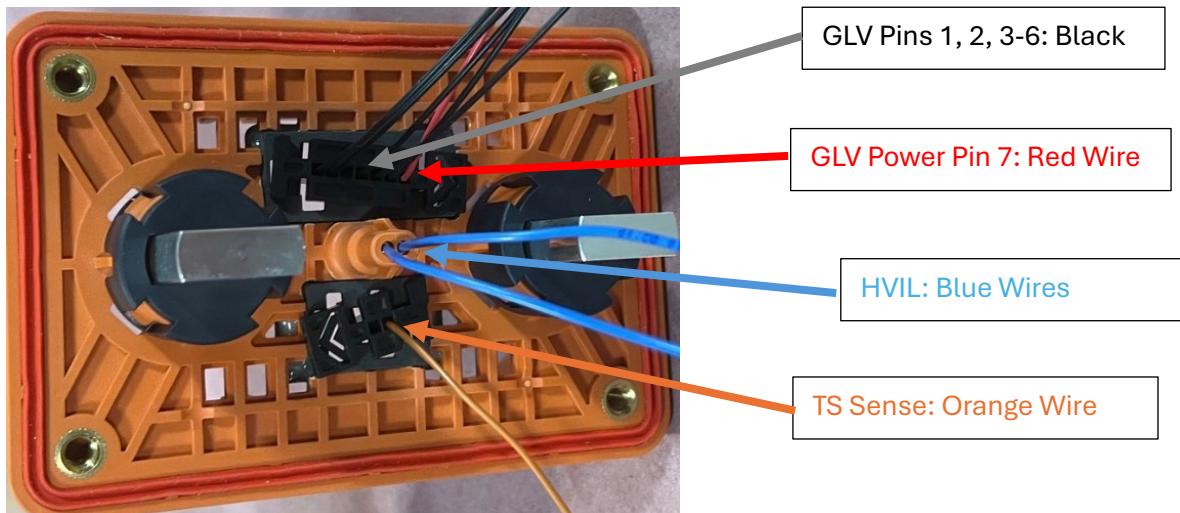


Option B: Energy Meter in HV- Path

## GLV WIRING

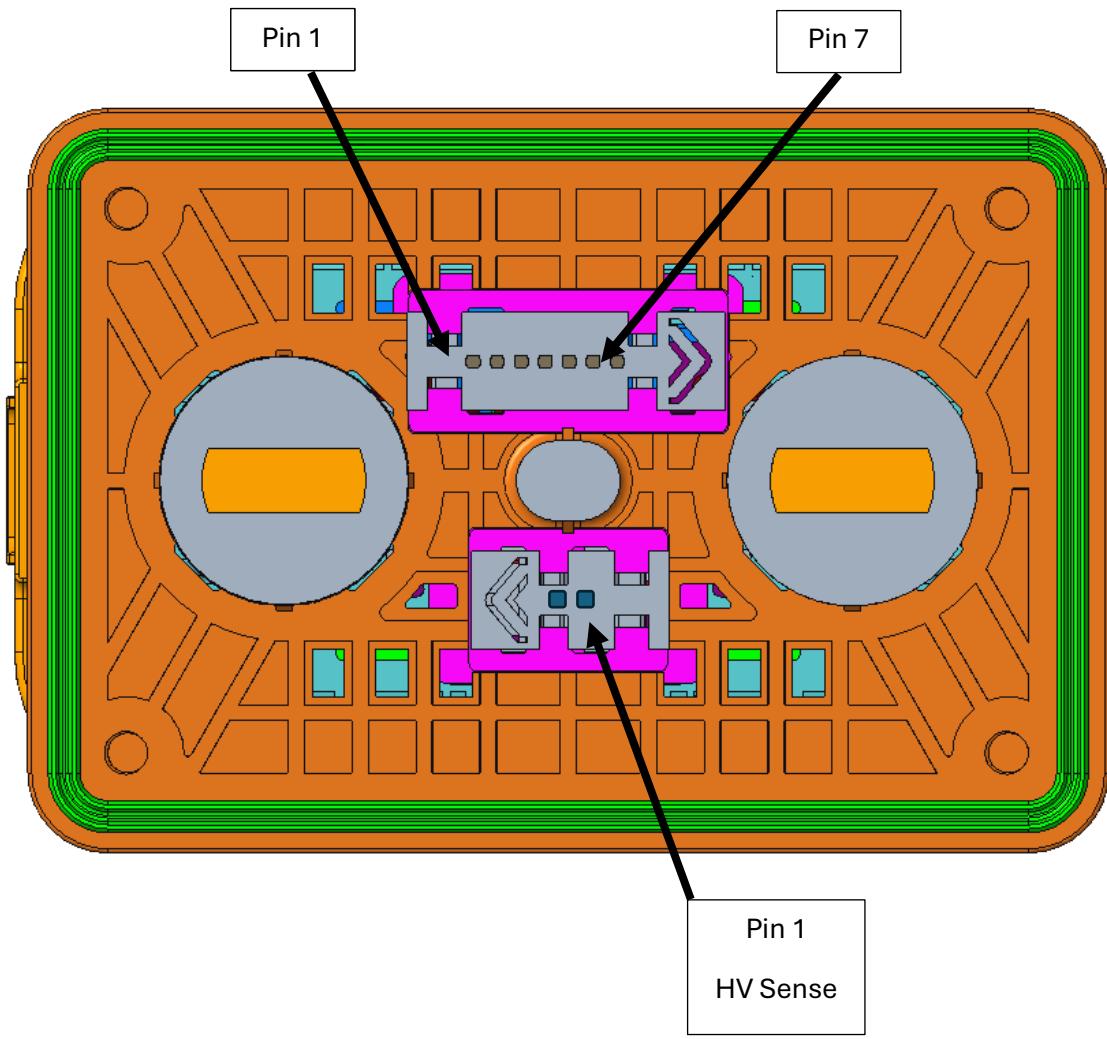
The Energy Meter must be provided with GLV power from the vehicle.

Pin	Function
1	Temp Sense Return
2	Temp Sense One Wire
3	No Connection
4	CAN Low
5	CAN High
6	GLV Negative
7	GLV Positive



The Energy Meter receptacle is provided with 300 mm long leads terminated and installed in all low current connections of the Energy Meter. The other end of the leads is left unterminated and should be terminated as needed by the teams.

***The GLV wiring must not be restrained to allow the connectors to float in the receptacle.*** This is to allow alignment with the Energy Meter when installed.



Part Description	Supplier	Description	Part Number
7 pin, Emeter Base	Molex or Distributor	7 Pin Connector	466230701
2 pin, Emeter Base	Molex or Distributor	2 Pin Connector	466230201
Molex Female Pins	Molex or Distributor	Molex 20 awg Pins	43030-0001

### GLV Specifications

Voltage Input: 6 – 38V  
 Current Draw: ~125mA  
 CAN Baud Rate: 500k

## CAN MESSAGING

The Energy Meter provides a CAN bus connection which will allow access to the real time data within the Energy Meter. The CAN bus also allows the addition of team signals to the Energy Meter data log. These team signals are not required and are provided for the convenience of the team.

Use of the CAN bus connection of the Energy Meter is optional for non-driverless teams. The CAN bus connection is required for driverless teams to provide RES and other required signals.

All signals are little endian (Intel).

### Measurement Message

Message Id: 0x10d (11 bit ID)

Transmitted by Energy Meter

Rate: 20ms

Data Byte	0	1	2	3	4	5	6	7
Signals	Current [A] float				Voltage [V] float			

### Status Message

Message Id: 0x40d (11 bit ID)

Transmitted by Energy Meter

Rate: 100ms

Data Byte	0	0	0	0	1	2	3	4	5	6	7			
Data Bit	0	1	2	3										
Signals	Violation	Logging	Fault Active	Fault Prev Active	Energy [Whr] float									

### Temperature Message

Message Id: 0x60d (11 bit ID)

Transmitted by Energy Meter

Rate: 250ms

The temperature message includes a multiplexor signal. The first bits of the first byte of the message (the multiplexor) are used to determine the meaning of bytes 3-7.

All temperatures are sent as an unsigned byte with the following scaling.  $\text{degC} = \text{raw} * 0.5$

Data Byte	0	0	1	2	3	4	5	6	7
Data Bit	0-2	3-7							
Signal	0	Num Sensors	Min Temp	Max Temp	Temp 0	Temp 1	Temp 2	Temp 3	Temp 4
	1				Temp 5	Temp 6	Temp 7	Temp 8	Temp 9
	2				Temp 10	Temp 11	Temp 12	Temp 13	Temp 14
	3				Temp 15	Temp 16	Temp 17	Temp 18	Temp 19
	4				Temp 20	Temp 21	Temp 22	Temp 23	Temp 24
	5				Temp 25	Temp 26	Temp 27	Temp 28	Temp 29
	6				Temp 30	Temp 31			

### Team Data 1 Message

Message Id: 0x30d (11 bit ID)

Received by Energy Meter

Data Byte	0	1	2	3	4	5	6	7
Signals	Team Signal 1 sint32				Team Signal 2 sint32			

### Team Data 2 Message

Message Id: 0x30e (11 bit ID)

Received by Energy Meter

Data Byte	0	1	2	3	4	5	6	7
Signals	Team Signal 3 sint32				Team Signal 4 sint32			

## TEMPERATURE SENSORS

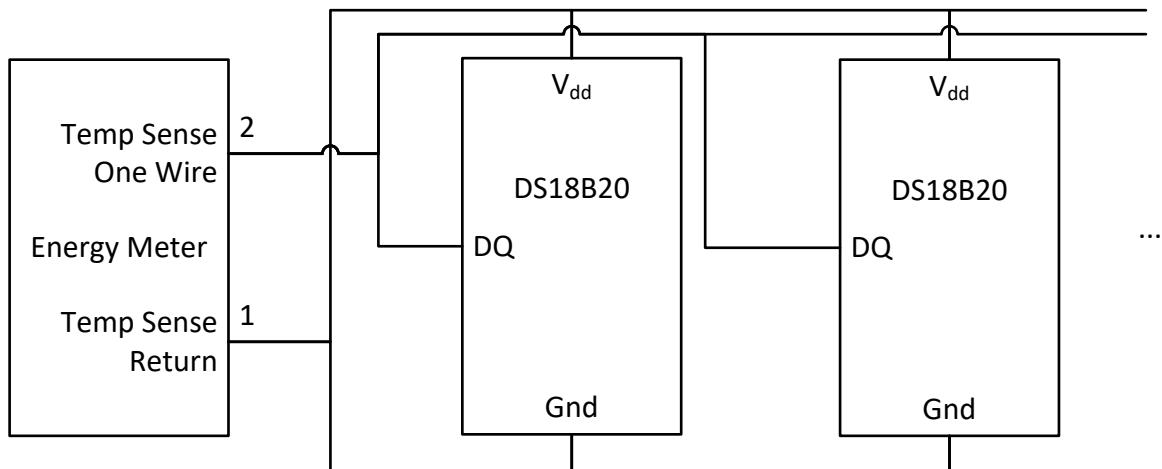
Teams are required to have at least one Energy Meter temperature sensor per Module in the Tractive Battery Pack.

The temperature sensors must be in the hottest region of each Module and meet EV.7.5.4.

The sensors must also have appropriate levels of electrical isolation between the sensor and cell. It is recommended to use a thermally conductive, electrically insulating thermal interface material (such as 3M 5519).

The sensors used must be an Analog Devices DS18B20 (any package) wired for parasite power Vdd connected to Gnd. Multiple sensors should be connected in parallel.

There are many counterfeit sensors on the market. Counterfeit sensors will not be accepted. Teams are encouraged to only purchase from trusted suppliers to ensure they are receiving genuine parts.



The Energy Meter temperature sense input is galvanically isolated from both Tractive System and GLV. Teams may choose one of the two configurations:

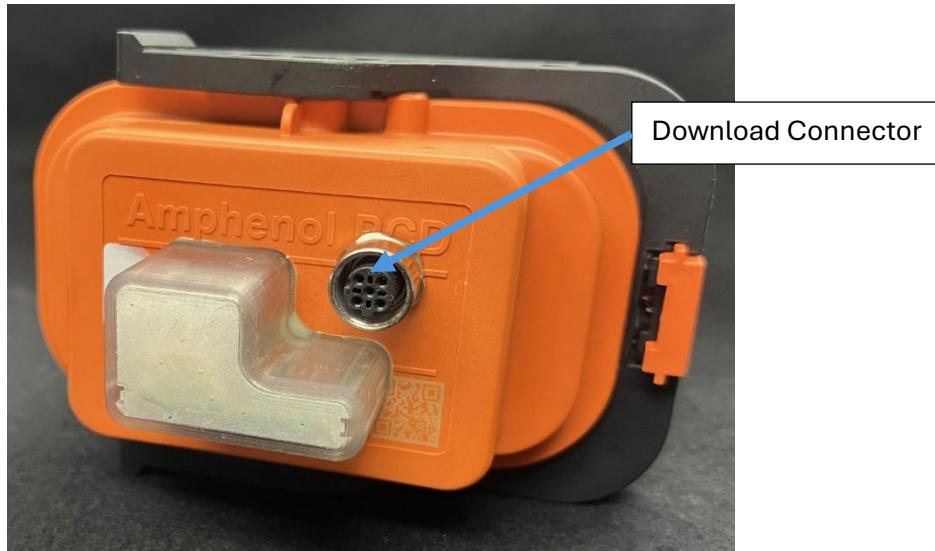
- 1) Make connections only between Energy Meter and temperature sensors as shown above. This will leave the temp sensors referenced to neither Tractive System nor GLV. In this case, the temp sense wiring will be considered as Tractive System with respect to the rules.
- 2) In addition to connecting the temp sensors as shown above, also provide a connection between Temp Sense Return and GLV ground. In this case the temp sense wiring will be considered as GLV wiring with respect to the rules.

## DOWNLOAD CONNECTOR

The download connector is located on top of the Energy Meter and must be accessible without removing the Energy Meter from the vehicle.

Teams are not allowed to extend or relocate the download connector.

Cabling to connect to the Energy Meter will be provided at the download stations at competition.



## Operation

The Energy Meter requires GLV power to log data. Once GLV power is applied and the Energy Meter has booted, it will begin logging into a new file when the Tractive System voltage is detected to be  $> 60V$ . The Energy Meter will stop logging when the Tractive System voltage is detected to be  $< 60V$ .

The Energy Meter has a status LED visible through the translucent cover near the download connector. The LED has the following indications:

Condition	Pattern	Description
Booting Up	solid red	
Idle	orange single flash	
Idle with Fault	red single flash	
Logging	Orange single flash off	
Logging with Fault	Red single flash off	
Server Operation	orange flashing	
Server Operation with Fault	red flashing	

## **DOWNLOADING**

Downloading data from the Energy Meter will be the responsibility of the teams.

Download stations will be available at the competition near Dynamic events, the practice track, and EV Technical Inspection. The download station will provide a cable that must be plugged into the download connector on the Energy Meter. During the download process the Energy Meter will be powered by the download cable and GLV power is not required.

The status of the download process will be available through the FSAE website and the status LED on the Energy Meter. Teams may use this to monitor the download progress.

Data will be publicly available to download from the FSAE website.

After data has been transferred to the FSAE site teams will be required to associate their dynamic event runs to the data files. The team must ensure that data is downloaded from the Energy Meter and associated to their Dynamic event runs prior to the deadline. Teams do not have to be connected to the download station to associate their Dynamic runs to the data files.

### **Downloading**

Once the green download cable is connected to the Energy Meter, the Energy Meter will be powered by the download station and GLV power is not required.

The status of the download process will be visible by the status LED on the Energy Meter.

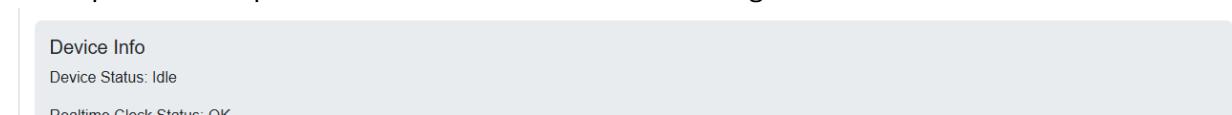
Teams may view the data transfer and monitor the transfer process online.

1. Navigate to result.fsaeonline.com portal OR via the FSAE Mobile App select Live Results
2. Select My Team's Result
3. Enter car number and click GO
4. Select E-Meter Data

It will take approximately 10 – 15 seconds for the Energy Meter to make connection to download station to begin data transfer. The webpage does not need to be refreshed; it will do that when Connection Status changes like image below showing that and the Command in Progress.

The screenshot shows the 'Energy Meter' interface. At the top, it displays the E-Meter ID: 11E510, Last Connected to Internet: 6/9/2025 3:16:13 PM EDT, and Connection Status: Connected. A prominent message in a box states 'Command In Progress' with 'SendRecordingList: Sending'. Below this, under 'Pending File Transfers', it lists two entries: '250609-182311.tdms: Pending Upload' and '250609-182349.tdms: Pending Upload'.

Data upload is complete when there is no Command In Progress and the Device Status is Idle.



All recordings that are uploaded throughout duration of the competition will be visible under Recordings like shown in image below:

## Recordings

Start Time	Filename	Meter	Signature	Duration	Violations	Peak Current	Peak Power	Events / Runs	Actions
12/31/1969 7:00 PM	700101-000025.tdms	11E46F	Valid	1064	0	0.19900	93.65459		<button>TDMS</button> <button>PLOT</button> <button>ASSOCIATE EVENTS</button> <button>EDIT NOTE</button>
12/31/1903 7:00 PM	250609-174219.tdms	11E510	Valid	48	0	0.01400	0.00200		<button>TDMS</button> <button>PLOT</button> <button>ASSOCIATE EVENTS</button> <button>EDIT NOTE</button>

Additional information on the buttons under Actions:

**TDMS** – this will give you raw data and can be downloaded

**PLOT** – gives you a quick glance of data via plot. This plot graph can be zoomed in/out as needed

**\*ASSOCIATE EVENTS** – will use to associate data to dynamic runs.

**\*EDIT NOTE** – this is only visible to the team data associated with or the EV Tech/Scoring volunteers

*\*These two buttons require you to log into your account on fсаeonline.com to associate data or edit any notes.*

### REMINDER:

Teams only need to be connected to the download station to download data from Energy Meter. Once files are downloaded, teams can disconnect from the download station to free up for other teams.

## ASSOCIATING DATA

Recordings must be associated to event runs. This allows the scoring system to understand which recordings have data for the dynamic event runs.

To associate data to events, select the Associate Events button of a recording which has data from an event. If not already logged into an fsaeonline.com account, the browser will navigate to the login page. Then, the browser will be directed to a page like this:

### Associate Events

Recording
Start Time: 12/31/1969 7:00 PM ET
End Time: 12/31/1969 7:18 PM ET
Filename: 700101-000025.tdms

### Events and Runs

Run Time	Event Key	Raw Time	Corrected Time	Status	Associate
6/14/2024 11:25 AM ET	ACCEL-EV	4.94925	4.94925		<span>Not Associated</span>
6/14/2024 11:26 AM ET	ACCEL-EV	4.89425	4.89425		<span>Not Associated</span>
6/14/2024 11:36 AM ET	ACCEL-EV	5.09813	5.09813		<span>Not Associated</span>
6/14/2024 11:38 AM ET	ACCEL-EV	5.12013	5.12013		<span>Not Associated</span>

Toggle the Not Associated / Associated button in the Associate column for each event run contained in this data file to the Associated state. The associate state will change to a green Associated, and the association will be reviewed by a judge and approved. Teams may associate and unassociate data from a run if they make a mistake but ONLY before a Judge Reviews and accepts it.

Run Time	Event Key	Raw Time	Corrected Time	Status	Associate
6/14/2024 11:25 AM ET	ACCEL-EV	4.94925	4.94925	Pending Judge Review	<span>Associated</span>

Multiple runs can be contained in and associated to a single recording file. Multiple recordings can be associated to the same event in the case that TS power was cycled during a run producing multiple data files.

After associating data to dynamic event runs, the Team Data page will show that the data has been associated to the event like the example below shows:

Start Time	Filename	Meter	Signature	Duration	Violations	Peak Current	Peak Power	Events / Runs	Actions
12/31/1969 7:00 PM	700101-000025.tdms	11E46F	Valid	1064	0	0.19900	93.65459	ACCEL-EV	<span>TDMS</span> <span>PLOT</span> <span>ASSOCIATE EVENTS</span> <span>EDIT NOTE</span>

### Please Note:

A recording can contain multiple runs, and a run could contain multiple recordings.

**REMINDER:**

- Teams should have all Energy Meter data associated to Dynamic Runs by or before 6PM on Friday Dynamic Event Day.