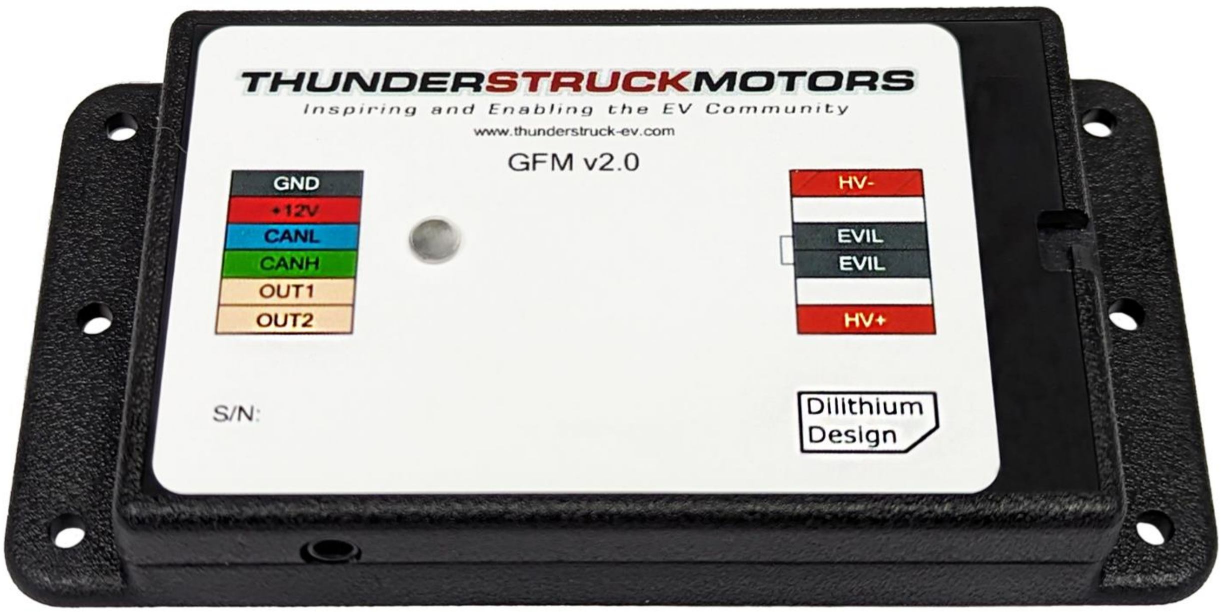
THUNDERSTRUCKMOTORS
Inspiring and Enabling the EV Community

Ground Fault Monitor V2



Manual v1.0
1 February, 2024

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OVERVIEW

The Thunderstruck Motors GFM (Ground Fault Monitor) measures the isolation between an electrical system ground and a separate High Voltage (HV) isolated system. It is designed for use in a wide range of Electric Vehicle (EV) systems and is highly configurable.

The GFM measures isolation between the two systems by applying a known resistance between the low voltage ground and both HV buses (positive and negative) in an alternating sequence, then measuring the very small resulting current. The advanced measurement algorithm allows the GFM to make accurate measurements in rapidly changing and noisy systems. The isolation measurement is reported in several forms: fault resistance, ohms/volt, and average fault location. Symmetrical, asymmetrical, intermittent, and capacitive faults can all be measured by the system.

The GFM intelligently uses measured isolation metrics to evaluate two configurable fault thresholds (warning and fault). The GFM has two outputs that may be configured to represent these faults, allowing an operator to create warning lights and system interlocks. The present state of the fault, the number of occurrences, and the history of each fault is available to the user. These fault conditions, as well as all measurements, are available over CAN bus using sID (standard ID) and eID (extended ID) based protocols.

Features

- Rapid and accurate isolation measurement
- Highly configurable
- Wide voltage range (30-500V)
- Fault location detection
- 2x programmable outputs
- 1x CAN Bus
- All measurements and information available over CAN bus
- CAN control of isolation measurement
- Factory calibrated
- Built in compatibility with:
    - TSM MCU
    - TSM EV Display
    - Fellten CCS Controller

Applications

- Automotive EV
- Marine EV
- Electric Vehicle Supply Equipment (EVSE)
- Hybrid Vehicles
- Energy Storage Systems

SPECIFICATIONS

General					
Parameter	**Units**	**Min**	**Typ**	**Max**	**Comments**
Weight	g		60		Without connectors or harnesses.
Environment Temperature	°C	-20		85	
Overall dimensions (LxWxH)	mm		117x59x15		
Ingress Protection (IP)			IP30 equivalent		Protects against small tools and wires, no water protection.

Figure 1 – General Specifications

Electrical – Low Voltage					
Parameter	**Units**	**Min**	**Typ**	**Max**	**Comments**
Supply Bus Voltage	V	9	12	15	
Supply Bus Power	mW		300	500	
Output current (`out1`, `out2`)	mA			200	Grounding/sinking output.
Output voltage (`out1`, `out2`)	V	0		15	For an open output.(1)
Output impedance (closed), (`out1`, `out2`)	Ω	0	0	40	
Output impedance (open), (`out1`, `out2`)	MΩ	14	15	20	
Internal CAN termination resistance	Ω	none	none	120	See *CAN Hardware*
Serial Baud Rate	kbps		115200		
Serial voltage level	V		5		5V TTL Hardware
Note 1: Applying unrestricted voltage straight to an output may cause an overcurrent condition and damage the device. All outputs should sink a load that consumes 200mA or less.					

Figure 2 – Low Voltage Specifications

Electrical – High Voltage					
Parameter	**Units**	**Min**	**Typ**	**Max**	**Comments**
HV operational sense voltage	V	30		500	Outside of this range measurement will be degraded and an `isofault` condition will be pushed.
HV absolute voltage	V	0		600	HV circuit isolation integrity not guaranteed outside of range.
Internal measurement resistance	MΩ		2.18		Fault created in the system while the GFM makes an isolation measurement.
HV current consumption (measurement ON)	µA	<1		275	
HV current consumption (measurement OFF)	nA		10	400	

Figure 3 – High Voltage Specifications

Electrical – High Voltage Measurement					
Parameter	**Units**	**Min**	**Typ**	**Max**	**Comments**
HV Voltage measurement accuracy	%		1		
Fault resistance measurement range	kΩ	0		65535	Excluding GFM internal measurement resistance.
Fault resistance measurement accuracy	%		5		
Fault resistance measurement noise	kΩ		±100		

Isolation measurement range	Ω/V	0		65535	Includes GFM internal measurement resistance.
Isolation measurement period	Seconds	1	1	120	Configurable using `isorate` parameter.
Isolation measurement initialization time	Seconds	5		120	Configurable using `intimin` parameter.
Fault reaction time	Seconds	1		5(1)	
Note 1: can increase if `isorate` is set higher than 0					

Figure 4 – High Voltage Measurement Specifications

INSTALLATION AND WIRING

The GFM is a high voltage device and is designed to be installed inside of a protected and high voltage safe enclosure. For example, in a typical EV it is recommended to install the GFM inside of a high voltage battery box or inside of a high voltage contactor box. It is important to follow all relevant regulations and safety practices when working with the GFM or any other high voltage device.

Included Components

A complete kit of the GFM should contain the following components:

- 1ea GFM Unit
- 1ea HV Harness Assembly
- 2ea EVIL pre-pinned wires
- 1ea LV Connector
- 1ea LV Connector wire removal tool

Separately sold relevant components:

- Serial Cable
- Indicator light / display
- Terminals for connecting HV harness to HV pack bus
- HV fuse and holder for HV sense wires

Hardware and Dimensions

The GFM enclosure is based on the Serpac part#: WM010I,BK.

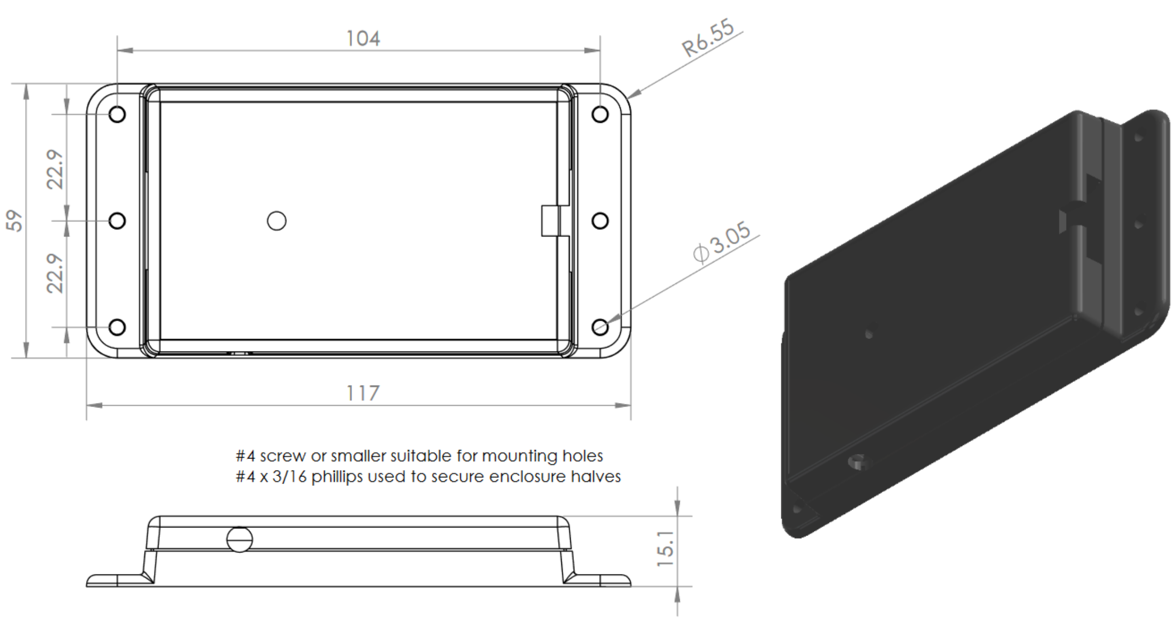

Figure 5 – Mechanical Drawing

Connectors

The GFM has three connectors; the Low Voltage (LV), Serial Port, and High Voltage (HV) connector.

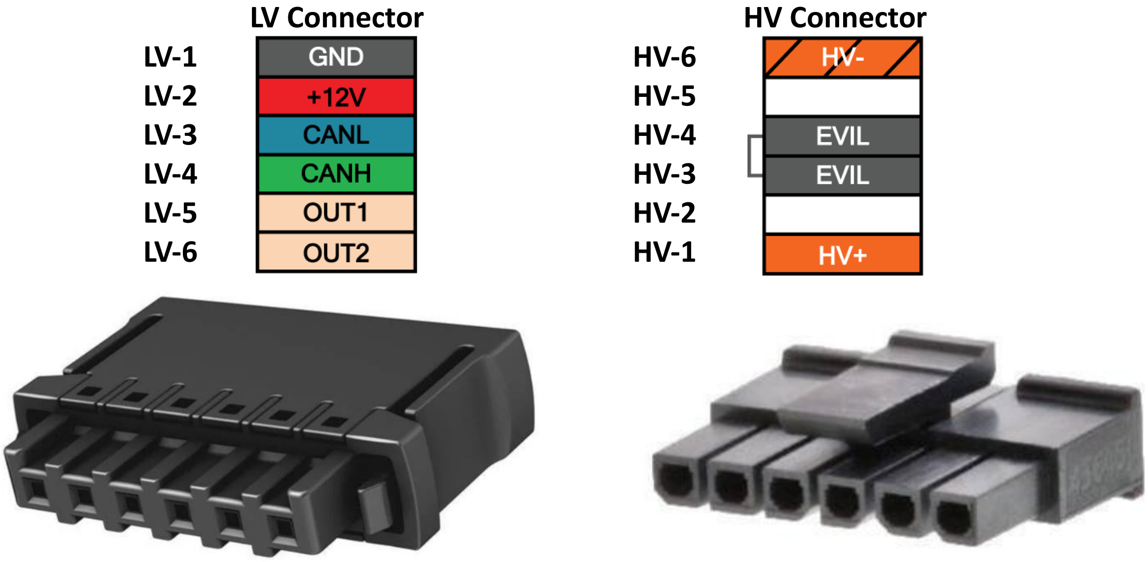

Figure 6 – Connector Illustrations

Connector Details					
Connector Name	**Manufacturer**	**Mating Part #**	**Circuits**	**Style**	**Wire Gauge**
Low Voltage (LV)	Harting	14310613101000	6	Pin-less wire push-in	20-24AWG(1)
High Voltage (HV)	Molex	43645-0600	6	Pre-assembled crimped harness	20-24AWG
Serial Port	TSM	TTL-232R-5V-AJ	3	3.5mm 'Aux' style	
Connector Pinouts					
Pin (wire side, left to right)	**Pin Name**	**Description**			
LV-1	GND	Connect to chassis/12v system ground.			
LV-2	+12V	Powers the GFM.			
LV-3	CANL	CAN bus low			

LV-4	CANH	CAN bus high
LV-5	OUT1	Configurable grounding output.
LV-6	OUT2	Configurable grounding output.
HV-1	HV+	Connects to HV pack positive. Wire must be properly rated and protected- the shorter the length the better.
HV-2	N/A	Circuit left empty for isolation purposes.
HV-3	EVIL / HVIL	EV interlock, or HV interlock. Used to interrupt circuit that disables the HV system if any HV connections are removed. HV-3 and HV-4 are internally connected directly to each other with a small trace.
HV-4	EVIL / HVIL	
HV-5	N/A	Circuit left empty for isolation purposes.
HV-6	HV-	Connects to HV pack negative. Wire must be properly rated and protected. The shorter the length the better.
Note 1: Harting har-flexicon connectors require 20AWG thin-walled insulation or smaller wire. Standard 20AWG wire will not fully seat into the connector and risk circuit problems including shorts. **Recommended 20 AWG:** 20 AWG TXL (extra thin wall) **Not Recommended 20 AWG:** 20 AWG SXL (thick wall), 20 AWG GXL (standard wall)		

Figure 7 – Connector Specification and Pinout

The Harting connector used for the Low Voltage connector is a pin-less design. First, strip the wire to 4.50-6.25mm (~0.18-0.25"), then insert the wire into the circular hole on the connector. The wire should lock into place and the wire insulation should sit slightly inside of the hole.

To remove a wire from the Low Voltage connector, use the provided LV Connector wire removal tools. Just insert the tool into the rectangular hole of the connector and gently remove the wire. The wire tool may be depressed in the direction of the wire to better unlock the wire.

Typical Circuit Design

The circuit diagram below illustrates a recommended option for high voltage design, as well as showing the typical wiring that could be used to create an interlock circuit as well as a warning indicator (see the *OPERATION* section). There are other acceptable ways to wire a system, including placing the GFM on the other side of the main contactors or having 'accessory' high voltage circuits that are separate from the main contactors.

This is a simplified circuit diagram and does not include many important components like fuses, switches, control units (BMS, VCU, MCU, ECU, etc…), and other components that depend on the specific implementation.

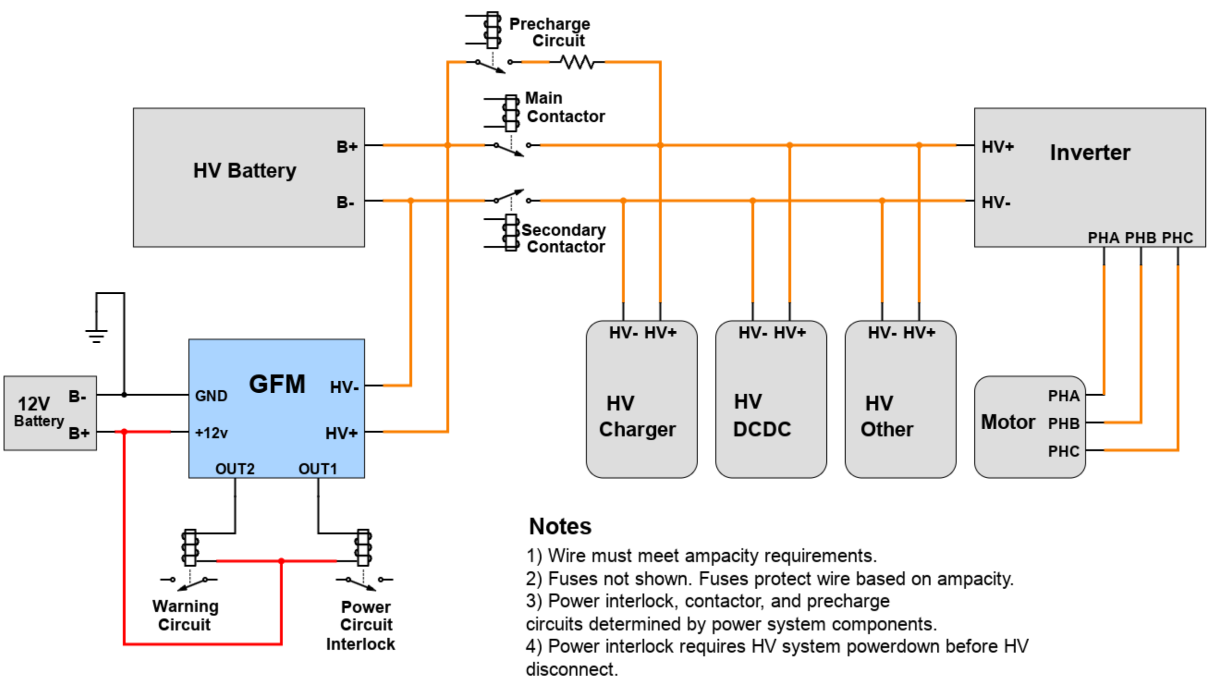

Figure 8 – Typical EV Circuit Diagram

CONFIGURATION

The default configuration of the GFM is designed to be suitable for most isolation monitoring applications. To be flexible to a wide group of end users, the GFM has many configurable parameters that change its behavior.

If the default configuration is deemed appropriate for the end user, it is recommended to at least review and configure the `maxpv` parameter. This parameter should be set to the maximum design voltage of the system. This will help the GFM make worst-case isolation calculations.

Parameter Library

The configurable parameters for the GFM are listed below. Most parameters are changed via the **`set`** command. Boolean parameters are changed via the `enable` and `disable` command.

For example:

```
GFM> set maxpv 403.2
GFM> enable zevccs
GFM> set out1 isofault
```

Parameter Name	Units	Min	Max	Default	Description
System Parameters					
lbv	V	0	15	0	Low bus voltage – defines threshold for a low 12v bus fault.
hbv	V	0	15	0	High bus voltage – defines threshold for a high 12v bus fault.
out1	enum	n/a	n/a	n/a	Default: –IsoFaultLatch See *Output Mapping*
out2	enum	n/a	n/a	n/a	Default: IsoWarn See *Output Mapping*
Canbus Parameters					
canbr	kbps	250	500	250	CAN baud rate
zevccs	Boolean			Disabled	CAN protocol for Zero EV CCS controller aka Fellten CCS controller.
canopen	Boolean			Enabled	CANOpen/sID CAN protocol.
j1939	Boolean			Enabled	J1939/eID CAN protocol.
Pack Parameters					

`lpv`	Volts	0	500	20.0	Low Pack Voltage - threshold for a low pack fault.
`lpvdelay`	Seconds	0	120	0	Time hysteresis for `lpv`.
`hpv`	Volts	0	500	500	High Pack Voltage – threshold for a high pack fault.
`hpvdelay`	Seconds	0	120	0	Time Hysteresis for `hpv`.
Isolation Parameters					
`isowarn`	Ω/V	0	5000	1000	Threshold for an isolation warning.
`isowarndelay`	Seconds	0	120	0	Time hysteresis for `isowarn`.
`isofault`	Ω/V	0	5000	500	Threshold for an isolation fault.
`isofaultdelay`	Seconds	0	120	0	Time hysteresis for `isofault`.
`isoduration`	Seconds	1	Inf	inf	The GFM will cease HV isolation measurements after this time. `inf` means the isolation can continue indefinitely.
`isorate`	Seconds	0	120	0	Period of time between the start of one series of isolation measurements and another. A full isolation measurement sequence takes ~2 seconds.
`initmin`	Seconds	0	120	5	The minimum amount of time after power on before the GFM can move from "init" to "active" and begin evaluating fault conditions. Useful for avoiding fault declaration during an extended startup process.
`maxpv`	Volts	0	500	50.0	Voltage used to calculate isolation value. This parameter will automatically increase if the measured voltage exceeds the configured value.
`isometer`	Boolean			enabled	Enables/disables the HV isolation measurement.

Figure 9 – Configuration Parameters

OPERATION

HV Isolation measurement

Unless `isometer` is disabled, the GFM will begin to make isolation measurements after being powered on. The GFM does this by connecting a known resistance between HV+ and chassis, then HV- and chassis repetitively at a rate of 1-2Hz (by default). As a result, the measured voltage between chassis and either HV bus can oscillate at the frequency of the isolation measurement. The amplitude of this observed oscillation depends on the level of isolation.

Isometer State

"State" is a summary of the types of measurements being made by the isometer. The current state can be seen by entering `show` in the serial interface. The three states are "Idle", "Init", and "Active".

Idle

In the Idle state, the GFM will not make any isolation measurements, meaning that it will not apply its internal test resistance to either HV bus. This is often used to prevent the GFM from causing an error inside other Isolation Monitors present in the system, such as when connected to a DC Fast Charging station.

Init

In the Init state, the GFM will take isolation measurements as normal. However, the GFM will not process an isolation fault or warning during this state. This is to allow the GFM enough time to collect sufficient data to make an accurate assessment of system isolation.

Active

Isolation measurement is done normally, and the GFM will process isolation faults and warnings.

If `isometer` is enabled the GFM will proceed from the "Idle" state to the "Init" state. The GFM will continue to take measurements until the initialization is complete. By default, <5 seconds is required for initialization, but this time can be extended using the `initmin` parameter if more time to establish the system is required. Once complete with initialization, the GFM will proceed to the "Active" state. In the Active state, isolation data will be processed using the configured isolation thresholds for faults.

If `isometer` on the GFM is disabled via the serial interface **`disable isometer`** command, over CAN, or via the `isoduration` parameter, then the GFM will go to the "Idle" state once the ongoing isolation measurement step is complete. This will always take <1 second. Once in the "Idle" state, the GFM ceases isolation measurement and any isolation fault determination.

The GFM may return to the "Init" state from the "Idle" state if commanded to. If Initialization has already been successfully completed, the GFM will skip the "Init" state and proceed straight from "Idle" to "Active".

System Status and Conditions

There are six conditions that are evaluated by the GFM. All six conditions contribute to the “Warn” status, but only some of the conditions contribute to the “Fault” status. A “Fault” status always overrides any “Warn” status. Status only affects the LED behavior and provides a simplified summary of overall system condition.

External systems can simply look at the GFM’s Status over CAN to determine system safety instead of attempting to evaluate the transmitted measurement data.

All GFM conditions also have an associated “Latch” and “Hist” suffix. The Latch suffix says whether the fault has occurred during the current power cycle. The Hist suffix reflects whether the condition has ever occurred. There is also a count of the number of times a condition has occurred during the current power cycle, and the Latch variations of the conditions evaluate to true if the count of the particular condition is greater than 0.

See *Output Mapping* for more info on conditions.

System Conditions				
Condition	**Full Name**	**Is Warn?**	**Is Fault?**	**Evaluation**
`lbv`	Low Bus Voltage	Yes	No	Is supply bus voltage < `lbv` (if `lbv` is not configured to 0)
`lbv`	High Bus Voltage	Yes	No	Is supply bus voltage > `hbv` (if `hbv` is not configured to 0)
`lpv`	Low Pack Voltage	Yes	No	Is pack voltage < `lpv` (if `lpv` is not configured to 0)
`lpv`	High Pack Voltage	Yes	No	Is pack voltage > `hpv` (if `hpv` is not configured to 0)
`isowarn`	Isolation Warning	Yes	No	Is Isolation (Ω/V) < `isowarn` OR `isofault` is TRUE
`isofault`	Isolation Fault	Yes	Yes	Is Isolation (Ω/V) < `isofault` OR pack voltage < 30.0V OR pack voltage > 500.0V

Figure 10 – System Conditions

Fitting the GFM into various systems

There are three primary ways the GFM can be used in a HV system. Depending on requirements, some systems use one, two or all three of the following methods.

A) HV safety interlock, via CAN bus
B) HV safety interlock, via programmable output
C) HV safety warning indicator, via programmable output

In the case of either interlock (A and B), it is the job of the device in the system that controls the contactors to make the system safe. This device, typically a VCU (Vehicle Control Unit) or BMS

(Battery Management System), upon detecting a failed interlock signal should proceed to take steps to safely shut the system down and open the main contactors.

Safety Interlock via CAN Bus

The GFM can be configured to transmit data over CAN bus. This can come in a few different formats, including CANOpen (sID) and J1939 (eID). Other devices can be configured to listen to this data over CAN and respond to fault conditions to protect system safety.
See the *CAN Bus* section for more.

Safety Interlock via Programmable Output

The two outputs are mappable to make them easy to use as a system safety interlock. A well-designed interlock is NO (Normally Open) or only closed/ active when the system is both powered ON and OK. This is to ensure that all contributing devices to an interlock must be powered ON and contributing an OK signal before the interlock signal is completed.

For Example:

```
OUT1        : -IsoFaultLatch
```

This configuration is suitable for using OUT1 as an interlock signal. In this configuration, the output will be `GND` (grounded) when the system is ON and `isofaultlatch` is NOT true. If `isofault` were to occur at any point during the power cycle of the GFM, then `isofaultlatch` would become TRUE, and `OUT1` would become `OFF` (not grounded/floating).

See *Output Mapping* for more.

Note: The GFM is not designed to directly control contactors, or to contribute to the direct control of contactors. Doing so may increase the likelihood of unsafe contactor disconnection before a system is allowed to attempt a safe shut down, or the unsafe connection of contactors without following appropriate startup and precharge procedures. Always use a device designed to directly control contactors when the system requires these procedures to be followed.

Warning Indicator via Programmable Output

The simplest form of involving the GFM in a system is through the usage of a HV Safety Indicator, or Isolation Warning Indicator. Many organizations and regulations require an indicator that illuminates if an isolation fault is detected. In some cases, an indicator as well as one of the interlocks described above is required.

To set up an Isolation Warning Indicator is simple, and the default configuration of the GFM is designed to use `OUT2` for this.

For Example:

```
OUT2        : IsoWarn
```

This configuration is suitable for controlling an isolation warning indicator. If there is currently an isolation warning (Isolation is less than `isowarn`) then the condition `isowarn` is TRUE, and the output will be `GND`.

If required, an isolation warning indicator can be wired to be normally on. In this case, the isolation warning indicator will be ON when the GFM is OFF or if `isowarn` is TRUE. One way to do this is to use a normally closed (NC) relay to power the Isolation Warning Indicator, and control that relay with the following output:

```
OUT2      : -IsoWarn
```

LED

On the front face of the GFM is an LED that provides a quick assessment of the internal state of the device. There is always at least some activity on the LED if the device is powered on and working correctly. If there is no LED activity then the GFM is either powered off or faulty.

LED Blink Pattern	
GFM state	**Blink rate**
Init	Slow, 0.5Hz
Active	Fast, 2Hz
Idle	Solid

LED Color	
GFM Status	**LED Color**
OK	Green
Warn	Yellow
Fault	Red

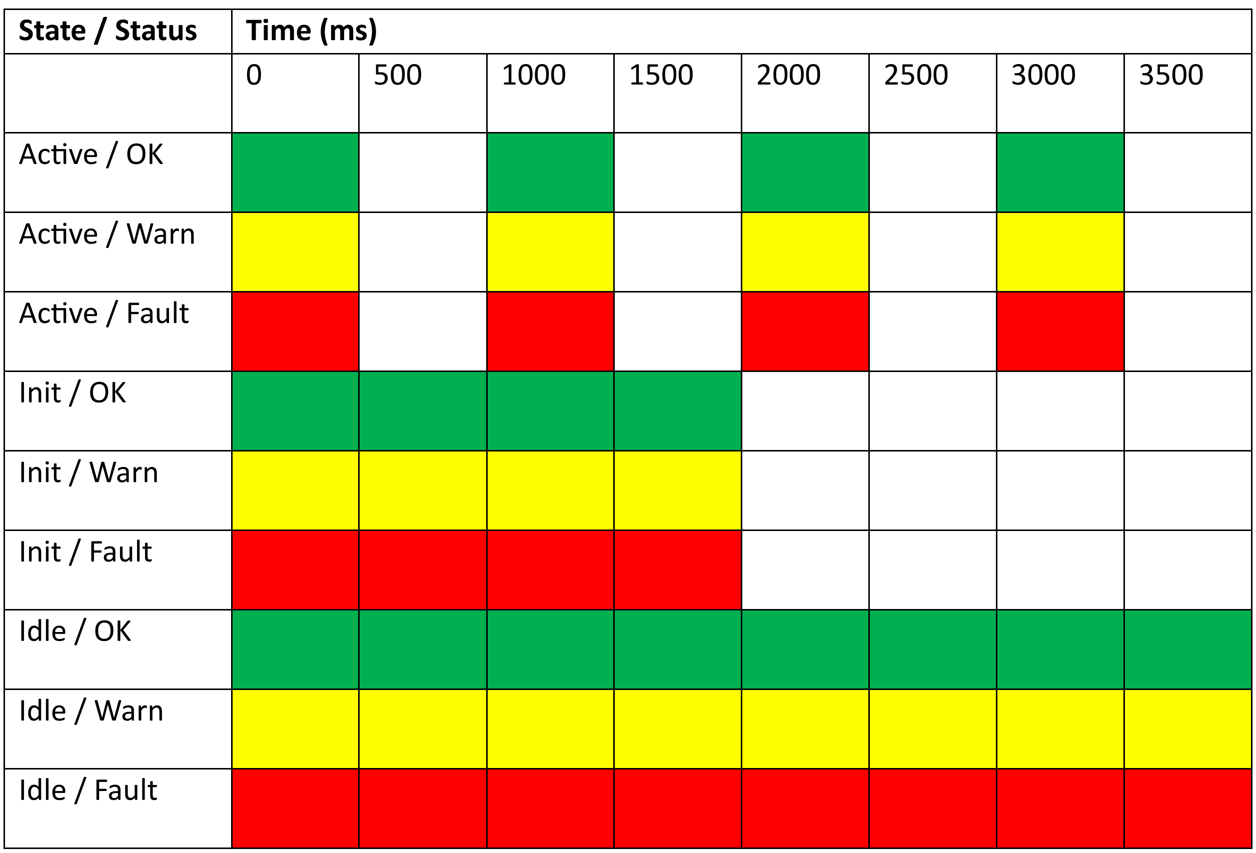

Figure 11 – LED Behavior

SERIAL INTERFACE

Terminal Installation

A terminal application such as PuTTY (Windows) or Coolterm (Mac or Windows) is needed on the host computer. See the Serial Port Utilities document for installation and connection details: www.thunderstruck-ev.com/images/companies/1/DD_SerialPortUtilities_v1.3.pdf
Baud rate: 115200

Primary Serial Commands

The serial interface has several primary commands. All commands that can be entered into the GFM start with one of these primary commands.

- `Help`
- `SHow`
- `SEt`
- `ENable`
- `DISable`
- `TRace`
- `REset`
- `UPGRADE`

Certain commands have shortcuts available. Shortcuts are indicated by the capital letters shown in the command listing.

For example, `reset` can be shortened to `re`:

```
GFM> reset
  REset [CONFIG|FAULT]
        config    - reset configuration to defaults
        fault     - reset fault history
GFM> re
  REset [CONFIG|FAULT]
        config    - reset configuration to defaults
        fault     - reset fault history
```

Entering most of these commands on their own will result in a contextual help dialog that lists all possible uses of that particular command. These contextual help dialogs are listed below.

help

```
GFM> help
  SHow [<>|Version|Config|Stats]
        <>        - status
        version   - firmware version
        config    - configuration
  SEt [ <>        - 'set' help
        isofault  - IRPV critical threshold
        isowarn   - IRPV fault threshold
        canbr     - can baud rate
        lpv       - low pack voltage
        lpvdelay  - low pack voltage delay
```

```
        hpv       - high pack voltage
        hpvdelay  - high pack voltage delay
        lbv       - low bus voltage
        lbvdelay  - low bus voltage delay
        hbv       - high bus voltage
        hbvdelay  - high bus voltage delay
        out<n> {isofault|isowarn|lpv|hpv|lbv|hbv|
           isofaultlatch|isowarnlatch|etc.
           isofaulthist|isowarnhist|etc.
       ]
  ENAble | DISable [ <>
                  - 'enable' and 'disable' help
        zevccs    - ZEVCCS control
       ]
  MEasure [ <>    - 'measure' help
        pp        - Ground Fault+
        pn        - Ground Fault-
        pv        - Pack Voltage
        12v       - 12v
       ]
  REset [CONFIG|FAULT]
        config    - reset configuration to defaults
        fault     - reset fault history
  TRace [CANbus|OFF]
        can       - enable CAN tracing
        off       - disable all tracing
        isolation - enable isolation measurement tracing
  UPGRADE         - performs a firmware upgrade
GFM>
```

show

```
GFM> sh
--STATUS--------
  status     : OK
  state      : Active
  pack       : 51.3 V
  supply bus: 11.19 V
  isolation : 18838 ohms/v
  leakage    : 1736K (@  3.4V)
  OUT1       : GND
  OUT2       : OFF
  uptime     : 0 hour(s), 0 minute(s), 38 second(s)
--FAULTS--------
>Name            >State  >Count  >Hist
LPV              false    0      TRUE
IsoWarn          false    0      TRUE
IsoFault         false    0      TRUE

GFM>
```

set

```
GFM> set
    'set' help
    SEt [ <>
        isofault     - isolation critical threshold
        isofaultdelay
```

```
                    - time hysteresis for isofault
        isowarn     - isolation fault threshold
        isowarndelay
                    - time hysteresis for isofault
        canbr       - can baud rate
        lpv         - low pack voltage
        lpvdelay    - low pack voltage time hysteresis
        hpv         - high pack voltage
        hpvdelay    - high pack voltage time hysteresis
        lbv         - low bus voltage
        lbvdelay    - low bus voltage time hysteresis
        hbv         - high bus voltage
        hbvdelay    - high bus voltage time hysteresis
        isoduration - isolation measurement time
        isorate     - time between each measurement
        initmin     - minimum time for iso initialization
        maxpv       - design maximum of the HV pack
        out<n> {isofault|isowarn|lpv|hpv|lbv|hbv}
           isofaultlatch|isowarnlatch|lpvlatch|<etc.>|
           isofaulthist|isowarnhist|lpvhist|<etc.>}
            example: 'set out1 -isofault'
            example: 'set out2 isowarn lpv hpv'
        ]
GFM>
```

enable/disable

```
GFM> enable
    'enable'/'disable' help
    ENable | DISable [ <>
        zevccs      - ZEVCCS CAN control
        isometer    - HV isolation measurement
        canopen     - CANOpen CAN interface
        j1939       - J1939 CAN interface
        ]
GFM>
```

trace

```
GFM> trace
    'trace' help
    TRace [ <>
        can         - CAN bus messages
        ISOmeter    - isometer measurements
        off         - disable all tracing
    ]
GFM>
```

reset

```
GFM> reset
  REset [CONFIG|FAULT]
        config    - reset configuration to defaults
        fault     - reset fault history
GFM>
```

upgrade

```
GFM> upgrade

 ***                   Starting GFM Upgrade                            ***
 *** 1) Exit from the terminal application                             ***
 *** 2) Start the bootloader and download a new .hex file              ***
 *** 3) Restart                                                        ***
```

Output Mapping

The outputs on the GFM may be configured to any of the conditions listed in the *System Status and Conditions* section. In addition, each condition also has a corresponding "Latch" and "Hist" condition. Any condition can be logically reversed by preceding the condition with a hyphen "-". Multiple conditions may also be configured to a single output. In this case, if any of the outputs are TRUE, then the output is `GND` (grounded).

For example:

```
GFM> set out1 lpv
OUT1 set to: LPV
```

This output will be `GND` if `lpv` is TRUE.

```
GFM> set out1 -isofault
OUT1 set to: -IsoFault
```

This output will be GND if IsoFault is FALSE.

```
GFM> set out1 isowarn lpv hpv lbv hbv
OUT1 set to: IsoWarn LPV HPV LBV HBV
```

This output will be `GND` if `isowarn` OR `lpv` OR `hpv` OR `lbv` OR `hbv` is TRUE

```
GFM> set out1 -isofaultlatch -isowarn
OUT1 set to: -IsoFaultLatch -IsoWarn
```

This output will be `GND` if `isofaultlatch` is FALSE OR `isowarn` is FALSE.
In other words, the output is `GND` until there is an active `isowarn` OR `isofault` was ever TRUE during this power cycle.

```
GFM> set out1 -isofaulthist
OUT1 set to: -IsoFaultHist
```

The output is `GND` unless an `isofault` has ever occurred, even in previous power cycles.

CAN BUS

CAN Bus is digital communication standard that provides a highly resilient interface between industrial, automotive, and marine devices. There are many standards that define the specific format of the data that devices send and receive on a CAN bus network. However, in general, devices are NOT compatible unless they are designed to be. Some devices with highly configurable CAN bus interfaces can be configured utilize the GFM's included protocols.

Supported Protocols

Any of these protocols can be enabled or disabled via the serial interface.

Name	ID Format (sID or eID)	Message ID's	Relevant devices
CANOpen	sID	0x293	EVDisplay-MCU
J1939	eID	0x14ff30e0, 0x14ebd0d8	MCU
ZEVCCS	sID	0x357	ZEV CCS Controller

Figure 12 – Supported CAN Protocol Overview

Full details about these protocols are defined in the .dbc files available from TSM.

CAN Hardware

CAN bus networks consist of the devices (nodes) connected to the network, the wires that connect these devices, and the CAN termination resistors.

All CAN transceivers on a network must share the same reference voltage (ground/chassis). The GFM has a non-isolated CAN bus, meaning that there is not a separate CAN ground connection, the CAN ground is shared with the 12V GND connection. Some devices have isolated CAN transceivers that have a separate connection for CAN ground.

On the GFM PCB there is a DIP switch that can be switched to enable/disable the onboard CAN termination resistor. By default it is disabled.

CAN Network wiring guidelines:

- CAN High and CAN Low wires must be twisted at a rate of ~1 complete turn per inch or tighter.
- In an electrically noisy environment, The CAN High and CAN Low twisted pair should be shielded by a wire shield that is connected to chassis/ground on one end.
- All CAN devices should share a voltage reference (ground/chassis). If there is an isolated device, it has a CAN ground that should be connected to a shared ground/chassis.
- A CAN network should be <40m in overall length and any stubs/branches should be <0.3m.
- There should be two total CAN termination resistors, each 120 ohms. These resistors should be located on the farthest ends of the CAN network and connect between CAN high and CAN low.

FIRMWARE

As of the date of this manual, the most recent available firmware version is:
v2.0.7

Contact TSM for firmware updates and feature requests.

Firmware Update

The GFM uses the same 8-bit firmware update procedure as other TSM 8-bit products.
The GFM serial baud rate is 115200.

For more information, review the "Serial Port Utilities" document available at www.thunderstruck-ev.com

Serial Port Utilities
www.thunderstruck-ev.com/images/companies/1/DD_SerialPortUtilities_v1.3.pdf?1684256128393

WARRANTY AND SUPPORT

ThunderStruck Motors offers a high level of support and warranty consideration for anyone purchasing our products. The DIY industry invites participants of all skill levels, and our goal is to meet their needs with tolerance, understanding and flexibility as our way of contributing to success of the electric transportation movement.

Warranty

The Thunderstruck GFM is guaranteed against operational and material defects for one year after the device purchase date. The recommended first point of contact for warranty consideration is the company which sold the product. If purchased directly from ThunderStruck Motors, please use the contact information below.
Because the customer is responsible for the device installation and wiring, the product warranty does not cover errors such as incorrect wiring connections or device placement, exceeding voltage limits, physical damage to any part of the unit, or any device failure caused by misuse or modification by the customer.

Support

Customers purchasing products directly from ThunderStruck Motors have access to support for instruction and troubleshooting needed during product installation and operation. Customers purchasing from vendors selling our products receive support first from the vendor and then from ThunderStruck Motors if the vendor is unsuccessful or unresponsive.

Contact Us

e-mail: connect@thunderstruck-ev.com
Phone: 707.578.7973
Text: 707.582.0799
Hours: M-F 9AM to 5PM - Pacific Time
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2985 Dutton Ave. Ste 3
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SAFETY AND DISCLAIMER

High voltage electricity can quickly cause injury or death.
Only trained personnel should work with high voltage, and all relevant regulations and best practices should be followed.

Some examples of electrical safety best practices are:

- Always use appropriately rated high voltage Personal Protective Equipment (PPE) when circuits that have the ability to exceed 60V are present. Gloves, face mask, helmet, and fire proof clothing are all examples of PPE that may be required.
- Always measure circuit voltage before touching or connecting any circuit. Never assume that a circuit is 'dead' or disconnected.
- Never work alone.
- When applicable, use a "Lockout Tagout" system.

Disclaimer:
The use of the GFM and these instructions is at your own risk. ThunderStruck Motors and Dilithium Design are not responsible for any damages or injury that occur during the use of GFM or these instructions.

The information and illustrations contained in this manual are intended to assist qualified technicians and personnel install the equipment correctly. However, it is the responsibility of the individuals working with this manual to ensure that the information contained in this manual is accurate, and that the work that is being done is safe and correct. If there is any uncertainty about the correct way to use this product, DO NOT attempt to proceed by referring to the manual verbatim.

DOCUMENT HISTORY

Revision Number	Date	Description
1.0	1 February 2024	Initial release