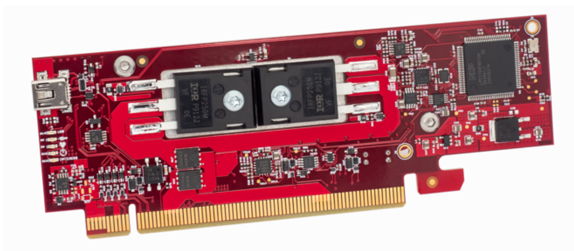


Overview

The Acroname MTM DC Load Module (MTM-Load-1), part of Acroname's MTM (Manufacturing Test Module) product series, is a software-controlled electronic load module with voltage, current, power, and resistance control. The MTM-Load-1 allows MTM system designers to easily and modularly add power supply loading to their test system designs.

The MTM-Load-1 provides a stable, consistent and robust way to load a wide range of devices, optimized for constant current applications. Hardware constant current control with software constant current, voltage, power, and resistance control allows for fast transient response and application versatility.

Built using Acroname's industry-proven and well-adopted BrainStem® technology, resources on the MTM-Load-1 are controlled via Acroname's powerful and extensible BrainStem® software APIs.

Typical applications include:

– Manufacturing functional testing
– Validation testing
– Automated test development
– Motor driver testing
– Battery testing

Features

– 1 Fully software-controlled regulated input with ~100uV/~100uA resolution, up to a 30V/10A current limit (Rail0)
– 1 BrainStem I²C FM+ (1Mbit/s) bus
– 4 overvoltage, short-circuit and over-current protected digital GPIOs
– Remote/Kelvin sense (Rail0)
– Rail output current voltage-mirror (Rail0)
– Rail output enable indicator (Rail0)
– On-board local temperature sensor for monitoring and over-temperature shutdown

Description

The MTM-Load-1 module is a key component for manufacturing test and R&D of devices requiring precision voltage measurements. For more information on the MTM platform architecture, please refer to www.acroname.com.

The MTM-Load-1 implements an on-board BrainStem controller running a RTOS (Real-Time Operating System), which provides a USB host connection, Independent operating capability and the BrainStem interface, for control of the MTM resources identified in this datasheet.

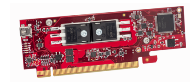
The MTM-Load-1 provides a main power input rail. The rail is a fully regulated input designed for precise DC loading applications for a wide input voltage (0 to 30V) and current (0 to 10A) range. The voltage and current measurements are captured by a 24bit ADC to allow for high resolution (100uV and 100uA) over the full range of the load. The rail can be configured to maintain specific current, voltage, power, or resistance set points to allow for diverse applications from loading constant power onto a DC power supply or constant current onto a LiPo battery. All of these features are easily controlled via the BrainStem API.

Within the MTM platform architecture, the MTM-Load-1 module can operate either independently or as a component in a larger network of MTM modules. Each MTM-Load-1 is uniquely addressable and controllable from a host by connecting via the on-board USB connection, the card-edge USB input or through other MTM modules on the local MTM/BrainStem I2C bus.

Acroname's BrainStem™ link is established over the selected input connection. The BrainStem link allows a connection to the on-board controller and access to the available resources in the MTM-Load-1. The MTM-Load-1 can then be controlled via a host running BrainStem APIs or it can operate independently by running locally embedded, user-defined programs based on Acroname's BrainStem Reflex language in the RTOS.

IMPORTANT NOTE:

The MTM-Load-1, like all MTM modules, utilizes a PCIe connector interface but is for use strictly in MTM-based systems – it should never be installed in a PCI slot of a host computer directly. Insertion into a PC or non-MTM system could cause damage to the PC.



Absolute Maximum Ratings

Stresses beyond those listed under ABSOLUTE MAXIMUM RATINGS can cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions beyond those indicated under RECOMMENDED OPERATING CONDITIONS is not implied. Exposure to absolute-maximum rated conditions for extended periods affects device reliability and may permanently damage the device.

Parameter	Minimum	Maximum	Units
Input Voltage, V_{supply}	6.0	12.0	V
Input Current, I_{supply}	0.0	2.0	A
Rail0 Voltage	0.0	35.0	V
Rail0 Current	0.0	12.0	A
Rail0 Thermal Shutdown	-	85.0	°C
Voltage to any IO pin	-0.5	V_{supply}	V
Voltage to any I2C pin	0.0	5.5	V

Table 1: Absolute Maximum Ratings

The MTM system is designed to be used in a system where V_{supply} is the highest voltage connected to all MTM modules. Each module is designed to withstand V_{supply} continuously connected to all IOs, excepting those specified above, including accidental reverse polarity connection between V_{supply} and ground (0V). As with all products, care should be taken to properly match interface voltages and ensure a well-architected current-return path to ground. As with all devices utilizing USB interfaces, care should be taken to avoid ground loops within the USB subsystem. When using the USB interface, ground must be at 0V potential to avoid damaging connected host systems.

Handling Ratings

Parameter	Conditions/Notes	Minimum	Typical	Maximum	Units
Ambient Operating Temperature, T_A	Non-Condensing	0.0	25.0	70.0	°C
Storage Temperature, T_{STG}		-10.0	-	85.0	°C
Electrostatic Discharge, V_{ESD}	IEC 61000-4-2, level 4, contact discharge to edge connector interface	0.0	-	±8000	V

Table 2: Handling Ratings

Recommended Operating Ratings

Values presented apply to the full operating temperature range.

Parameter	Conditions/Notes	Minimum	Typical	Maximum	Units
Input Voltage, V_{supply}		6.0	-	12.0	V
Rail0 Voltage		0.0	-	30.0	V
Rail0 Current		0.0	-	10.0	A
Voltage to any IO pin		0	-	3.3	V
Voltage to any I2C pin		0	-	3.3	V

Table 3: Recommended Operating Ratings

Block Diagram

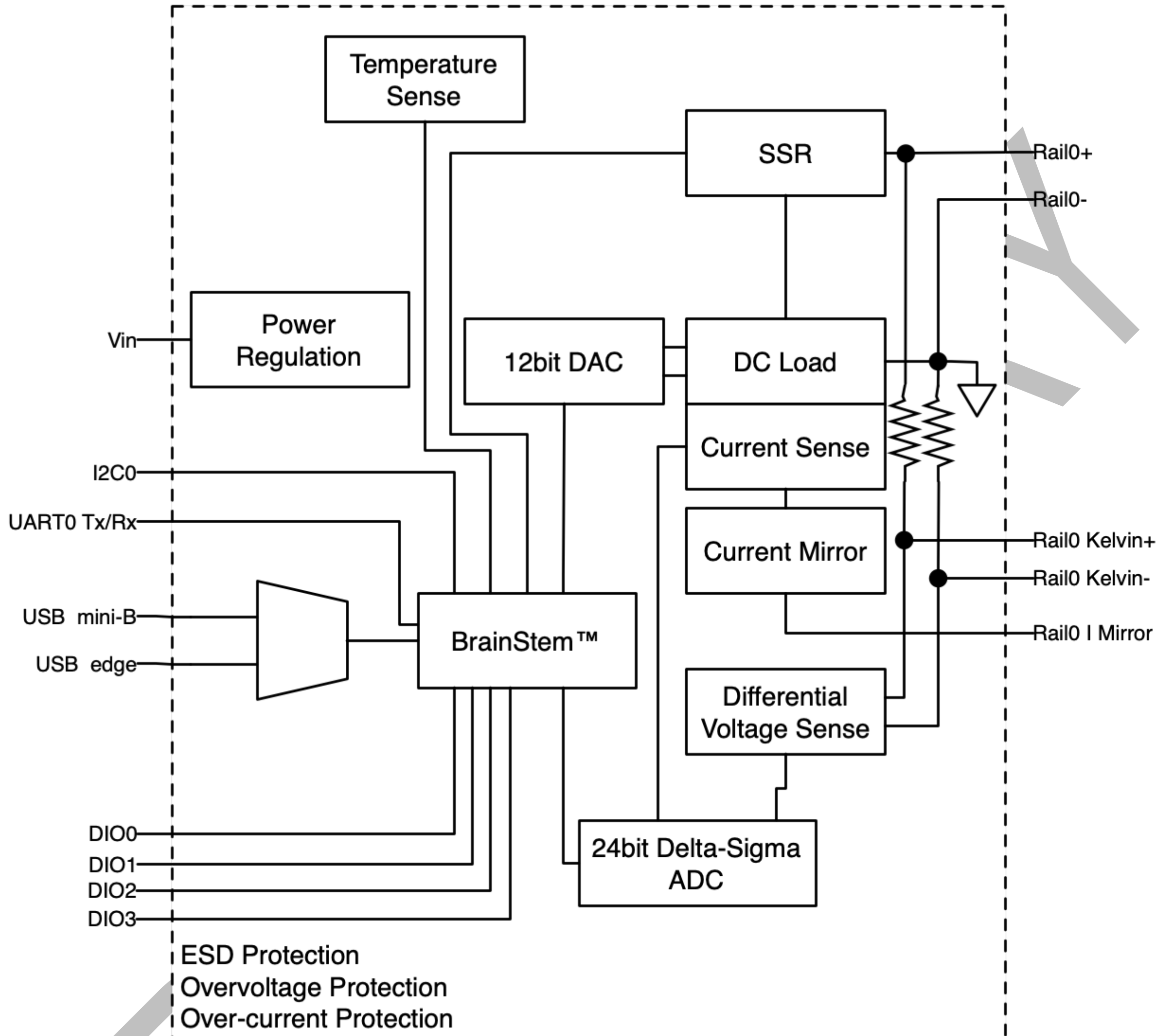
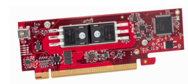


Figure 1: MTM-Load-1 Block Diagram

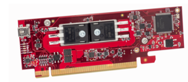


Typical Performance Characteristics

Values presented apply to the full operating temperature range.

Parameter	Conditions/Notes	Minimum	Typical	Maximum	Units
Base Current Consumption, I_{supply}	Input voltage = 6V Input voltage = 12V	225 120	250 140	275 160	mA
Rail0 Input Voltage, V_{RAIL0}	Software controlled	0.0	-	30.0	V
Rail0 Input Voltage Limit Range		-0.7	-	35.0	V
Rail0 Input Current, I_{RAIL0}	Software controlled	0.0	-	10.0	A
Rail0 Input Current Limit Range		-1.0	-	12.0	A
Rail0 Thermal Shutdown		-	-	85	°C
Rail0 Thermal Shutdown Hysteresis	After thermal shutdown event	15.0	-	-	°C
Rail0 Voltage Control Resolution		-	100	-	uV
Rail0 Current Control Resolution		-	100	-	uA
Rail0 Voltage Accuracy	15V load	-	0.01	-	%
Rail0 Current Accuracy	5A load	-	0.01	-	%
Rail0 Current Voltage-Mirror[1]			0.5		V/A
Rail0 Current Mirror Zero-offset		-	15	20	mV
Rail0 Current Mirror Output Accuracy	I_{out} ≤ 500mA I_{out} > 500mA	- -	2 0.5	5 1	%
Rail0 Peak Power		-	-	150	Watts
Rail0 Continuous Power	@25°C Ambient	-	50	-	Watts
Rail0 Turn On Delay		-	-	-	ms
Rail0 Slew Rate	10% to 90% of command	-	0.2	-	A/us
Reset Low Threshold		-	1.2	-	V
I2C SDA, SCL Pins		0.0	3.3	5.0	V
Digital Output V_{HI}		-	3.3	-	V
Digital Input Logic High, V_{IH}		2.15	-	-	V
Digital Input Logic Low, V_{IL}		-	-	1.1	V
Digital Output Drive Current	Output high; short to GND Output high into 2.97V	- -	20.0 3.15	30.0 -	mA
Digital Output Sink Current	Output low; short to V_{supply}	-	-20.0	-30.0	mA
Digital Output Short Duration	Output high	-	Infinite	-	hours
Digital Output Overvoltage	V_{supply} on pin	-	Infinite	-	hours
Digital Output Sink Current		-	-	-20.0	mA
Digital Output Source Current	<10% voltage drop (V_{output} >= 2.97V)	-	-	3.15	mA

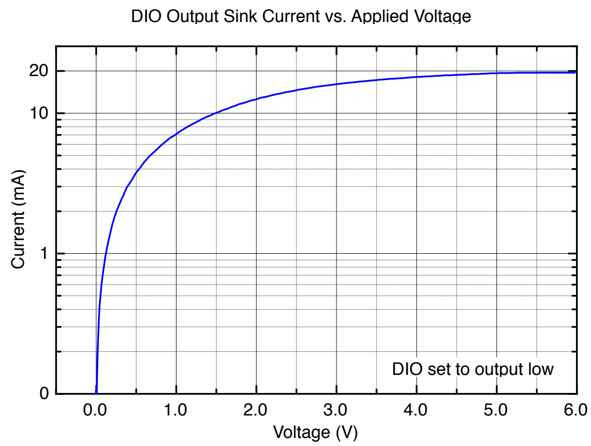
[1] Current output voltage-mirror must be connected to high impedance

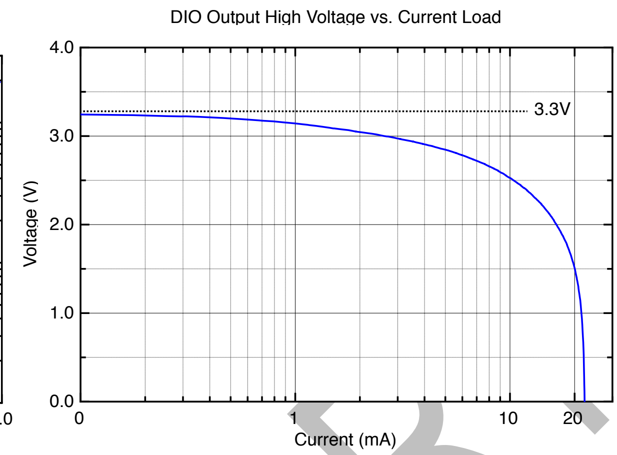


Digital Sample Rate[2]	Mac OS X Windows 10 Linux – 14.04 LTS Reflex	- - - -	700 1000 850 8200	1000 1000 1000 -	Hz
Digital Input Resistance	Configuration mode set to both Input and High-Z	-	4.25	4.45	MΩ
Digital Input Leakage Current	Configuration mode set to both Input and High-Z	-	110	-	uA

Table 4: Typical Performance Characteristics

[2] Host dependent, test was done as a single instruction, subsequent instructions may affect performance. Measurements taken using BrainStem Library 2.3.2. The Nyquist frequency should be considered when referring to these values.





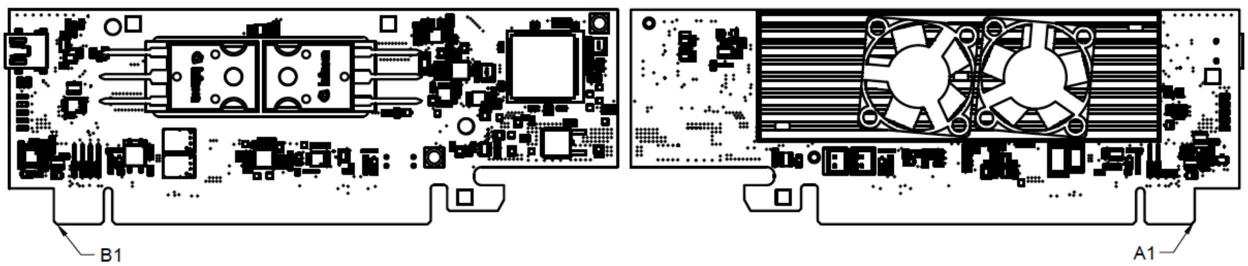
Work power range available soon

Step response available soon.

Pinout Descriptions

WARNING: Acroname's MTM line features a PCIe connector that is common in most desktop computers; however, they are NOT intended nor designed to work in these devices. Do NOT insert this product into any PCIe slot that wasn't specifically designed for this product! Failure to follow this warning WILL result in damage to this product and any device you connect it to.

The MTM edge connector pin assignments are shown in the following table. Please refer to Table 3: Recommended Operating Ratings for appropriate signal levels.



Pins Common to all MTM Modules

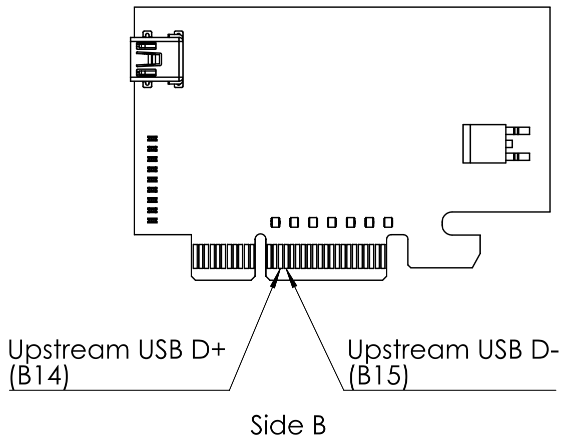
Edge Connector Side A	Edge Connector Side A Description	Edge Connector Side B	Edge Connector Side B Description
1	GND	1	Input Voltage, V_{supply}
2	GND	2	Input Voltage, V_{supply}
3	GND	3	Input Voltage, V_{supply}
4	GND	4	Input Voltage, V_{supply}
5	Reset	5	Input Voltage, V_{supply}
6	GND	6	Reserved, Do Not Connect
7	GND	7	Reserved, Do Not Connect
8	I^2C0 SCL	8	GND
9	I^2C0 SDA	9	GND
10	GND	10	Reserved, Do Not Connect
11	GND	11	Reserved, Do Not Connect
12	Module Address Offset 0	12	Module Address Offset 2
13	Module Address Offset 1	13	Module Address Offset 3

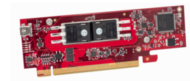
Pins Specific to MTM-Load-1

Edge Connector Side A	Edge Connector Side A Description	Edge Connector Side B	Edge Connector Side B Description
14	Reserved, Do Not Connect	14	USB Upstream Data +
15	Reserved, Do Not Connect	15	USB Upstream Data -
16:17	Reserved, Do Not Connect	16:17	Reserved, Do Not Connect
18	RAIL0 Kelvin Sense Negative Return	18	RAIL0 Kelvin Sense Positive Return
19	GND (RAIL0 -)	19	RAIL0 +
20	GND (RAIL0 -)	20	RAIL0 +
21	GND (RAIL0 -)	21	RAIL0 +
22	GND (RAIL0 -)	22	RAIL0 +
23	Digital IO 1	23	Digital IO 0
24	RAIL0 Current Mirror (1V/2A)	24	RAIL0 Power Enable Status
25:29	Reserved, Do Not Connect	25:29	Reserved, Do Not Connect
30	Digital IO 3	30	Digital IO 2
31:57	Reserved, Do Not Connect	31:57	Reserved, Do Not Connect
58	GND (RAIL0 -)	58	RAIL0 +
59	GND (RAIL0 -)	59	RAIL0 +
60	GND (RAIL0 -)	60	RAIL0 +
61	GND (RAIL0 -)	61	RAIL0 +
62	GND (RAIL0 -)	62	RAIL0 +
63:82	Reserved, Do Not Connect	63:82	Reserved, Do Not Connect

Upstream USB Connectivity Options

All MTM modules with upstream USB connections (excluding MTM-EtherStem) have two methods for connection via USB: through the Mini-B connector, or through pins B14 and B15 of the PCIe edge connector (below). The upstream mode defaults to AUTO, which prioritizes based on the presence or absence of VBUS at the Mini-B connector.





Module Hardware and Software Default Values

The MTM-Load-1 module utilizes a subset of BrainStem entity implementations that are specific to the hardware's capabilities. Table 5: MTM-Load-1 Hardware and Software Default Values details the BrainStem API entities and macros used to interface to the MTM-Load-1 module. For C and C++ developers, these macros are defined in `aMTMLoad1.h` from the BrainStem development package. For Python development, the module `MTM-Load-1` class defines the extent of each entity array.

While the BrainStem API entities define the full potential functionality of a given interface, not all features are supported by the MTM-Load-1 module. Table 5: MTM-Load-1 Hardware and Software Default Values defines each of the options implemented with each entity, which varies by entity index. Calling an unsupported entity option will return an appropriate error (e.g.: `aErrInvalidEntity`, `aErrInvalidOption`, `aErrMode`, or `aErrUnimplemented`) as defined in `aError.h` for C and C++ and the `Result` class in Python.

Parameter	Index	Macro Name or Implemented Options	Notes
Module Definitions:			
Module Base Address	14	aMTMLOAD1_MODULE _ADDRESS	See aMTMLoad1.h
Entity Class Definitions:			
`rail` Entity Quantity	1	aMTMLOAD1_NUM_RAILS	
`Temperature` Entity Quantity	1	aMTMLOAD1_NUM_TEMPERATURES	
`digital` Entity Quantity	4	aMTMLOAD1_NUM_DIGITALS	
`i2c` Entity Quantity	1	aMTMLOAD1_NUM_I2C	
`Store` Entity Quantity	2	aMTMLOAD1_NUM_STORES	
`system` Entity Quantity	1		
`timer` Entity Quantity	8	aMTMLOAD1_NUM_TIMERS	

Table 5: MTM-Load-1 Hardware and Software Default Values[3]

[3] Refer to `aMTMLoad1.h` within the BrainStem Development Kit download for actual file.

Capabilities and Interfaces

The MTM-Load-1 module software is built on Acroname's BrainStem technology. The module adheres to the BrainStem protocol on I²C and uses BrainStem software APIs. For the most part, functionality that is unique to the MTM-Load-1 is described in the following sections; refer to Table 6: Supported MTM-Load-1 BrainStem Entity API Methods for a complete list of all available API functionality. All shortened code snippets are loosely based on the C++ method calls – Python and Reflex are virtually the same. Please consult the BrainStem Reference for implementation details[4].

System Entities

Every BrainStem module includes a single System Entity. The System Entity allows access to configuration settings such as the module address, input voltage, control over the user LED and many more.

Saving Entity Settings

Some entities can be configured and saved to non-volatile memory. This allows a user to modify the startup and operational behavior for the MTM-Load-1 away from the factory default settings. Saving system settings preserves the settings to become the new default. Most changes to system settings require a save and reboot before taking effect. Use the following command to save changes to system settings before reboot:

```
stem.system.save()
```

Saved Configurations	
Software Offset	I2C Rate
Router Address	I2C Pullup State
Heartbeat Rate	Boot Slot

Store Entities

Every BrainStem module includes several Store entities and on-board memory slots to load Reflex files (for details on Reflex, see BrainStem Reference online http://acroname.com/entities/index.html). One Reflex file can be stored per slot. Store[0] refers to the internal memory, with 12 available slots, and store[1] refers to RAM, with 1 available slot.

Rail Entities

Rail 0 on the MTM-Load-1 module is powerful (no pun intended); it allows other devices and peripherals to provide power to the MTM-Load-1 module where it is precisely loaded. The rail is a software-adjustable constant voltage, constant current, constant power, or constant resistance rail. This rail is accessed through a BrainStem rail class entity. The MTM-Load-1 module implements a subset of the BrainStem rail class for the load rail. Table 6: Supported MTM-Load-1 BrainStem Entity API Methods summarizes the implemented rail entity options.

The rail can be switched on or off using the `setEnableExternal` and `setDisableExternal` API.

RAIL0 Current Limit Setting

The current limit for the rail can be configured in software from 0A to 12A, the rail will compromise the voltage, power, or resistance regulation to maintain the max specified current. Setting values outside the allowable range will return an error (`aErrRange 13`). If the wrong operating mode is configured (Example: Attempting to setCurrent while in ConstantVoltage mode) an error will be returned (`aErrConfiguration 17`).

```
stem.rail[0].setCurrentLimit(microamps)
```

RAIL0 Current Setting

The current setpoint for the rail can be configured in software from 0A to 10A. Setting values outside the allowable range will return an error (`aErrRange 13`). The rail will attempt to maintain the specified current through all input voltage variations once the rail is enabled with the operational mode set to constant current.

```
stem.rail[0].setCurrent(microamps)
```

RAIL0 Voltage Limit Setting (Min/Max)

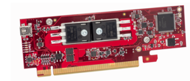
The voltage limits for the rail can be configured in software from -0.7V to 35V. The rail will operate normally between the minimum and maximum voltage limits. If the upper or lower limit is crossed, the load will automatically disable the rail and set the corresponding over/under voltage fault bit in the Operational State variable. Setting values outside the allowable range will return an error (`aErrRange 13`).

```
stem.rail[0].setVoltageMinLimit(microvolts
)
stem.rail[0].setVoltageMaxLimit(microvolts
)
```

The voltage minimum limit can be conveniently used for battery discharging to prevent the load from over drawing the battery.

RAIL0 Voltage Setting

The voltage regulation setpoint is adjustable through the API across the operating range. Setting values outside the allowable range will return an error (`aErrRange 13`). If the



wrong operating mode is configured (Example: Attempting to setCurrent while in ConstantVoltage mode) an error will be returned (`aErrConfiguration 17`).

```
stem.rail[0].setVoltage(microvolts)
```

RAIL0 Power Limit Setting

The power limit for the rail can be configured in software from 0W to 150W. The rail will operate normally below this limit. If the limit is crossed, the load will automatically disable the rail and set the corresponding over power fault bit in the Operational State variable. Setting values outside the allowable range will return an error (`aErrRange 13`).

```
stem.rail[0].setPowerLimit(milliwatts)
```

RAIL0 Power Setting

The power regulation setpoint is adjustable through the API across the operating range. Setting values outside the allowable range will return an error (`aErrRange 13`). If the wrong operating mode is configured (Example: Attempting to setCurrent while in ConstantVoltage mode) an error will be returned (`aErrConfiguration 17`).

```
stem.rail[0].setPower(milliwatts)
```

RAIL0 Resistance Setting

The resistance regulation setpoint is adjustable through the API across the operating range. Setting values outside the allowable range will return an error (`aErrRange 13`). If the wrong operating mode is configured (Example: Attempting to setCurrent while in ConstantVoltage mode) an error will be returned (`aErrConfiguration 17`).

```
stem.rail[0].setResistance(milliohms)
```

RAIL0 Operational Mode

The rail operational mode is a bit field combination of the hardware configuration and the operational mode.

Bits	Descriptions
0:3	Hardware Configuration
4:7	Operational Mode

The rail is a set of semiconductors being held in their linear region, which means the power path of the rail cannot be reconfigured and is fixed to the linear state (auto is also accepted). Attempting to configure the rail into another hardware state will result in an error (`aErrConfiguration 17`).

Mode	RAIL Hardware Configuration Description
0	Auto (railOperationalModeAuto)
1	Linear (railOperationalModeLinear)

The rail has four different operational modes.

Mode	RAIL Operational Modes Description
0	Constant Current (railOperationalModeConstantCurrent)
1	Constant Voltage (railOperationalModeConstantVoltage)
2	Constant Power (railOperationalModeConstantPower)
3	Constant Resistance (railOperationalModeConstantResistance)

Default operational mode is configured as railOperationalModeLinear and railOperationalModeConstantCurrent.

The operational modes can be configured through the API:

```
mode = railOperationalModeLinear |
  railOperationalModeConstantCurrent

stem.rail[0].getOperationalMode(mode)
stem.rail[0].setOperationalMode(mode)
```

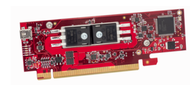
RAIL0 Temperature Limit

The rail also features over-temperature protection. An over-temperature condition occurs when the board temperature crosses the safe operating threshold (85°C). The rail is automatically disabled and cannot be enabled until the temperature goes below the hysteresis set point (85°C - 15°C → 70°C). Clear faults with the clearFaults() method via the software API.

RAIL0 Operational State

The rail operational state will give all the details about the current status of the rail entity.

```
stem.rail[0].getOperationalState(state)
```



The value *state* is a 32-bit value, defined by the following bit fields:

Bits	RAIL Operational State Description
0	Initializing (railOperationalState_Initializing)
1	Enabled (railOperationalState_Enabled)
2	Fault (railOperationalState_Fault)
3-7	Reserved
8-15	Hardware Configuration (railOperationalState_HardwareConfiguration)
16	Over Voltage Fault "OV" (railOperationalStateOverVoltageFault)
17	Under Voltage Fault "UV" (railOperationalStateUnderVoltageFault)
18	Over Current Fault "OC" (railOperationalStateOverCurrentFault)
19	Over Power Fault "OP" (railOperationalStateOverPowerFault)
20	Reverse Polarity Fault "RV" (railOperationalStateReversePolarityFault)
21	Over Temperature Fault "OT" (railOperationalStateOverTemperatureFault)
22-23	Reserved
24-31	Operating Mode (railOperationalStateOperatingMode)

On startup, the Initializing bit will be set. Once the system is ready to load, the bit will be cleared, typical time is less than 1 second.

The Enabled bit represents the actual state of the rail and will be set whenever the rail is active and cleared whenever the rail is inactive.

The Fault bit will be set whenever the rail has experienced a fault condition. Along with the Fault bit, a bit(s) will be set in the Fault bits region of the state variable (bits 16-21). Clear faults with the clearFaults() method via the software API

The Hardware Configuration bit field will represent the current hardware configuration of the rail entity. The MTM-Load-1 will only ever report being in linear mode.

Mode Enum	RAIL Hardware Configuration Description
0	Linear (railOperationalStateLinear)

Fault Bits:

- Over voltage fault: the max voltage limit has been broken.
- Under voltage fault: the min voltage limit has been broken.
- Over current fault: the current limit has been exceeded.
- Over power fault: the power limit has been exceeded.
- Reverse polarity fault: the hardware RVP protection has been triggered due to a reverse voltage detected on the rail pins.
- Over temperature fault: the temperature limit of the rail (85°C) has been exceeded.

The Operating Mode bit field will reflect the current operational mode: constant current, constant voltage, constant power, or constant resistance.

Mode Enum	RAIL Operational Modes Description
0	Constant Current (railOperationalStateConstantCurrent)
1	Constant Voltage (railOperationalStateConstantVoltage)
2	Constant Power (railOperationalStateConstantPower)
3	Constant Resistance (railOperationalStateConstantResistance)

RAIL0 Temperature

RAIL0's subsystem power stage temperature can be monitored above the load circuitry. Reading this value is possible through the API.

```
stem.rail[0].getTemperature(temperature)
```

Temperature monitoring is also used internally to prevent the power regulation stage from over-heating and preserving the power stage. If an over-temperature condition occurs, the MTM-Load-1 module will disable load circuitry and disconnect the rail until the user cycles the rail enable.

RAIL0 Kelvin Sensing

Remote sensing can be applied to compensate for line loss in a system often found in high transient load applications. The MTM-Load-1 provides a "4-wire" interface to provide accurate voltage measurement to the MTM-Load-1 to adjust appropriately and dynamically. The kelvin connections are always enabled, if connected externally the wire drop will be compensated for and there will be full voltage precision. If NOT connected externally, there is 100 ohm connections to the rail on the board which will provide local voltage measurements with a slight loss of precision.

Digital Entities

The MTM-Load-1 has four (4) digital input/outputs (DIO) controlled by the digital entity. Each DIO is controllable via software and is independently current limited for both source and sink currents.

All DIO are input and output capable.

```
stem.digital[0].setConfiguration(mode)
stem.digital[0].getConfiguration(mode)
```

The *mode* parameter is an integer that correlates to the following:

- 0 (digitalConfigurationInput)
- 1 (digitalConfigurationOutput)
- 4 (digitalConfigurationHiZ)

If a digital pin is configured as output mode, setting the digital logic level:

```
stem.digital[0].setState(level)
```

If a digital pin is configured as input mode, reading the digital logic level:

```
stem.digital[0].getState(level)
```

If a digital pin is configured in HighZ mode its internal circuitry has been disconnected to create a high impedance. There are no functions that can act on this configuration.

Digital	Input	Output	HighZ	RCServo
DIO0	Yes	Yes	Yes	None
DIO1	Yes	Yes	Yes	None
DIO2	Yes	Yes	Yes	None
DIO3	Yes	Yes	Yes	None

I²C Entities

The MTM-Load-1 includes access to a single I²C bus operating at a set 1Mbit/s rate.

NOTE: The 1Mbit/s bus, while user-accessible, is also used for primary BrainStem communication so there may be other, non-user-initiated traffic as well, particularly with linked BrainStem units.

The maximum data size for individual `read` and `write` operations on an I²C bus through the BrainStem API is 20 bytes. Sending more than 20 bytes of information has to be done as an iterated sequence.

For example, sending 2 bytes (0xBEEF) through the I²C bus to a device with an address 0x42 would be written:

```
stem.i2c.write(0x42, 2, 0xBEEF)
```

Reading 2 bytes of data from a device with an address 0x42 would be written:

```
stem.i2c.read(0x42, 2, buffer)
```

Where *buffer* would be a char array in C++.

Each I²C bus also includes, as a convenience, software-controllable 330Ω pull-up resistors on the SDA and SCL lines, disabled by default. When using the MTM-Load-1 in a linked system (communicating over the 1Mbit/s bus), only a single set of pull-ups along the bus should be enabled in order for the I²C bus to work properly (if more than one set is enabled, the lines cannot be pulled low for communication). Similarly, when using a single MTM device to communicate with an external device over the I²C bus, either the internal pull-ups can be enabled, or external hardware pull-ups added.

```
stem.i2c.setPullUp(bEnable)
```

The `bEnable` parameter is an integer that correlates to the following:

- 0 (I²C pull-ups off)
- 1 (I²C pull-ups on)

Temperature Entities

The MTM-Load-1 has on board temperature sensor located by the load circuitry to keep track of the temperature of the board and load circuitry. The temperature value can be read using the following function:

```
stem.temperature.getTemperature(temp)
```

MTM-Load-1 Supported Entity Methods Summary

Detailed entity class descriptions can be found in the BrainStem Reference (http://acroname.com/entities/index.html). A summary of MTM-Load-1 class options are shown below. Note that when using Entity classes with a single index (aka, 0), the index parameter can be dropped. For example:

```
stem.system[0].setLED(1) → stem.system.setLED(1)
```

Entity Class	Entity Option	Variable(s) Notes
digital[0-3]	setConfiguration	
	getConfiguration	
	setState	
	getState	
i2c[0]	write	
	read	
	setPullup	Disabled by default. I2C communication requires a single set of pull-ups enabled across the bus.
rail[0]	setCurrent	
	getCurrent	
	getCurrentSetpoint	
	setCurrentLimit	
	getCurrentLimit	
	getTemperature	
	setEnable	
	getEnable	
	setVoltage	
	getVoltage	
	getVoltageSetpoint	
	setVoltageMinLimit	
	getVoltageMinLimit	
	setVoltageMaxLimit	
	getVoltageMaxLimit	
	setPower	
	getPower	
	getPowerSetpoint	
	setPowerLimit	
	getPowerLimit	
	setResistance	
	getResistance	
	getResistanceSetpoint	

	setOperationalMode	
	getOperationalMode	
	getOperationalState	
	clearFaults	
store[0-1]	getSlotState	
	loadSlot	
	unloadSlot	
	slotEnable	
	slotDisable	
	slotCapacity	
	slotSize	
system[0]	Reset	
	save	
	setLED	
	getLED	
	setBootSlot	
	getBootSlot	
	getInputVoltage	
	getVersion	
	getModuleBaseAddress	
	getModuleSoftwareOffset	
	setModuleSoftwareOffset	
	setHBInterval	
	getHBInterval	
	getRouterAddressSetting	
	getModule	
	getSerialNumber	
	setRouter	
	getRouter	
	getModel	
temperature[0]	getTemperature	
timer[0-8]	getExpiration	
	setExpiration	
	getMode	
	setMode	

Table 6: Supported MTM-Load-1 BrainStem Entity API Methods[4]

[4] See BrainStem software API reference at https://acroname.com/reference/ for further details about all BrainStem API methods and information.

LED Indicators

The MTM-Load-1 board has a number of LED indicators to assist with MTM system development, debugging, and monitoring. These LEDs will be shown in the diagrams below.

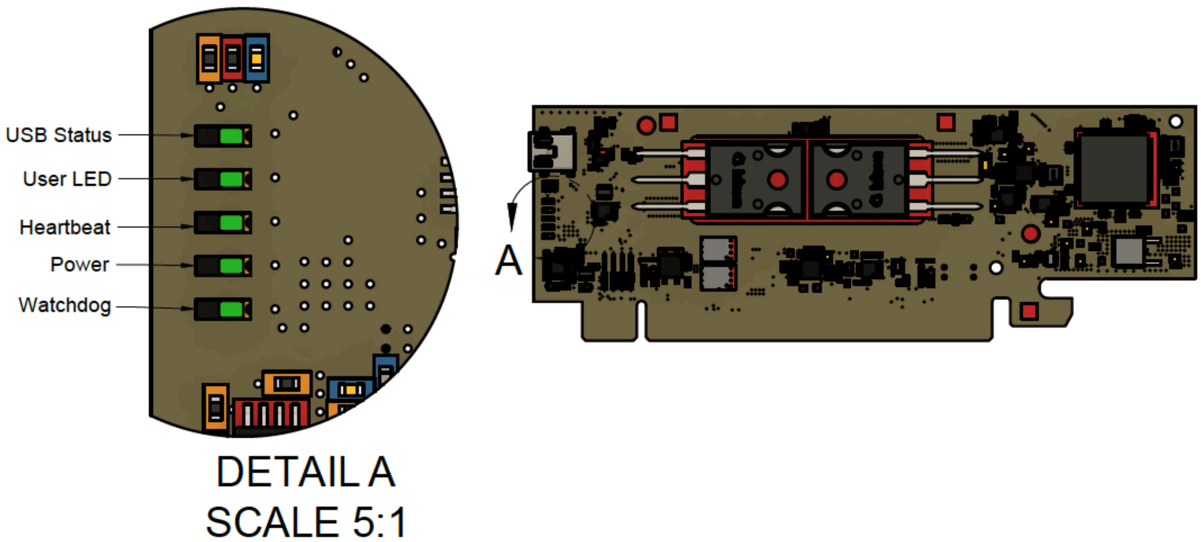


Figure 2: MTM-Load-1 LED Indicators

Application Examples

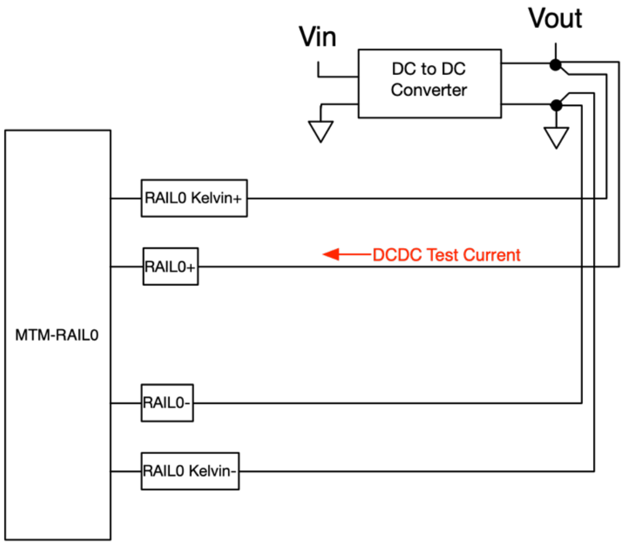


Figure 3 Loading a DC to DC Converter for verifying output-current-ability.

Edge Connector Interface

All MTM products are designed with an edge connector interface that requires a compatible edgeboard connector on the carrier PCB. Acroname recommends the through-hole PCI-Express (PCIe) Vertical Connector. The connectors can be combined with an optional retention clip, as shown below.

MTM Product	Manufacturer	Manufacturer Part Number	Description
MTM-Load-1	Amphenol FCI Samtec	10018784-10203TLF PCIE-164-02-F-D-TH	PCI-Express 164-position vertical connector
MTM-Relay	Amphenol FCI Samtec	10018784-10203TLF PCIE-164-02-F-D-TH	PCI-Express 164-position vertical connector
MTM-DAQ-2	Amphenol FCI Samtec	10018784-10202TLF PCIE-098-02-F-D-TH	PCI-Express 98-position vertical connector
MTM-IO-Serial	Amphenol FCI Samtec	10018784-10202TLF PCIE-098-02-F-D-TH	PCI-Express 98-position vertical connector
MTM-PM-1	Amphenol FCI Samtec	10018784-10201TLF PCIE-064-02-F-D-TH	PCI-Express 64-position vertical connector
MTM-USBStem	Amphenol FCI Samtec	10018784-10201TLF PCIE-064-02-F-D-TH	PCI-Express 64-position vertical connector
MTM-EtherStem	Amphenol FCI Samtec	10018784-10201TLF PCIE-064-02-F-D-TH	PCI-Express 64-position vertical connector
All Models	Amphenol FCI	10042618-003LF	PCI-Express Retention Clip (optional)

Table 7: PCI-Express Edge Connectors for MTM Products

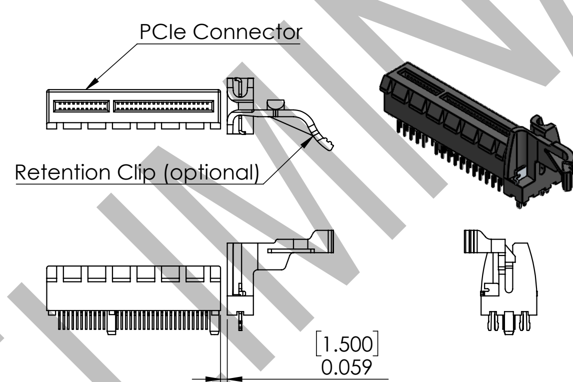


Figure 4: PCIe Vertical Connector with optional Retention Clip

MTM Edge Connector Specifications	Description
Contact Finish	Gold
Card Thickness	0.0625" [1.59mm]
Number of Rows	2
Number of Positions	Variable (see Table 7: PCI-Express Edge Connectors for MTM Products)
Pitch	0.039" (1.00mm)

Table 8: MTM Edge Connector Specifications

Amphenol FCI Drawings and Layout: http://portal.fciconnect.com/Comergent//fci/drawing/10018784.pdf

Amphenol FCI Product Specification: http://portal.fciconnect.com/res/en/pdffiles/Specs/gs-12-233.pdf

Samtec Product Catalog: http://suddendocs.samtec.com/catalog_english/pcie.pdf

Mechanical

Dimensions are shown in inches [mm]. 3D CAD models are available through the MTM-Load-1 product page's Downloads section.

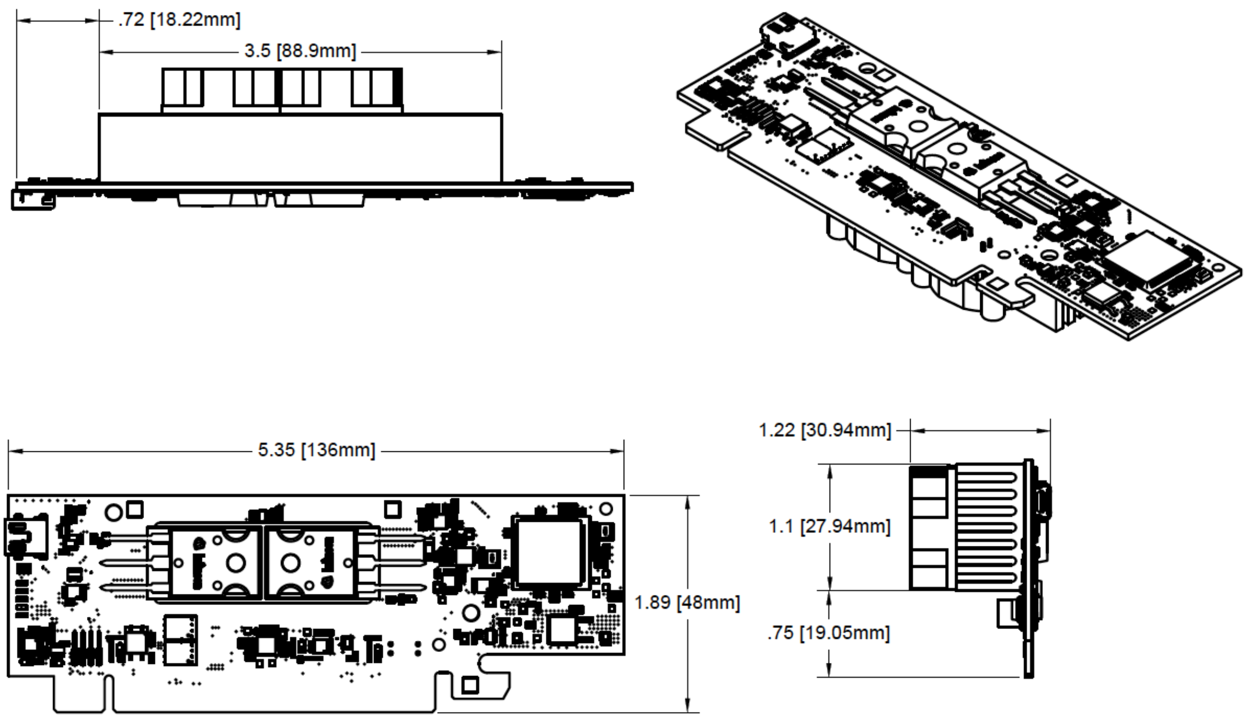


Figure 5: MTM-Load-1 Mechanical

Module Address Hardware Offset Configuration

A hardware offset is one of two ways to modify the devices Module/I2C address. For detailed information on BrainStem networking see the reference guide.

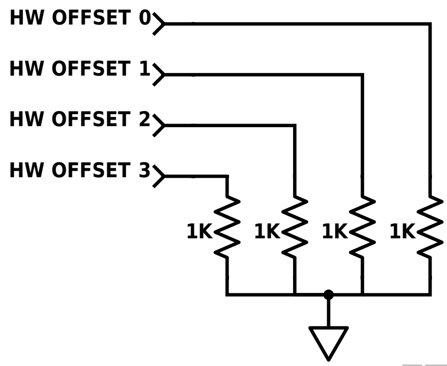


Figure 6: Module Address Hardware Offset

Document Revision History

All major documentation changes will be marked with a dated revision code

Revision	Date	Engineer	Description
1.0	October, 2019	GCF	Initial Release
1.1	Feb 2020	JG	Update product naming