SWITCHERGEAR
GEAR TO CONTROL YOUR POWER SWITCHES

Module MIO001

3/2-channel thermal management
NTC thermistor/Fan control, isolated

REFERENCE MANUAL

Features

Standard module for SwitcherGear

Interface for thermal management

- *Temperature measurement*
- *Control of 24 VDC variable speed DC fans*

3 inputs for temperature sensors

- *10k NTC thermistors*

2 fan control interfaces

- *24 VDC digital outputs for PWM speed control*
- *24 VDC digital inputs for tachometer speed sensor*

All channels isolated

12-way plug-able screw terminal

Suggested C2000 peripherals: EPWM, ECAP, SPI

Applications

Temperature measurement

Control of variable speed DC fans

Thermal management

- *power converter heatsinks*
- *cabinets and enclosures*

General Description

Ordering Information

Order Code	***Description***
MIO001	*SwitcherGear module, 3/2-channel thermal management interface, NTC thermistor/ Fan control, isolated*

Module Quick Start

1. **Set the configurable features.**
   Determine the feature settings that are required for the system under control. If necessary, change the default solder jumper settings. Refer to the Configuration section.

2. **Review the allocation of the MCU interface signals.**
   Confirm that the MCU interface signals connect to appropriate pins on the host MCU. Refer to your SwitcherGear configuration document and Table 3.

3. **Insert into the base slot.**
   Refer to your SwitcherGear configuration document for the location of modules.

4. **Connect the external wiring to the system connector.**
   Refer to Table 1 for the pin-out of the system connector.

Standard Interfaces

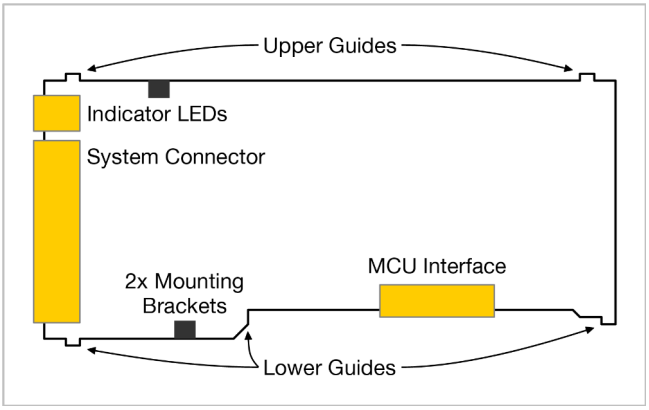

Figure 1: Parts of a SwitcherGear module.

System Connector

A 12-way plug-able terminal strip connector is used to connect external system wiring to the MIO001 module.

Table 1 shows the pin-out of this connector. The connections for each channel are arranged in groups to facilitate wiring to external devices.

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Table 1: System connector

Pin	Signal	Description
1 (Top)	NTC0	Terminal for NTC thermistor channel 0
2	NTC1	Terminal for NTC thermistor channel 1
3	NTC2	Terminal for NTC thermistor channel 2
4	NTCGND	Common ground terminal for NTC thermistor channels 0 to 2
5	VDC0	24 VDC supply input for fan control interface 0
6	TACH0	Tachometer sensor signal input of fan control interface 0
7	PWM0	PWM control signal output of fan control interface 0
8	COM0	COM supply input for fan control interface 0
9	VDC1	24 VDC supply input for fan control interface 1
10	TACH1	Tachometer sensor signal input of fan control interface 1
11	PWM1	PWM control signal output of fan control interface 1
12 (Bottom)	COM1	COM supply input for fan control interface 1

Table 2: Indicator LEDs

Appearance	Left Column		Right Column	
	Colour	Description	Colour	Description
	Green	PWM, fan control interface 0	Green	Tachometer, fan control interface 0
	Green	PWM, fan control interface 1	Green	Tachometer, fan control interface 1
	-	-	-	-
	-	-	-	-

Table 3: MCU interface

Pin	Signal	Description
D0	CSn	Chip select for SPI bus, active-low logic input signal.
D1	SCLK	Clock signal for SPI bus, logic input signal.
D2	SIMO	Slave-in master-out signal for SPI bus, logic input signal.
D3	SOMI	Slave-out master-in signal for SPI bus, logic output signal.
D4	DO0	PWM control signal of fan control interface 0, logic input signal.
D5	DO1	PWM control signal of fan control interface 1, logic input signal.
D6	DI0	Tachometer sensor signal of fan control interface 0, logic output signal.
D7	DI1	Tachometer sensor signal of fan control interface 1, logic output signal.
D8	-	-
D9	-	-
D10	-	-
D11	-	-
A0	-	-
A1	-	-
A2	-	-
A3	-	-

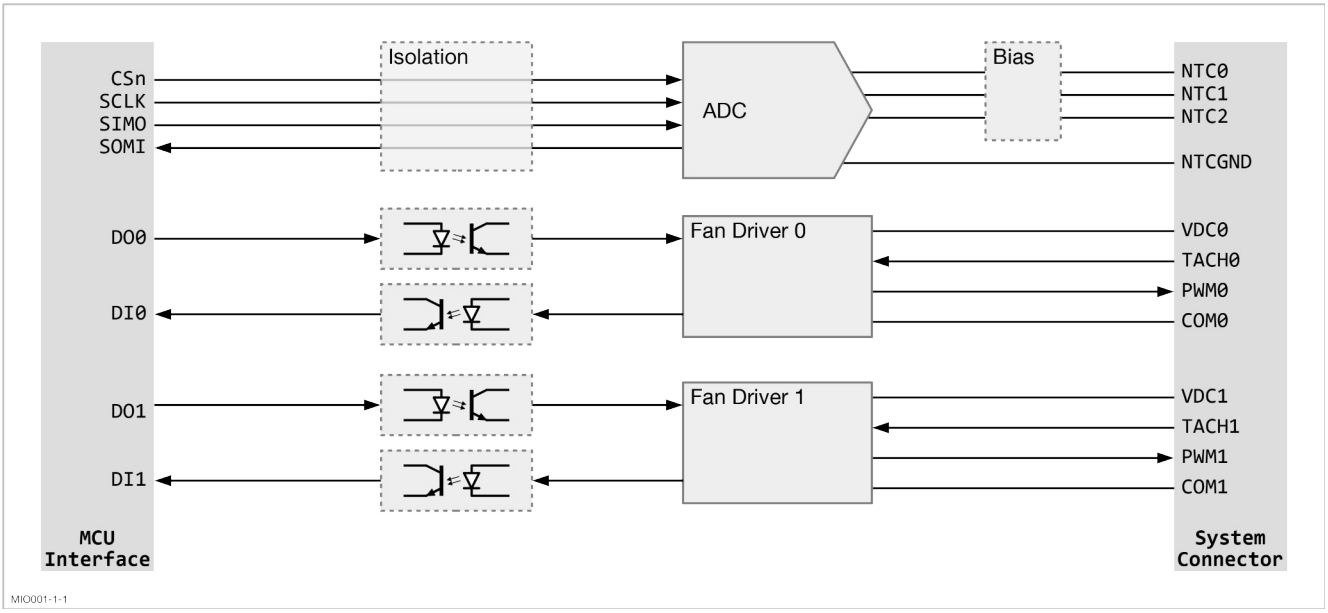

Figure 2: Functional block diagram of the MIO001 module.

The connector can be keyed by inserting coding keys into the slots on the header. (A suitable coding key is Phoenix Contact part number 1734634.) The corresponding moulded key on the plug must be removed to allow insertion into the header.

Indicator LEDs

Four miniature indicator LEDs on the front panel show the status of the module. Refer to Table 2 for details.

For typical speed controlled fans, the brightness of the PWM indicator varies in proportion to the demanded speed.

MCU interface

The MCU interface contains analogue and digital signals that allow interaction between the module and the host MCU. The MCU interface supports up to 12 digital inputs/outputs and up to 4 analogue outputs.

Refer to Table 3 for details of the signals provided by the MCU interface of this module.

The signals in the MCU interface must be routed to appropriate pins of the host MCU. Refer to the SwitcherGear Configuration Document for your specific SwitcherGear unit for information on the routing of signals between the installed modules and the host MCU.

Configuration

The MIO001 module has no user configurable hardware features.

Functional Description

The MIO001 module includes multiple hardware interfaces that enable a SwitcherGear modular controller to perform thermal management. The module allows the measurement of temperature in up to three locations and the speed control of two variable speed DC fans. The module includes the following interfaces to support these functions:

- 3 analogue inputs to measure the resistance of NTC thermistor sensors.
- 2 fan driver interfaces, each comprising one digital output for PWM control of the fan speed and one digital input that accepts the signal from a tachometer sensor to measure the actual fan speed.

Figure 2 shows these hardware interfaces and how they connect to the MCU interface and the System Connector.

The digital output and input channels of the MIO001 module are specified for operation at 24 VDC and should be used with variable speed fans that are operated from a 24 VDC supply.

Temperature Sensor Channels

The temperature sensor channels are used to measure the resistance of a temperature sensor connected between the `NTCx` and `NTCGND` terminals. The internal bias network and the temperature sensor form a voltage divider that is measured by the ADC (analogue-to-digital converter).

The ADC is Texas Instruments ADC124S101. This ADC has a conversion resolution of 12 bits. See the section SwitcherWare Library for information about a software driver for this part. Otherwise, consult the datasheet of this part for details on the SPI protocol.

Each sensor channel includes a filter to remove interference.

Digital Outputs

The digital outputs are intended to drive the PWM control input of a 24 V variable speed fan, but could be used for any other similar purpose.

Figure 3 shows the structure of the digital output and how it connects to an external fan. In addition to the `PWMx` output terminal, the `VDCx` and `COMx` supply terminals must also be connected. The polarity must be observed when connecting to an external circuit. The terminals are protected against reverse polarity and over-current.

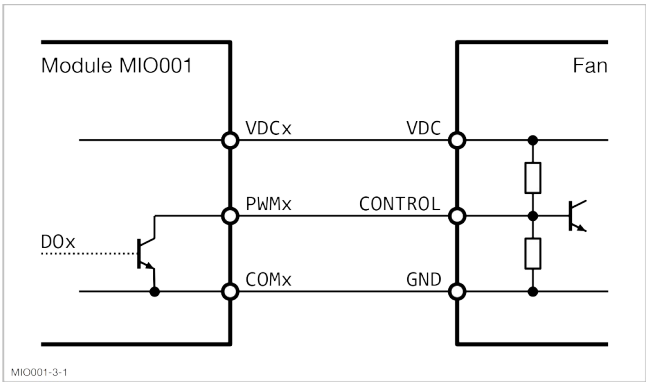

Figure 3: Structure of a digital output channel and connection to the PWM control input of a variable speed fan.

When the logic signal DOx is low, the digital output is OFF and the PWMx output has a high impedance. In this state, no load current can flow and the voltage applied to the terminals by the external circuit must be kept within operating limits.

When the logic signal DOx is high, the digital output is ON and there is a low impedance between the PWMx and COMx terminals. In this state, the output voltage is low and the external circuit must limit the current within operating limits.

For typical speed controlled fans, the fan will run at maximum speed when power is applied to the fan and system connector of the MIO001 module, but the controller power is off. The fan will continue to provide cooling in this condition. The fan may briefly operate at full speed when the controller is turned on and before the speed control updated.

Digital Inputs

The digital inputs are intended to receive the tachometer sensor output of a 24 V variable speed fan, but could be used for any other similar purpose. The digital inputs meet the switching requirements of an IEC 61131-2 Type 3 switch.

Figure 4 shows the structure of the digital input and how it connects to an external fan. In addition to the TACHx input terminal, the VDCx supply terminal must also be connected. The polarity must be observed when connecting to an external circuit. The input is protected against reverse polarity.

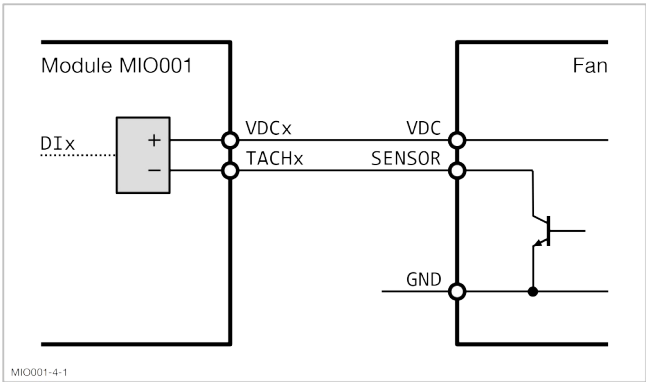

Figure 4: Structure of a digital input channel and connection to the tachometer sensor output of a variable speed fan.

The logic state of the digital input is determined by the voltage difference between the VDCx and TACHx terminals. The transfer characteristic of the digital input is shown in Figure 5. The logic threshold includes hysteresis to reduce the effects of noise.

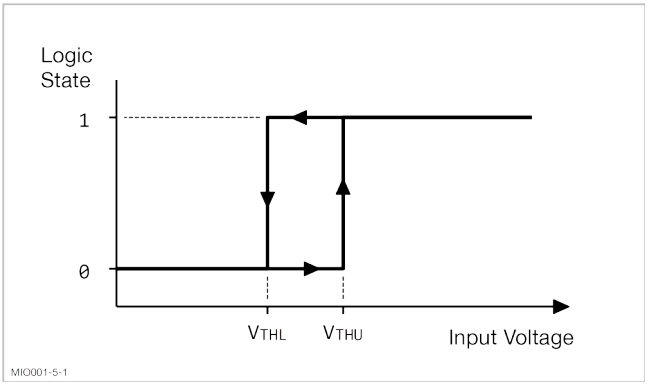

Figure 5: Transfer characteristic of tachometer digital input.

When the external driving circuit is in a high impedance state, the voltage at the sensor output is VDC and the voltage *between* the digital input terminals is low.

When the external driving circuit is in a low impedance state, the voltage at the sensor output is GND and the voltage *between* the digital input terminals is high. In this state, the voltage at the terminals must be within the operating limits.

The digital input includes a current limiting circuit, which means that a separate current limiting resistor is not required to limit the current when the external driver is on.

Isolation

All external interfaces are galvanically isolated from the controller side circuitry to prevent circulating currents in the external wiring and reduce electromagnetic interference (EMI). The isolated circuits are intended to be connected only to extra low voltage field circuits.

> **WARNING!**
> The isolated circuits of the system connector interfaces must not be connected to any circuit that is connected to a mains supply or a supply above extra low voltage.

The fan control interfaces are individually isolated from the controller and each other. The NTC thermistor channels are group isolated – they are connected to each other, but isolated from the controller and the fan control interfaces. Figure 2 shows this isolation arrangement.

Applications Information

The MIO001 module enables temperature management of heatsinks, cabinets and enclosures. It provides the ability to measure temperature in three locations, to control the speed of two fans and to measure the actual speeds of the fans.

User software should coordinate these features to implement an overall thermal management system. For example, a simple control could use a look-up table to set the fan speed according to the measured temperature. A feedback control could also be used. More sophisticated schemes are possible, for example using the estimated losses in the power converter as a control input.

The actual fan speed can be used as a simple monitoring tool to ensure that the fan has not failed.

Fan speed can be sensitive to back-pressure in the air flow and causes the fan to run much slower than the speed set by the PWM

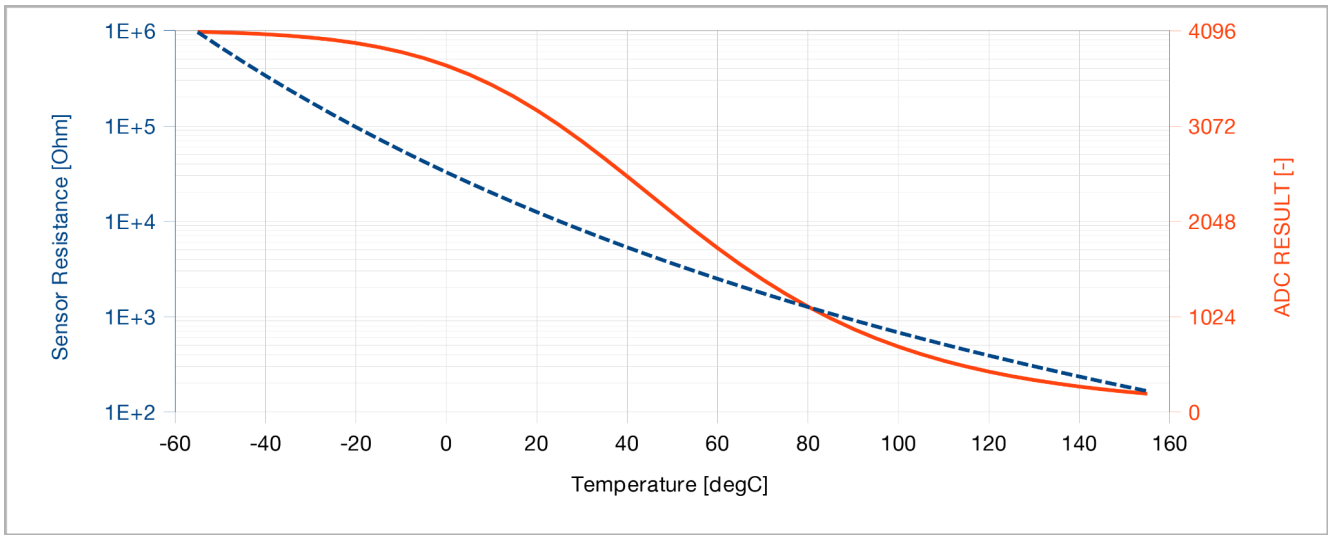

Figure 6: Variation with temperature of the resistance of TDK B57703M0103A NTC thermistor probe and the ADC conversion result of the MIO001 module. Note that the left side scale is logarithmic and the right side scale is linear.

control signal. This can be corrected by using the measured fan speed used as a feedback quantity for a controller that regulates the speed of the fan to a reference speed.

A large difference between the speed demanded by the PWM control signal and the speed measured by the tachometer sensor could indicate a problem with the fan or a blockage in the air-flow, e.g. a filter has become clogged with dust.

Temperature Measurement

The temperature sensor inputs include a bias resistor that is suited to NTC thermistor sensors with a room temperature resistance of 10 kΩ.

The NTC thermistor is connected between a `NTCx` channel input and the common `NTCGND` terminal, as shown in Figure 7. To reduce electrical interference, the two wires of the thermistor should be twisted along their entire length.

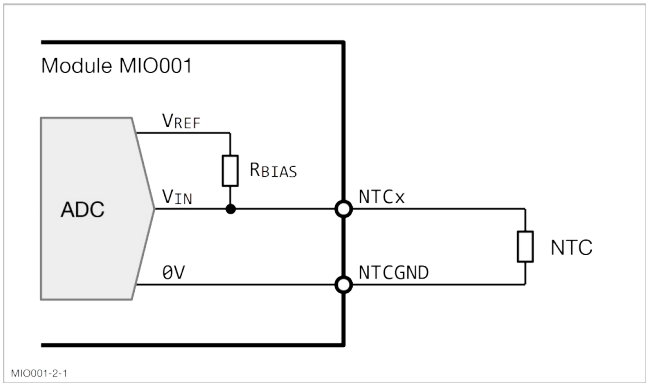

Figure 7: Connection of an external NTC thermistor.

The conversion result of the ADC is given by

$$\text{RESULT} = 4096 \left[\frac{R_{NTC}}{R_{NTC} + R_{BIAS}} \right]$$

where 4096 is the number of discrete levels that the 12-bit ADC is able to resolve. The resistance of the NTC thermistor can be calculated using

$$R_{NTC} = R_{BIAS} \left[\frac{\text{RESULT}}{4096 - \text{RESULT}} \right]$$

which is independent of the reference voltage, V_{REF}.

Once the resistance is known, the corresponding temperature can be determined using a table of temperature-resistance data or an equation for the sensor. Consult the datasheet or application notes of the NTC thermistor.

The resistance of the wiring adds to the resistance of the NTC thermistor and gives rise to a small error in temperature. Standard wiring is not normally a problem, but care should be taken to ensure that the overall requirements for temperature measurement accuracy are not affected.

Figure 6 shows the behaviour of a typical NTC thermistor sensor. The sensor resistance drops sharply as temperature increases. The conversion result of the ADC has an S-shaped curve with temperature. The best temperature measurement accuracy is in the steeper regions of the curve, between about -10 degC and 120 degC in this example.

Variable Speed Fan

The MIO001 module can be used with most 24 VDC variable speed fans. The fan's PWM control input must be compatible with an open-collector output. The fan's tachometer sensor output can be an open-collector or push-pull type.

The MIO001 module can be used with fans that have only PWM control, only a tachometer sensor, or both PWM control and tachometer sensor.

Figure 8 shows the recommended connection of a variable speed fan to the MIO001 module. The power supply should be connected directly to the fan, so that only control signals and no power flows in the control wiring.

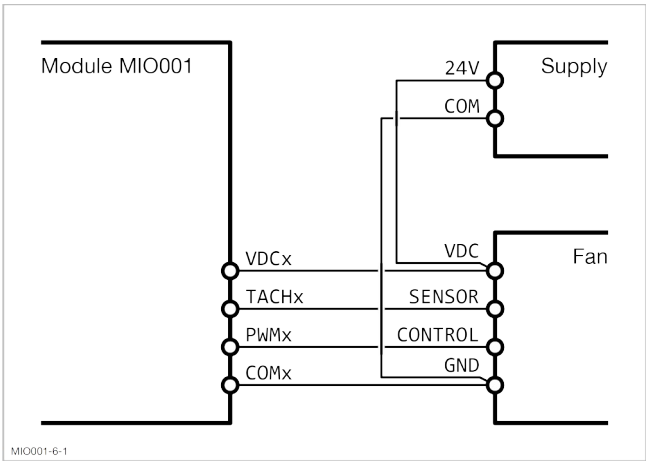

Figure 8: Connection of a DC variable speed fan and power supply.

To reduce electrical interference, the wires should be twisted together along their entire length.

External Wiring

The pluggable terminal strip can accept bare conductors with cross sectional area in the range 0.15 mm^2 to 1.5 mm^2. The acceptable range for conductors terminated with bootlace ferrules is 0.25 mm^2 to 0.5 mm^2.

Host MCU

Texas Instruments C2000

When using a C2000 microcontroller, the serial interface signals of the module should be connected to either a SPI peripheral or a multi-channel buffered serial port (McBSP, which has a SPI mode). The CSn signal can be driven by either a strobe pin under the control of the SPI resource, or a GPIO pin under user control. This allocation is summarised in Table 4.

Table 4: C2000 pins allocation for serial interface

MCU Interface Signal	**C2000 Pin Allocation**	
	SPI Perpheral	**McBSP Peripheral**
SCLK	SCLK	CLKX
SIMO	SIMO	DX
SOMI	SOMI	DR
CSn **(peripheral control)**	$\overline{\text{SPISTE}}$	FSX
CSn **(user control)**	GPIO	GPIO

The digital output signals should be connected to the two PWM outputs of a single EPWM peripheral. For example, the two outputs of peripheral EPWM7 are EPWM7A and EPWM7B. The EPWM peripheral should be configured to generate two independent PWM signals for control of fan speed.

Alternatively, ECAP modules have a PWM output mode that can be used to generate the PWM control signal. The digital output signals of the MCU interface must be connected to a GPIO pin with an OUTPUTXBAR signal in the GPIO multiplexer. The GPIO pin can then be mapped to the output of the ECAP peripheral. The mapping is performed using the OUTPUTXBAR of the C2000 MCU.

The digital input signals can be connected to any GPIO pins. Each pin can then be mapped to the input of an ECAP peripheral. The mapping is performed using the INPUTXBAR of the C2000 MCU.

The ECAP peripheral should be configured to measure the period of the fan's tachometer speed signal.

SwitcherWare Library

The SwitcherWare Library from Denkinetic includes code resources to handle the low-level hardware configuration and provide a simple-to-use interface for the MIO001 module. See the SwitcherWare documentation for the class `ModuleMIO001` for more information. The SwitcherWare library also includes examples for using the MIO001 module and many others.

Warnings

⚠	WARNING! The length of cables connected to the module front panel connector must not be longer than 3 m.
⚠	WARNING! The user is responsible to ensure that the cables and connectors used for external wiring have insulation and/or separation distances that provide isolation from live parts and from earth.
⚠	WARNING! The user is responsible to ensure that cables and connectors used for external wiring that carry live voltages have insulation and/or separation distances that provide protection against indirect contact.
⚠	WARNING! The user is responsible to ensure that the installation provides protection against direct contact.

Absolute Maximum Ratings

Stresses above these ratings may cause permanent damage. These are stress ratings only – functional operation is not implied. Exposure to absolute maximum conditions for extended periods may affect reliability.

Parameter	Conditions		Max	Unit
Fan Driver Voltage			±32	V
Fan Driver Input and Output Current			20	mA

Electrical Characteristics

The following specifications apply for V_{DC} = 24 V, T_A = 25 °C, unless otherwise noted.

Parameter	Conditions	Min	Typ	Max	Unit
NTC THERMISTOR MEASUREMENT					
Reference Voltage, V_{REF}			3.3		V
Input Voltage Range		0		V_{REF}	V
Bias Resistance, R_{BIAS}			3300		Ω
Bias Resistance Error		-1		1	%
ADC SCLK Frequency				16	MHz
ADC Conversion Error		-0.1		0.1	%
Effective Number Of Bits, ENOB		11.2	11.7		Bits
FAN DRIVER SUPPLY					
Applied Voltage (VDCx - COMx)		0	24	30	V
PWM DIGITAL OUTPUT					
Output Voltage (PWMx - COMx)	Off state	0		30	V
On-State Voltage Drop	Load current = 10 mA			0.8	V
Load Current		0		20	mA
Propagation Delay, Turn-On			2	5	µs
Propagation Delay, Turn-Off			15	20	µs
TACHOMETER DIGITAL INPUT					
Input Voltage (VDCx - TACHx)		0		30	V
Threshold Voltage, Upper, V_{THU}				10	V
Threshold Voltage, Lower, V_{THL}		7			V
Hysteresis Voltage (V_{THU} - V_{THL})			1		V
Current Limit	Input voltage > V_{THU}		2.4		mA
Propagation Delay, Turn-On			5	10	µs
Propagation Delay, Turn-Off			30	50	µs

Revision History

Revision	Date	Changes From Previous Release
1	7 Dec 2021	▪ Original release.