SWITCHERGEAR
GEAR TO CONTROL YOUR POWER SWITCHES

Module AIN004

4-channel analogue input
Sensor current 20 to 200 mA

REFERENCE MANUAL

Features

Standard module for SwitcherGear

Current input channels for sensors

Individually configurable channels

- *12 current input ranges from 20 mA to 200 mA*
- *Bipolar or unipolar mode*

Analogue output for connection to ADC of host MCU

Gain accuracy 1%

±12 V power supply output for external sensors

- *Short-circuit and over-current protected*

12-way pluggable screw terminal

Applications

Power system measurements with current output sensors such as:

- *Closed-loop hall-effect sensors*
- *SwitcherGear SNI001 current sensor*
- *SwitcherGear SNV005 voltage sensor*
- *4 to 20 mA loop transmitters*

General Description

The AIN004 module is a current input module with configurable current input range and polarity mode for each channel. The current input is converted to a voltage output in the range 0 to 3 V, which is routed to the ADC of the host MCU.

The AIN004 module is ideal for use with current output sensors to measure current and voltage in power converter systems. It provides ±12 V supply outputs to power the external sensors. The pin-out of the system connector makes the wiring of external sensors very easy.

Ordering Information

Order Code	***Description***
`AIN004`	*SwitcherGear module, 4-channel analogue input, sensor current 20 to 200 mA.*
`SNI001`	*SwitcherGear accessory, ±70 A current sensor for power converters.*
`SNV005`	*SwitcherGear accessory, ±1000 V voltage sensor for 1200 V IGBT power converters.*

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

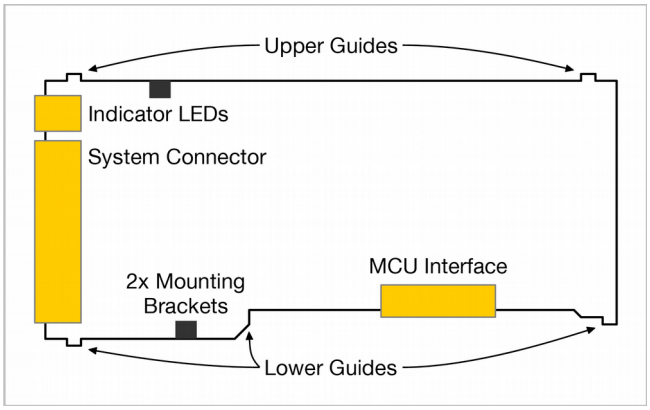

Figure 1: Parts of a SwitcherGear module.

System Connector

A 12-way pluggable terminal strip connector is used to connect external sensor wiring to the AIN004 module.

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

The AIN004 module uses the polarity convention where current flowing into the analogue current input pins is positive current.

The connector can be keyed by inserting the supplied red coding keys into the slots on the header. The corresponding moulded key on the plug must be removed to allow insertion into the header.

Indicator LEDs

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

Table 1: System connector

Pin	Signal	Description
1 (Top)	+12V	+12 V supply output.
2	II0	Analogue current input for channel 0.
3	−12V	−12 V supply output.
4	+12V	+12 V supply output.
5	II1	Analogue current input for channel 1.
6	−12V	−12 V supply output.
7	+12V	+12 V supply output.
8	II2	Analogue current input for channel 2.
9	−12V	−12 V supply output.
10	+12V	+12 V supply output.
11	II3	Analogue current input for channel 3.
12 (Bottom)	−12V	−12 V supply output.

Table 2: Indicator LEDs

Appearance	Left Column		Right Column	
	Colour	Description	Colour	Description
● ○	Green	+12 V supply for output drivers	-	-
● ○	Green	−12 V supply for output drivers	-	-
○ ○	-	-	-	-
○ ○	-	-	-	-

Table 3: MCU interface

Pin	Signal	Description
D0	-	-
D1	-	-
D2	-	-
D3	-	-
D4	-	-
D5	-	-
D6	-	-
D7	-	-
D8	-	-
D9	-	-
D10	-	-
D11	-	-
A0	VOUT0	Analogue voltage output for channel 0.
A1	VOUT1	Analogue voltage output for channel 1.
A2	VOUT2	Analogue voltage output for channel 2.
A3	VOUT3	Analogue voltage output for channel 3.

MCU Interface

The MCU interface connects analogue and digital signals between the modules and the host MCU.

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

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

Current Range

The current input range of each channel can be set using solder jumpers according to Table 4.

Table 4: Configuration of current range

Current Range	Range Jumpers			
	100	50	30	20
Not Used (default)	Open	Open	Open	Open
20 mA	Open	Open	Open	Short
30.06 mA	Open	Open	Short	Open
50 mA	Open	Short	Open	Open
70 mA	Open	Short	Open	Short
80.06 mA	Open	Short	Short	Open
100 mA	Short	Open	Open	Open
120 mA	Short	Open	Open	Short
130.06 mA	Short	Open	Short	Open
150 mA	Short	Short	Open	Open
170 mA	Short	Short	Open	Short
180.06 mA	Short	Short	Short	Open
200 mA	Short	Short	Short	Short

Note that the contribution of the 30 mA jumper to the current input range is actually 30.06 mA. Scaling of the sampled signal should take this 0.2% deviation into account if such accuracy is required in the application.

Polarity Mode

The polarity mode of each channel can be set to bipolar or unipolar mode using solder jumpers according to Table 5.

Table 5: Configuration of polarity mode

Polarity mode	Jumpers	
	MxA	MxB
Unipolar (default)	Open	Open
Bipolar	Short	Short

In unipolar mode, an input current of zero is mapped to an output voltage of 0 V. A positive input current with magnitude equal to the channel's current range is mapped to an output voltage of 3 V.

In bipolar mode, a negative input current with magnitude equal to the channel's current range is mapped to an output voltage of 0 V. An input current of zero is mapped to an output of 1.5 V. A positive input current with magnitude equal to the channel's current range is mapped to an output voltage of 3 V.

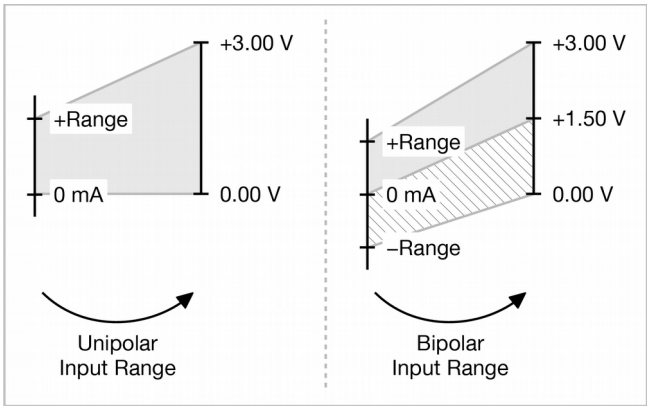

Figure 2: The effect of polarity mode on the mapping from input current range to output voltage range.

Solder Jumpers

Modules are supplied with all solder jumpers in the open state. These default feature settings are highlighted in grey in the configuration tables.

If a different configuration is required for your application, you must change the solder jumper settings before using the SwitcherGear.

Solder jumpers allow configuration of SwitcherGear modules. They function like a switch to control the features of the module. Jumpers consist of two adjacent pads on the rear side of the module circuit board. The jumper can be shorted (switch closed) by making a solder bridge across the pads. The jumper can be opened (switch open) by removing the solder bridge.

The solder jumpers are intended for one-time-only configuration. No warranty is provided for damage to solder jumpers. Only skilled personnel who are trained in correct soldering technique should undertake the configuration of the solder jumpers. Incorrect technique or excessive temperature can result in the pads of the solder jumper detaching from the circuit board, rendering the jumper permanently open-circuit.

Observe the following precautions when configuring solder jumpers:

- Anti-static handling procedures.
- Turn off power before removing or inserting modules.
- Use a fine-tip soldering iron with adjustable temperature.
- Use only lead free solder and compatible tools.
- Use the minimum temperature required to perform the task.
- Do not heat the jumper for more than 5 seconds. Allow to cool before re-applying heat.
- To remove solder from a jumper, use a narrow (e.g. 1.5 mm), fluxed solder-wicking braid.

Functional Description

Protection

Filtering and protection devices prevent external interference from affecting measurements or damaging the module.

Unused current inputs should be left open circuit – the internal burden resistor will tie the input to ground. Unused current inputs must not be tied to any of the power supply outputs.

Care should be taken when connecting the current inputs to external sources of power. The inputs can be damaged by excessive currents. There is no risk of damage when the current inputs are supplied by the module's own power supplies.

External Power Supply

The AIN004 module provides ±12 V power supplies to allow simple operation of external sensors. Resettable fuses protect the supplies against short-circuit and over-current faults.

Isolation

The current inputs are not galvanically isolated from the SwitcherGear controller. If isolation from the power system is required, external sensors with appropriate insulation characteristics must be used.

Applications Information

Sensors

The AIN004 module can be used with any current output sensor with the correct current range. This includes Hall-effect sensors that are commonly used to measure voltage and current in power converters.

It is also possible to use the AIN004 module with current transmitter sensors. The sensor should be connected between the +12V supply and the IIx current input pins of the system connector. The channel should be configured for 20 mA current range and unipolar mode. Ensure that the sensor can operate from a supply voltage of 10.5 V.

Measurement Resolution

You should configure the input current range to be as narrow as your application allows, because this will give the best measurement resolution from the ADC of the MCU.

Current Range

You should use the smallest current range that meets the sensor measurement requirements. If the exact range isn't available, then use the next highest range.

For example, a DC link voltage sensor produces an output of 20 mA for an input of 1000 V. You should set the AIN004 module input channel to unipolar 20 mA input current range. The output voltage from the AIN004 module will cover the entire conversion range of the ADC. For a 12-bit ADC the integer conversion range is 0 to 4095. The sensor measurement range is split into 4096 conversion counts, so the ADC resolution is 0.24 V of DC link voltage.

If you use the 200 mA input current range, the 20 mA signal covers only one tenth of the ADC conversion range, 0 to 409. The ADC resolution is 2.4 V of DC link voltage.

The use of the wrong current range clearly has a detrimental effect on the quality of the measured DC link voltage signal. The controller will experience higher levels of noise and possibly even stability issues.

Polarity Mode

Bipolar mode is typically used for sensors that measure an AC quantity, e.g. load current of an induction motor, line-line voltage of the AC mains supply, etc.

Unipolar mode is typically used for sensors that measure quantities that are unipolar, e.g. DC link voltage, current from a PV string, etc. Unipolar mode should be used where it is appropriate because it offers twice the resolution and signal-to-noise ratio for ADC sampled signals compared to bipolar mode.

Burden Resistance

The burden resistance, or input resistance, of the AIN004 module depends on the current range jumper settings. It can be calculated as 1.5 V divided by the range setting in mA.

Some sensors have a minimum value of load resistance specified for certain combinations of supply voltage and ambient temperature. The load resistor dissipates power that would otherwise overheat the sensor. The low burden resistance of the AIN004 module may not meet these minimum requirements. In such cases, add resistance in series with the current output of the sensor to make up the total required load resistance. Consult documentation for your chosen sensor for more information.

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 acceptance range for conductors terminated with bootlace ferrules is 0.25 mm^2 to 0.5 mm^2.

It is normally sufficient to use an unscreened cable to connect sensors to the AIN004 module. Best practice dictates that the length of this cable should be minimised. The use of a screened cable can increase noise immunity, though this should not be used as a substitute for a short cable length. If a screened cable is used, the screen should be connected to earth at one end and left unconnected at the other end.

Host MCU

The voltage output signals of the AIN004 module are typically routed to the inputs of the ADC of the host MCU.

For the measurement of currents in PWM voltage-source converters, the sampling instant of the ADC should be synchronised to the PWM carrier. Depending on the type of PWM used, various synchronisation schemes are possible.

Consult documentation for the host MCU for information about how to configure the ADC.

Sensor Signal Chain

The following examples demonstrate the signal chains for various sensor measurements. The signal chain comprises an external sensor, the AIN004 module and the analogue-to-digital converter (ADC) in the host MCU. Each of these components transforms the signal according to its own transfer characteristic.

Example 1

Measurement of sinusoidal AC line currents up to 10 A RMS. This is a common requirement for motor drives and grid converters.

The peak line current is 14.1 A. The measurement range must include the positive and negative peak line current, and should also include a margin to allow for overload. A suitable measurement range is from –20 A to 20 A.

Measure the line current with a LA 55-P current sensor from LEM. This is a closed-loop, hall-effect current sensor with a maximum input current rating of 50 A RMS. The output of the sensor is a current that is proportional to the instantaneous input current. The transfer ratio is 1000:1. So for an input current range of ±20 A, the sensor output current range is ±20 mA. This transformation is shown in the left side of Figure 3.

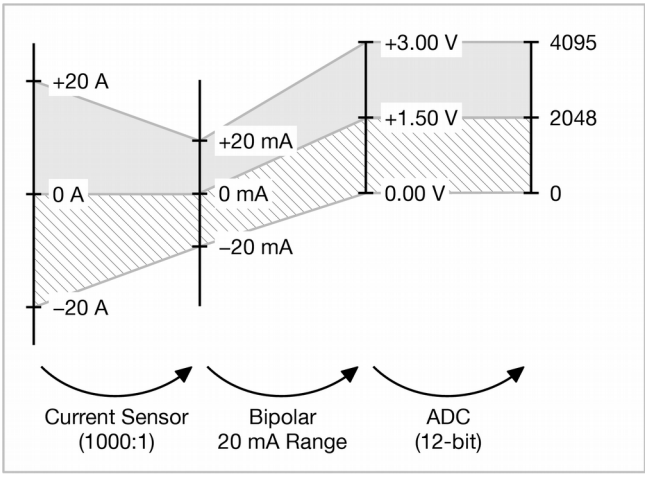

Figure 3: Signal chain for the measurement of AC line current in the range –20 A to 20 A.

The output current of the current sensor is connected to one input channel of the AIN004 module. This channel should be configured for bipolar mode and a current range of 20 mA. The module maps the input current range of –20 mA to 20 mA to an output voltage range of 0.0 V to 3.0 V.

The output voltage of the AIN004 module is routed through the controller Base to one input channel of the ADC in the host MCU. The output of the ADC is an integer that is proportional to the voltage at its input. For the Texas Instruments F28335 controlCARD and Denkinetic MC28377D MCU modules, the ADC has an input range from 0.0 V to 3.0 V and a resolution of 12 bits. A zero-scale input voltage produces an output value of 0 and a full-scale input voltage produces an output value of 4095 (2^12-1).

You can use the signal chain diagram to calculate values at any stage in the chain and for any value in the working range. For example, an ADC value of 1500 corresponds to an ADC input voltage of 1.099 V, a sensor output current of -5.35 mA and a line current of –5.35 A.

The input rating of this current sensor allows it to be used for measurement ranges up to ±70 A. The current range of the AIN004 module channel should be set to achieve the desired overall measurement range.

Note that the active output voltage range of the AIN004 module is always 0.0 V to 3.0 V. The input current range as defined by the jumpers is mapped to this output range.

For the MCUs quoted in this example, the ADC input voltage range is the same as the AIN004 module output voltage range. This is a design choice made for the SwitcherGear controller system that simplifies signal chain analysis. Other MCU ADCs may have slightly different input voltage ranges that do not match exactly the AIN004 module output voltage range. They require a modified signal chain analysis to calculate the corresponding sensor measurement range.

Example 2

Measurement of bi-directional DC currents up to 180 A. This applies in bi-directional DC-DC converters, e.g. buck, boost, buck/boost, etc.

Measure the DC current with a LF 305-S/SP10 current sensor from LEM, which has a maximum input current rating of 300 A RMS and a transfer ratio of 2000:1. The sensor output current range is ±90 mA, as shown in Figure 4.

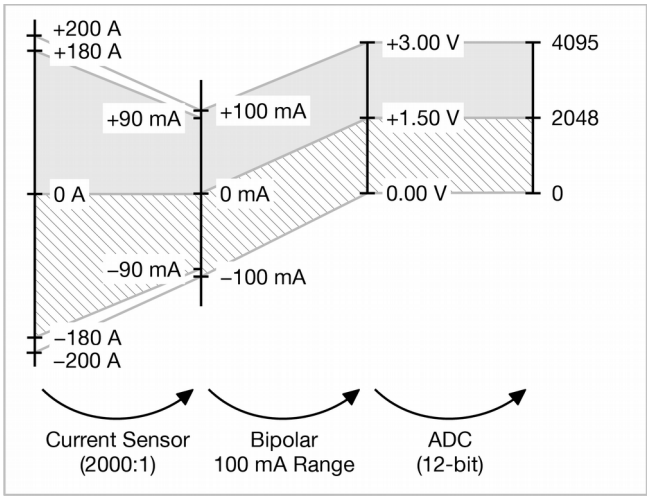

Figure 4: Signal chain for the measurement of DC current in the range –200 A to 200 A.

The AIN004 module input channel should be configured for bipolar mode. Since there is no 90 mA current range, the next highest range is chosen, 100 mA. The module maps the input current range of –100 mA to 100 mA to the same output voltage range of 0.0 V to 3.0 V.

The actual measurement range is now ±200 A rather than the original requirement of ±180 A.

If only a uni-directional current measurement is required, the polarity mode of the AIN004 module channel should be configured to unipolar mode.

Example 3

Measurement of DC link voltage up to 1000 V.

Measure the DC link voltage with the SNV005 voltage sensor from Denkinetic. The output of the sensor is a current that is proportional to the instantaneous input voltage. The transfer ratio is 20 µA/V. So for an input voltage range of 0 to 1000 V, the sensor output current range is 0 to 20 mA. This transformation is shown in the left side of Figure 5.

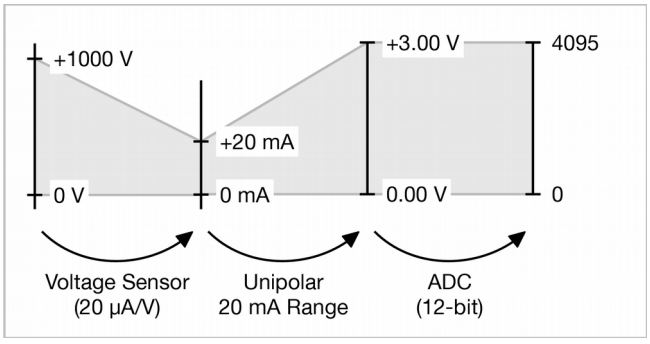

Figure 5: Signal chain for measurement of DC link voltage in the range 0 V to 1000 V.

The output current of the voltage sensor is connected to one input channel of the AIN004 module. This channel should be configured for unipolar mode and a current range of 20 mA. The module maps the input current range of 0 mA to 20 mA to an output voltage range of 0.0 V to 3.0 V.

Example 4

Measurement of AC supply voltage up to 480 V RMS. This is a common requirement for grid converters, where a PLL is used to synchronise the current controller to the AC supply voltage.

Measure the AC line-line or line-neutral voltages with the SNV005 voltage sensor from Denkinetic. The sensor input voltage range is now ±1000 V, which corresponds to an output current range of ±20 mA, as shown in Figure 6.

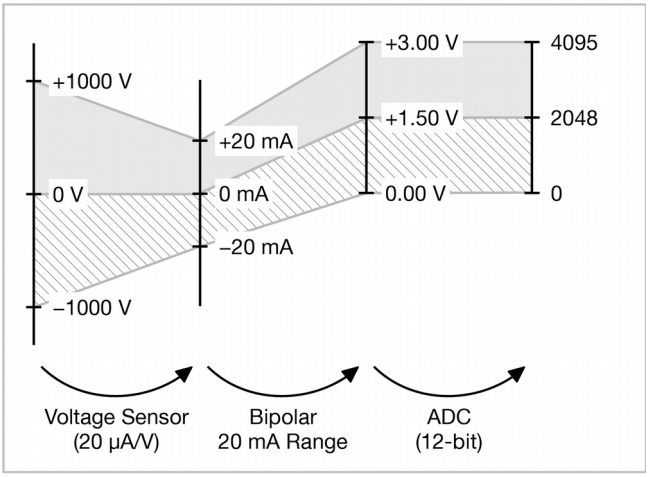

Figure 6: Signal chain for measurement of AC line-line or AC line-neutral voltage in the range –1000 V to 1000 V.

The AIN004 module input channel should be configured for bipolar mode and a current range of 20 mA. The module maps the input current range of –20 mA to 20 mA to the same output voltage range of 0.0 V to 3.0 V.

SwitcherWare Library

The SwitcherWare Library from Denkinetic provides the `AinPinScaled` class to handle ADC conversions and the reverse-mapping of ADC values to measured values.

Warnings

The length of cables connected to the module front panel connector must not be longer than 3 m.

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.

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.

The user is responsible to ensure that the installation provides protection against direct contact.

This Module does not provide galvanic isolation between SwitcherGear and the system under control. The user is responsible for selecting isolated sensors with appropriate insulation.

The current inputs can be permanently damaged by currents beyond the configured input range.

Electrical Characteristics

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

Parameter	Conditions	Min	Typ	Max	Unit
CURRENT INPUT RANGE					
20 mA Jumper			20		mA
30 mA Jumper			30.06		mA
50 mA Jumper			50		mA
100 mA Jumper			100		mA
VOLTAGE OUTPUT					
Full-Scale Output Range		0		3	V
Bandwidth		200			kHz
ACCURACY					
Gain				±1.2	%
Offset	Unipolar mode		±0.2	±0.4	mV
	Bipolar mode		±0.1	±0.2	mV
EXTERNAL SUPPLY					
Positive Supply Voltage	No load	11.8	12.2	12.6	V
Negative Supply Voltage	No load	–11.8	-12.2	–12.6	V
Output Current	Per output, up to 60 °C	0.3			A
	All outputs combined	1.0			A
Source Resistance	Load current 0.3 A			1	Ω
Short-Circuit Current	Per output		0.07		A

Revision History

Revision	Date	Changes From Previous Release
1	27 Nov 2014	▪ Original release.
2	20 Sep 2017	▪ Add figure for mapping of polarity modes. ▪ Add signal chain examples. ▪ Add SwitcherWare information.