Module AOV001

4-channel analogue output
Isolated voltage –10 V to +10 V

REFERENCE MANUAL

Features

Standard module for SwitcherGear

Four voltage output channels

Voltage output range ±10 V with 5 mV resolution

Outputs are group isolated

Outputs are short-circuit protected

12-way pluggable screw terminal

Applications

Interfacing to industrial systems

Real-time output of internal control variables

General Description

The AOV001 module is a voltage output module with output range of –10 V to +10 V. The module is controlled by the host MCU with a 3-wire serial interface.

Ordering Information

Order Code	***Description***
AOV001	*SwitcherGear module, 4-channel analogue output, isolated voltage –10 V to +10 V*
AIN003	*SwitcherGear module, 4-channel analogue input, isolated industrial signalling.*

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

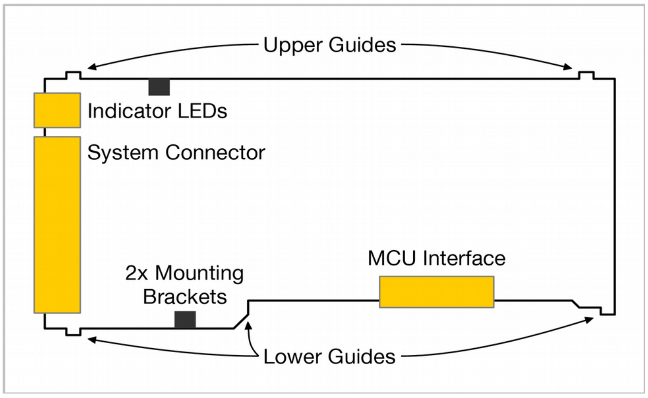

Figure 1: Parts of a SwitcherGear module.

System Connector

A 12-way pluggable screw terminal connector is used to connect system wiring to the AOV001 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 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

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

MCU interface

Refer to Table 3 for details of the digital and analogue signals provided by the AOV001 module.

Denkinetic Pty Ltd
contact@denki.com.au

Table 1: Front panel connector

Pin	Signal	Description
1 (Top)	AO0	Analogue voltage output for channel 0.
2	COM	Common reference output for all channels.
3	AO1	Analogue voltage output for channel 1.
4	COM	Common reference output for all channels.
5	AO2	Analogue voltage output for channel 2.
6	COM	Common reference output for all channels.
7	AO3	Analogue voltage output for channel 3.
8	COM	Common reference output for all channels.
9	-	-
10	-	-
11	-	-
12 (Bottom)	FIELDGND	External field ground.

Table 2: Front panel indicator LEDs

Appearance	Left Column		Right Column	
	Colour	Description	Colour	Description
	Green	+15 V supply for output drivers	Green	−15 V supply for output drivers
	-	-	-	-
	-	-	-	-
	-	-	-	-

Table 3: Module-base interface

Pin	Signal	Description
D0	CSn	Chip select input. Active-low.
D1	SCLK	SPI clock input.
D2	SIMO	SPI data input.
D3	-	-
D4	-	-
D5	-	-
D6	-	-
D7	-	-
D8	-	-
D9	-	-
D10	-	-
D11	-	-
A0	-	-
A1	-	-
A2	-	-
A3	-	-

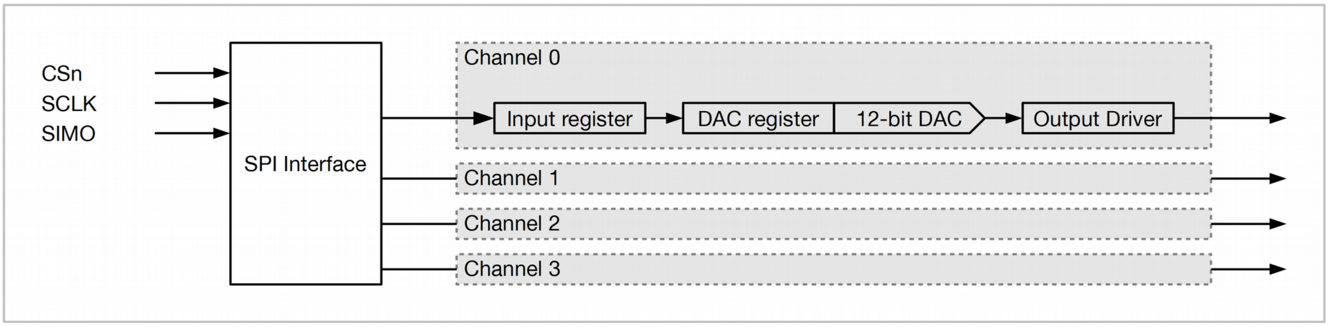

Figure 2: Functional block diagram of the AOV001 module. The module-host interface is on the left and the front panel connector is on the right.

Refer to the SwitcherGear configuration document for your specific SwitcherGear unit for information on the mapping of the module signals to the host microcontroller on the base board.

Configuration

The AOV001 module has no configurable features.

Functional Description

The AOV001 module is a 4-channel analogue voltage output module. As shown in Figure 2, the signal chain consists of a SPI interface and, for each channel, a 12-bit DAC and output driver.

The analogue output of each channel is set by using the SPI bus to write an integer value to the DAC register. A DAC register value of 0 corresponds to the zero-scale output of –10 V, and 4095 corresponds to the full-scale output of 10 V. The 12-bit DAC register spans 2^12 = 4096 counts, from 0 to 4095 inclusive. So the actual maximum analogue output is one count lower than the full-scale output.

The analogue output is set according to the equation

$$Output = \left[20V \times \frac{DAC}{4096} \right] - 10V$$

where DAC is in the range from 0 to 4095. For a change in the DAC value of one count, the output voltage changes by 4.88 mV (20 V ÷ 4096).

The DAC register value required for a particular output voltage is given by

$$DAC = 4096 \times \left[\frac{Output + 10V}{20V} \right]$$

where Output is in the range -10 V to 10 V, and valid values for DAC are in the range 0 to 4095 and not 4096.

For example, writing a value of 410 to the DAC register sets the output to –8.00 V. To set the output to 0.00 V, write the value 2048 to the DAC register.

SPI Serial Bus

The AOV001 module uses the DAC7565 digital-to-analogue converter device from Texas Instruments. Consult the manufacturer's datasheet for detailed information about the SPI serial bus protocol used by the device. This is a low-level hardware protocol that transfers data between the microcontroller and the DAC device.

See the section SwitcherWare Library if you prefer to not interact directly with the low-level hardware.

Applications Information

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**

Serial Interface Pin	C2000 Pin Allocation	
	SPI Perpheral	McBSP Peripheral
SCLK	SCLK	CLKX
SIMO	SIMO	DX
SOMI	SOMI	DR
CSn (peripheral control)	SPISTE	FSX
CSn (user control)	GPIO	GPIO

SwitcherWare Library

The SwitcherWare Library from Denkinetic includes methods to handle the low-level hardware configuration and provide a simple-to-use interface to the AOV001 module.

Signal Visualisation

The AOV001 module is ideal for the visualisation of digital quantities in the SwitcherGear system. These quantities can be viewed in real-time with an oscilloscope, or captured with a data-logger.

There are many practical uses, including

- comparison of analogue quantities in the power system and their digitised equivalent in the digital controller;
- visualisation of internal control variables, which exist only in the digital control domain;
- visualisation of debug signals;
- data-logging of any digital control quantity.

The transfer of data using the SPI port is fast enough to enable updating of variables at the switching frequency of most IGBT converters without affecting the real time control process.

Visualisation with an oscilloscope

The probe compensation feature of oscilloscopes can be used to convey the scaling information for the visualised signals.

Consider the case of a variable that represents the measured voltage of a 230 V single-phase AC supply. The peak to peak

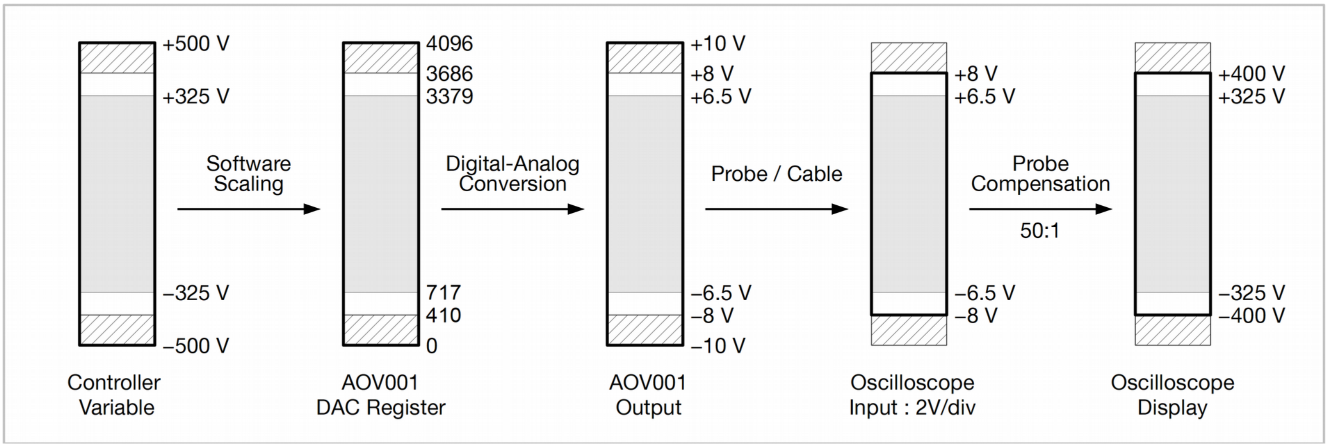

Figure 3: Transformation of a variable in the controller to the oscilloscope, through the AOV001 module.

range of this variable is around ±325 V. This range must be scaled to the physical output range of the AOV001 module, e.g. ±10 V.

Without any additional information, the oscilloscope will just capture this as a ±10 V signal and the original scaling information is lost. However, using the probe compensation feature that most oscilloscopes have, the captured signal can be scaled to the range of the original variable. Once this scaling has been configured, other oscilloscope functions, such as automated measurements and math functions, will also give their results in the correctly scaled range.

The steps to follow:

1. Configure the oscilloscope channel with vertical scaling 2 V/div and 0 V offset to centre of display. These settings match the ±10 V output range of the AOV001 module, so do not alter once set. Changes to the signal scaling should be made using the probe compensation feature only.

   Note that most oscilloscopes have 8 vertical divisions (four positive, four negative), resulting in a capture range of ±8 V.

2. Check the oscilloscope to see what values of probe compensation are allowed. Some oscilloscopes allow any value to be used, while others allow selection from a list of preferred values, e.g. 10, 20, 50, 100, etc.

3. Choose a probe compensation value that maps the range of the variable to ±8 V. Keep the physical signal as large as possible by choosing the smallest value that achieves the mapping. This improves noise immunity and signal resolution.

4. Configure the oscilloscope channel with the chosen probe compensation value.

5. In the host software, apply a scaling factor to map the variable to the physical output voltage.

In the example, a probe compensation value of 50 is a good choice. This maps the variable range of ±325 V to a physical range of ±6.50 V. The full ±10 V output range corresponds to a ±500 V variable range. The variable should be scaled so that ±500 V maps to a DAC register range of 0 to 4096. See Figure 3 for the correspondence between the various ranges.

Warnings

⚠ Use shielded cable for wiring to external devices.

⚠ The length of cables connected to the module front panel connector must not be longer than 30 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.

Electrical Characteristics

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

Parameter	**Conditions**	**Min**	**Typ**	**Max**	**Unit**
OUTPUT ACCURACY					
Gain Error				0.4	%
Offset Error	Output 0 V			50	mV
Non-Linearity				0.05	% FS
OUTPUT CHARACTERISTICS					
Short-Circuit Current			25		mA
Load Resistance		1			kΩ
Load Capacitance				1	nF
Source Resistance	DC		0.1		Ω
Settling Time To 0.05%	¼ to ¾ scale step, load 1 kΩ || 220 pF		7		µs
Slew Rate	±10 V output transition		2		V/µs

Revision History

Revision	Date	Changes From Previous Release
1	23 May 2018	▪ Original release.