AMS6140-01

PRELIMINARY DATASHEET

Temperature stabilized infrared detection module with an integrated amplifier and temperature controller

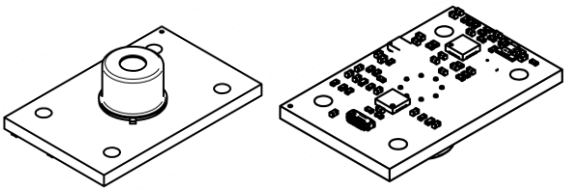


FIGURE 1. The AMS6140-01 detection module

FEATURES

- Spectral range: 2.2 to 6.8 µm or 7.2 µm[1]
- Active area: 1 mm × 1 mm
- Built-in temperature controller
- Pin configurable chip temperature
- Low 1/f noise corner
- Bandwidth: DC up to 2.6 MHz
- Single, low-voltage power supply: 3.3 V
- Differential output
- Small board-to-board connector
- Small dimensions: 30 mm × 19 mm × 10 mm
- III-V material
- Low weight: 5 g
- Evaluation kit and additional accessories available

APPLICATIONS

- Gas detectors with MEMS, LED, or laser sources
- Temperature sensors
- Embedded systems
- Portable devices

GENERAL DESCRIPTION

The AMS6140-01 is a cost-effective infrared detection module designed for high-volume applications. It includes the PVMA-1TE-6-1x1-TO39-pSiAR-70 infrared detector which is optimized for wavelengths up to 6 µm. The built-in amplifier and temperature controller provide constant responsivity over a wide range of ambient temperatures. Wide frequency bandwidth and low 1/f noise corner frequency provide efficient measurements with generally available sources of radiation, including MEMS heaters and pulsed LEDs or lasers. With differential output, the module offers easy connectivity over tiny and low-cost connectors with high immunity to electromagnetic interference. Small dimensions provide easy mechanical and thermal integration with the target device. Planar silicon window with anti-reflection coating facilitates applications with narrow-band IR sources.

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[1] Responsivity is higher than 10% of peak value within this range for chip temperature 20ºC

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CONNECTIVITY

The AMS6140-01 feature a tiny connector with 14 signal pins and 2 high current pins. The description of pins and pins ordering are shown in TABLE 1, FIGURE 2, and FIGURE 3.

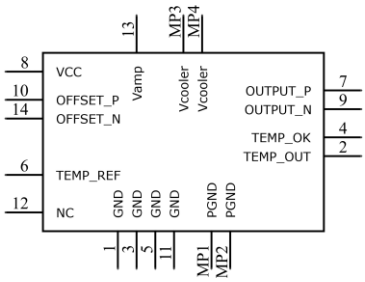


FIGURE 2. Pinout of the module connector

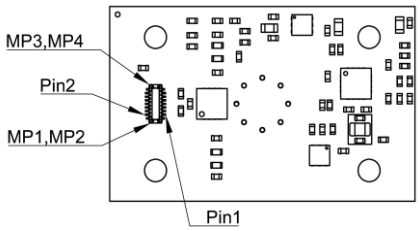


FIGURE 3. Pins ordering on the module connector

The recommended mating connector is Amphenol 101R014FB110. Please refer to chapter MECHANICAL REQUIREMENTS for more information.

TABLE 1. Pin functions

Pin number	Symbol	Function
1, 3, 5, 11	GND	Signal and amplifier supply ground
7	OUTPUT_P	Positive signal output
9	OUTPUT_N	Negative signal output
12	NC	Not used. Leave floating
2	TEMP_OUT	Analog temperature output. For more information see the chapter THERMAL DESIGN
4	TEMP_OK	Comparator output signal. Set to high when the temperature of the chip is close to the desired value. For more information see the chapter THERMAL DESIGN
6	TEMP_REF	Temperature reference voltage. Can be used to change the temperature of the chip. For more information see the chapter THERMAL DESIGN
13	V_{amp}	Amplifier supply input
8	V_{cc}	Internal supply voltage output. Use only to set DC offset voltage using OFFSET_P and OFFSET_N. For more information see the chapter SIGNAL OUTPUTS. Do not use it for any other purpose
10	OFFSET_P	DC offset for positive signal output. Leave floating if no output offset is required. Connect directly to V_{cc} to introduce the maximum possible DC offset. The optional resistor can be used if a lower value of DC offset is required. For more information see the chapter SIGNAL OUTPUTS
14	OFFSET_N	DC offset for negative signal output. Leave floating if no output offset is required. Connect directly to GND to introduce the maximum possible DC offset. The optional resistor can be used if a lower value of DC offset is required
MP3, MP4	V_{cooler}	Supply voltage input for the temperature controller. Can be connected to V_{amp}. For more information see the chapter POWER SUPPLY
MP1, MP2	PGND	Ground path for temperature controller. Connect to GND

ABSOLUTE MAXIMUM RATINGS

Do not stress the device above the limits specified in this chapter since it may cause permanent damage to the device.

TABLE 2. Absolute maximum ratings

Parameter	Rating
Amplifier supply, V_{amp}	5.5 V
Temperature controller supply, V_{cooler}	5.5 V
TEMP_REF voltage	-0.1 V to 3.1 V
OFFSET_N and OFFSET_P voltage	-0.1 V to 3.1 V
Ambient operating temperature (with ideal heatsink)	-40°C to 65°C, non-condensing
Storage temperature	-50°C to 85°C

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SPECIFICATION

+3.3 V supply, T_{amb} = 20°C, R_{load} = 1 MΩ to ground, unless otherwise noted.

TABLE 3. Module specification for chip temperature T_{chip} = -20°C

Parameter	Test conditions, remarks	Value			Unit
		Min.	Typ.	Max.	
SPECTRAL CHARACTERISTICS					
Cut-on wavelength	At 10% of the peak responsivity		2.2		µm
Peak wavelength, λ_{peak}			4.2		µm
Cut-off wavelength	At 10% of the peak responsivity		6.8		µm
Responsivity	At λ_{peak}		220		V/W
Detectivity	At λ_{peak}, f = 1 kHz		1.0×10^9		cm·Hz$^{1/2}$/W
OPTICAL					
Active area width			1		mm
Active area length			1		mm
Acceptance angle, Φ			70		deg.
Linearity range	10% deviation, see FIGURE 10		5.3		mW
	5% deviation, see FIGURE 10		2.8		
OUTPUT PERFORMANCE					
Output differential offset	No radiation, OFFSET_P and OFFSET_N floating	-5		20	mV
Output single-ended common mode voltage, V_{CM}	OFFSET_P and OFFSET_N floating		1.22		V
Output single-ended common mode voltage	OFFSET_P and OFFSET_N floating, R_{load} = 50 Ω		0.61		V
Output impedance, R_{OUT}	OUTPUT_P and OUTPUT_N, single-ended		50		Ω
Output voltage swing, negative	OUTPUT_P and OUTPUT_N, single-ended		0.2		V
Output voltage swing, positive	OUTPUT_P and OUTPUT_N, single-ended		2.2		V
Low cut-off frequency, f_{lo}	DC coupling		0		Hz
High cut-off frequency, f_{hi}	R_{load} = 50 Ω		2.6		MHz
POWER SUPPLY					
Supply current on V_{amp} and GND pins	R_{load} = 50 Ω		50		mA
Supply current on V_{cooler} and PGND pins			550		mA
THERMAL					
Thermal resistance[2], θ_{T-S}	Hot side of built-in TEC to cooling surface of the module		10		K/W
Thermal power, P_{cool}	Dissipated through heatsink		1.2		W
Maximum temperature difference[2], ΔT_{max}	Provided by built-in TEC cooler		60		°C
Area of cooling surface, S_C	Board surface which can be used to transfer heat to the heatsink		450		mm^2
OTHER					
TEMP_REF voltage	When left floating		1.54		V
TEMP_REF input resistance			17		kΩ
OFFSET_N and OFFSET_P input resistance, R_{OFFSET}			3.3		kΩ
OFFSET_N and OFFSET_P input capacitance			100		nF
V_{CC}			3.0		V
TEMP_OK current	Sourcing/sinking			0.1	mA
TEMP_OK high voltage		2.7			V
TEMP_OK low voltage				0.3	V

[2] See chapter THERMAL DESIGN for more details

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+3.3 V supply, T_{amb} = 20°C, R_{load} = 1 MΩ to ground, unless otherwise noted.

TABLE 4. Module specification for chip temperature T_{chip} = 20°C

Parameter	Test conditions, remarks	Value			Unit
		Min.	Typ.	Max.	
SPECTRAL CHARACTERISTICS					
Cut-on wavelength	At 10% of the peak responsivity		2.2		µm
Peak wavelength, λ_{peak}			4.4		µm
Cut-off wavelength	At 10% of the peak responsivity		7.2		µm
Responsivity	At λ_{peak}		160		V/W
Detectivity	At λ_{peak}, f = 1 kHz		4.2×10^8		cm·Hz$^{1/2}$/W
OPTICAL					
Active area width			1		mm
Active area length			1		mm
Acceptance angle, Φ			70		deg.
Linearity range	10% deviation, see FIGURE 10		5.5		mW
	5% deviation, see FIGURE 10		5.2		
OUTPUT PERFORMANCE					
Output differential offset	No radiation, OFFSET_P and OFFSET_N floating	-5		5	mV
Output single-ended common mode voltage, V_{CM}	OFFSET_P and OFFSET_N floating		1.22		V
Output single-ended common mode voltage	OFFSET_P and OFFSET_N floating, R_{load} = 50 Ω		0.61		V
Output impedance, R_{OUT}	OUTPUT_P and OUTPUT_N, single-ended		50		Ω
Output voltage swing, negative	OUTPUT_P and OUTPUT_N, single-ended		0.2		V
Output voltage swing, positive	OUTPUT_P and OUTPUT_N, single-ended		2.2		V
Low cut-off frequency, f_{lo}	DC coupling		0		Hz
High cut-off frequency, f_{hi}	R_{load} = 50 Ω		2.3		MHz
POWER SUPPLY					
Supply current on V_{amp} and GND pins	R_{load} = 50 Ω		50		mA
Supply current on V_{cooler} and PGND pins			20		mA
THERMAL					
Thermal resistance[3], θ_{T-S}	Hot side of built-in TEC to cooling surface of the module		10		K/W
Thermal power, P_{cool}	Dissipated through heatsink		0.1		W
Maximum temperature difference[3], ΔT_{max}	Provided by built-in TEC cooler		60		°C
Area of cooling surface, S_C	Board surface which can be used to transfer heat to the heatsink		450		mm^2
OTHER					
TEMP_REF voltage	When left floating		1.54		V
TEMP_REF input resistance			17		kΩ
OFFSET_N and OFFSET_P input resistance, R_{OFFSET}			3.3		kΩ
OFFSET_N and OFFSET_P input capacitance			100		nF
V_{CC}			3.0		V
TEMP_OK current	Sourcing/sinking			0.1	mA
TEMP_OK high voltage		2.7			V
TEMP_OK low voltage				0.3	V

[3] See chapter THERMAL DESIGN for more details

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TYPICAL PERFORMANCE CHARACTERISTICS

+3.3 V supply, T_{amb} = 20°C, R_{load} = 1 MΩ to ground, unless otherwise noted.

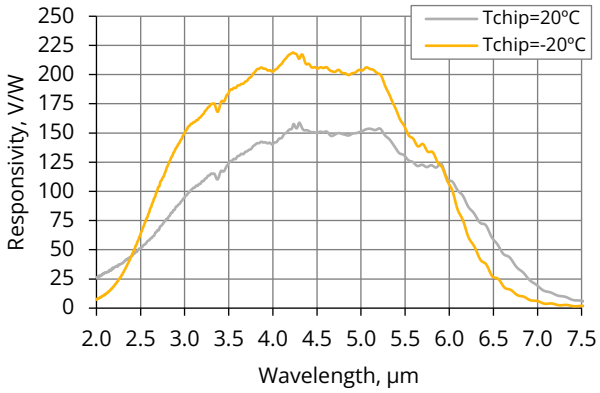


FIGURE 4. Spectral characteristics for different temperatures of detection chip

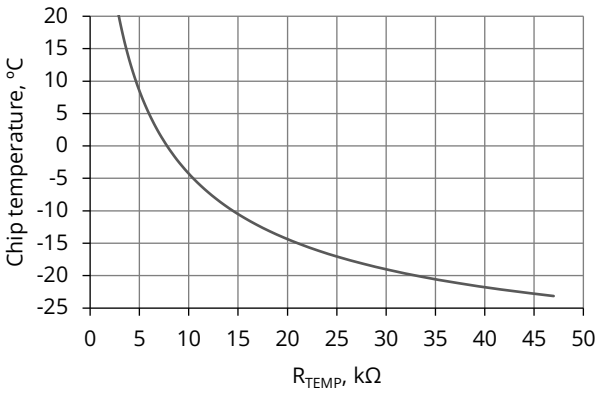


FIGURE 5. Detection chip temperature vs resistance connected to TEMP_REF pin (see FIGURE 12)

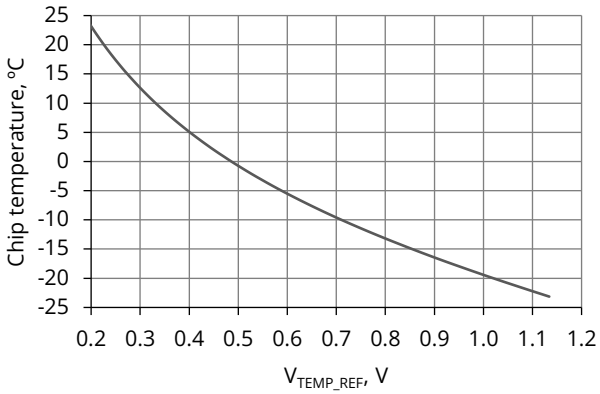


FIGURE 6. Detection chip temperature vs voltages on TEMP_REF and TEMP_OUT pins (see FIGURE 13)

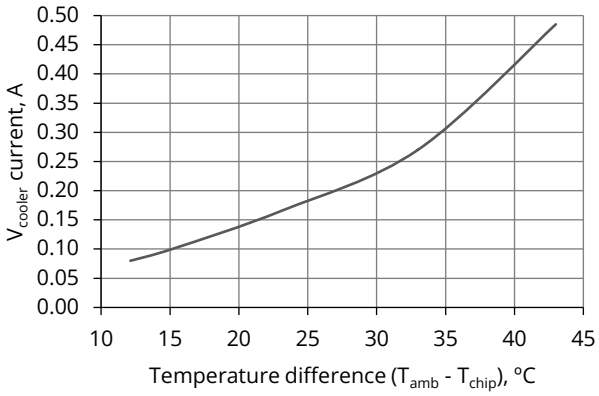


FIGURE 7. Supply current vs temperature difference between detection chip and ambient. The thermal resistance of the attached heatsink: 2.5 K/W

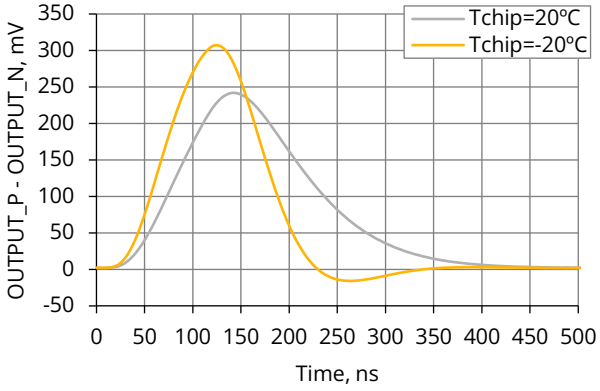


FIGURE 8. Pulse response for different temperatures of detection chip, R_{load} = 50 Ω

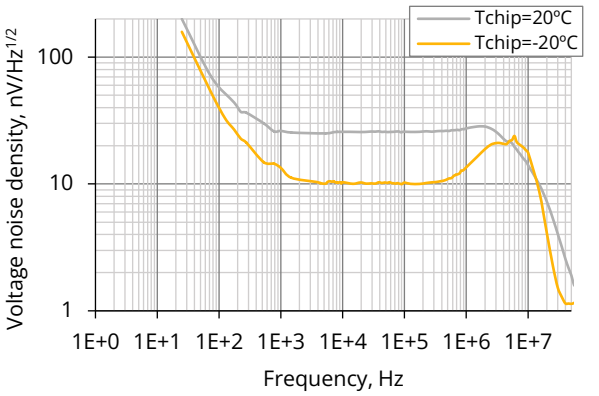


FIGURE 9. Differential output noise density for different temperatures of detection chip

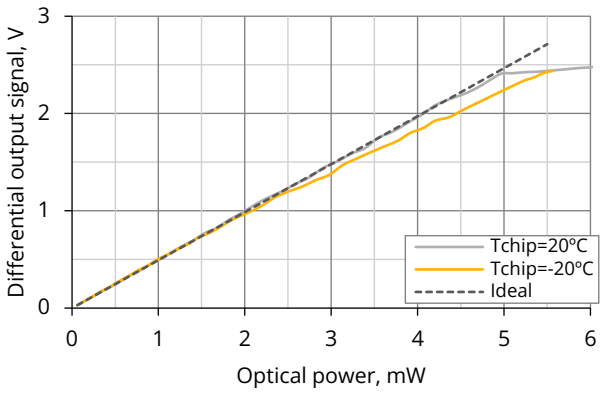


FIGURE 10. Output signal vs input power

POWER SUPPLY

The module can be powered from a single voltage source, but special care is required to avoid interference between the amplifier circuit and the temperature controller circuit.

There are two supply paths present on the socket: V_{amp}/GND and V_{cooler}/PGND. V_{amp}/GND are used to supply the amplifier circuit. A 1 µF capacitor should be placed close to the module connector. V_{cooler}/PGND pins are used to supply the built-in thermoelectric cooler (TEC) and require an additional 1 µF decoupling capacitor. The simplified supply pattern is presented in FIGURE 11.

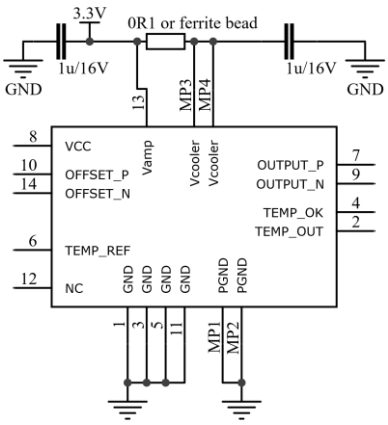


FIGURE 11. Recommended power supply decoupling

In some applications, a built-in temperature controller can influence the output signal. The following methods can be used to reduce interference between the temperature controller and output signal:

1. Separate power supplies with EMI ferrite.
2. Add a common mode filter on the V_{cooler}/PGND to separate it from V_{amp}/GND.
3. Add a common mode filter on the differential signal output.
4. Add a small resistor (0.1 Ω) to the V_{cooler} supply.

The choice of proper solution depends on the nature of the interference and has to be considered individually for each design.

TEMPERATURE CONTROL

The module has a built-in thermoelectric cooler and provides easy pin-configurable temperature adjustment with a single resistor, external voltage source, or DAC output.

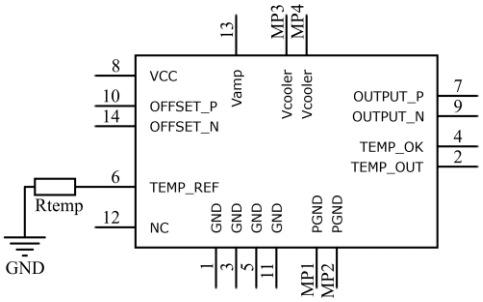


FIGURE 12. Adjusting chip temperature with a single resistor

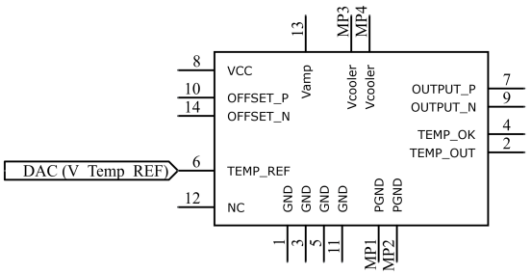


FIGURE 13. Adjusting chip temperature with an external digital-to-analog converter

The module provides constant responsivity only when the chip temperature is stable. After powering on the module the built-in temperature controller starts the cooling process. Before the controller reaches its stable point, parameters of the module (i.e. voltage responsivity) should be considered unknown. There are a couple of approaches to deal with this issue:

1. Time-based. In most applications, the chip will reach the desired temperature in less than 5 seconds. Therefore V_{amp} and V_{cooler} should be enabled 5 seconds before the first measurement.
2. Comparator + time-based. TEMP_OK is a simple comparator output that will be asserted high when chip temperature is close to or lower than desired. Make sure that TEMP_OK is kept high for at least 1 second before the first measurement.
3. ADC-based. TEMP_OUT provides voltage related to the current temperature of the chip. In steady-state TEMP_OUT and TEMP_REF should be equal. As before, make sure that TEMP_OUT and TEMP_REF are close enough for at least 1 second.

The only 3rd method is a fully-featured solution that can detect unpredicted situations when the system is operating (i.e. decreasing performance of thermal interface material). However, it requires additional ADC which has some impact on the price of the final device. Therefore, pricewise, 1st and 2nd methods can be considered as simplified solutions.

There is also a fully analog solution for 3rd method, which is presented in FIGURE 14. U1B buffers voltage from the TEMP_REF pin. R1-R2-R3-R4 shifts the potential a little up (R1-R2) and down (R3-R4) to define the borders of the window. U1C asserts output if the TEMP_REF pin is too high, and U1D asserts output if the TEMP_OUT pin voltage is too low, compared to shifted potentials.

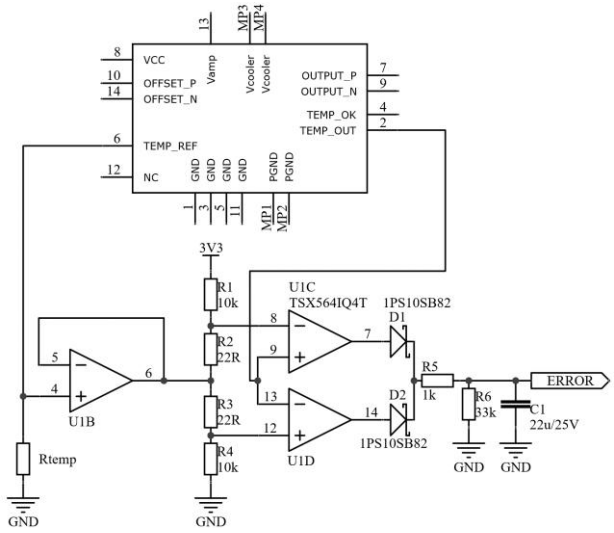


FIGURE 14. Example of analogue window detector to monitor the temperature of the detection chip

THERMAL DESIGN

There are two sources of heat that need to be separately considered. First is the TEC cooler mounted inside of the detector. It is strongly coupled to the surrounding cooling surface on top of the PCB and requires an external heat sink. The example is presented in FIGURE 15.



FIGURE 15. Cross-section of example application with attached heatsink

The heatsink is not provided with the module. Its size and required performance depend on the application and target price of the final device.

The second source of heat is the electronic components on the bottom of the PCB. For applications with high cooling power, it is recommended to leave the bottom side of the module uncovered. An example of such a solution is presented in FIGURE 22.

The simplified thermal model for application presented in FIGURE 15 is presented in FIGURE 16.

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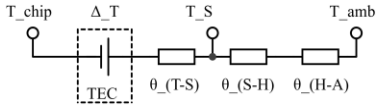


FIGURE 16. Simplified thermal model for a typical application consisting of AMS module (TEC + θ_{T-S}), thermal interface material (θ_{S-H}), and heatsink (θ_{H-A}). T_{chip} is the temperature of the detection chip, T_S is the temperature of the cooling surface, T_{amb} is the ambient temperature

The lowest possible chip temperature can be calculated as:

$$T_{chip}=T_{amb}+P_{cool}\cdot(\theta_{H-A}+\theta_{S-H}+\theta_{T-S}) - \Delta T_{max} \quad (1)$$

where:

- T_{chip} is the temperature of the detection chip
- T_{amb} is ambient temperature,
- P_{cool} is thermal power dissipated through the cooling surface,
- θ_{H-A} is the thermal resistance between the heatsink and air,
- θ_{S-H} is the thermal resistance between the cooling surface and heatsink,
- θ_{T-S} is the thermal resistance between the hot side of the built-in TEC cooler and the cooling surface of the module,
- ΔT_{max} is the maximum temperature difference that can be generated by the built-in TEC cooler.

θ_{S-H} depends mainly on the used thermal interface material or grease and can be calculated using the following formula:

$$\theta_{S-H}=\frac{t}{\lambda\cdot S_c}\cdot K_f \quad (2)$$

where:

- t is the thickness of the thermal interface material,
- λ is the thermal conductivity of the thermal interface material,
- S_c is the area of the cooling surface,
- K_f is a correction factor due to non-uniform heat transfer through the cooling surface, typically equal to 2.0

Example 1

The module will be mounted on a passive heatsink.

- Range of ambient temperatures: T_{amb} = 0°C to 30°C
- Chosen temperature of detection chip: T_{chip} = -5°C
- Thermal conductivity of grease: 1 W/m·K
- Grease thickness: 0.1mm
- Unknown: required thermal resistance of heatsink (θ_{H-A})

Using equations (1) and (2) thermal resistance of heatsink can be expressed as:

$$\theta_{H-A} = \frac{T_{chip}+\Delta T_{max}-T_{amb}}{P_{cool}}-\theta_{S-H}-\theta_{T-S} \quad (3)$$

In this example thermal grease θ_{S-H} can be calculated as follows:

$$\theta_{S-H}=\frac{1\cdot10^{-4}\text{m}}{1\frac{\text{W}}{\text{m}\cdot\text{K}}\,450\cdot10^{-6}\text{m}^2}\cdot2=0.44\frac{\text{K}}{\text{W}} \quad (4)$$

Worst case scenario is the highest possible ambient temperature, which in this example is 30°C, what yields:

$$\theta_{H-A} = \frac{\text{-5°C+60°C-30°C}}{1.2\text{W}}-0.44\frac{\text{K}}{\text{W}}-10\frac{\text{K}}{\text{W}}=10.39\frac{\text{K}}{\text{W}} \quad (5)$$

Heatsink with thermal resistance not worse than 10.39 K/W will be sufficient to provide thermal stability of the AMS6140-01 module.

Example 2

The module will be mounted on an active cooled metal rail with constant temperature and very good cooling capacity.

- Temperature of cooling rail: 10°C
- Thermal conductivity of grease: 1 W/mK
- Grease thickness: 0.1mm
- Unknown: best available temperature of detection chip

Grease parameters are identical to the previous example, therefore thermal resistance of the interface between the module and the cooling rail is already calculated in (4). θ_{H-A} equals zero since the cooling rail has infinite performance. Using equations (1) and (2) the best available temperature of the detection chip can be calculated as:

$$T_{chip}=10\text{°C}+1.2\text{W}\cdot\left(0+0.44\frac{\text{K}}{\text{W}}+10\frac{\text{K}}{\text{W}}\right)-60\text{°C}\approx-37\text{°C} \quad (6)$$

Conclusion

The range of ambient temperatures where detection chip temperature is kept on a constant value depends strongly on heatsink parameters. The design of the final device requires a trade-off between price, size, and performance. However, it is also possible to keep a small and cheap heatsink and extend the range of

ambient temperatures introducing multiple ranges of ambient temperatures and changing the voltage of the TEMP_REF (see FIGURE 6) pin according to current conditions. The final device needs to be calibrated separately for each range of ambient temperatures. An example of this approach is presented in TABLE 5. The values should be considered as an example only since they depend on the heatsink parameters.

TABLE 5. Example ranges of ambient temperatures

Ambient temperature, °C	Chip temperature set by TEMP_REF pin, °C
30...50	25
15...35	10
0...20	-5

In this example, three ranges of ambient temperatures and three corresponding desired chip temperatures are presented. The voltage on the TEMP_REF pin should be adjusted according to ambient temperature with small hysteresis to avoid unwanted oscillations on the edges of the ranges. The relation between TEMP_REF voltage and chip temperature is presented in FIGURE 6.

SIGNAL OUTPUTS

Output signals paths or wires have to be as short as possible and placed close to each other to minimize loop area formed by them and therefore reduce EMI interference.

The impedance of both outputs is fixed to 50 Ω. If fast pulsed source of radiation is used and the shape of the rising or falling slope is important, both outputs should be terminated with 50 Ω to GND. In this case please use precise resistors with a tolerance not worse than 0.1% to keep the signal path symmetrical. The termination pattern is presented in FIGURE 17.

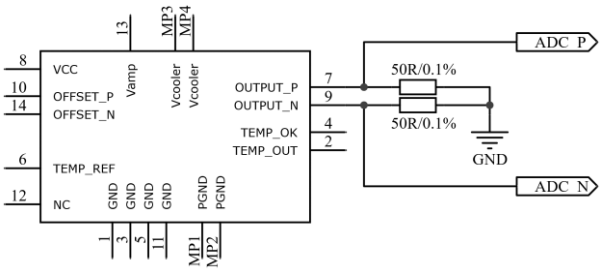


FIGURE 17. Outputs termination for high-speed signals

However, in most typical applications signal termination is not necessary. Provided slowly changing radiation sources are used and/or signal paths are short, outputs may be left unterminated. Connecting outputs to high impedance has one additional benefit: bigger dynamic range of output voltages, since common-mode voltage is bigger for unterminated outputs.

The module is designed to keep the DC output offset to as low value as possible. However is some applications (i.e. direct connection to differential ADC) it may be beneficial to introduce some known value to the DC component. This can be done by connecting the OFFSET_P pin to V_{cc} and OFFSET_N pin to GND.

This approach can be used to match the full scale of differential ADC. If lower offset is required additional resistors may be used, according to FIGURE 18.

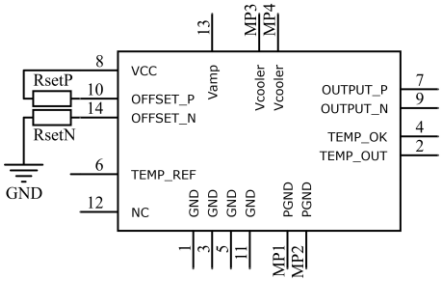


FIGURE 18. Adjusting differential offset of outputs using two resistors. R_{setP} and R_{setN} can be set to 0 Ω for maximum available offset

Connecting OFFSET_P to VCC (using a resistor or short-circuit) will lower the DC component on OUTPUT_P while connecting OFFSET_N to GND will rise the DC component on OUTPUT_N. If R_{setP} and R_{setN} R_{se} represent non-zero values, please use thin-film resistors to avoid additional flicker noise.

For high impedance loads the impact of R_{setP} and R_{setN} on the outputs can be calculated using the following formulas:

$$V_{DC_OUTPUT_P}=V_{CM}-\frac{(V_{CC}-V_{CM})}{R_{OFFSET}+R_{setP}}\cdot 1800\ \Omega \quad (7)$$

$$V_{DC_OUTPUT_N}=V_{CM}+\frac{V_{CM}}{R_{OFFSET}+R_{setN}}\cdot 1800\ \Omega \quad (8)$$

For matched impedance loads the values calculated with the formula should be divided by 2.

In most applications, an additional voltage amplifier will be necessary. FIGURE 19 shows one of the possible solutions.

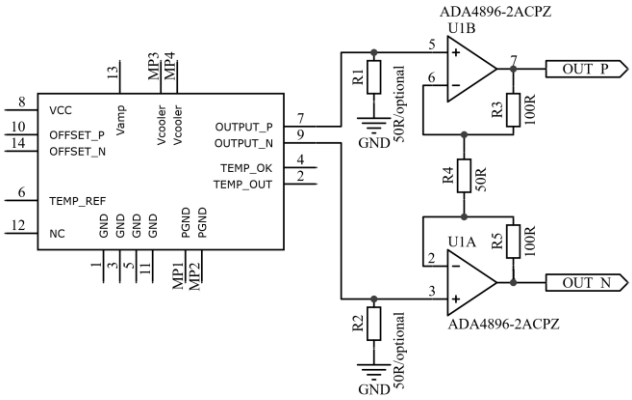


FIGURE 19. Example differential voltage amplifier with gain=5 and DC coupling. R1/R2 are not required for slowly changing signals

This topology of the amplifier is a "simplified instrumentation amplifier". It "copies" common-mode voltage from input to output and amplifies only the differential component. Changing the common-mode voltage to another value is possible using a fully differential amplifier such as LTC6404-1 or LTC6409. Regardless of the chosen solution, please use precise resistors with a tolerance not worse than 0.1% to keep the signal path symmetrical. R_1 and R_2 provide impedance match and can be omitted for slowly changing signals and/or short connection paths.

In most applications, DC component does not provide any information and can be neglected. In such situations, AC coupling is strongly recommended, since the DC component depends on the temperature of the chip as well as the temperature of the surrounding environment. An example of AC coupling is presented in FIGURE 20.

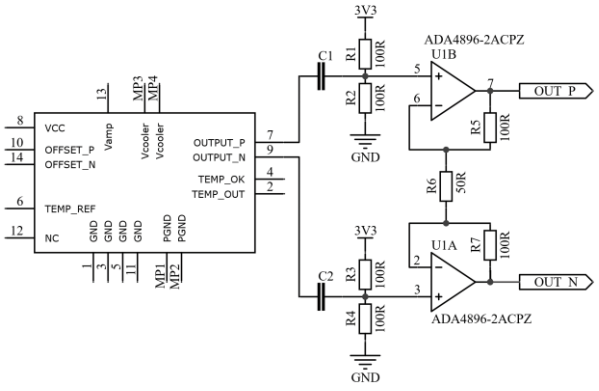


FIGURE 20. Example differential voltage amplifier with gain = 5 and AC coupling

Choose the values of R1, R2, R3, and R4 to set the desired common mode voltage on OUT_N-OUT_P pair. Use low tolerances to keep differential DC component at low values.

Assuming symmetry of "positive" and "negative" paths (i.e. C1=C2, R1=R2, R2=R4), low cut-off frequency is equal to:

$$f_{low3dB} = \frac{1}{2\pi\left(R_{OUT} + \frac{R_1 \cdot R_2}{R_1 + R_2}\right) C_1} \quad (9)$$

For example:

if $C_1 = C_2 = 10\ \mu F$ and $R_1 = R_2 = R_3 = R_4 = 100\ \Omega$ then low cut-off frequency is equal to 159.15 Hz.

In most applications setting low cut-off frequency to value 10 to 100 times lower than the lowest signal frequency is sufficient. This should not be a problem even for slow signals since impedance matching is not required in this case and therefore R_1, R_2, R_3 and R_4 can have high values.

MECHANICAL REQUIREMENTS

The module has to be mounted on a heatsink. Operations without a heatsink are possible, however not recommended. All four holes have to be used to minimalize mechanical stress and provide a proper thermal connection between the module and the heatsink. If required, thermal grease or any thermal interface material can be used to improve heat transfer. For more information please see the chapter THERMAL DESIGN.

To minimalize the risk of unexpected disconnection of the plug it needs to be fixed to the module using at least two mounting holes. Two connection types are recommended:

- Semi-flexible PCB. Receptacle *Amphenol 101R014FB110* has to be placed on the rigid part and the flexible part can be used to connect signals and power supplies to another PCB (FIGURE 22).
- Direct board to board connection. All components on the module are not higher than 1mm, which enables direct stacking of PCBs using the *Amphenol 101R014FB110* receptacle.

In both cases, the distance between the module and the external PCB needs to be precisely fixed to 1mm to avoid stress on the connector. One of the possible solutions are SMT spacers: *Würth Elektronik 9774010943*

MECHANICAL LAYOUT

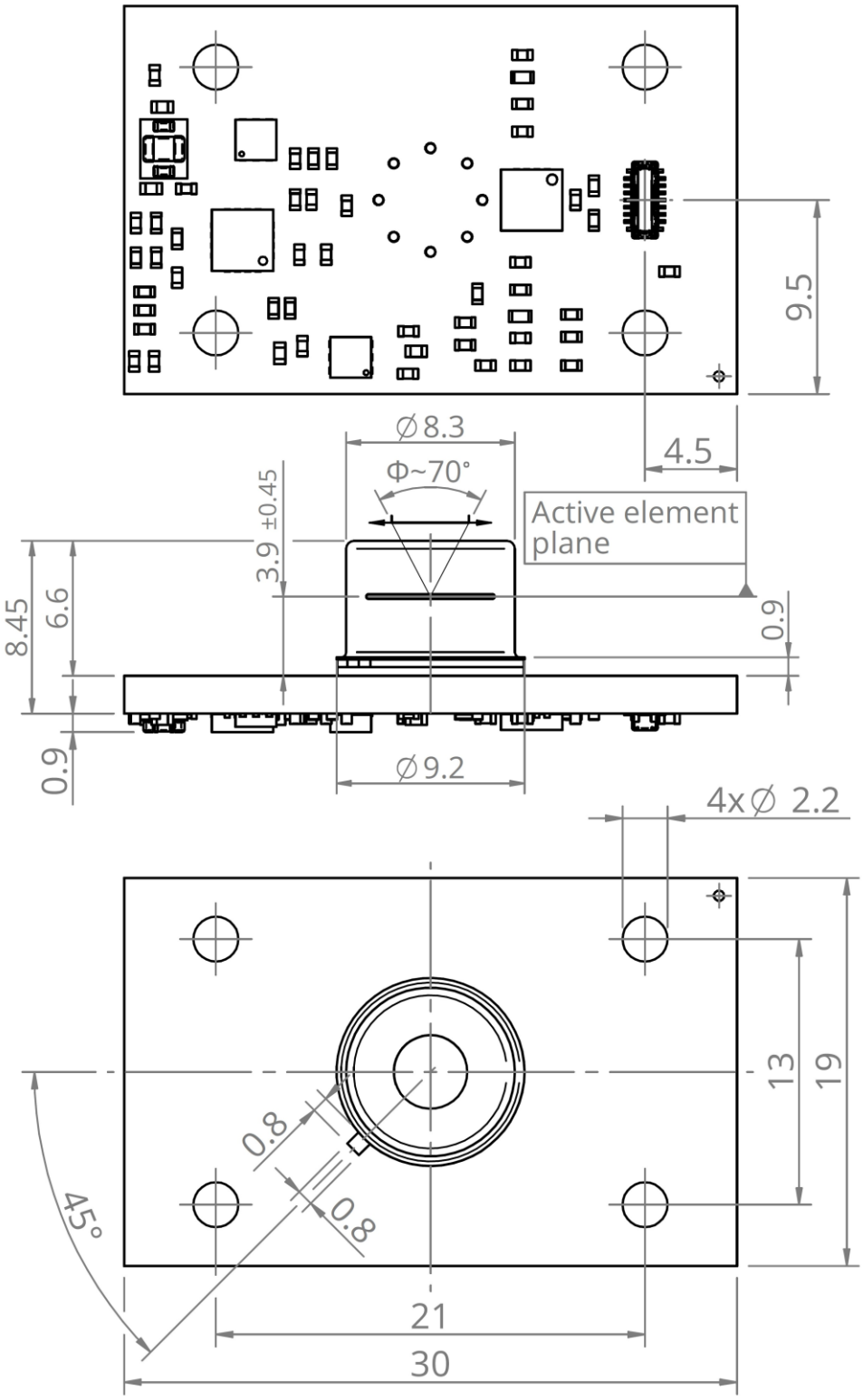


FIGURE 21. Dimensions of the AMS6140-01 (given in mm)

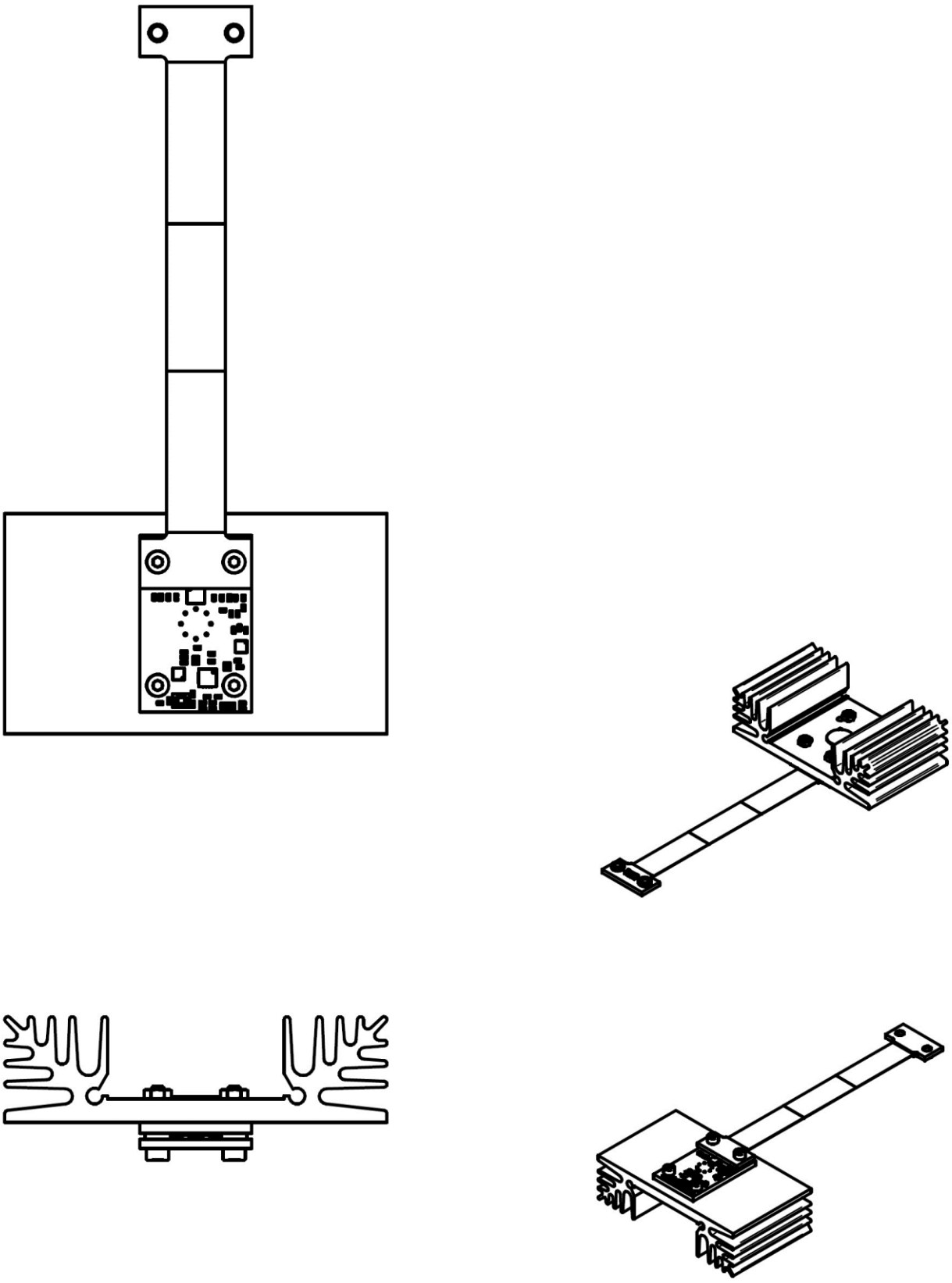


FIGURE 22. Example application of the AMS6140-01 with the flexible PCB