Ernst-Abbe-Hochschule Jena
University of Applied Sciences

Hes·so // VALAIS WALLIS
School of Engineering

Degree Programme
Systems Engineering

Major Power & Control

Diploma 2015

Yves Ravedoni

Modelling and thermal analysis of a seismic borehole sensor

Professor
Dr. Detlef Redlich

Expert
Dr. Joseph Moerschell

Submission date of the report
04.09.2015

HES-SO Valais-Wallis • rte du Rawyl 47 • C.P. • 1950 Sion 2
+41 27 606 85 23 • hei@hevs.ch • www.hevs.ch

☒ FSI ☐ FTV	Année académique / *Studienjahr* **2014/15**	No TD / *Nr. DA* **pc/2015/37**
Mandant / *Auftraggeber* ☒ HES—SO Valais ☐ Industrie ☒ Etablissement partenaire *Partnerinstitution* **FH Jena**	Etudiant / *Student* **Yves Ravedoni** Professeur / *Dozent* **Joseph Moerschell**	Lieu d'exécution / *Ausführungsort* ☐ HES—SO Valais ☐ Industrie ☒ Etablissement partenaire *Partnerinstitution*
Travail confidentiel / *vertrauliche Arbeit* ☐ oui / ja [1] ☒ non / nein	Expert / *Experte* *(données complètes)* **Detlef Redlich** FH Jena	

Titre / *Titel*

Modellierung und thermische Analyse eines Bohrlochseismometers

Description / *Beschreibung*

Im Rahmen dieser Arbeit soll ein Bohrlochseismometer auf seine Eignung für die speziellen Einsatzbedingungen untersucht werden, insbesondere für den Betrieb bei erhöhter Umgebungstemperatur.

Das Bohrlochseismometer besteht aus 3 orthogonal angeordneten Geophonen, einer Datenacquisitionselektronik, und einer Mikrocontroller-Karte, welche die Daten zwischenspeichert und über eine serielle Schnittstelle weiterleitet.

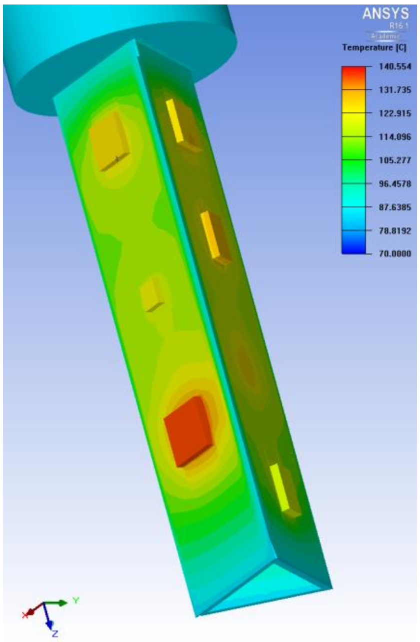
Um einen vorhandenen Labor-Prototypen für den Einsatz im Bohrloch weiterzuentwickeln, sind Im Einzelnen sind folgende Arbeiten auszuführen:

- Einarbeitung in die thermische Modellierung mit finiten Elementen.
- Modellierung des Bohrlochseismometers mit dem Gehäuse, den Sensoren und den Elektronikmodulen.
- Ermittlung der Erwärmung der verschiedenen Bauteile.
- Auswahl von Hochtemperatur-Bauteilen.
- ~~Zuverlässigkeitsanalyse und Untersuchung eines Redundanzkonzepts.~~

Signature ou visa / *Unterschrift oder Visum* Responsable de l'orientation *Leiter der Vertiefungsrichtung:*.................................... [1] Etudiant / Student :	Délais / *Termine* Attribution du thème / *Ausgabe des Auftrags:* 18.05.2015 Remise du rapport / *Abgabe des Schlussberichts:* 04.09.2015 Défense orale / *Mündliche Verfechtung:* Semaine | Woche 38

[1] *Par sa signature, l'étudiant-e s'engage à respecter strictement la directive DI.1.2.02.07 liée au travail de diplôme. Durch seine Unterschrift verpflichtet sich der/die Student/in, sich an die Richtlinie DI.1.2.02.07 der Diplomarbeit zu halten.*

Rapport reçu le / *Schlussbericht erhalten am* .... Visa du secrétariat / *Visum des Sekretariats* ....



Modelling and thermal analysis of a seismic borehole sensor

Graduate Ravedoni Yves

Bachelor's Thesis
| 2015 |

Degree programme
Systems Engineering

Field of application
Major Power & Control

Supervising Professor
Dr. Detlef Redlich
Detlef.redlich@fh-jena.de

Expert Professor
Dr. Joseph Moerschell
Joseph.moerschell@hevs.ch

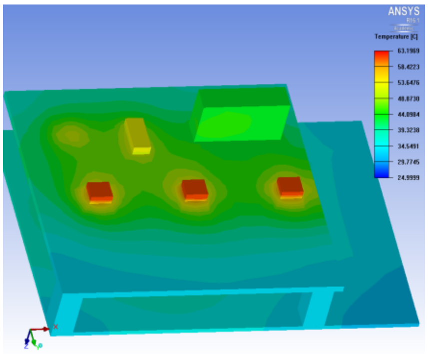
Partner
Fachhochschule
Ernst-Abbe Hochschule
Jena - Deutschland

Objectives

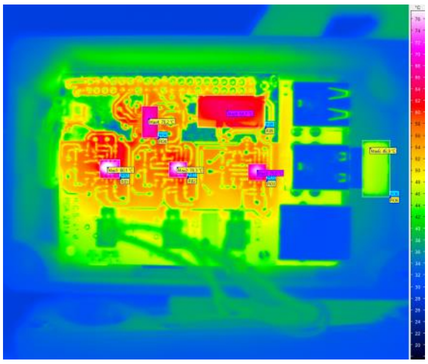
Analysis and adaptation of an acquisition system for a seismometer to enable operation at high temperatures (up to 180 [°C]). The simulation software and thermal measurements are used to validate theoretical results.

Methods | Experiences | Results

This thesis has been prepared in Jena, in Germany, as part of an exchange. The first step entails studying an existing sensor. Thermal measurements are performed. The temperature of components is established, it will confirm that the components work within a correctly prescribed operational temperature range. The measured environment is created by FEM thermal simulation software. The results are compared and simulation parameters are adjusted so that the simulation results correspond to the reality. For the second step, the housing of the sensor is altered to be placed in a borehole at a temperature of 180 [°C], a pressure of 25 [bar] and a depth of 3 [km]. The design of the printed circuit board is analysed, the electronic components are selected to operate at the required temperatures. Thermal simulation is used to certify that each component does not exceed the prescribed maximum operating temperature. The "graphite heat spreader" and "Peltier" elements (thermoelectric cooler) are studied whilst seeking to improve results.



Thermal simulation on the PCBs of the existing sensor. The ambient temperature is 25 [°C]. Without housing.



Infrared picture of the existing sensor in its housing. The ambient temperature is 25.5 [°C]. ε=0.9

TABLE OF CONTENTS

I. GENERAL SPECIFICATIONS

List of the tasks undertaken during this thesis:

- Mastering of Ansys Workbench, Ansys “Icepak”, Pcad, CoCreat software
- Simulation and measurement of power dissipation on an existing sensor
- Temperature measurement on the existing sensor and the components
- Thermal simulation on the existing sensor
- Researching components for the new sensor
- Analysing different circuit board designs
- Simulating the new sensor in different temperatures and specifications
- Thesis documentation
- Preparation of an “oral defence” of the thesis

II. INTRODUCTION

1. Objectives

The aim of the work is to present two seismic sensors that work in high temperatures (70°C and 150°C). This implies resolving the problem by seeking electronic devices and PCB designs that will work in harsh conditions.

General components have a maximal temperature of 85°C. Durability cannot be certified the when the electronics are used at temperatures over 85°C.

There are three options to provide a solution to problems caused by high temperatures:

- Different Printed Circuit Board (PCB) design
- Cooling systems (static or dynamic)
- Use of High temperature electronics.

A thermal simulation analysis is made to know the temperatures of each of the components. This will help to prevent any temperature damage of the sensor and will improve the reliability, giving a good performance. To start with, an existing sensor is analysed.

2. Aim of a seismic sensor

2.1 General aspects

A seismic sensor is built to measure earth movements, such as earthquakes. These vibrations have low frequencies, from 2 to 100 Hz.

There are three categories of movement sensors.

- Seismometers, made with a complex mechanism, is designed for low frequency measurements. The disadvantage is their big size and their fragility.
- Geophones, made with a magnet in a coil. They are optimised for low frequencies (4-400Hz). These sensors are generally used to measure seismic waves or vibrations on industrial machines.
- Accelerometers, made to measure acceleration amplitudes rather than movement waves. They can be built into integrated circuits.

In this thesis, geophones sensors are used because they are smaller, more practical and less fragile than seismometers and more performant than accelerometers for seismic measures.

Three sensor are used to measure the three axis.

2.2 Borehole

The aim of this “seismic borehole sensor” is to provide a constant monitoring of seismic waves activity, and reveal the earthquake movements for general seismic database.

The new seismic sensor is designed to make measurements in boreholes. This is a static measure; the sensor is physically placed at the bottom of the borehole and left there for many years.

Borehole seismic measurements provide precise values (less signal noise) and quicker seismic results than earth surface sensors. This is because with depth there is more rocks and a bigger density that bring a better signal.

3. Environment

These are the constraints due to depth in a borehole are:

- High temperature
- Dust and water
- High pressure
- Size constraints
- Power supply and data transfers

The general geothermal average gradient is about 25 [°C/km] (Analog Device, technical article MS-2707).

For this thesis, environment values were given. The first variant has an environment temperature $T_{nominal}$ = 150 [°C] and a maximal environment temperature of T_{max}=180 [°C]. The maximal depth is 3 [km] long and the pressure is P=24 [bar]. The second variant has an environment temperature $T_{nominal}$ = 75 [°C] and a maximal environment temperature of T_{max}=100 [°C]. The maximal depth is 1km long and the pressure is P=24 [bar].

III. RESEARCH ON EXISTING SENSOR

1. Overview

1.1 Background

The existing seismic sensor is the "semester" work of three colleagues. Their aim was to develop and create a seismic sensor that measures low frequency movement in 3 directions from the ground or a building. Values are filtered and saved before they are sent to a general server. The server is able to show values of different sensors.

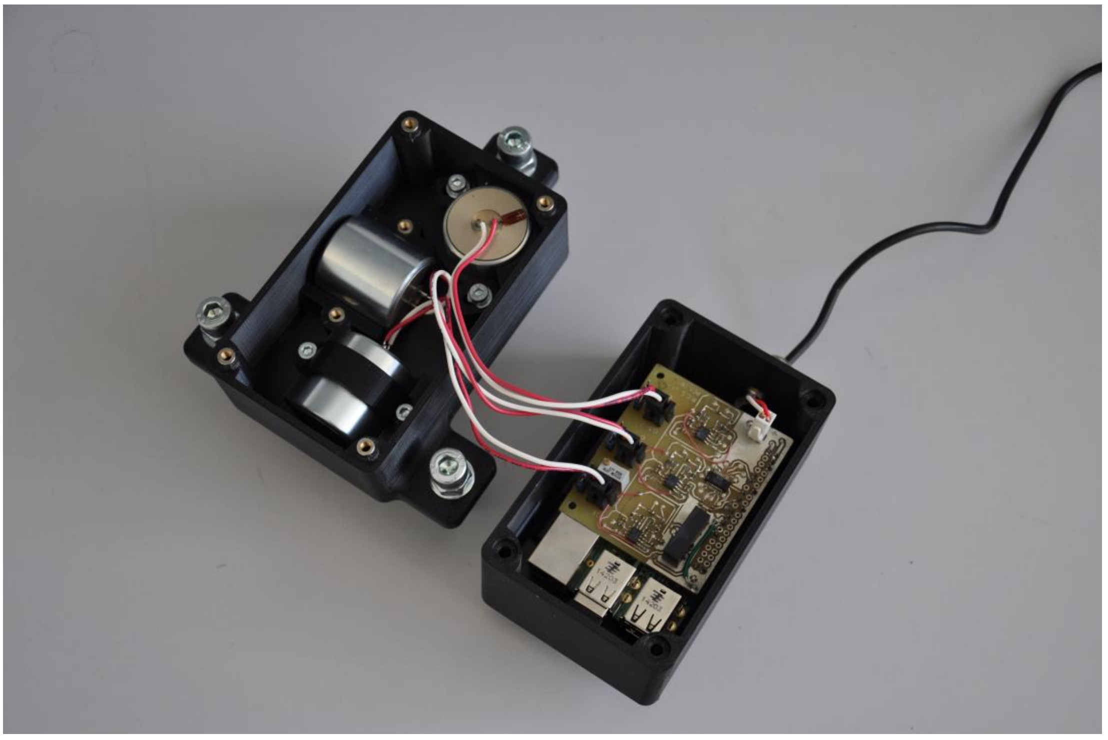


Figure 1 Existing sensor, when it is open

This seismic sensor is made with general electronic components. Three geophones measure linear displacement. The first PCB board contains an analogue signal treatment component, analogue/digital converter component, and power units. The second PCB is a "Raspberry PI B+" microcomputer used to collect measured values and send them to a computer via a wireless connexion. The housing is made from ABS plastic printed on a 3D printer. Choices were made to have a sensor that is able to obtain values, send them, and show them on a screen. Because of lack of time, precision and optimisation are limited.

1.2 Electrical schematics

The following diagram shows the electronic structure. The scheme is in annexe 1.

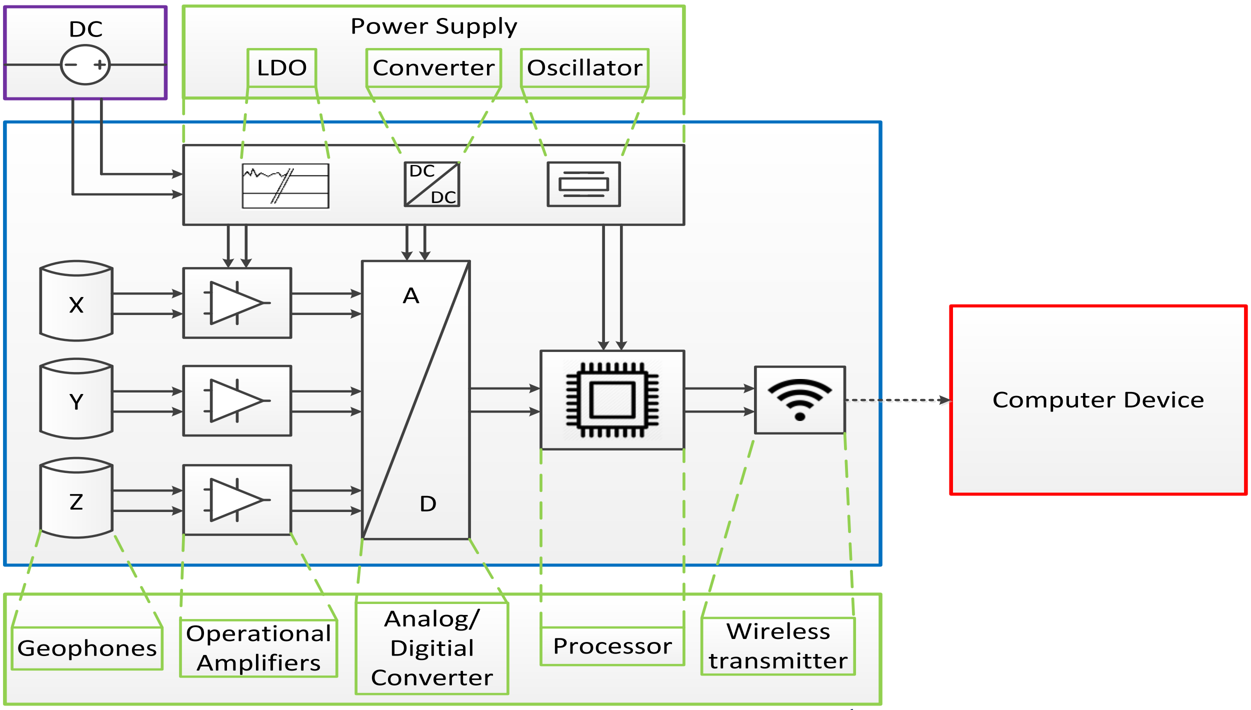


Figure 2 Existing sensor, electronic diagram[1]

For each axis (X, Y and Z), the input signal coming from the geophone goes to a fully differential operational amplifier and is then filtered. All three signals are then digitised through an analogue/digital converter. With a SPI interface, measured data are transferred to the "Raspberry PI" processor. The processor sends data wirelessly to the connected server.

The power is supplied by a 5V LDO (Low DropOut regulator) and a DC/DC converter that creates a -5V. An oscillator is also needed for the sampling frequency of the AD converter.

The components on the PCB are represented on the following picture.

1.3 Thermal characteristics

The Table 1 shows the maximal temperature of the used components. Their Datasheets can be found in annexes 4-7.

[1] Inspired by report „Reseau de capteur sismiques“, Thomas Oggier, Yannick Dayer et Fabien Clerc, 04/09/2014

Type	Component name	Maximal temperature [°C]
Geophone	GS-11D	100
Operational amplifier	OPA1632	85
Analogue/digital converter	ADS1254	85
Processor	BCM2835 ARM	85
Wireless device	TEW-648UBM	85
DC/DC converter	TMC 0505D	85
5V LDO	ADP3338	85
Oscillator	TXC 7C	85
Resistor & Capacitor	General SMD	85

Table 1 Existing sensor, maximal temperature of components

The maximal given temperature is that of the components and not that of the environment. More details are explain in the chapter III.1.4.1.

The components on the PCB are represented on the following pictures.

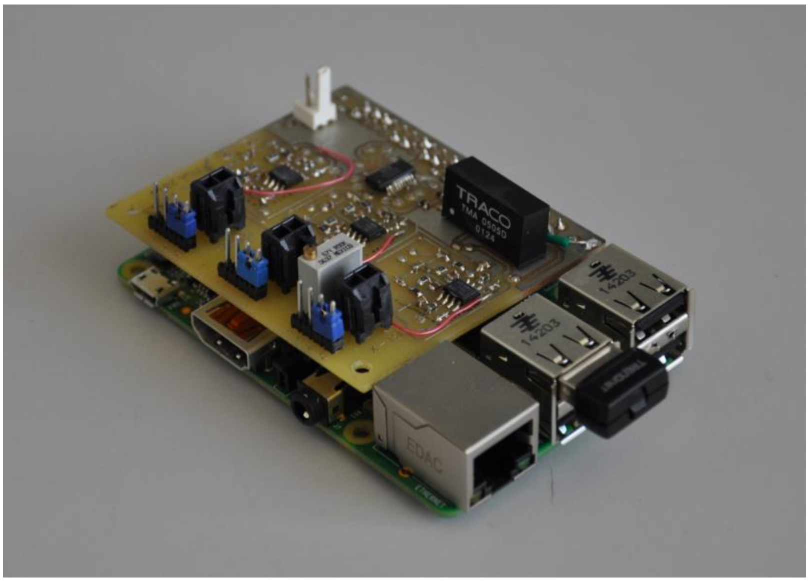


Figure 3 Real PCB of the existing sensor

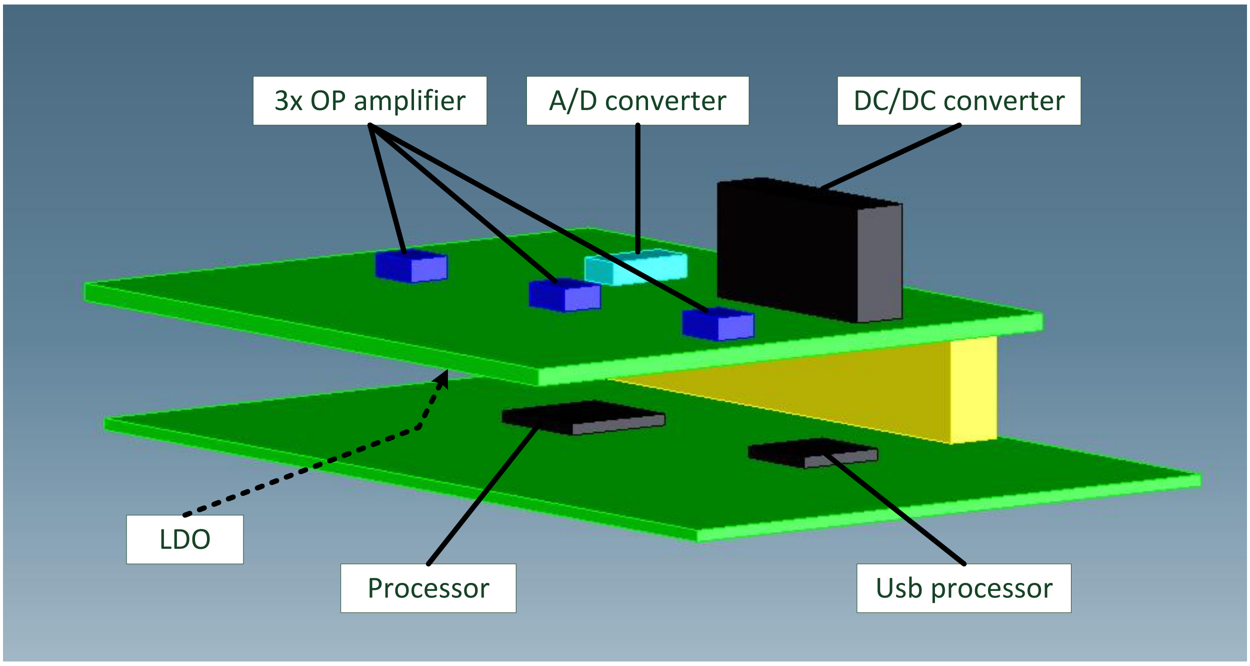


Figure 4 Simplified PCB of the existing sensor

1.4 Power dissipation

The heat source value of each component is called power dissipation. It's related to the losses of components due to their efficiency. Power dissipation value is needed to calculate the temperature that every component reaches.

1.4.1 Temperature of components

The "thermal flow resistive diagram" is a way to know the temperature of components. It can be calculated using the value of power dissipation, thermal resistivity and environment temperature.

In general, a representation of the thermal flow is made in correlation with an electrical circuit. The correlations are the followings:

Power dissipation ~ Current	Pd [W] ~ I
Delta temperature ~ Voltage	$\Delta\theta$ [°C] ~ U
Thermal resistor ~ $\frac{1}{Thermal\ condictivity}$ = resistor	$R = \frac{\Delta\theta}{Pd} = \frac{1}{\lambda} = \left[\frac{°K}{W}\right]$

The Figure 5 shows the thermal flow diagram of a component into a housing. This representation will help to visualise the heat flow from a component, which dissipates its heat to the environment.

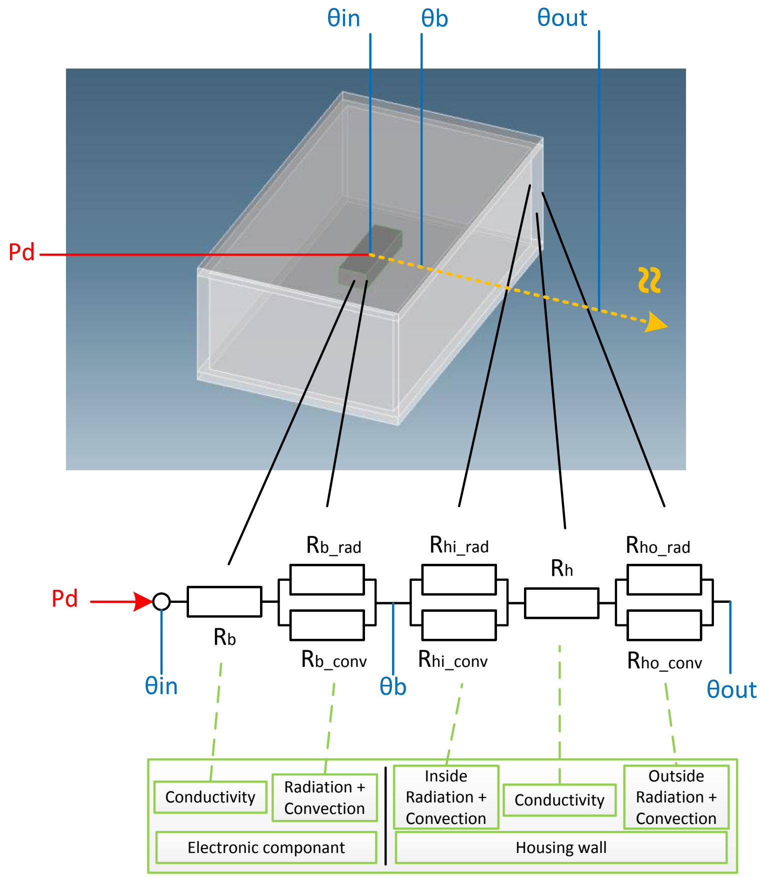


Figure 5 Thermal flow from an electronic heat source through a housing to environment

To simplify comprehension, only one direction of the thermal flow is showed on Figure 5. To find the temperature of the component θ_{in} and inside the housing θ_b, its use the power dissipation value, the thermal resistances and the environment temperature. A computer works the same way, but it calculates the whole environment to have more exact values.

Every material has an inner thermal resistance (opposite of thermal conduction). Unit are in $[W{*}mm^{-1}{*}K^{-1}]$. For example, ABS = 0,15-0,3 $[W{*}mm^{-1}{*}K^{-1}]$ and Epoxy = 0,3-10 $[W{*}mm^{-1}{*}K^{-1}]$.

On every surface there is convection and radiation, always represented in parallel.

Here is usual convection[2] in $[W{*}m^{-2}{*}K^{-1}]$ at 20 [°C] between

- A body and free air 2-25
- A body and a liquid 50-1'000
- A body and a forced air flow 25-250
- A body and a forced liquid flow 50-20'000
- A body and a changing phase fluid 2'500-100'000

[2] Data from script “Ansys tutorial, Für das Analyse-System Steady State Thermal und Komponentensystem Icepak” Prof. Dr. Detlef Redlich, 2011.

In this thesis, components have free air convection. The value is approximated at 5 [W*m^-2*K^-1].

Radiation value is between 0 and 1, and is unitless. When there is no radiation, ε=0. A body with maximal radiation is called a black body, and emission coefficient is nearly ε=1.

Material	Emission coefficient
Epoxy	0,79
Copper	0,3
Gold	0,26
PVC	0,97
Solder mask	0,8

Table 2 Average emission coefficient for different materials in temperature of 22-150 [°C].[3]

With Radiation constant, Stefan-Boltzmann constant ($\sigma=5{,}67*10^{-8}$ [W*m^-2*K^-4]), and the environment temperature, the surface conductivity can be calculated.

$$H_{radiation} = 4 \cdot \frac{\varepsilon}{\varepsilon-1} \cdot \sigma \cdot T_{ambient}{}^{3} \quad [W{*}m^{-2}{*}K^{-1}]$$

Equation 1 [4]

Conductivity, convection and radiation are dependent on the environment temperature. For example, equation 2 and 3 show that a ceramic component (ε=0.9) will have a surface conductivity of 51,3 [W*m^-2*K^-1] at 20 [°C] and 154,5 [W*m^-2*K^-1] at 150 [°C].

$$H_{radiation,20} = 4 \cdot \frac{0.9}{1-0.9} \cdot \sigma \cdot 293^3 = 51{,}3 \quad [W{*}m^{-2}{*}K^{-1}]$$

Equation 2

$$H_{radiation,150} = 4 \cdot \frac{0.9}{1-0.9} \cdot \sigma \cdot 423^3 = 154{,}5 \quad [W{*}m^{-2}{*}K^{-1}]$$

Equation 3

Radiation increases exponentially with the ambient temperature. Equation 4 and 5 are with the same temperature but a smaller emission coefficient (ε=0.5).

$$H_{radiation,20} = 4 \cdot \frac{0.5}{1-0.5} \cdot \sigma \cdot 293^3 = 5{,}7 \quad [W{*}m^{-2}{*}K^{-1}]$$

Equation 4

$$H_{radiation,150} = 4 \cdot \frac{0.5}{1-0.5} \cdot \sigma \cdot 423^3 = 17{,}2 \quad [W{*}m^{-2}{*}K^{-1}]$$

Equation 5

[3] Data from script “Ansys tutorial, Für das Analyse-System Steady State Thermal und Komponentensystem Icepak” Prof. Dr. Detlef Redlich, 2011.
[4] Equation from script „Systemes Energetiques - Thermodynamique“ Michel Bonvin et Jessen Page, 2015

With an emission coefficient (ε=0.5), the surface conductivity is 5,7 [W⁎m^{-2}⁎K^{-1}] at 20 [°C] and 17,2 [W⁎m^{-2}⁎K^{-1}] at 150 [°C]. In comparison, the radiation has a bigger surface conductivity than convection.

1.4.2 Heat sources

For the simulation, not all electronic components are taken into consideration. The analysis is only made with the main heat sources, such as the operational amplifier, the analogue/digital converter, the processor and the power supply.

In equation 6, a resistor of 1 [kΩ] with 5 [V] alimentation has only 25 [mW] of power which is 100 [%] power dissipation (active component).

$$P_d = P = \frac{U^2}{R} = \frac{5^2}{1000} = 25\ [mW]$$

Equation 6

Pd = 25 [mW] is an insignificant small value, it doesn´t have a big impact on the thermal analysis. Because all the resistors produce less power than 25 [mW], these have not been taken into consideration. Capacitors are passive components, so they don't have any power dissipation.

1.4.3 Power dissipation on existing sensor

In basic components, power consumption and power dissipation are not necessarily in the datasheet. This is the case for components in Table 1.

The power consumption of each component can be found by simulating the circuit. Unfortunately no corresponding components (OPA1632 and ADS1254) were working on Orcad-Pcad (the software employed). The LME49724 is an alternative operational amplifier that worked on Pcad, but power results were false (10 MW).

The last solution for this existing sensor is to measure on the PCB the voltage and the current, where it's possible, to define a power consumption. A percentage of this consumption is approximated as dissipation power.

Power measurement and estimation :	Pnom [mW]	Pmax [mW]	% off Power dissip.	Pdiss,min [mW]	Pdiss,max [mW]
Power green PCB	1342,74	1542,1			
Processor	850	976,2	90%	765,0	878,6
USB-processor	392,74	465,9	90%	353,5	419,3
Power yellow PCB	977,92	997,3			
3 OPamplifier	780	789,4	80%	624,0	631,5
1 OPamplifier	260	263,1	80%	208,0	210,5
AD converter	100	105,0	90%	90,0	94,5
DC/DC Converter	97,92	102,8	28%	27,4	28,8

Table 3 Existing sensor, power consumption and dissipation estimation

All the components are welded so it is only possible to measure the current and the power of each PCB. These measured values are in red. This power is divided between the components on the PCB, orange values (approximation). According to the efficiency of each component an approximation of power dissipation is made. These values are adjusted with simulation results to make them correspond with real temperature measurements.

2. Thermal measurements

Temperature measurements are made on the existing sensor. The values of major heating sources are measured. These temperatures are useful to compare and certify that simulation results are correct.

Three different measurement units are used.

Figure 6 Temperature measurement devices

Summary of the thermal measurement campaign:

1. Values measured with resistive sensor and thermal paste
2. First infrared camera values, only maximal values can be measured
3. Second infrared camera, maximal and average values. Measure when PCB is in and out of the housing.

4. Processor temperature with PT100 sensor and thermal paste. When PCB is in the housing.

5. Comparison between obtained maximal values

6. Comparison between average and maximal values (second camera)

2.1 Resistive sensor

The “Ahlborn Almemo” unit is a data logger that works with different kind of sensors. Data logger values can be seen on a computer.

The first contact probe has been used to measure the environment temperature and small components. The flat probe has been used for the Processor only, because other components are too small. Both sensors have a precision of +/- 0,1 [°C].

The following table shows the maximal measured temperature. This is made with PCB out of the housing. Other components are not accessible for thermal measures. Thermal paste is used to improve the contact between the sensor and the component. Even though thermal paste is present, error can be due to lack of the positioning precision and the thermal paste resistance.

	PT100 Contact Probe ZA 9030 FS1	PT100 Contact Probe ZA 9030 FS1	Delta T (with ambient)
	[°C]	[°C]	[°C]
Ambient	**22,1**		
OPA X		44,7	22,6
OPA Y		45,8	23,7
OPA Z		44,6	22,5
AD		41,1	19
TRACO		40,9	18,8

Table 4 Measuring results of Almemo sensors

The Table 5 shows the temperature of the processor when the PCB is in a closed housing. The measure is made with thermal paste. The probe is the “PT100 Flat probe ZA 9030 FS1”.

	PT100 Contact Probe ZA 9030 FS1	PT100 Flat Probe ZA 9030 FS1	Delta T (with ambient)
	[°C]	[°C]	[°C]
Ambient	**25,9**		
Processor		57,5	31,6

Table 5 Processor temperature when running in closed housing

2.2 Infrared camera

The infrared wavelength zone is from 700 nm to 1mm (visible is from 380-710 nm). Infrared cameras are designed to measure wavelengths in this range. Infrared radiation is treated and represented in human visible spectrum. A body emits and absorbs infrared wavelengths depending on its temperature and its surface material. By knowing the body surface material (coefficient of emissivity, epsilon ε) it is possible to know the temperature of the body (see chapter III.1.4.1 page 9).

The two following chapters present infrared camera pictures with thermal results of the existing sensor. Here is a list of source of errors in the thermal measurements:

- The set environment temperature is probably not exact
- The emission coefficient set on component zone is set as ε=0.6 or ε=0.7. It is not exact. It's should be around 0.8< ε <0.9 for plastic or ceramic black components.
- Measures have not been taken in darkness. Environment reflexion can distort values.

2.2.1 Camera 1

The Flir infrared camera is the first camera used.

All values are with PCB out of the housing. In Figure 7 and Figure 8 are examples of thermal infrared acquisition with the Flir camera. The emission coefficient is set as ε=0.7.

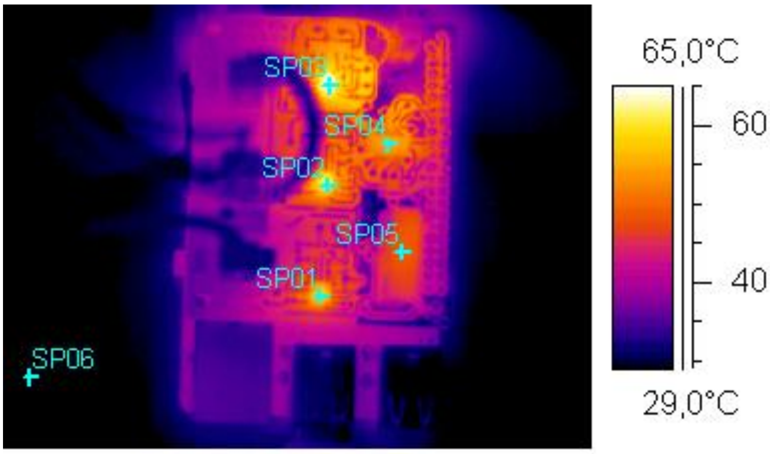


Figure 7 Infrared thermal acquisition with Flir camera, with measuring points. ε=0.7

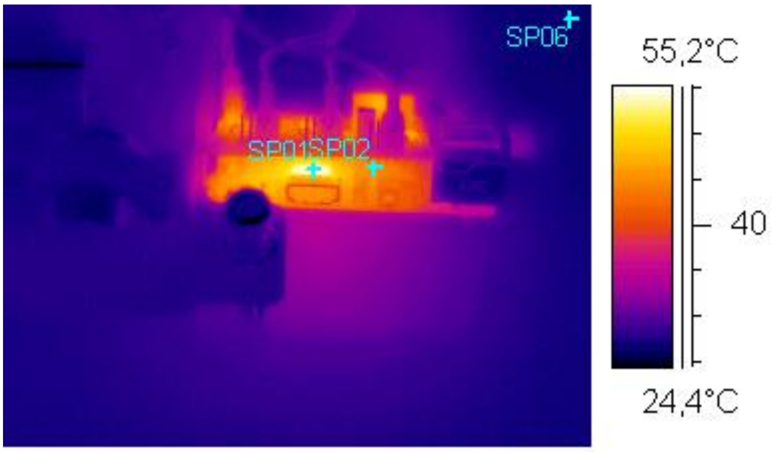


Figure 8 Processor infrared thermal acquisition with Flir camera, with measuring points. ε=0.7

Table 6 shows the measuring results.

Maximal temperature	Measuring points	Emission coefficient	Infrared Camera Flir SC500	Delta T (with ambient)
			[°C]	[°C]
Ambient			25,8	
OPamp X	Figure 7_SP01	0,7	58,9	33,1
OPamp Y	Figure 7_SP02	0,7	61,9	36,1
OPamp Z	Figure 7_SP03	0,7	66,2	40,4
AD conv.	Figure 7_SP04	0,7	54,8	29
DC/DC conv.	Figure 7_SP05	0,7	48,7	22,9
Geoph. X		0,7	29,9	4,1
Geoph. Y		0,7	25,8	0
Geoph. Z		0,7	25,8	0
Processor	Figure 8_SP01	0,7	55,4	29,6
Usb processor	Figure 8_SP02	0,7	45	19,2

Table 6 Measuring results of Flir camera

Geophones are not heat sources, values are incorrect because of their steel housing. The steel has an emission coefficient of ε=0,3-0,5 so it disrupts the infrared sensor.

2.2.2 Camera 2

“JenOptic” “VarioCAM” camera is a more recent camera and more powerful than the Flir camera. It’s more practical (runs on battery), it has a better resolution and functionality. The lens can be changed, and the software is powerful. Here is a picture during measurements.

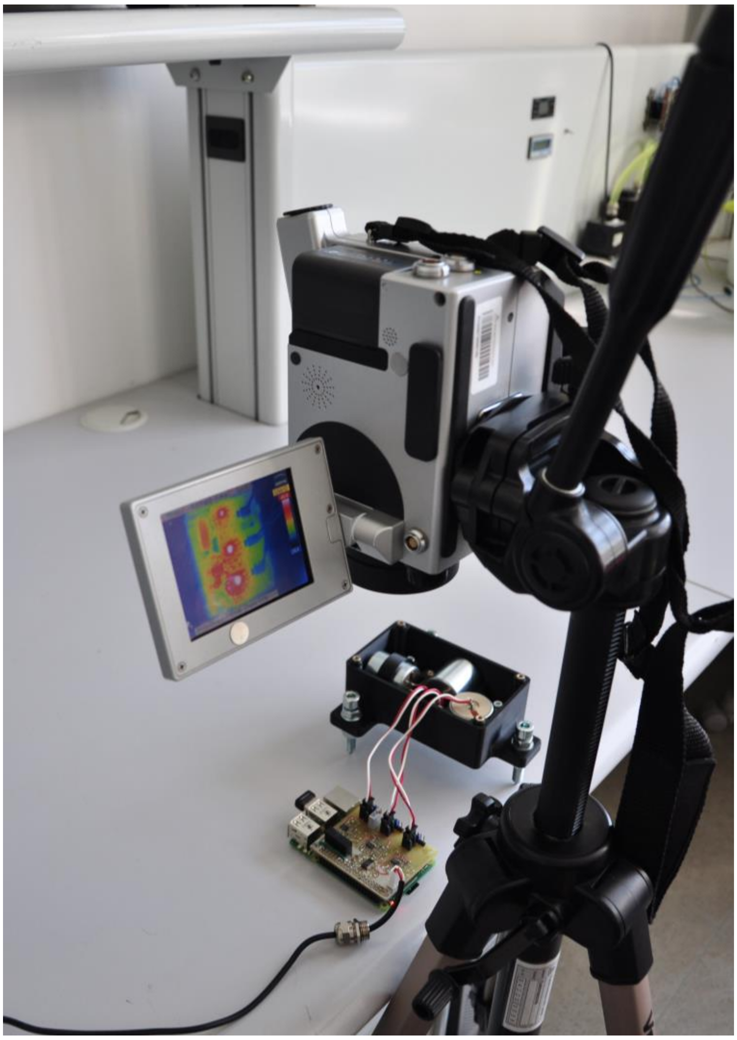


Figure 9 JenOptic VarioCAM during measurements

The Figure 10 and Figure 11 are infrared pictures taken with the JenOptic VarioCAM camera. The general emission coefficient is ε=0.9. The plastic housing of the electrical components has an emission coefficient of ε=0.7, so each component’s zone is set to this value. In Figure 11 components are not perpendicular to the camera, a smaller emissivity of ε=0.6 is supposed.

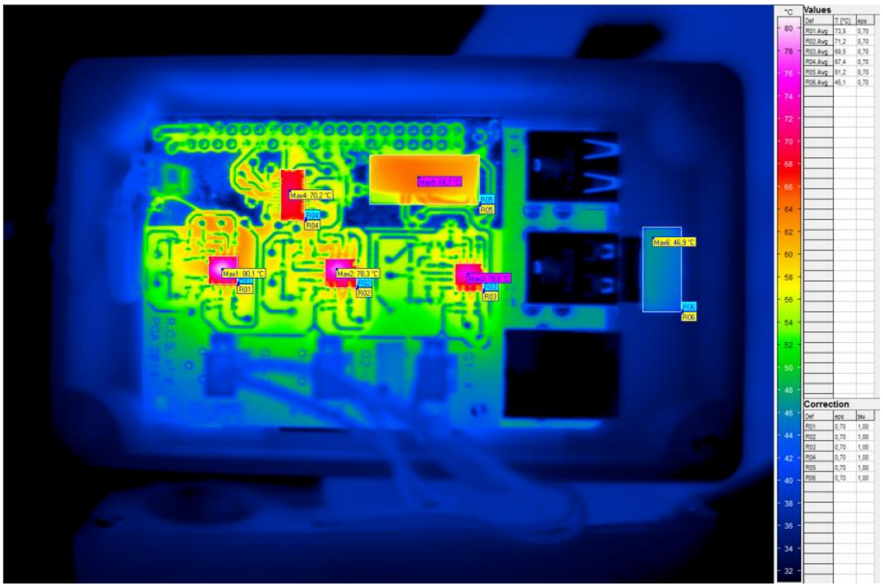


Figure 10 IR picture with VarioCAM, of existing sensor PCB just after being used in closed housing

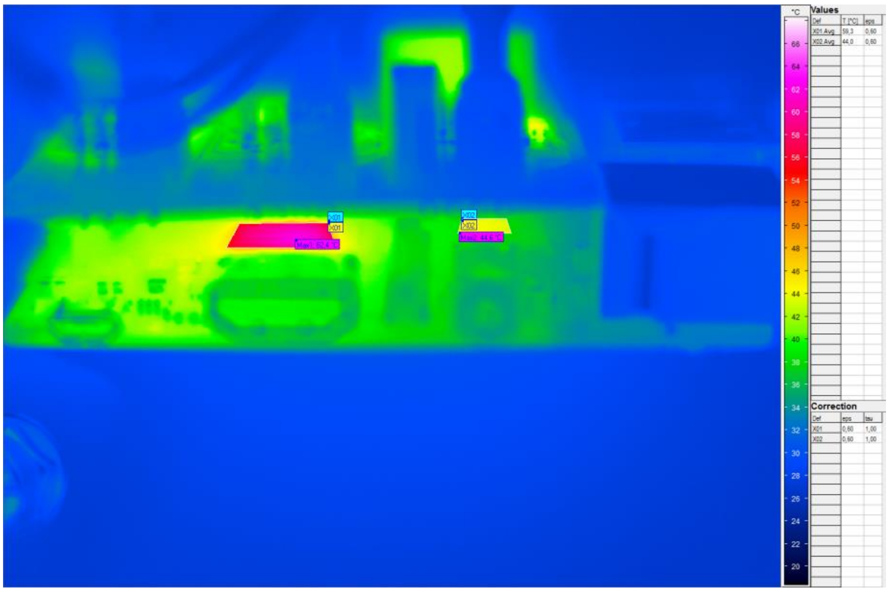


Figure 11 IR picture with VarioCAM, Processor and USB processor when PCB running out of the housing

The following table shows the maximal temperature of components. With or without the housing, the delta T value is nearly the same (absolute error < 4,4°C).

			PCB outside housing		PCB inside housing		
Maximal temperature	Measuring points	Emission coefficient	Infrared Camera VarioCAM Obj. 1.0/30	Delta T (with ambient)	Infrared Camera VarioCAM Obj. 1.0/30	Delta T (with ambient)	Delta T (with inside housing temp)
			[°C]	[°C]	[°C]	[°C]	[°C]
Ambient			**25**		**25,5**		
Inside housing			-	-	**37,5**	**12**	
OPamp X	_R03	0,7	61,9	36,9	75,8	50,3	38,3
OPamp Y	_R02	0,7	63,5	38,5	78,3	52,8	40,8
OPamp Z	_R01	0,7	63,2	38,2	80,1	54,6	42,6
AD conv.	_R04	0,7	53,8	28,8	70,2	44,7	32,7
DC/DC conv.	_R05	0,7	52	27	64,7	39,2	27,2
Geoph. X		0,6	28	3	30	4,5	-7,5
Geoph. Y		0,6	28	3	30	4,5	-7,5
Geoph. Z		0,6	28	3	30	4,5	-7,5
Processor	_X01	0,6	62,4	37,4	Can't be measured		
Usb processor	_X02	0,6	45	20	Can't be measured		
LDO		0,7	73,7	48,7	Can't be measured		
Wifi device		0,7	35,4	10,4	46,9	21,4	9,4

Table 7 Maximal temperature measured with VarioCAM

Figure 12 shows a thermal preview of the housing. This shows that temperature is hotter in the housing. The housing has a bad thermal conductivity, because it does not have the same global temperature.

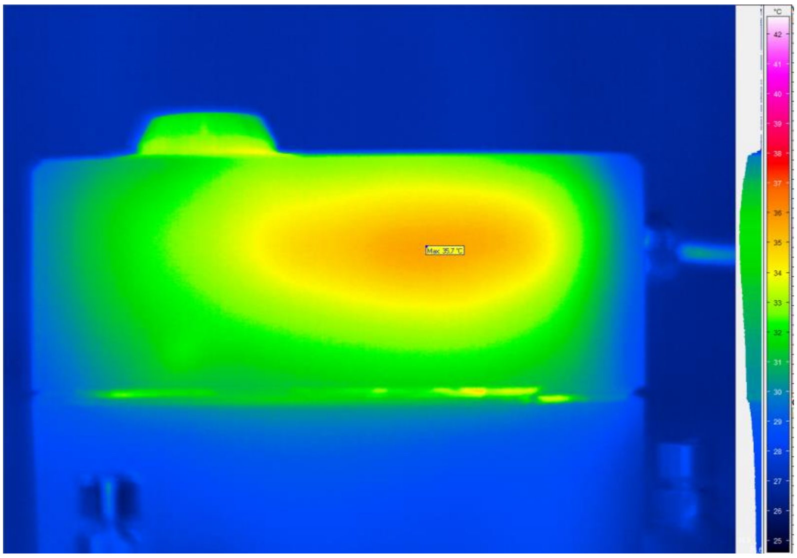


Figure 12 IR picture with VarioCAM, Preview of the housing temperature when sensor is working. ε=0.9

On the datasheet, the maximal operating temperature corresponds to the temperature of the package and not the Die. To compare the datasheets with the IR pictures, the average temperature of component's zone (on IR picture) is used. Average measured temperatures are in Table 8. These two temperatures correspond also to the results given by simulation.

			PCB outside housing		PCB inside housing		
Average temperature	Measuring points	Emission coefficient	Infrared Camera VarioCAM Obj. 1.0/30	Delta T (with ambient)	Infrared Camera VarioCAM Obj. 1.0/30	Delta T (with ambient)	Delta T (with inside housing temp)
			[°C]	[°C]	[°C]	[°C]	[°C]
Ambient			**25**		**25,5**		
Inside housing			-	-	**37,5**	**-21,4**	
OPamp X	_R03	0,7	55,7	30,7	69,4	43,9	31,9
OPamp Y	_R02	0,7	56,8	31,8	72,3	46,8	34,8
OPamp Z	_R01	0,7	56,9	31,9	72,8	47,3	35,3
AD conv.	_R04	0,7	53,8	28,8	67	41,5	29,5
DC/DC conv.	_R05	0,7	46,9	21,9	63	37,5	25,5
Geoph. X		0,6	26	1	30	4,5	-7,5
Geoph. Y		0,6	26	1	30	4,5	-7,5
Geoph. Z		0,6	26	1	30	4,5	-7,5
Processor	_X01	0,6	59,3	34,3	64,1	38,6	26,6
Usb processor	_X02	0,6	44,6	19,6	Can't be measured		
LDO		0,7	56,5	31,5	Can't be measured		
Wifi device		0,7	33,5	8,5	44,1	18,6	6,6

Table 8 Average temperatures measured with VarioCAM

2.3 Results analysis

Table 9 is a comparison of maximal measured values from Alhlborn, Flir, JenOptic sensors. This is when the PCB is out of the housing.

	Delta T (with ambient)			
Difference	Ahlborn sensors	Infrared Camera Flir SC500	Infrared Camera VarioCAM Obj. 1.0/30	Average
	[°C]	[°C]	[°C]	[°C]
OPamp X	22,6	33,1	36,9	30,9
OPamp Y	23,7	36,1	38,5	32,8
OPamp Z	22,5	40,4	38,2	33,7
AD conv.	19	29	28,8	25,6
DC/DC conv.	18,8	22,9	27	22,9
Geoph. X	-	4,1	3	3,6
Geoph. Y	-	0	3	1,5
Geoph. Z	-	0	3	1,5
Processor	-	29,6	37,4	33,5
Usb processor	-	19,2	20	19,6
LDO	-	-	48,7	48,7
Wifi device	-	-	10,4	10,4

Table 9 Comparison between maximal sensors values, when PCB is out of housing.

Table 9 shows that there is a big difference between the sensors. To make improvements, the results should be studied and the specifications (emission coefficient, dissipation power) adjusted.

With the JenOptic VarioCAM infrared values, the difference between maximal and average temperature is approximately 6 [°C].

	PCB outside housing			PCB inside housing		
Infrared Camera VarioCAM Obj. 1.0/30	Average temperature	Maximal temperature	Δ T	Average temperature	Maximal temperature	Δ T
	[°C]	[°C]	**[°C]**	[°C]	[°C]	**[°C]**
Ambient	25	25		25,5	25,5	
Inside housing	-	-		37,5	37,5	
OPamp X	55,7	61,9	**6,2**	69,4	75,8	**6,4**
OPamp Y	56,8	63,5	**6,7**	72,3	78,3	**6**
OPamp Z	56,9	63,2	**6,3**	72,8	80,1	**7,3**
AD conv.	53,8	53,8	**0**	67	70,2	**3,2**
DC/DC conv.	46,9	52	**5,1**	63	64,7	**1,7**
Geoph. X	26	28	**2**	30	30	**0**
Geoph. Y	26	28	**2**	30	30	**0**
Geoph. Z	26	28	**2**	30	30	**0**
Processor	59,3	62,4	**3,1**	Can't be measured		
Usb processor	44,6	45	**0,4**	Can't be measured		
LDO	56,5	73,7	**17,2**	Can't be measured		
Wifi device	33,5	35,4	**1,9**	44,1	46,9	**2,8**

Table 10 Difference between maximal and average temperature of components

Inside the housing the temperature increase is of 12 [°C]. The LDO is the hottest component. Operational amplifier and the processor get quite high temperatures because they are big heat sources for their size (chapter III.1.4).

3. Simulations

To make simulations, Ansys software are used. Ansys is a factory who produces software for multiphysics analyses.

Ansys "Workbench" offers three software: "Thermal static analyse", "Thermal transient analyse" and "Flow analyse". In this case "Thermal transient analyse" is not used because the sensor is in high stable temperatures for many years. It means it's a static simulation.

Finite Element Method (FEM) enables the simulation of a structure under various stresses by subdividing the structures in many finite elements. The software calculates every finite element characteristics and its influences to the following finite element. This is made with equations according to the demanding characteristics (Strength, thermal, Magnetics, etc.).

The following simulations (existing sensor only) are made with a 25 [°C] environment temperature in free air convection.

4. Thermal static simulations

Thermal static simulation is just an add-on software of Ansys Workbench called “Stationary state simulations”. It is used to simulate the temperature of elements in an environment. The object is imported, meshed, and then simulated with the given mechanical, thermal, environment characteristics.

Figure 13 and Figure 14 show the results of stationary state simulation.

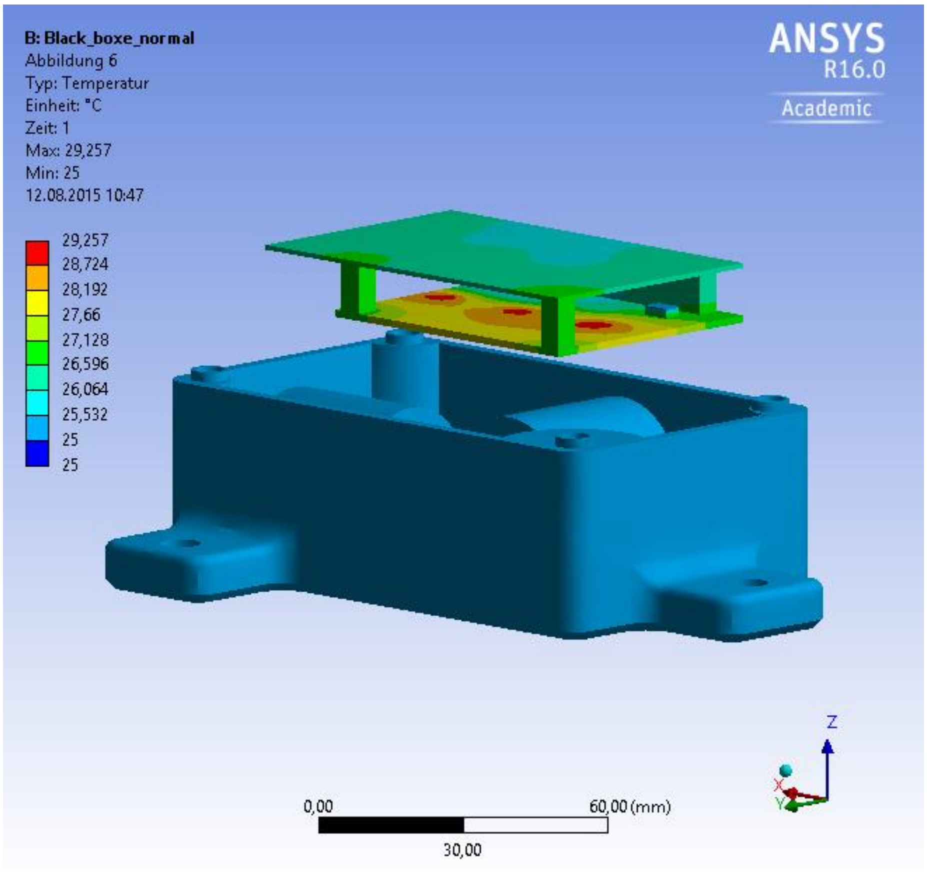


Figure 13 Result of stationary state simulation, PCB into housing (top removed for better view)

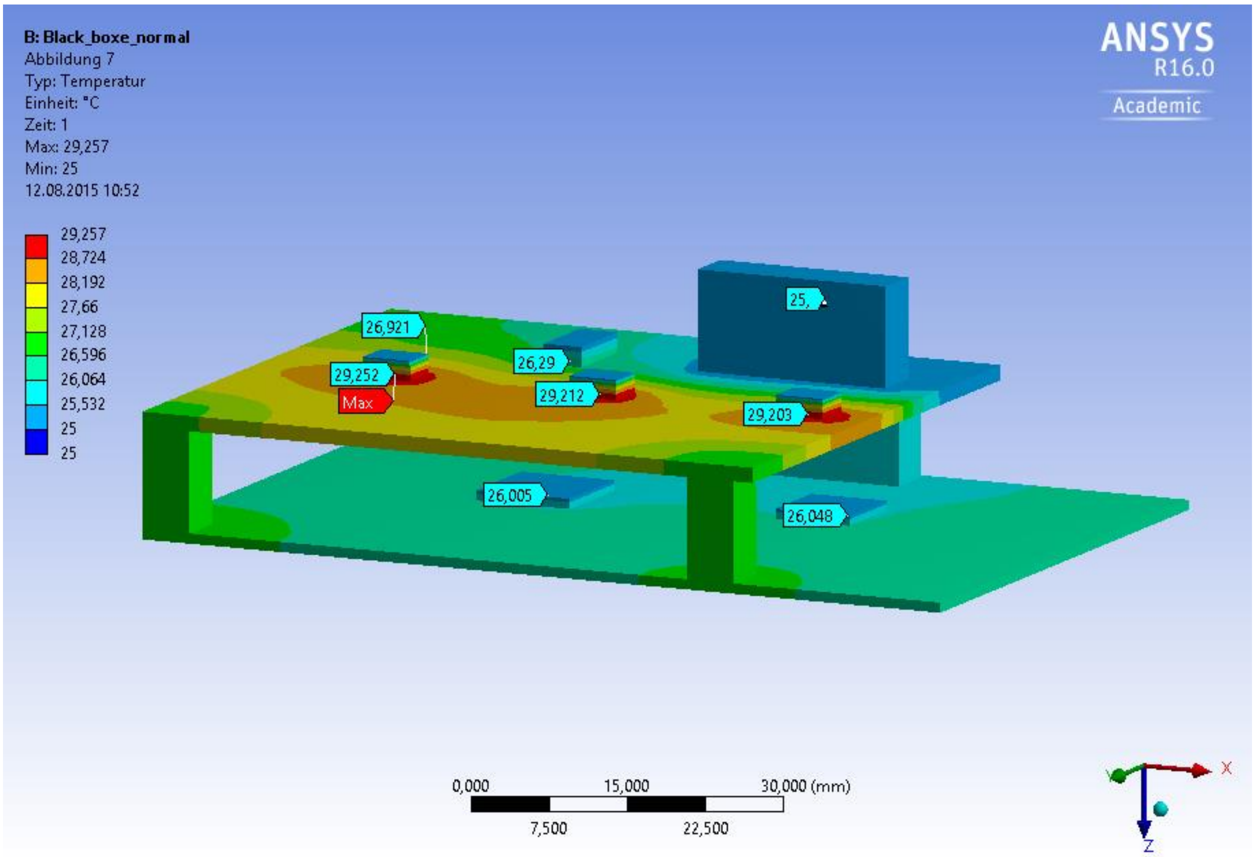


Figure 14 Result of stationary state simulation, PCB into housing (not represented) with component values [°C]

The maximal temperature is 29.3 [°C]. All temperature values are too small in comparison with the real measured temperatures shown in Table 8 (Maximal temperature = 72.3 [°C]).

Because of false results, this simulation method is excluded, leaving the fluent simulation.

On complex designs, such as the existing housing, this stationary state simulation requires the perfect convection and radiation values for each side of components. These values are unknown; they were attributed with general estimations, that's why results are not reliable.

5. Flow simulations

Icepak is a flow software from Ansys. It is designed to have quick precise results, but it cannot be interconnected to other multiphysics software. Icepak geometry can be built on or imported. A multi-level-hex-dominant method creates the mesh. The geometry can be simulated with radiation and specific environments (such as space environments) in static or dynamic. The results give object temperature, air temperature/direction/velocity. Copper resistive losses can be calculated. Macros can also simulate components behaviour such as Peltier elements.

The difference with "thermal static simulation" is that the air in the cabinet is meshed. With the gravity vector, this will allow natural convection to be observed. Iterative method is used to find a total sum of energy (in the cabinet) nearest to zero. This provides a stable balance of heat transfers and stable temperature values.

This method doesn't need exact values of radiation and convection.

5.1 Simplification

Icepak requires simplification of the design. There are different degrees of simplification depending on the complexity of components (1=prism and cylinder, 2=polygon, 3=CAD design). The degree of simplification will influence the mesh resolution.

The following pictures show two simulations made on Stationary state simulation. Figure 15 is made with normal housing, and Figure 16 is made with simplified housing. With the same characteristics, the maximal and components temperatures are the same. This fact proves that simplifying a design gives correct temperatures and errors are negligible.

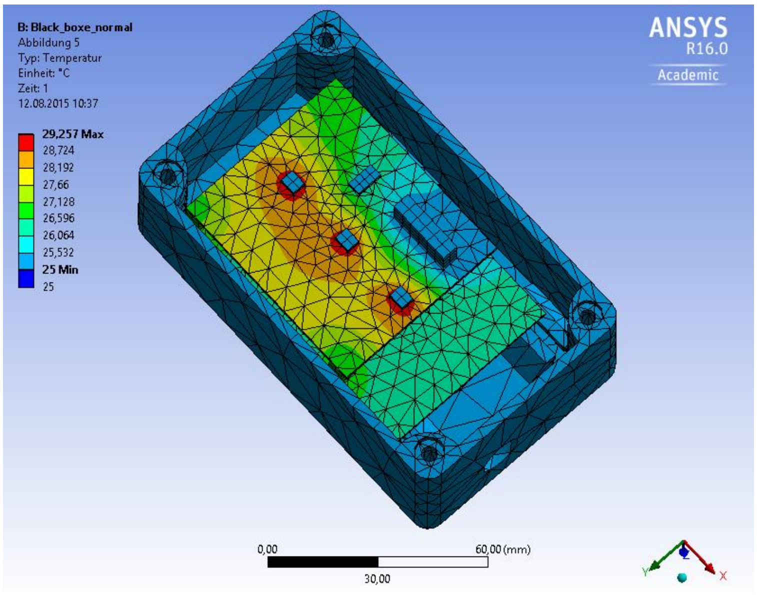


Figure 15 Result of stationary state simulation with normal housing

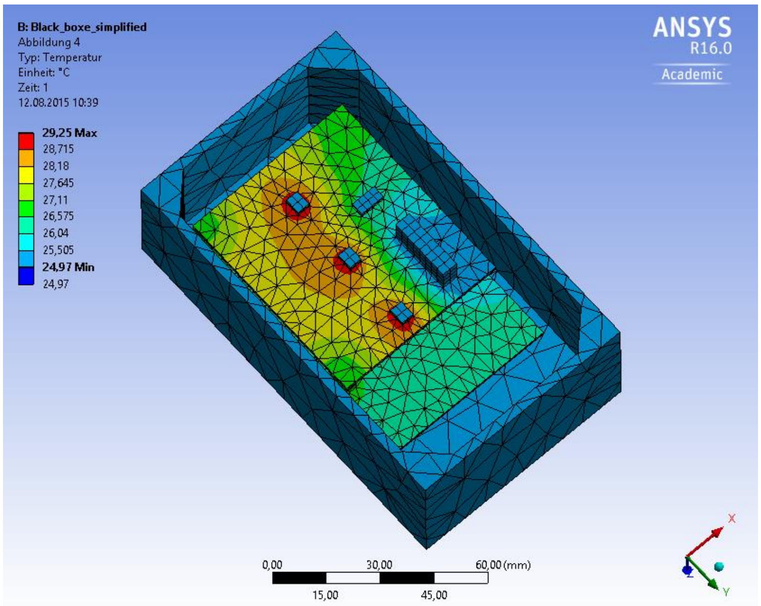


Figure 16 Result of stationary state simulation with simplified housing

5.2 Specifications

The Icepak simulations have these general characteristics:

- Gravity vector is opposite direction of Z axis
- Air has a laminar flow regime
- Pressure is of 1.01325 bar
- Radiation is activated, all objects have a "radiation to all objects" characteristic

Table 11 shows the attributed solid and surface materials of each component. It may not be the exact name. The chosen materials have emissivity and conductivity values that are close to the real components.

Objects	Surface Material		Solid material	
	Name	Emissivity	Name	Conductivity [W*m-1*K-1]
Housing	Plastics-infrared Opaque	0,9	ABS	0,17
Geophones	Steel-polished-surface	0,8	Steel-stainless	14,4
General heat sources (components)	Plastics-infrared Opaque	0,9	Ceramic_material	15
PCB (Raspberry PI)	Plastics-infrared Opaque	0,9	LP2	5,8
PCB (short length)	Plastics-infrared Opaque	0,9	LP1	1,8
Connector	Plastics-infrared Opaque	0,9	Mold_material	0,8
PCB spacers	Steel-polished-surface	0,8	Steel-stainless	14,4

Table 11 Surface and solid material specification for Icepak simulation

5.3 Results

Here are the results of simulating the existing sensor on Icepak software.

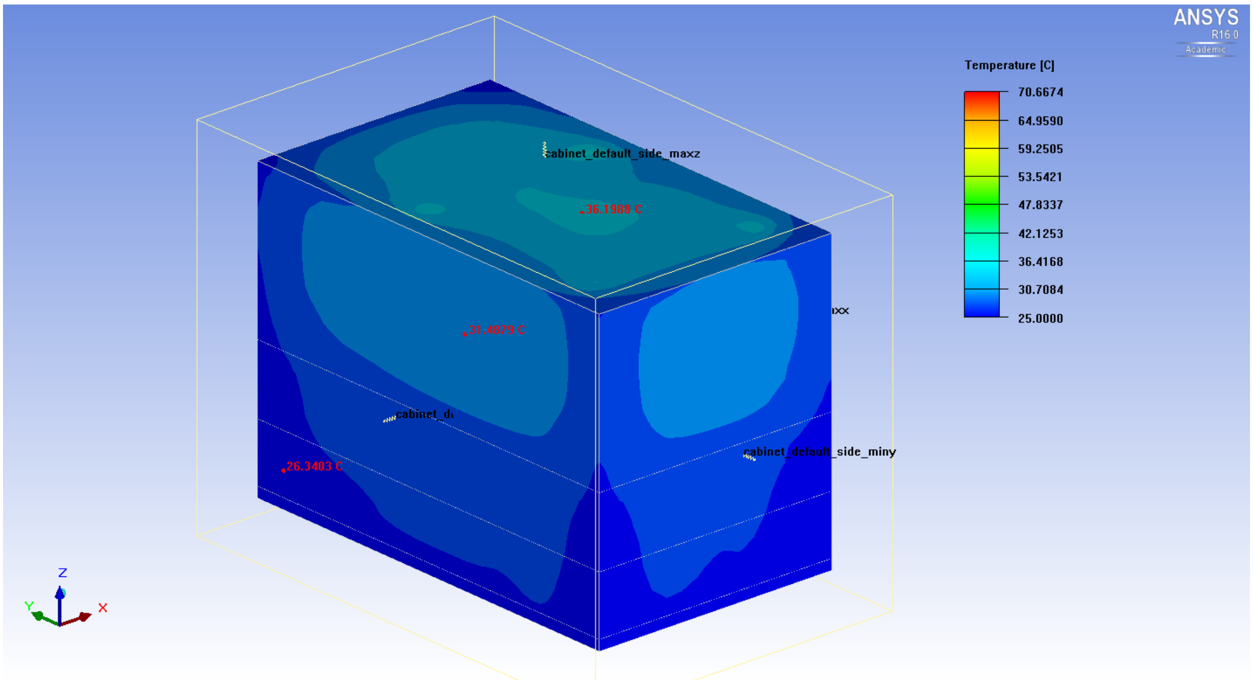


Figure 17 Result of Icepak simulation, housing temperature in open environment

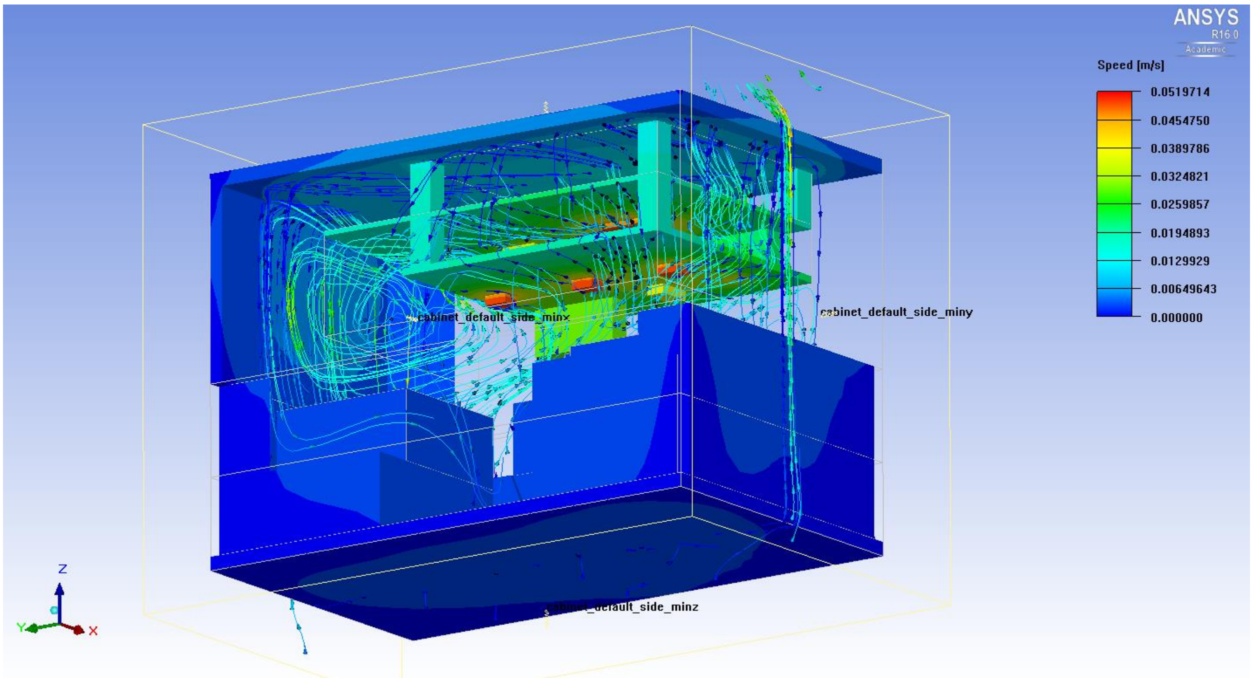


Figure 18 Result of Icepak simulation, air velocity in and out of the housing

Figure 18 and Figure 20 show the plan of the air speed. The velocity of V=0,078 m/s is so small that it doesn’t need to be taken into consideration. This is free air convection.

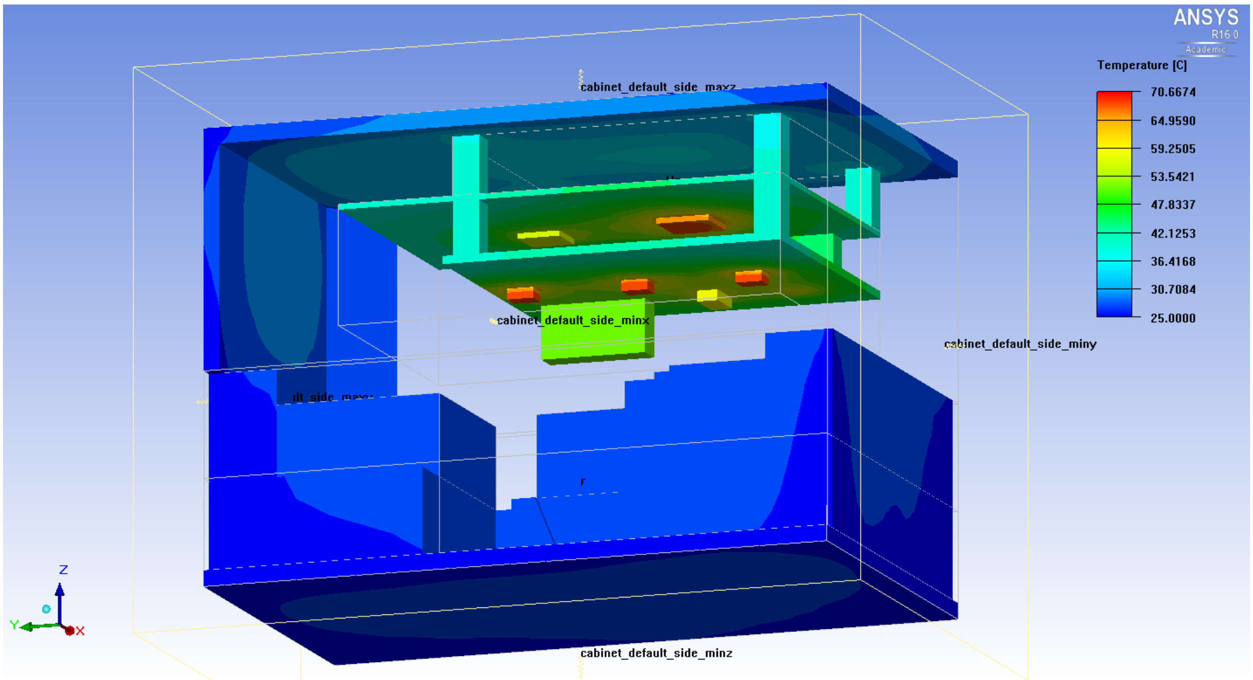


Figure 19 Result of Icepak simulation, components temperatures

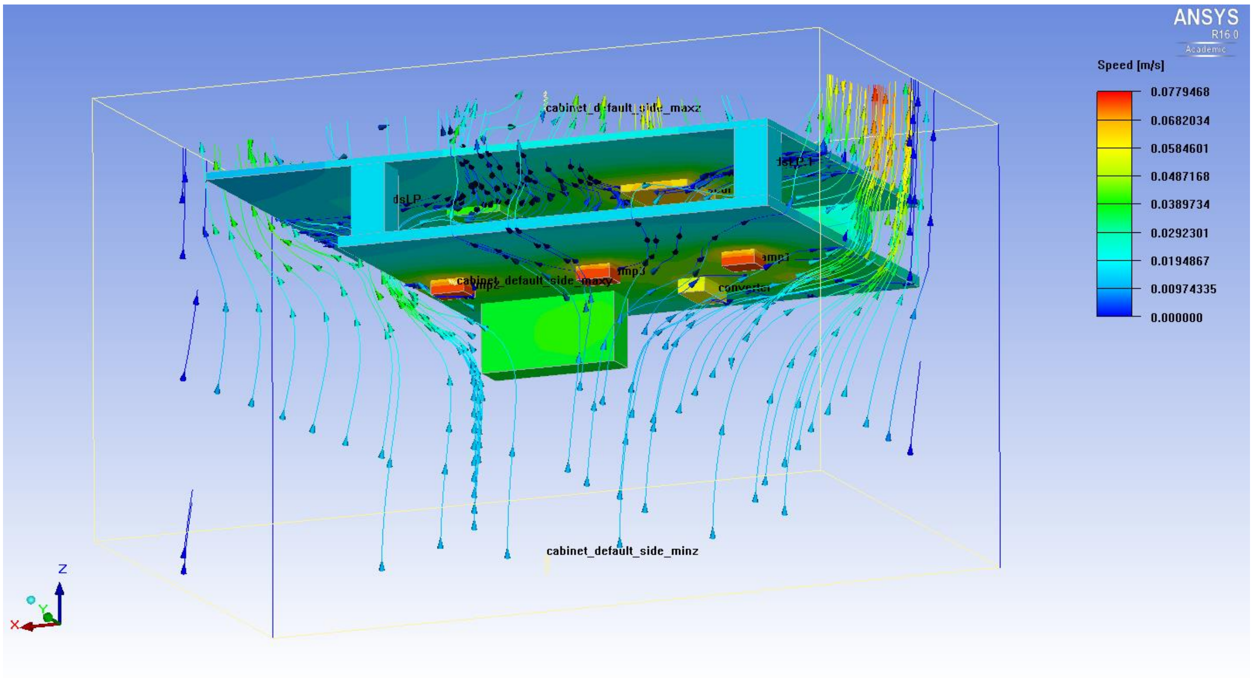


Figure 20 Result of Icepak simulation, PCB without housing, air velocity

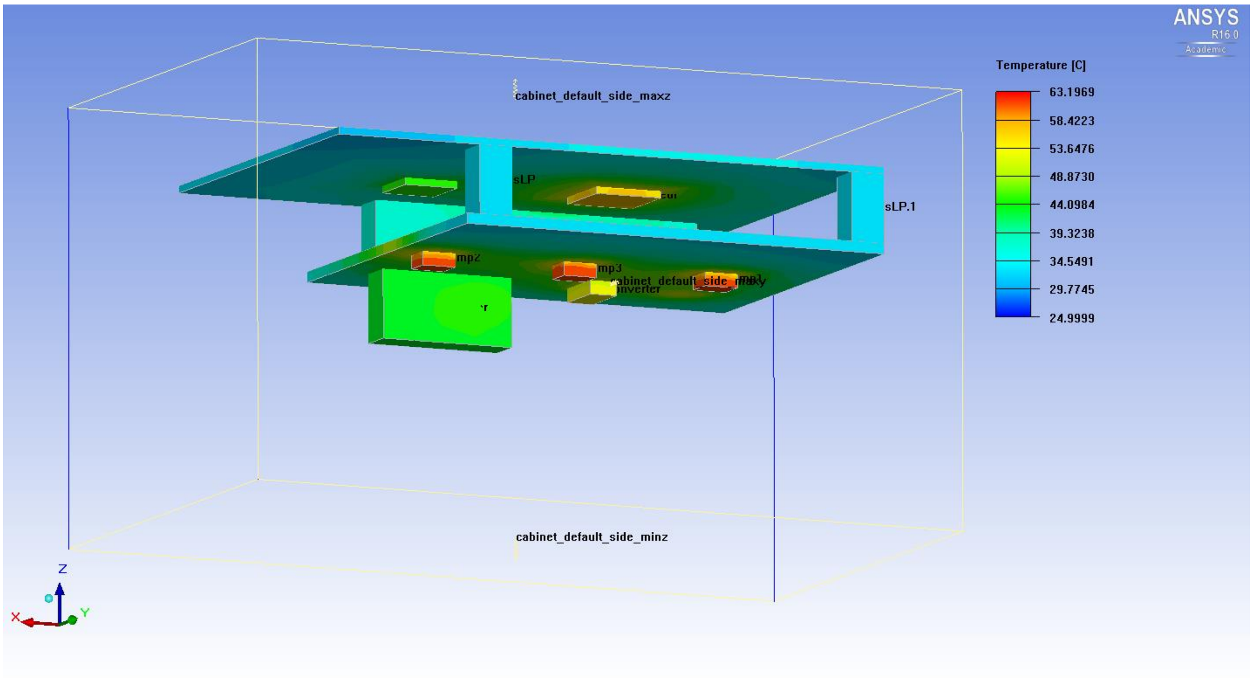


Figure 21 Result of Icepak simulation, PCB without housing, components temperature

The next table presents the power dissipation of each component and the result of the temperatures obtained.

In chapter III.1.4 Power dissipation has approximate values. In Table 12 these values have been adapted. Adaptation is made to bring temperatures close to reality (comparison in chapter III.6).

		Average values			
General Heat Sources	Power Dissipation	Icepak sim PCB outside housing	Delta T (with ambient)	Icepak sim PCB inside housing	Delta T (with ambient)
	[W]	[°C]	[°C]	[°C]	[°C]
Ambient		**25**		**25**	
OPamp X	0,199	61,9	36,9	69,4	44,4
OPamp Y	0,199	61,7	36,7	68,9	43,9
OPamp Z	0,199	63	38	70,7	45,7
AD conv.	0,137	53,7	28,7	61	36
DC/DC conv.	0,2307	45,1	20,1	52,9	27,9
Geoph. X	0,005	-	-	29,5	4,5
Geoph. Y	0,005	-	-	29,5	4,5
Geoph. Z	0,005	-	-	29,5	4,5
Processor	0,6486	58,6	33,6	69,5	44,5
Usb processor	0,2993	46,6	21,6	58,1	33,1
LDO	0,135	54,5	29,5	62	37

Table 12 Power dissipation of components, and obtained temperature results on Icepak simulation

6. Comparison between thermal measurements and simulation results

Now simulation results are compared with the reality using the "Delta T" value from Table 8 (page 20) and Table 12.

	Delta T (with ambient)			
PCB outside housing	Icepak simulation	Infrared Camera VarioCAM Obj. 1.0/30	Absolute Error	Relative Error
	[°C]	[°C]	[°C]	[%]
OPamp X	36,9	30,7	6,2	20%
OPamp Y	36,7	31,8	4,9	15%
OPamp Z	38	31,9	6,1	19%
AD conv.	28,7	28,8	-0,1	0%
DC/DC conv.	20,1	21,9	-1,8	8%
Geoph. X	-	-	-	-
Geoph. Y	-	-	-	-
Geoph. Z	-	-	-	-
Processor	33,6	34,3	-0,7	2%
Usb processor	21,6	19,6	2	10%
LDO	29,5	31,5	-2	6%

Table 13 Comparison between simulation and real temperatures. PCB outside housing

	Delta T (with ambient)			
PCB inside housing	Icepak simulation	Infrared Camera VarioCAM Obj. 1.0/30	Absolute Error	Relative Error
	[°C]	[°C]	[°C]	[%]
OPamp X	44,4	43,9	0,5	1%
OPamp Y	43,9	46,8	-2,9	6%
OPamp Z	45,7	47,3	-1,6	3%
AD conv.	36	41,5	-5,5	13%
DC/DC conv.	27,9	37,5	-9,6	26%
Geoph. X	4,5	4,5	0	0%
Geoph. Y	4,5	4,5	0	0%
Geoph. Z	4,5	4,5	0	0%
Processor	44,5	38,6	5,9	15%
Usb processor	33,1	-	-	-
LDO	37	-	-	-

Table 14 Comparison between simulation and real temperatures. PCB inside housing

To get simulation values as close as possible to reality, iterative method has been used. This provides the best results and the least errors.

Power dissipation and thermal conductivity of PCB are approximated values that have been adjusted to give the best results.

6.1 Improvements

To improve thermal dissipation of a component, the aim is to reduce the thermal resistance around it. This will keep the component temperature close to the environment temperature (small "Delta T (with ambient)" value).

To explain this, let's make a comparison of Figure 5 (page 10 of chapter III.1.4) and Figure 23. In Figure 23 the thermal resistance is reduced with a "graphite heat spreader" all around the electronic heat source. This conduction resistance (R_{gr_cond}, graphite heat spreader) will remove the convection and radiation resistance of the heat source component and the inside housing.

Graphite heat spreader has a very high thermal conductivity of 100-500 [$W_* mm^{-1}{}_* K^{-1}$]. It will make a good dissipation of the heat from the electric component. The "Delta T (with ambient)" will be smaller.

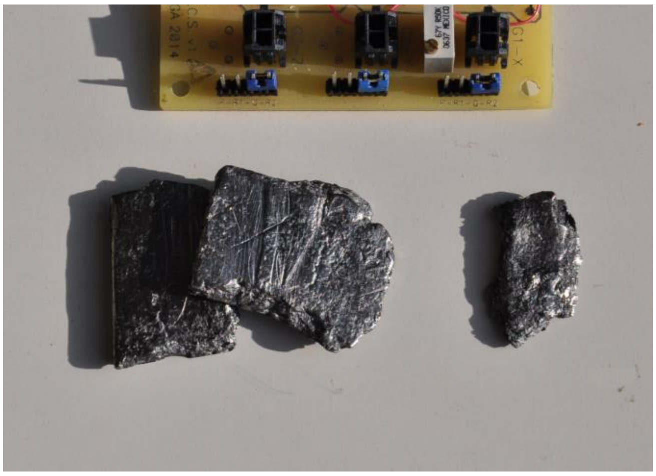


Figure 22 Three pieces of graphite heat spreaders

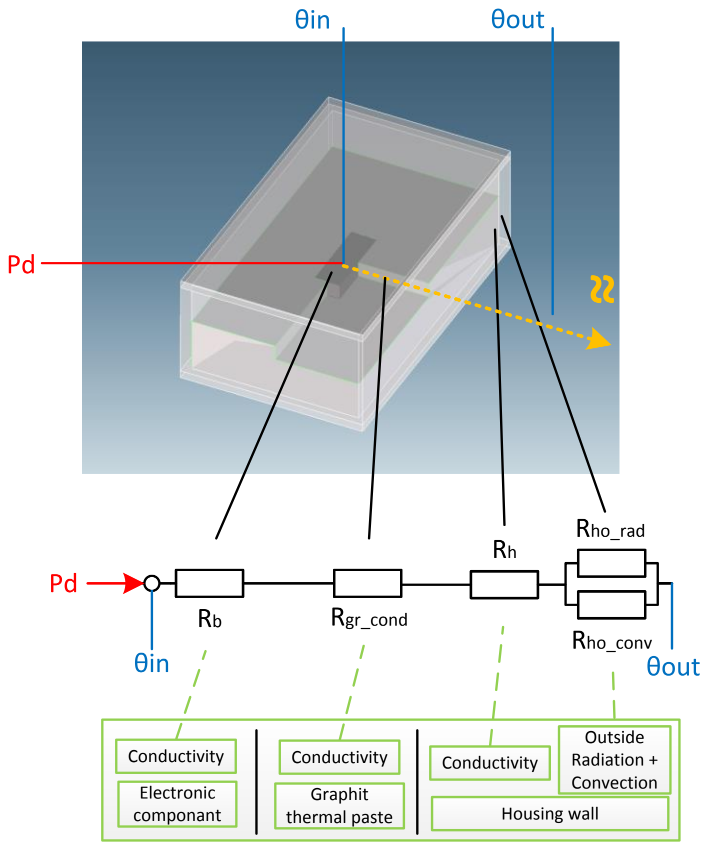


Figure 23 Thermal flow from an electronic heating source through graphite heat spreader and a housing to environment

In conclusion, to optimise the thermal flow on the existing sensor, thermal graphite heat spreader can be used. The housing should be of steel material with an outside non-metallic lacquer surface. This will reduce thermal resistivity, improve radiation and reduce the "Delta T (with ambient)" of the electronic components.

IV. REALIZATION

The existing sensor of chapter III was tested to verify that the simulation results give realistic and reliable values within an acceptable limit of precision. A new sensor is analysed and then simulated to prevent any temperature damage of the sensor while working in high temperatures.

1. Objectives and criteria

The new seismic sensor is designed to make measurements in boreholes. These are static measurements; the sensor is inserted at the bottom of the borehole and may be left there for many years.

The borehole seismic measurements provide precise values (the signal to noise ratio will be higher) and quicker seismic results than sensors on earth's surface. This is because with depth there is an increase in density and more rock. This provides better signal.

1.1 Environment and conditions

The following diagram represents the configuration of the sensor. It can be placed at depths ranging from 200 [m] to 1 [km]. The sensor will be placed at the bottom of the borehole. A 4x 1.5 [mm^2] shield cable is used to support the weight of the sensor on extraction. At ground level a PC or a data server presents the measurements. There is also a power supply unit used to administer the sensor in electricity.

There are different sizes of borehole. The smallest have a diameter of 90 [mm]. The sensor is designed to have a diameter smaller than 90 [mm].

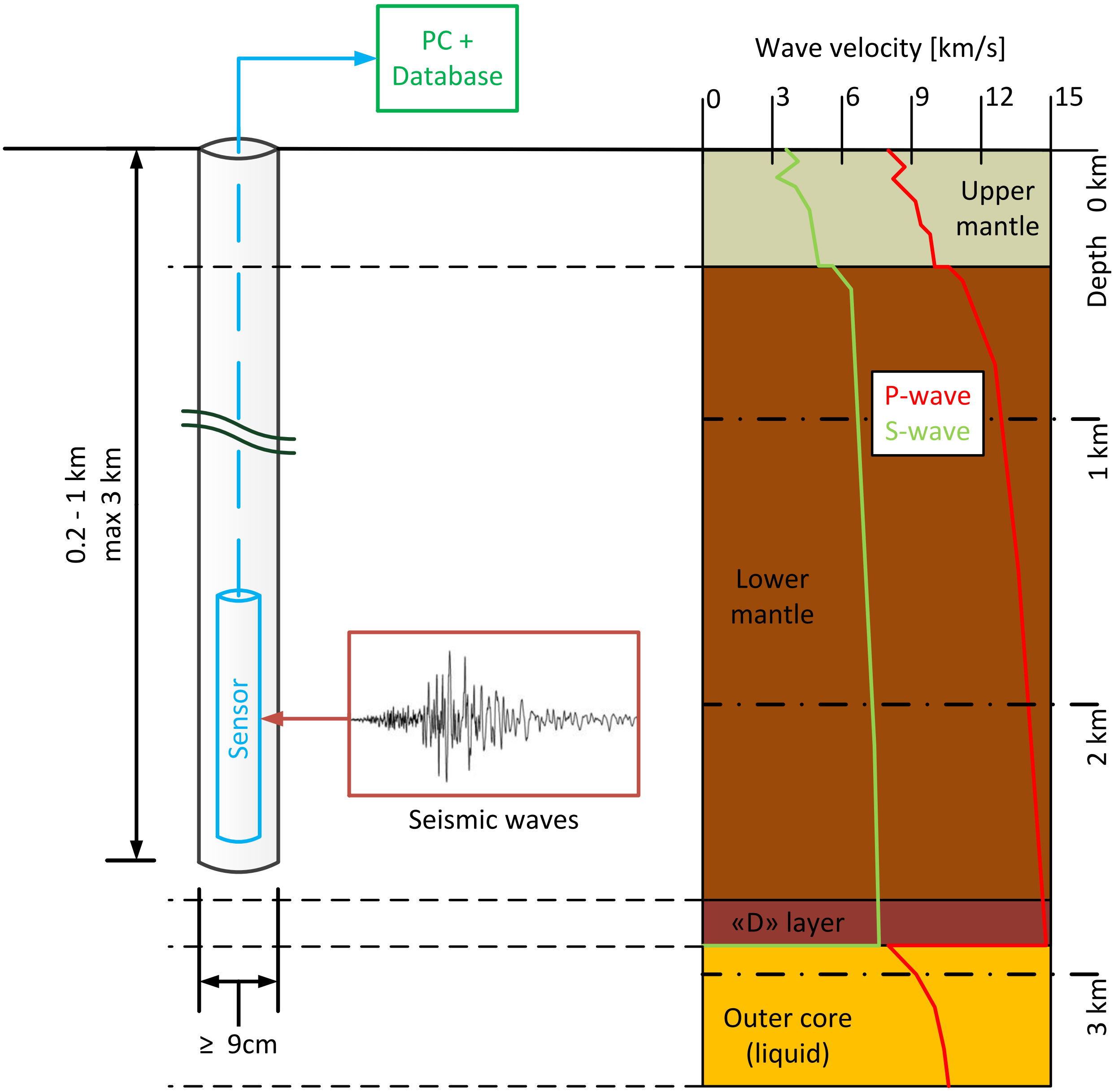


Figure 24 Representation of the sensor in the earth[5]

On the right of Figure 24 is the representation of the velocity of earthquake signal. The P-wave is the first signal and the S-wave is the second signal following the P-wave. The graph shows that the velocity of seismic waves increase with depth.

[5] Velocity graph inspired by data from web site "what on Earth" HTTP://WHATONEARTH.OLEHNIELSEN.DK/IMG/SEISMIC_VEL_EARTH.JPG 31.07.15

1.2 Mechanical design

The mechanical design of the new seismic sensor has been made in the Hes-so. It is designed for the most extreme case. The housing can resist 120 [bar] pressure (24 [bar] nominal, with a 5x security factor). It is made of stainless steel. The outside diameter is 60.32 [mm] for a length of 715 [mm] (variable).

Inside there are three geophones, one for every axis, and the PCB. The internal diameter for the PCB is 42.8 [mm]. The length is variable, dependant on the space needed for electronic components.

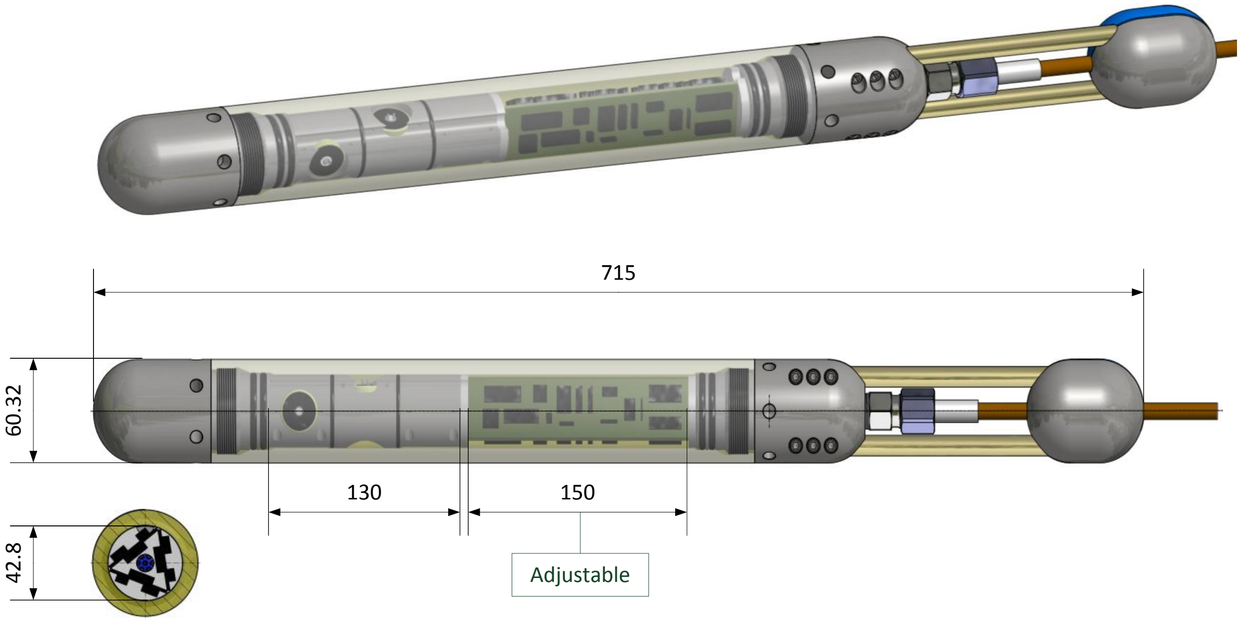


Figure 25 borehole sensor, with size in mm [6]

For thermal flow simulations, the sensor is simplified as in Figure 26.

[6] Image from „Sismomètre Plan B – A0100“ Christian Cachelin, 25.05.2015, Hes-so Valais-Wallis

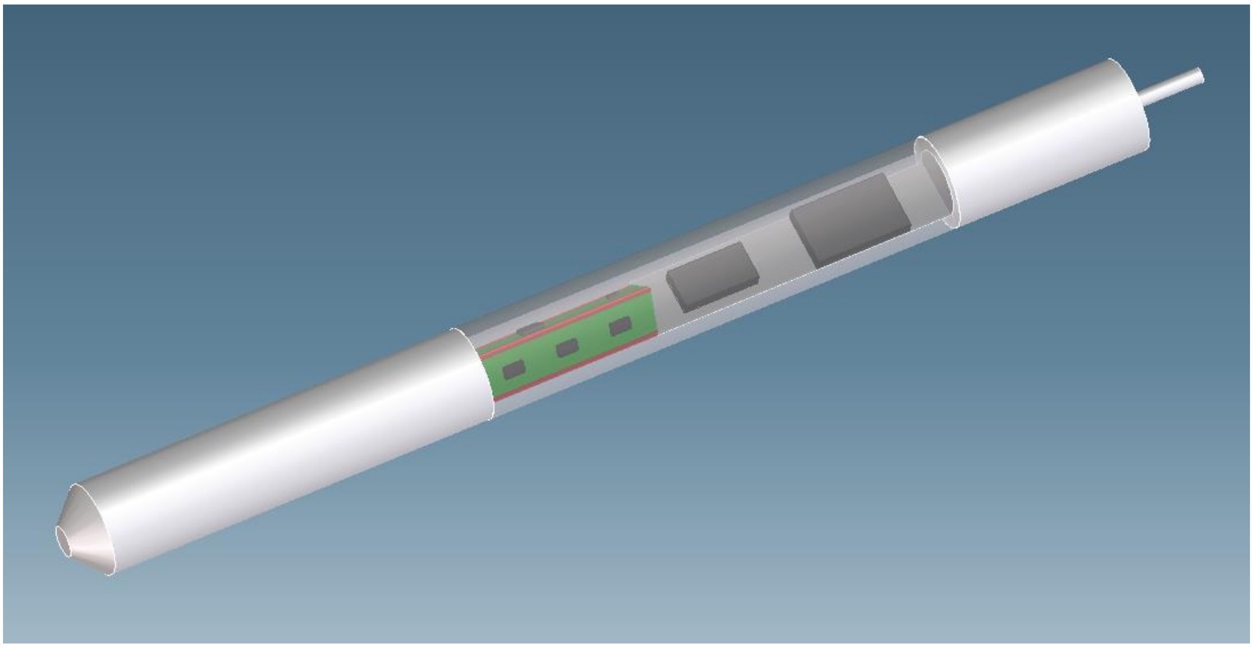


Figure 26 borehole sensor, made with simplified housing

1.3 Temperature conditions

The sensor is analyzed in two different situations. The two results are studied.

The first variant (in chapter IV.2) has the following specifications: an environment temperature $T_{nominal}$ = 150 [°C] and a maximal environment temperature of T_{max}=180 [°C]. The maximal depth at which it can be placed is 3 [km] long.

The second variant (in chapter IV.3) has an environment temperature $T_{nominal}$ = 70 [°C] and a maximal environment temperature of T_{max}=100 [°C]. The maximal depth is 1km long.

	Depth	Temp	Max, temp	Pressure
Variant 1 :	1-3 km	150 °C	180°C	24 bar
Variant 2 :	0.2-1 km	70 °C	100 °C	24 bar

Figure 27 General conditions for variant one and two

1.4 Electronic conception

For the 1st variant, compatible components are chosen, which will give good performance at the specified temperatures.

In the 2nd variant, the components are given. The power dissipation is set as 9 [W] and comparison is made between a normal design, a design with graphite heat spreader (to improve thermal conductivity) and a design with a Peltier element.

1.5 Electrical diagram and components

The electronic diagram of the sensor is almost the same as the existing sensor. There are also geophones, operational amplifiers, analogic/digital converters, and a processor. Instead of the wireless device, there is a transmitter that sends data to the computer. Also the power supply must be adapted to suit this borehole sensor.

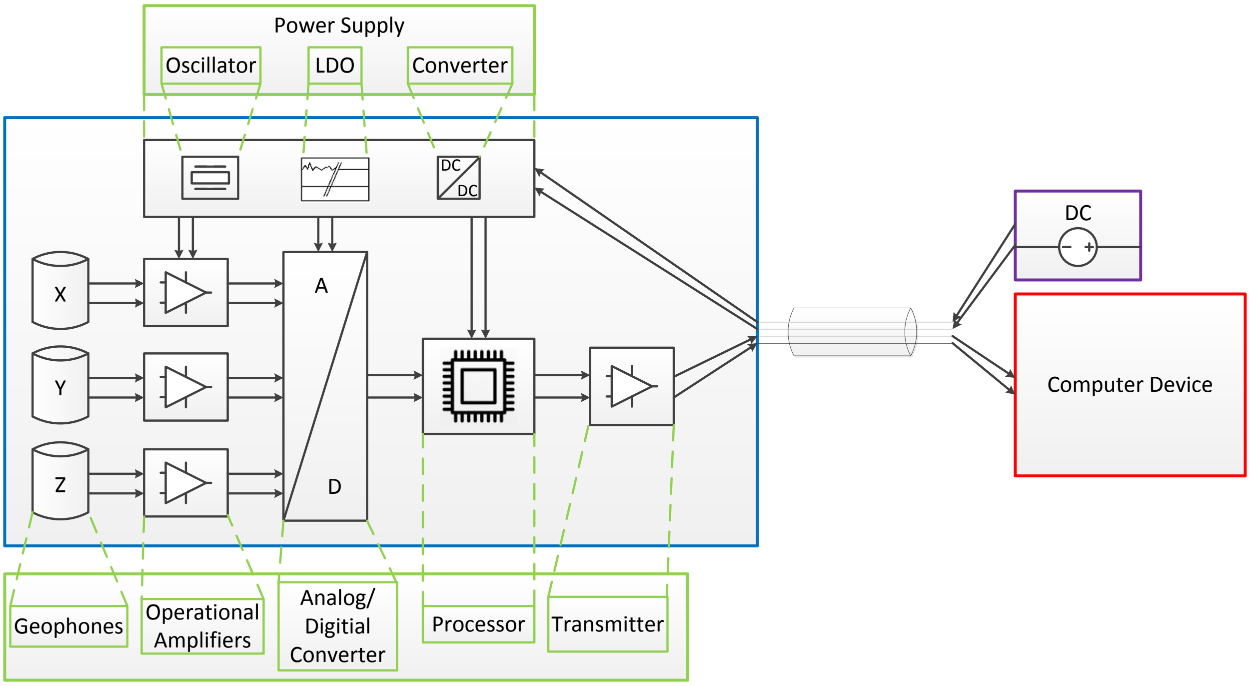


Figure 28 Borehole sensor, electronic diagram

2. Variant 1

The first analysed solution is a sensor running in an average temperature of T= 150 [°C] and a maximal temperature of 180 [°C]. This harsh environment requires high relativity components.

The strategy of this variant is to work with electronic components from the category “space”, “avionics” and “drilling holes”. These components are generally built to work to a maximal temperature of 180 [°C], or 210 [°C] with a ceramic housing.

2.1 Electronic components

There are not many components for the category “space”, “avionics” and “drilling holes”. The following components were chose for their compatibility and their general performances. The performance may be improved using other components, but in this case, the red components have been chosen for the simulation. Their Datasheets can be found in annexes 8-18.

		Maximal temperature		Datasheet
Type	Component name	SOIC package	Ceramic package	Maximal Power Dissipation
		[°C]	[°C]	[W]
Geophones	OMNI 2400	200		-
	SMC 1850	200		-
Operational amplifiers	AD8634	175	210	-
	AD8229	175	210	0.056
	INA129-HT	175	210	-
Analogue/digital converter	ADS1282-HT	175	210	-
Processor	SM470R1B1M-HT	150	220	-
DC/DC converters	HTA200 05DN	185		-
	HTB200 03R3SN	185		-
Reference	REF5025-HT	125	210	-
Transmittor (RS485)	SN65HVD	175	210	0.165

Table 15 Operating temperatures and power dissipation of components

2.2 Mechanical design

The PCB are set in a triangle in the sensor housing. This solution provides a bigger surface of PCB for the attributed length. It also has the advantage that some flexible PCB parts exist and therefore the three PCBs can be joined as one with two flexible parts.

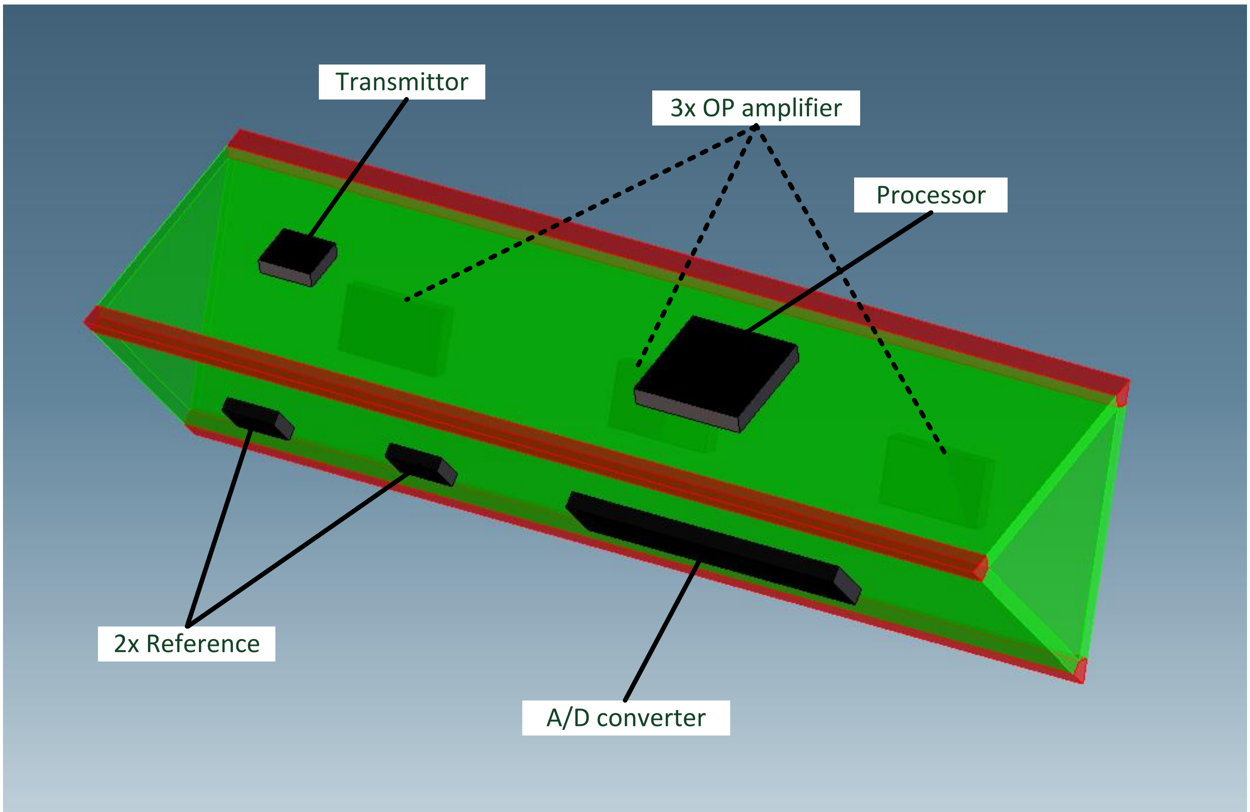


Figure 29 Variant 1, component disposition on the PCB

The power supplies are voluminous, so they are set individually on a base. The base helps to dissipate the heat to the sensor's housing.

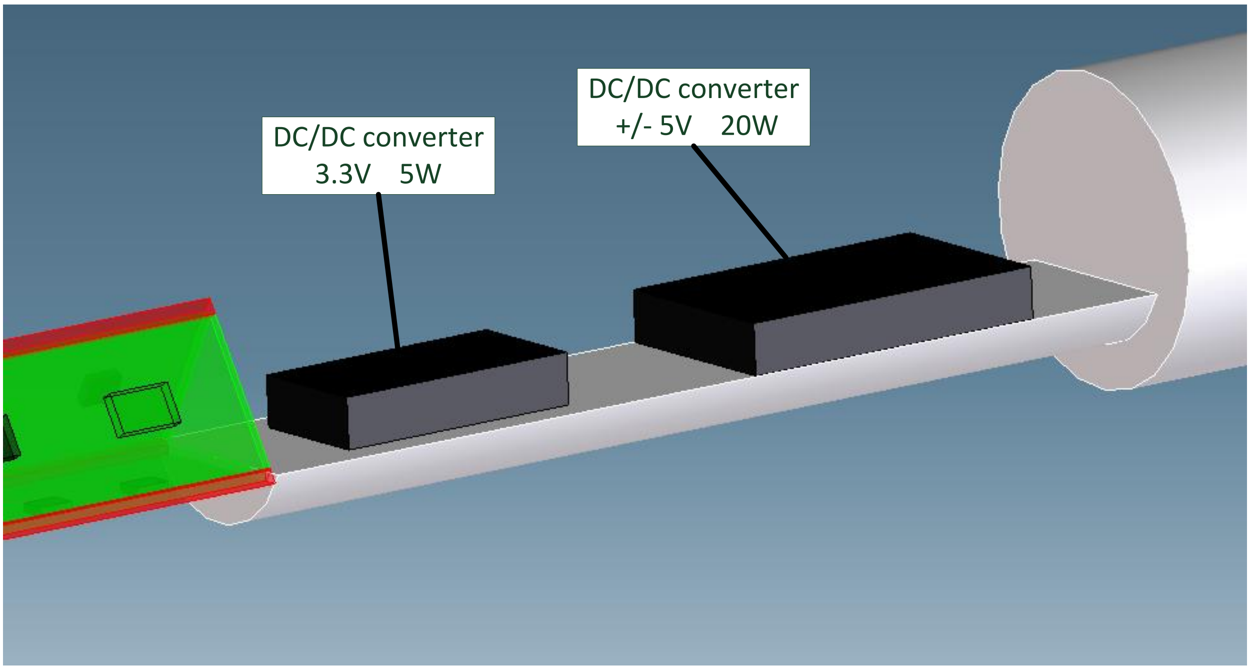


Figure 30 Variant 1 with two DC-DC converter on a stainless-steel base

2.3 Specifications of simulation

The flow simulation software "Icepak" is used to analyse the sensor. The round housing has been simplified.

The Icepak simulation has these general characteristics:

- Gravity vector is in the direction of Z axis
- Air has a laminar flow regime
- Pressure is of 1.01325 bar
- Radiation is activated, all objects have a "radiation to all objects" characteristic

Table 16 shows the attributed solid and surface materials of each component. It may not be the exact name. The chosen materials have emissivity and conductivity values that are close to the real components.

Objects	Surface Material		Solid material	
	Name	Emissivity	Name	Conductivity [W*m-1*K-1]
Housing	Steel-polished casting	0,52	Steel-stainless-300	14,6
DC-DC converter	Steel-Oxidised-surface	0,8	Ceramic_material	15,0
General heat sources (components)	Ceramic-surface	0,9	Ceramic_material	15,0
PCB	Plastics-infrared Opaque	0,9	PCB_solid_material	5,0
PCB connexion part	Plastics-infrared Opaque	0,9	PCB_solid_material	5,0

Table 16 Surface and solid material specification for Icepak simulation variant 1

2.4 Results

Here are the results of simulating the variant 1 sensor using Icepak software.

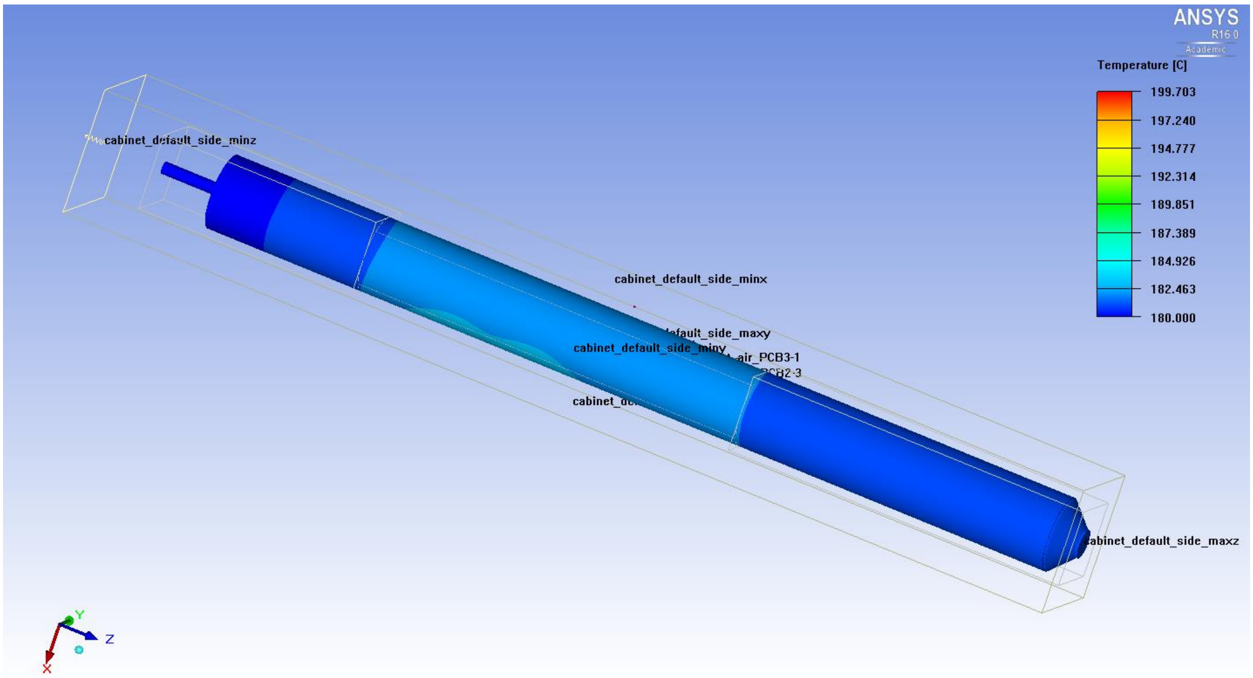


Figure 31 Simulation of variant 1, T_{amb}=180 [°C], housing

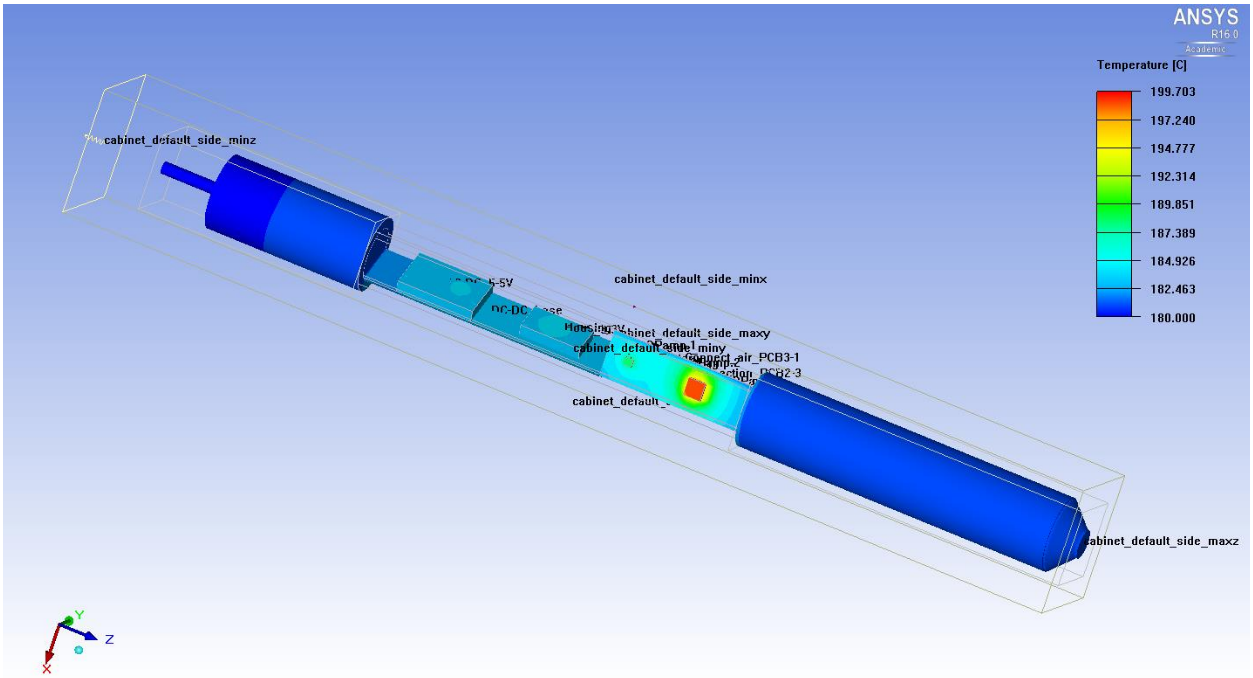


Figure 32 Simulation of variant 1, T_{amb}=180 [°C], inside housing

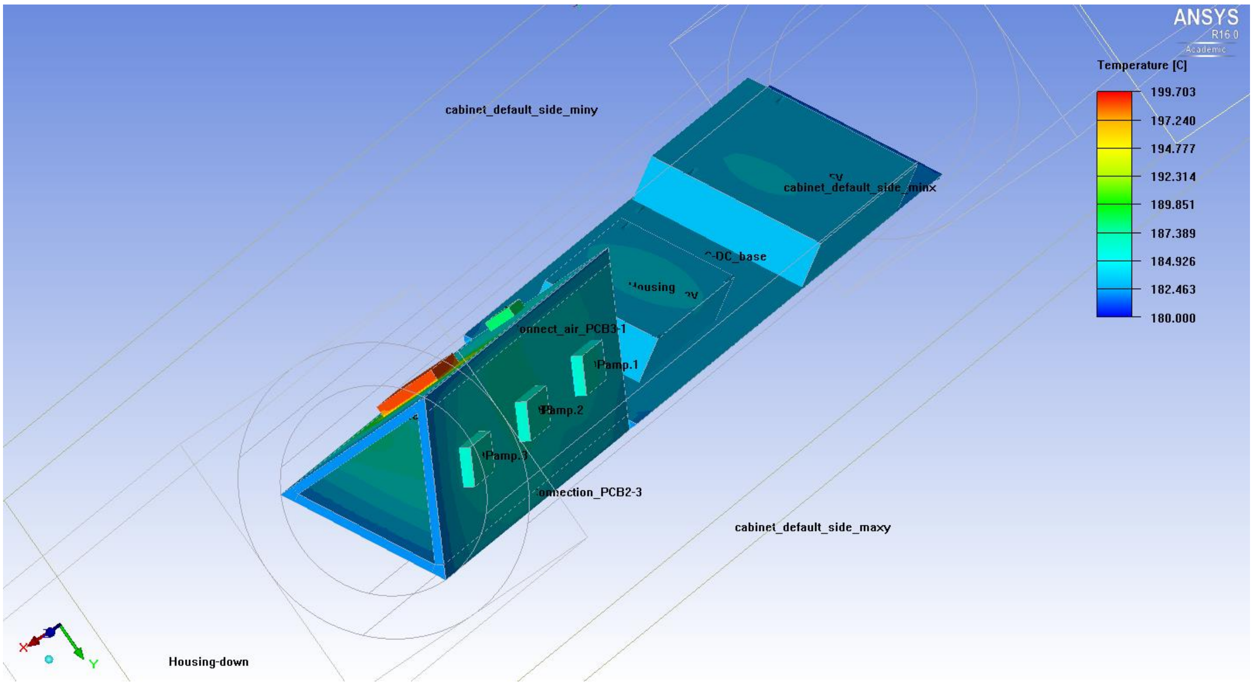


Figure 33 Simulation of variant 1, T_{amb}=180 [°C], PCB and DC-DC with base

Table 17 presents the attributed power dissipation (the unknown values were approximated).

Two environment temperatures have been simulated, the first with T=150 [°C], the second with T=180 [°C] which is the maximal accepted temperature.

			Average values	
Type	General Heating Sources	Power Dissipation	Simulation One	Simulation Two
		[W]	[°C]	[°C]
Ambient			**150**	**180**
Geophones	SMC 1850		151	181
OPamp	AD8229	0.09	155.3	186.6
AD conv.	ADS1282-HT	0.056	154.9	186.5
Processor	SM470R1B1M-HT	1	166.8	199.7
DC/DC conv.	HTA200 05DN	2	153.6	184.2
DC/DC conv.	HTB200 03R3SN	1.2	153.6	184.2
Reference	REF5025-HT	0.035	154.5	185.8
Transmittor	SN65HVD	0.165	157.5	188.9
Total power dissipation :		**4.838**		
Minumum			150	180
Maximum			**166.78**	**199.7**

Table 17 Variant 1, components Pd, and simulation temperature values

The results of simulation show that electronic components can work at the given temperature conditions but they must have a ceramic package (maximal value above 175 [°C]).

The geophones will not be submitted to temperatures over 200 [°C], because the temperature of the housing containing the geophones is about 182 [°C].

The DC/DC converters have a limit of 185 [°C]. In the second simulation, they reach 184.2 [°C]. This value is only with maximal environment temperature, so that means that these components will rarely be exposed to temperatures as high as 184.2 [°C]. The results can be improved with a graphite heat spreader all around the converters. That would probably keep converters under 182 [°C].

2.5 Cost and improvements

On variant 1, the cost of the studied electronic components (including geophones) is approximately 2'526 €. On the existing sensor these components have a cost of 659 €. This means that using high temperature components would cost a minimum of four times more than normal components.

Because high temperature components are expensive, their need has to be proven.

In this case, high temperature components are the best option. The cooling system with a Peltier element is useless, because the environment temperature is too high (the Peltier functionality is explained further in chapter IV.3.2 page 44).

An improvement can be made by using graphite heat spreader around the three PCB (see chapter IV.3.6 page 51 for example) and around the two DC/DC converters. As described in chapter III.6.1 (page 31) this will improve thermal conductivity and reduce the temperature of the components.

3. Variant 2

The second analysed solution is a sensor running in an average temperature of T= 70 [°C] and a maximal temperature of 100 [°C].

In this variant, the components are given. The power dissipation is set as 9 [W]. Comparison will be made between a normal simulation, a simulation with graphite heat spreader and a simulation with a Peltier element.

3.1 Electronic components

All the given components have a maximal temperature of 125 [°C]. Their power dissipation value has no importance because the total power dissipation is set as 9 [W].

The 9 [W] of power dissipation are divided between the PCB's components as shown in Table 18.

General Heating Sources	Quantity	Power Dissipation
		[W]
Operational amplifier (OPamp.)	3	0,7
Analog/digital converter (AD conv.)	1	1
Processor	1	1,6
Power supply (PS)	3	1
Reference	2	0,5
Transmitter	1	0,3
Total power dissipation		**9**

Table 18 Components and their power dissipation for variant 2

3.2 Peltier element

The Peltier element is a static component creating a heat flux between two surfaces. It is also called a TEC (thermoelectric cooler). This component is used in many applications (for example: car fridge). It is cheap but it has a bad efficiency.

As represented in Figure 34, a current is passes through a semiconductor that creates a temperature difference at each end (Peltier effect). Placed in parallel, semiconductors present two surfaces with different temperatures. A flow is created from the cold to the hot side. The maximal difference between the two surfaces is 70 [°C].

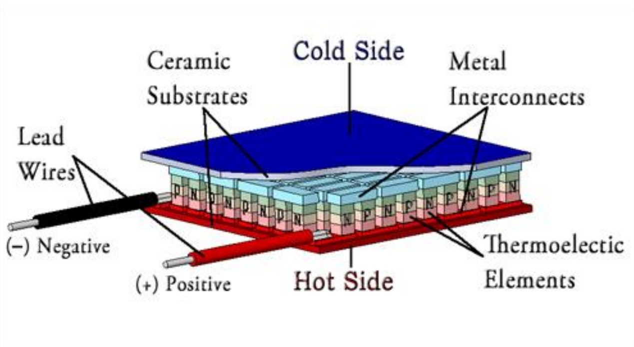


Figure 34 Design of Peltier element, with description [7]

Equation 7 shows that the amount of heat on the hot side is equal to the sum of the electric power consumption and the amount of heat on the cold side.

$$Q_h = P_{el} + Q_c \quad [\mathrm{W}]$$

Equation 7

[7] Figure from : http://home.arcor.de/glaube.u/spf-modul/Construction%20of%20TEM%20N.html

The electric power consumption depends on the amount of heat to evacuate (cold side) and the difference of temperature needed.

A Peltier element has not been chosen, because of wrong results of simulation.

3.3 Mechanical design

The PCB are still set in a triangle. This has a length of 150mm instead of 120mm (Variant 1) because the power supplies are included on the PCB and not on a separate base.

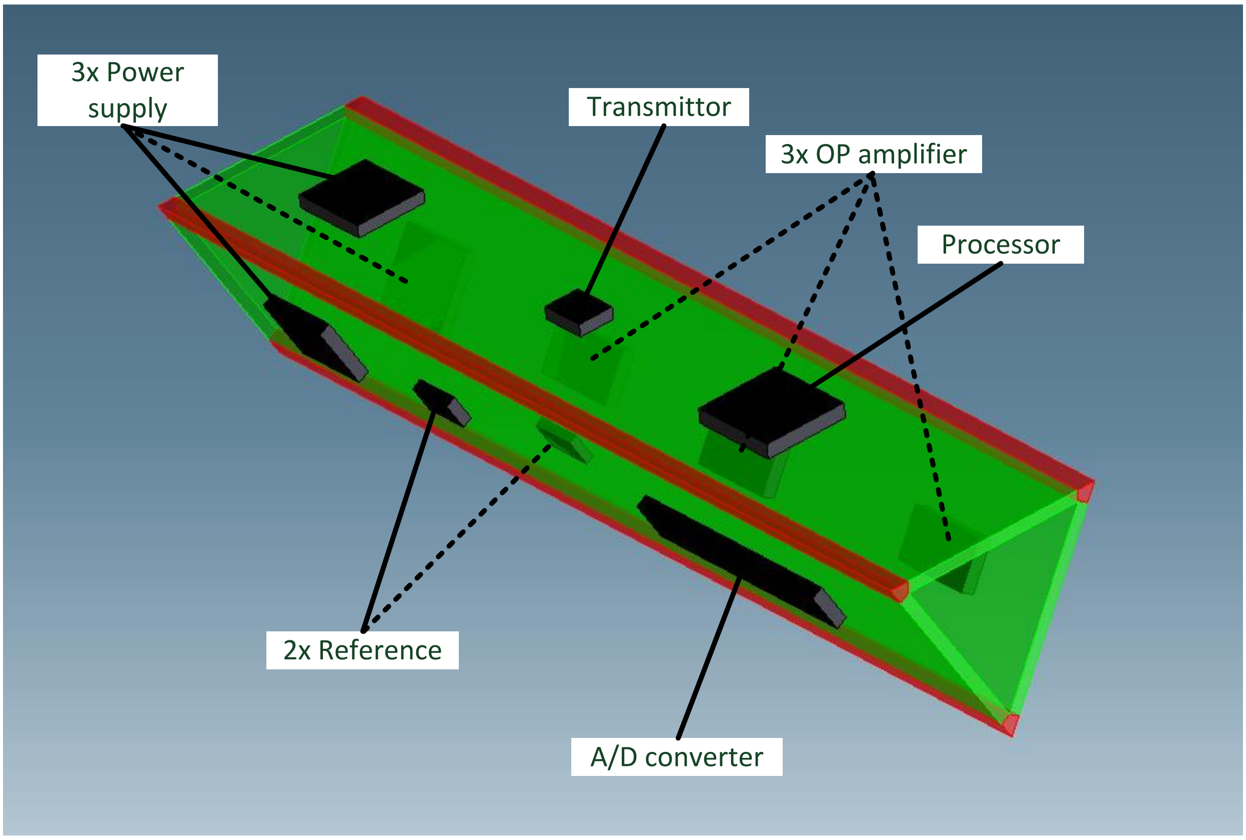


Figure 35 Variant 2, component disposition on the PCB

Figure 36 shows the housing for the Peltier element simulation. This is an experimentation to analyse if a thermos design built with two Peltier element would provide better performance. For this design, the diameter of the sensor had to be expended to an outside diameter of D=88mm. The inner thermos diameter is the same as in variant 1.

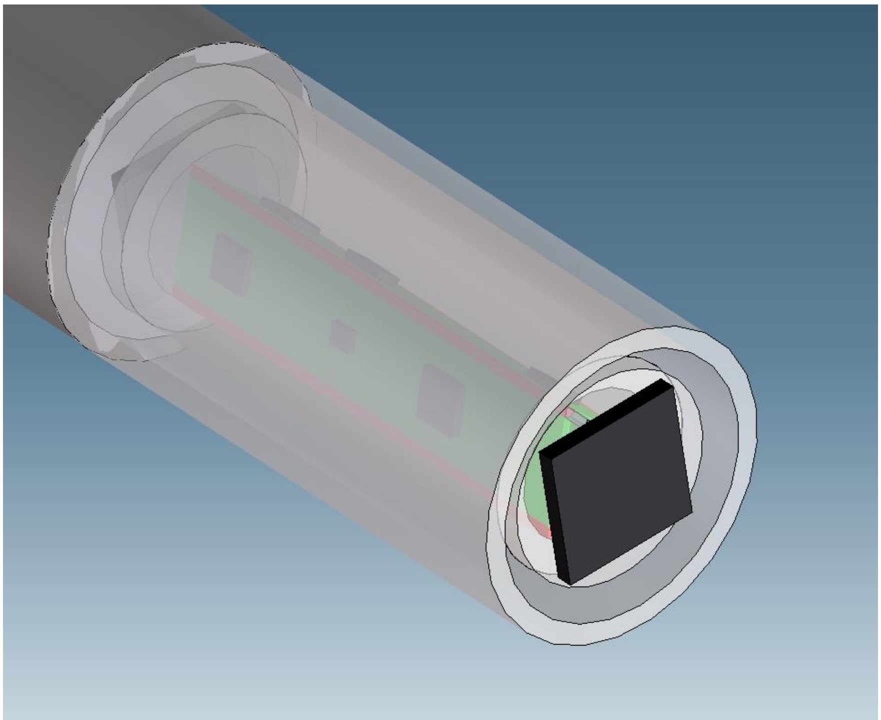


Figure 36 Housing designed with Peltier and thermos

Two Peltier elements have been placed, one at each end of the inner tube. The cold sides are placed on the inner tube, the hot sides are place on the housing to dissipate the heat to the environment.

3.4 Specifications of simulation

The flow simulation software "Icepak" is used to analyse the sensor. The round housing has been simplified.

The Icepak simulation has these general characteristics:

- Gravity vector is in the direction of Z axis
- Air has a laminar flow regime
- Pressure is of 1.01325 bar
- Radiation is activated, all objects have a "radiation to all objects" characteristic

Table 19 shows the attributed solid and surface materials of each component. It may not be the exact name. The chosen materials have emissivity and conductivity values that are close to the real components.

Objects	Surface Material		Solid material	
	Name	Emissivity	Name	Conductivity [W*m-1*K-1]
Housing	Steel-polished casting	0,52	Steel-stainless-300	14,6
General heat sources (components)	Ceramic-surface	0,9	Ceramic_material	15,0
PCB	Plastics-infrared Opaque	0,9	PCB_solid_material	5,0
PCB connexion part	Plastics-infrared Opaque	0,9	PCB_solid_material	5,0
Graphite heat spreader	Plastics-infrared Opaque	0,9	eGRAF_HITHERM_SRS_700	240,0

Table 19 Surface and solid material specification for Icepak simulation variant 2

3.5 Results

Figure 37 and Figure 38 are the "simulation 1" with the normal housing without graphite.

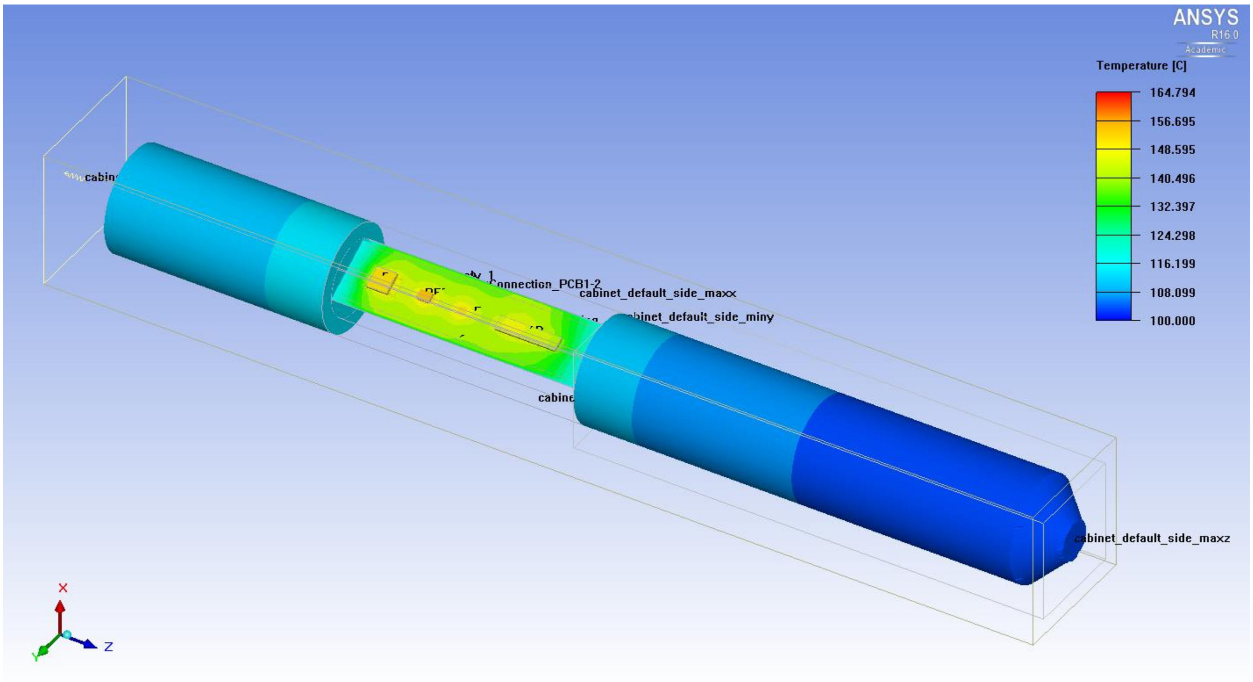


Figure 37 Simulation 1 of variant 2, Tamb = 100 [°C], without graphite, housing

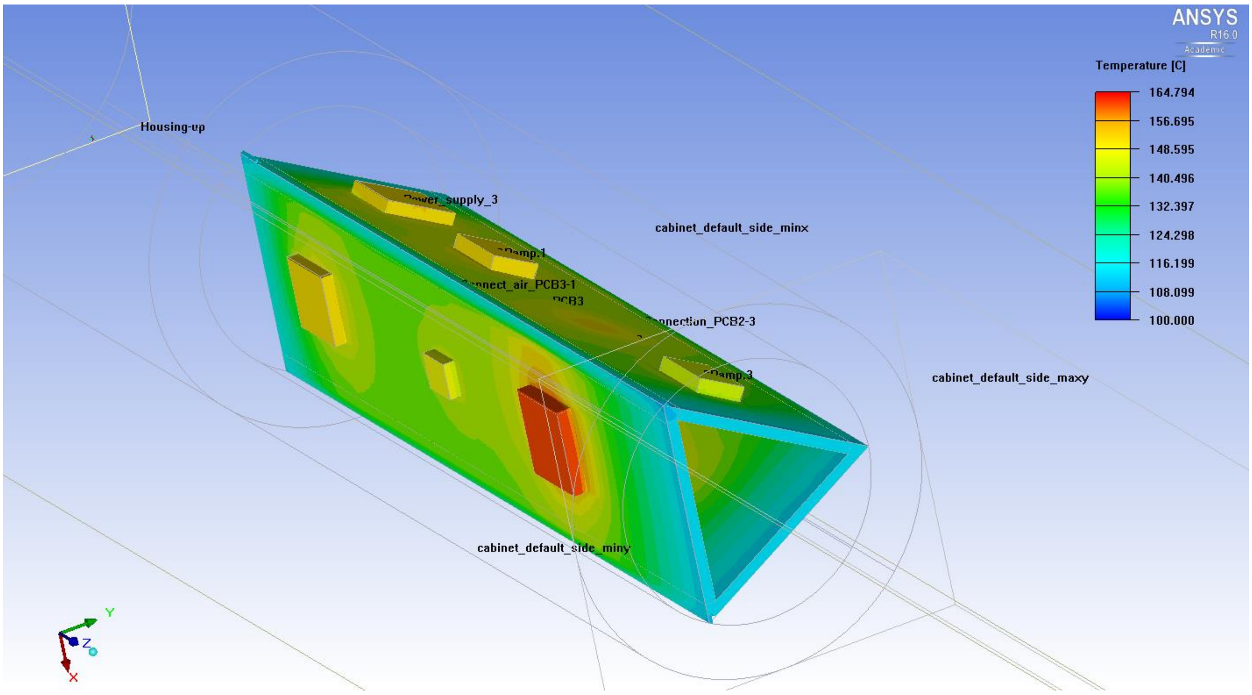


Figure 38 Simulation 1 of variant 2, Tamb = 100 [°C], with graphite, PCB

Figure 39 and Figure 40 are the “simulation 2” with graphite heat spreader all around the PCB.

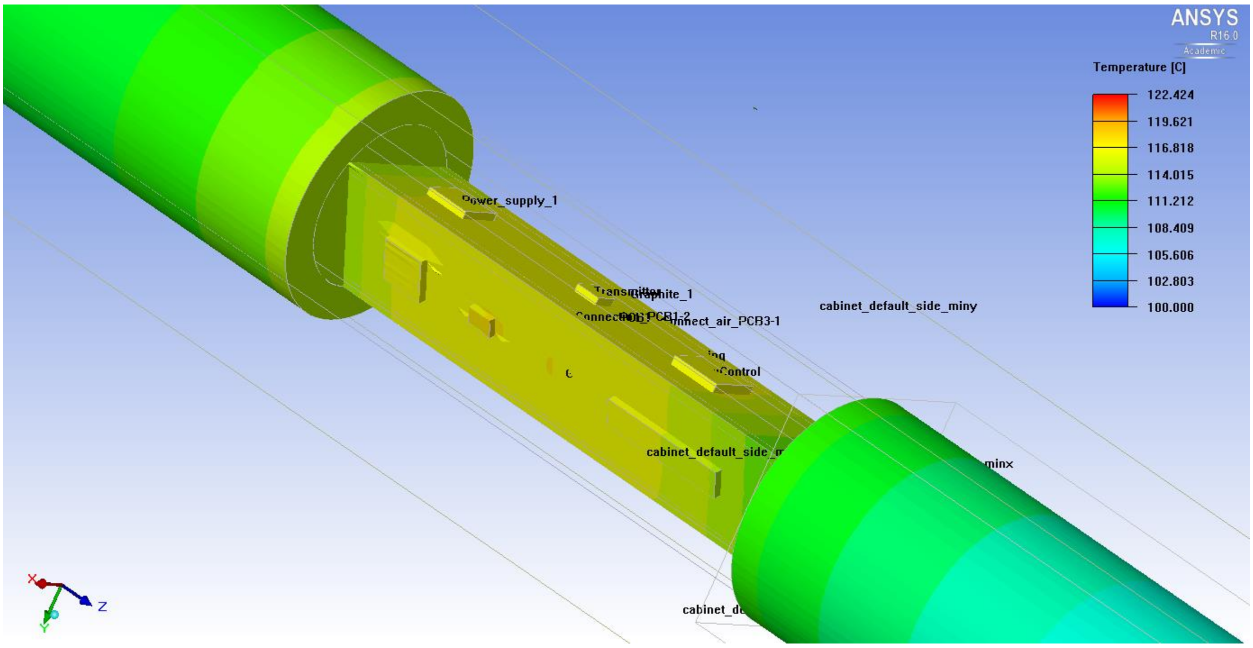


Figure 39 Simulation 2 of variant 2, T_{amb} = 100 [°C], with graphite heat spreader (not represented)

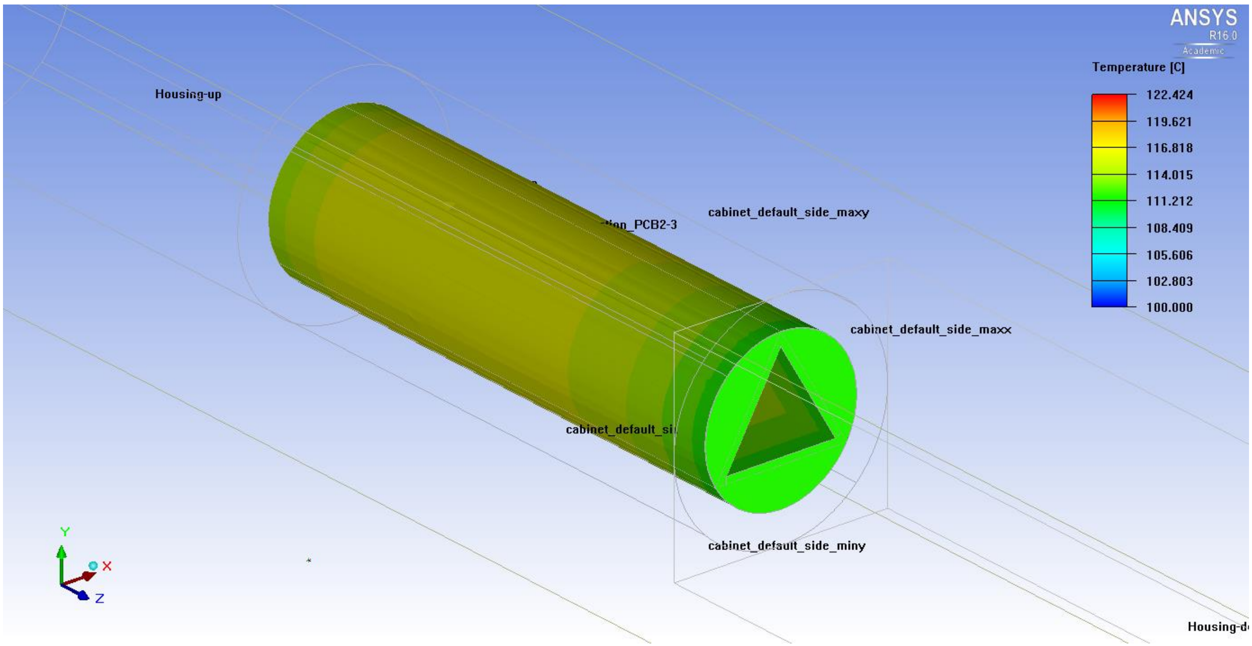


Figure 40 Simulation 2 of variant 2, T_{amb} = 100 [°C], graphite heat spreader and PCB

Figure 41 and Figure 42 are the "simulation 3" with two Peltier elements. Each Peltier element is set to absorb Q_c = 7 [W] (half of 9 [W] with a safety margin).

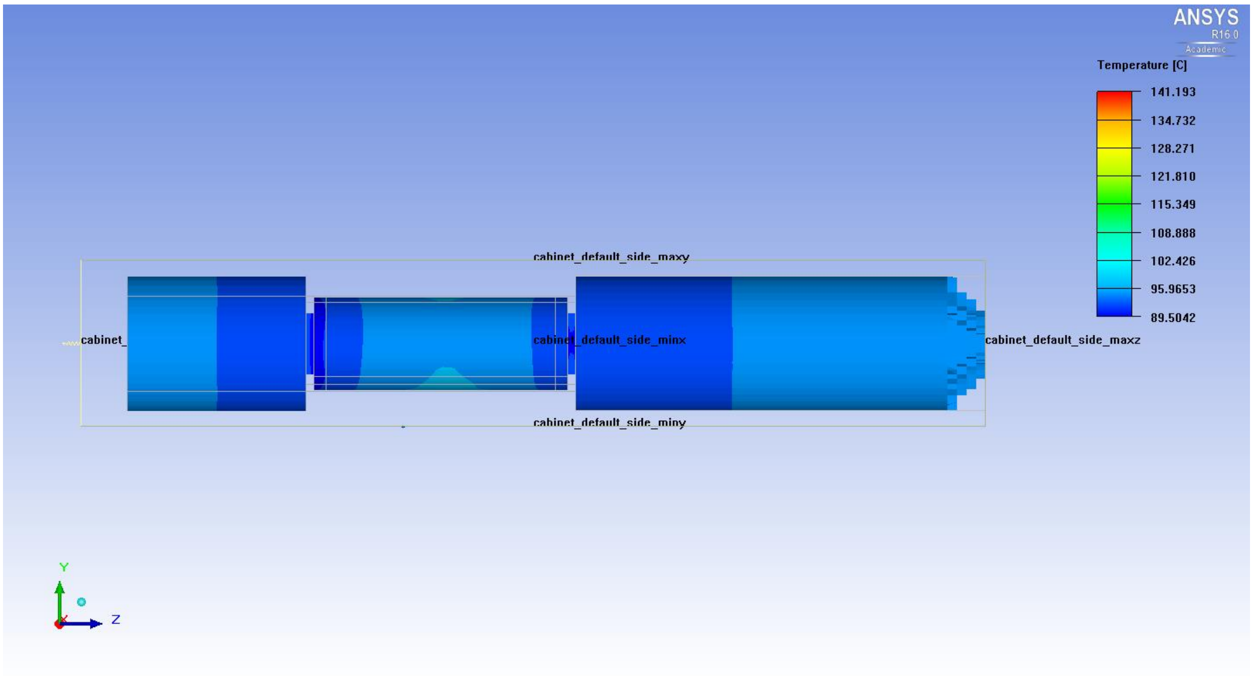


Figure 41 Simulation 3 of variant 2, T_{amb} = 100 [°C], with Peltier elements, inside thermos tube

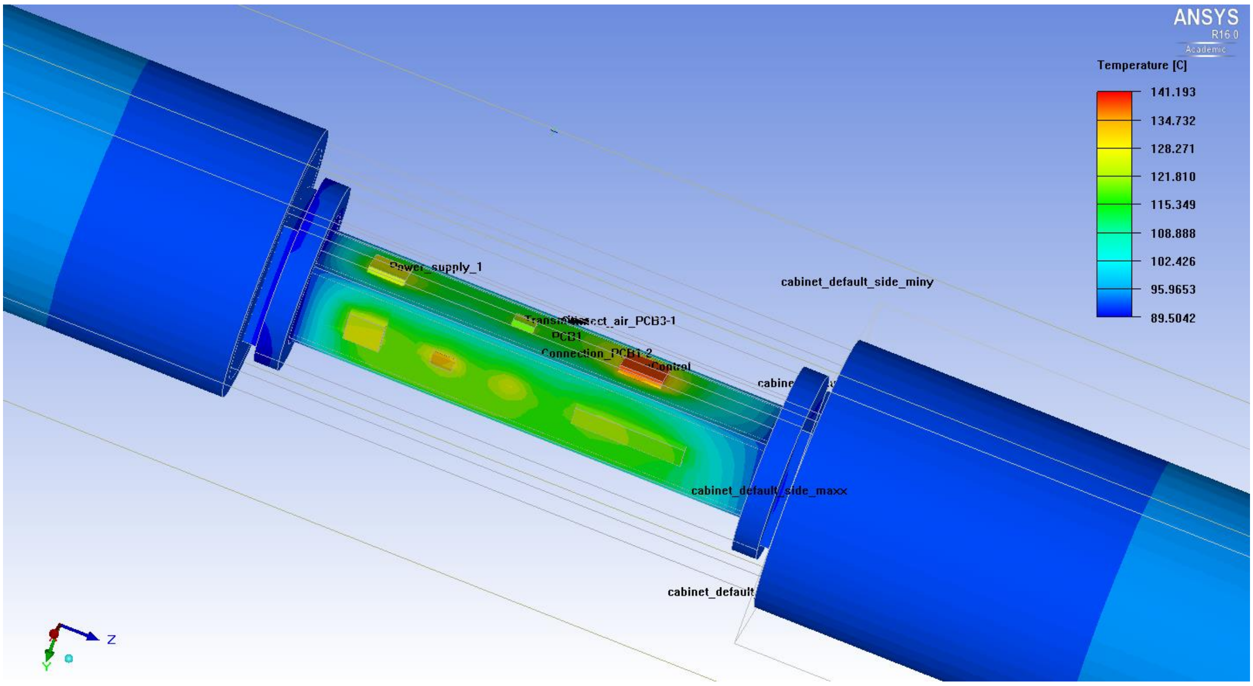


Figure 42 Simulation 3 of variant 2, T_{amb} = 100 [°C], with Peltier elements, PCB

The Peltier elements were simulated only with the absorbing Q_c value. Unfortunately no realistic solutions were found when the dispersion value Q_h was set. This means approximately 14 [W] were extracted from the inner thermos, but no heat flow was transferred to the outside housing. This simulation result of Peltier elements is therefore the "best case possible".

Two environment temperature have been simulated, the first with T=70 [°C], the second with T=100 [°C] which is the maximal accepted temperature.

General Heating Sources	Power Dissipation	Simulation 1 Normal Housing	Simulation 2 with graphite H. spreader	Simulation 3 With Peltier
	[W]	[°C]	[°C]	[°C]
Ambiant		**70**	**70**	**70**
OPamp.	0,7	128,1	90,7	102,2
AD conv.	1	123,3	89,7	93,3
Processor	1,6	140,5	90,4	112,4
P. supply	1	128,6	90,2	99,3
Reference	0,5	131,8	93,1	102,6
Transmitter	0,3	123,6	90,4	92,9
Minimum		**70**	**70**	**58,3**
Maximum		**140,6**	**95**	**112,4**

Table 20 Variant 2, T_{amb} = 70 [°C], components Pd, and simulation temperature values

General Heating Sources	Power Dissipation	Simulation 1 Normal Housing	Simulation 2 with graphite H. spreader	Simulation 3 With Peltier
	[W]	[°C]	[°C]	[°C]
Ambiant		**100**	**100**	**100**
OPamp.	0,7	151,1	118,1	122,8
AD conv.	1	148,1	117,2	129,2
Processor	1,6	164,7	117,9	
P. Supply	1	153,8	117,5	128,9
Reference	0,5	156,2	120,2	131,6
Transmitter	0,3	148,1	117,8	141,2
Minimum		**100**	**100**	**141,2**
Maximum		**164,7**	**122,4**	**89,5**

Table 21 Variant 2, T_{amb} = 100 [°C], components Pd, and simulation temperature values

The simulation 1 with the normal housing demonstrates that this design is not good because all components are above 125 [°C] (the maximal operating temperature of components). This case even with an ambient temperature of T_{amb} = 70 [°C].

The simulation 2 with the graphite heat spreader gives reliable results.

The results of simulation 3 with the Peltier element are not very satisfactory. At T_{amb} = 100 [°C], the processor and the transmitter heat over 125 [°C]. Even if results are "best case possible", they are not as good as the graphite heat spreader.

3.6 Improvements

The Simulation 3 with Peltier element has no convincing results. Figure 43 shows that at an ambient temperature of 100 [°C], components will be over 125 [°C]. In comparison with simulation 1, improvements are not significant (20 [°C] less). The mechanical design is more complex, therefore more expensive. The electrical consumption of Peltier element is not negligible (about 10-20 [W] per TEC) and the obtained results are not guaranteed.

The Simulation 2 with the graphite heat spreader is the best of these solutions. Further improvements could possibly be achieved using less graphite. The graphite doesn't need to be on all the length of the PCB; it could be limited to the area around the components. Graphite heat spreader is not expensive, it is easy to add to the design. Care must be taken for electrical insulation between the PCB and the graphite.

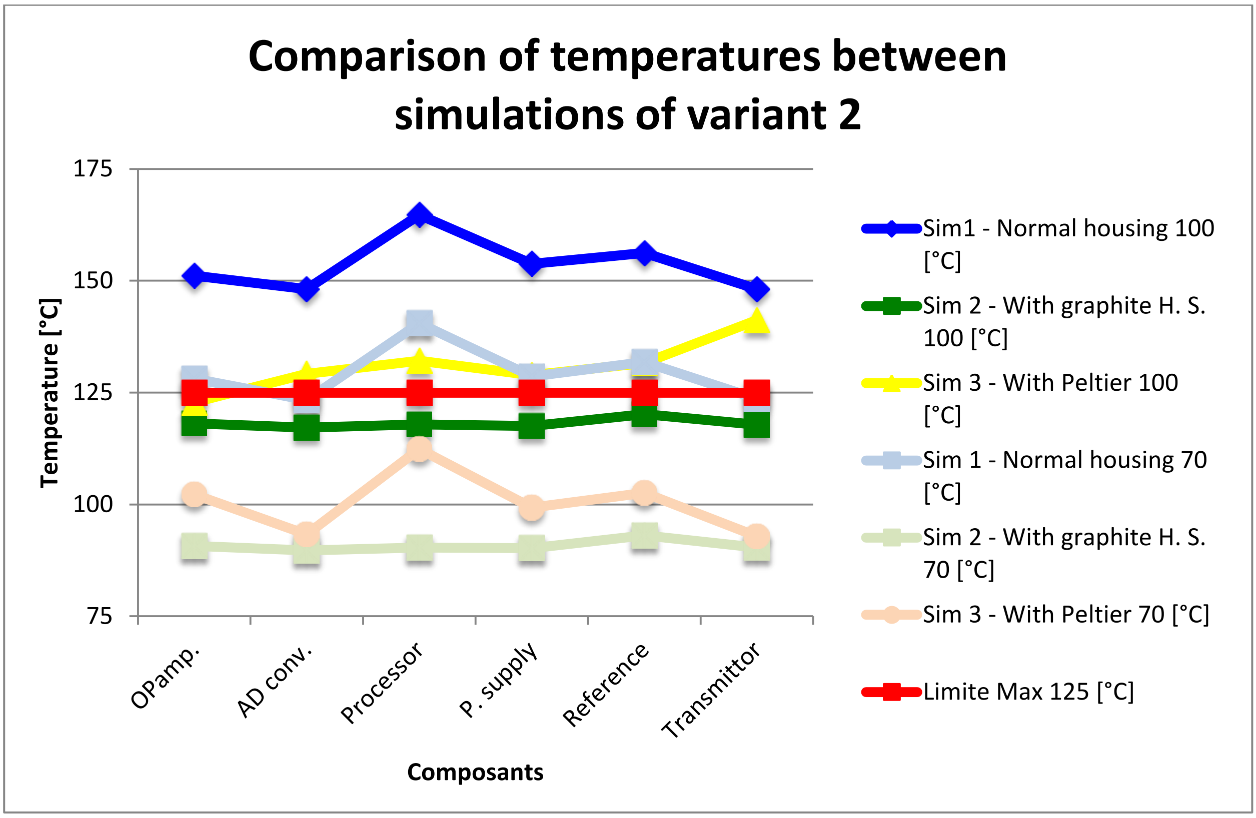


Figure 43 Comparison of the temperatures between simulations of variant 2

A design with Peltier element and graphite heat spreader in a thermos would probably be the best solution.

4. Analysis

Comparison between the existing sensor, variant 1 and variant 2.

4.1 Performance of models

Regarding the temperature, three models have been studied. The following table shows each design adapted to an appropriate temperature.

Ambient temperature	25 [°C] - [°C] max	70 [°C] 100 [°C] max	150 [°C] 180 [°C] max
Adapted model	Existing sensor	Variant 2 With graphite heat spreader	Variant 1 With high temperature components
Maximal component value	70,7 (@25[°C]) -	93,1 (@70[°C]) 120,2 (@100[°C])	166,8 (@150[°C]) 199,9 (@180[°C])
Pressure	- [bar]	25 [bar]	25 [bar]
Cost of studied electronic components	659 €	1’150 €	2’550 €

Figure 44 Adapted model for a specific ambient temperature

The two variants have a maximal “delta T with ambient” value of 20 [°C]. The existing sensor has a maximal “delta T with ambient” value of 45,7 [°C]. This is because during the development of the existing sensor, no interest has been taken to thermal flow.

All models have a different number of components, a different total power dissipation value and a different ambient temperature therefore it is difficult to make a general thermal analysis. Every model is analysed in its specific “Improvement” chapter.

4.2 Cost

The existing sensor with its components has a cost of 659 €. In variant 1, the cost of the studied electronic components (including geophones) is approximately 2’550 €. In variant 2, the cost of electronic components (including geophones) is approximately 1’150 €.

The existing sensor is not expensive, but it is not ready to be sold, some improvements should first be made. This could require more components, and may increase the price.

The variant 1, with high temperature components would cost a minimum of four times more than normal components. This is the cost of components from the category “space”, “avionics” and “drilling holes”. The advantage of this conception is that it is able to work at 180 [°C].

The variant 2, with components from the category “automotive”, would cost a minimum of 1’150€.

The new housing has no attributed price.

4.3 Improvements

At this time, the conception requires to be built. Then thermal measurements should be made at operating temperatures. The measurement results would certify simulations and give advice for future improvements. Then, at this point, further simulation of the sensor could be made.

According to mechanical possibilities of designs further PCB disposition in the housing could also be simulated. Such as two vertical PCBs in parallel, or "x" horizontal PCBs in parallel.

The Peltier element should be more studied to have correct simulation results. Then other designs with Peltier element could be simulated to found the best and cheapest result. For example the Peltier element could be set on the electronic components.

V. CONCLUSION

The first environment temperature is $T_{nominal}$ = 150 [°C] and with a maximal environment temperature of T_{max}=180 [°C]. A successful result has been found by using “high temperature” components from the “space” category (T_{max} = 210°C). This result is the “Variant 1”. Simulations have proven that the temperatures of the components are within an acceptable temperature range. The next step is to adjust the values of power dissipation, and the conduction value of the PCB, to suit realistic environment conditions. The scheme and the choice of the components should be analysed more carefully. A graphite heat spreader should be put around the DC/DC converter to improve dissipation.

The second environment temperature is $T_{nominal}$ = 70 [°C] and with a maximal environment temperature of T_{max}=100 [°C]. A successful result has been found by using components from the cathegory “Automotive” (T_{max} = 125°C) and a “graphite heat spreader” to improve the dissipation flow. This “graphite heat spreader“ greatly reduces the temperature and is necessary to stay in an acceptable temperature range. A design with a “Peltier” element has been studied and simulated. Unfortunately no realistic results have been found with this thermoelectric cooler. In the future, the specification of the “Peltier” element should be further investigated to find realistic solutions. But the obtained results show that improvements could be found by combining the “Peltier” elements with the “graphite heat spreaders” in a thermos design.

Unfortunately many specifications had to be approximated on the existing sensor. The results of the thermal camera have been misinterpreted. The analysis is not correct, but the steps are correct.

In conclusion, simulation has proven that a “graphite heat spreader” is necessary for working at an environment temperature of T = 70 [°C] and high temperature component are necessary for working at an environment temperature of T = 150 [°C]. At this time, the conception requires to be built. Then thermal measurements should be made at operating temperatures. The measurement results would certify simulations and give advice for future improvements. Then, at this point, further simulation of the sensor could be made.

The theme of this thesis was really interesting and captivating. I learned a lot about thermal aspects, thermal simulations and how to improve heat dissipation. I worked in almost complete independence and my assessment of some software problems took longer than necessary to find a suitable solution. Some decisions (for example: concerning emission coefficient) have not be taken correctly. Doing a thesis abroad (in Jena in Germany) was a great experience. It was a great opportunity to improve my German skills, to live in a new place and to discover a new “Fachhochschule”.

VI. THANKS

Dr. Detlef Redlich, expert Professor in Jena :

Thank you for your welcome and for this opportunity, for the good relationship, for the help with new software and for the help on the steps that follow. Also thanks for your patience in communication, and in speaking German slowly.

Dr. Joseph Moerschell, Professor in Sion :

Thank you for this interesting work and this opportunity, for the good collaboration, and for the general help during this thesis.

Volker Sesselmann, laboratory supervisor

Thank you for installing software on the computer and helping to run Pcad simulations.

Christian Cachelin

Thank you for designing the new seismic borehole sensor.

Benjamin Pietke

Thank you for modelling a simplified borehole sensor with triangle PCB on CoCreat software.

Cathy Ravedoni

Thank you for correcting the syntax of the report.

John Stevenson

Thank you for rereading the report.

VII. DATE ET SIGNATURE

Jena, 04 September 2015 Yves Ravedoni

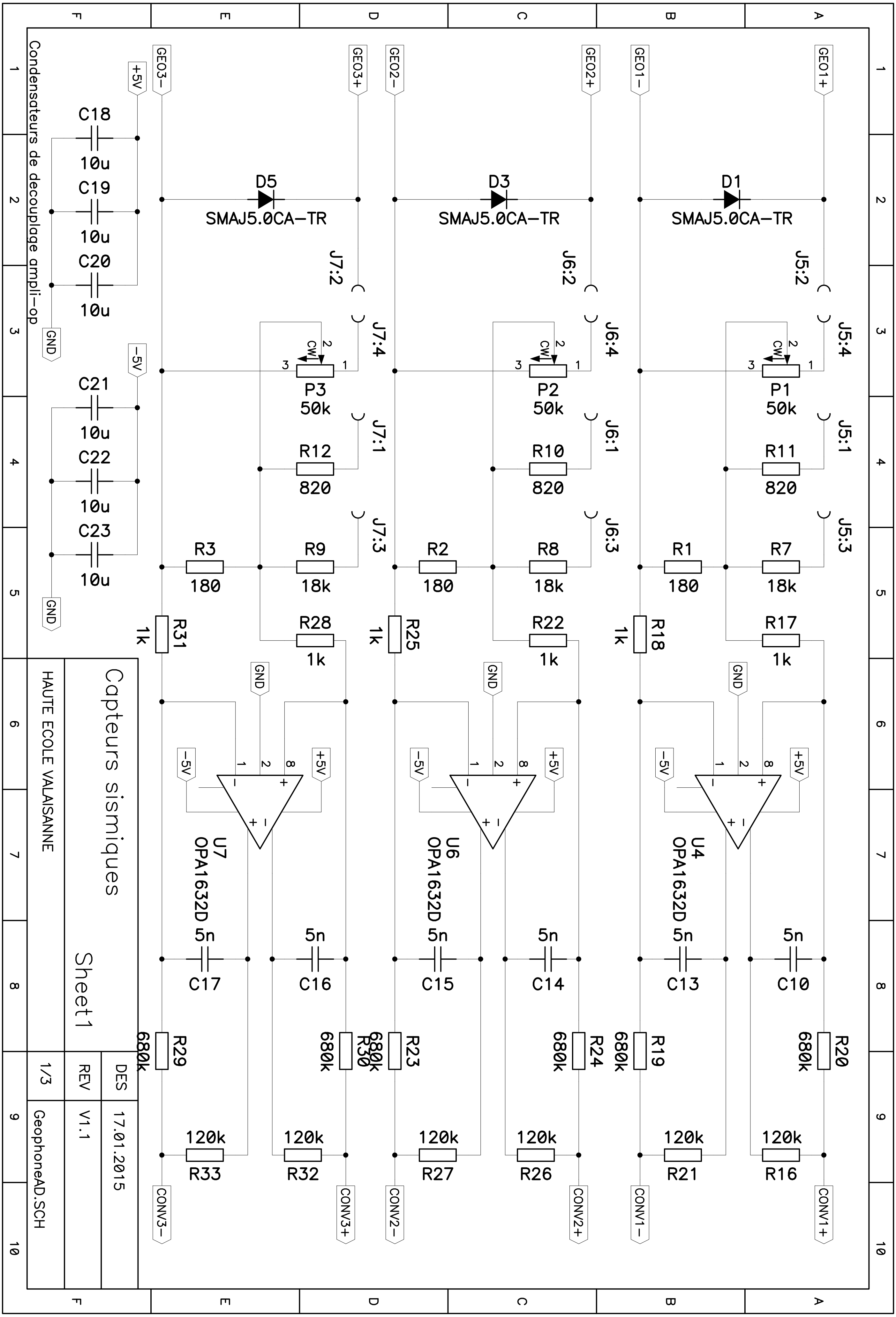
VIII. INDEX OF ANNEXES

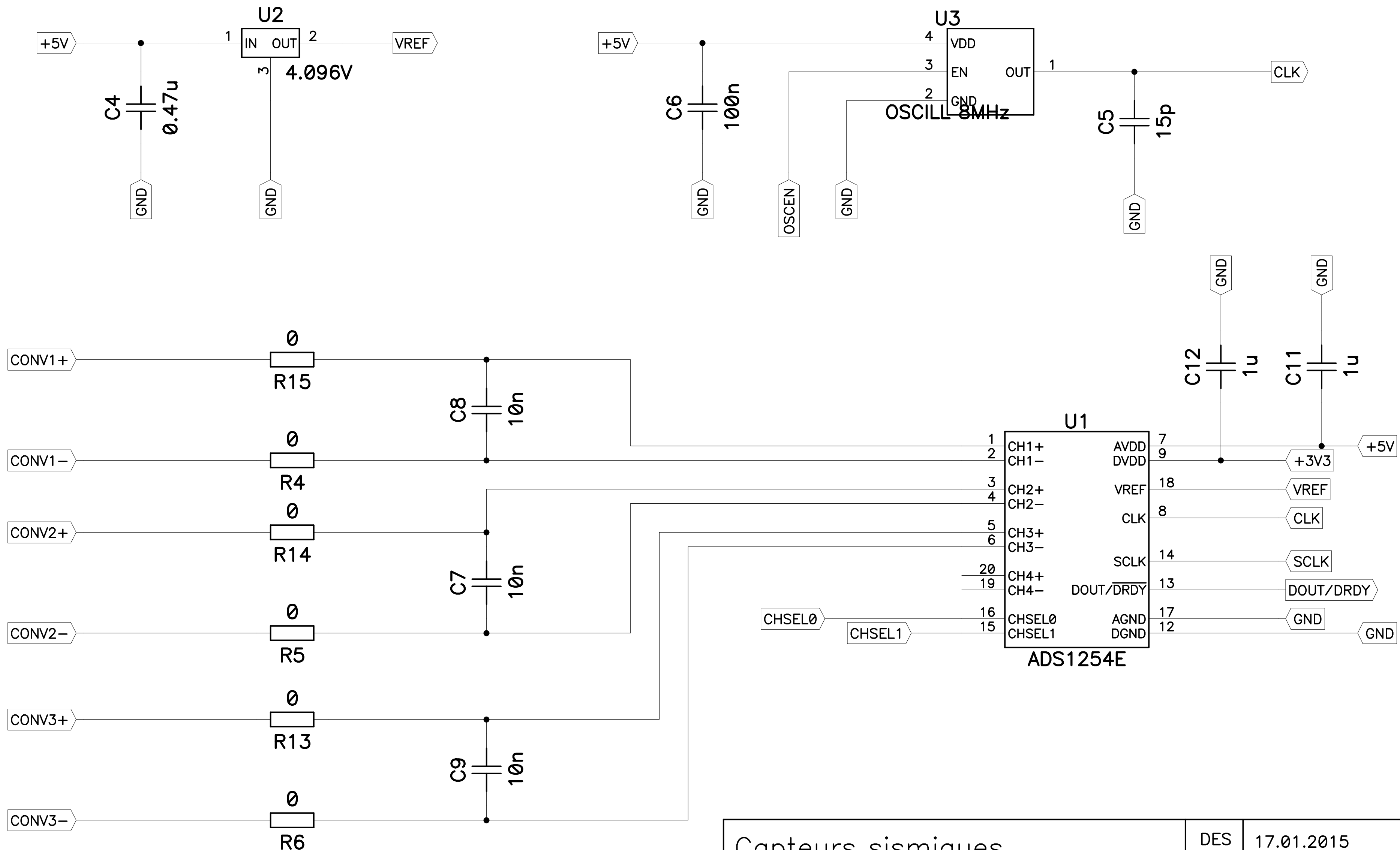
IX. INDEX OF FIGURES

X. INDEX OF TABLES

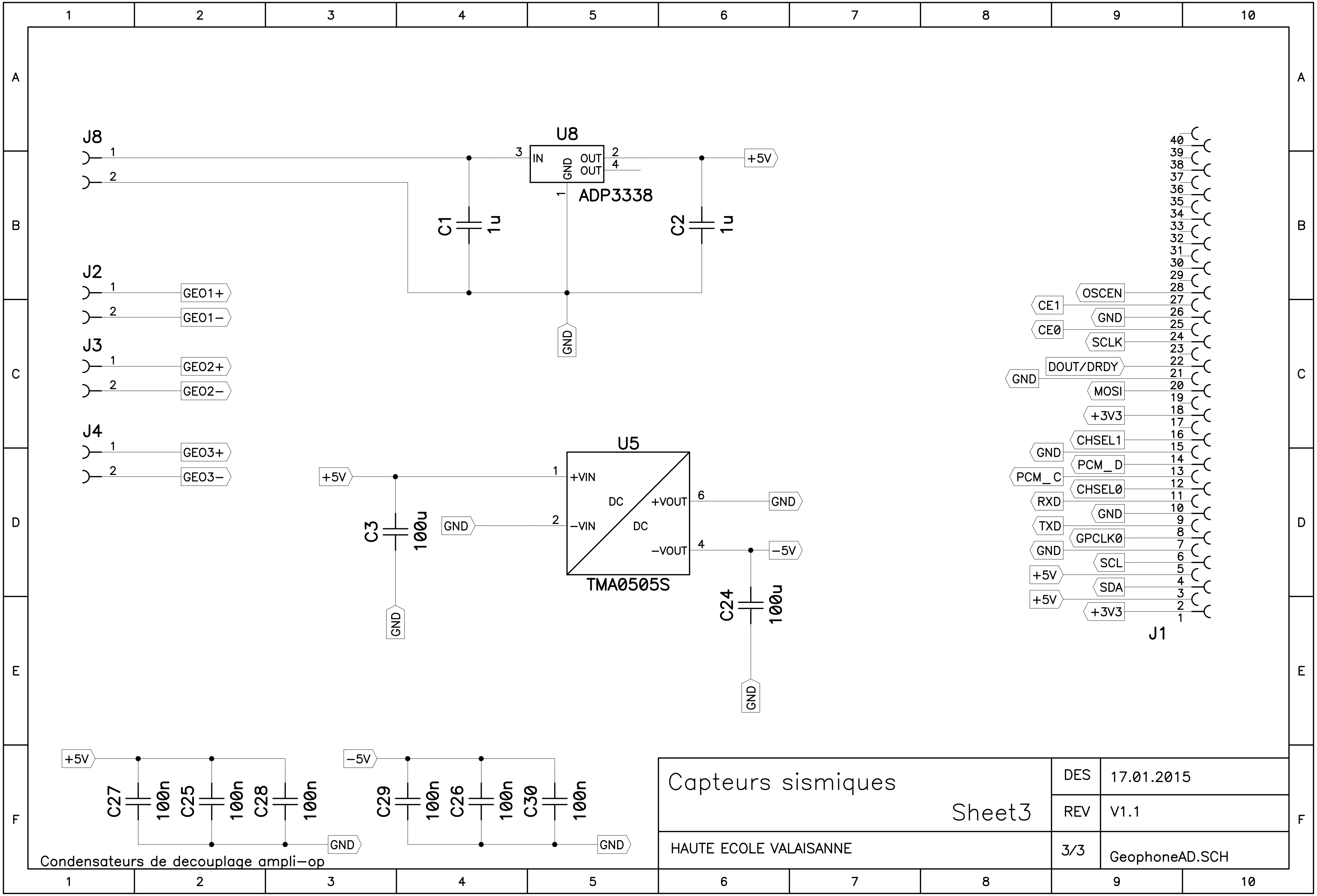
XI. BIBLIOGRAPHY

1. Page 7: „Reseau de capteur sismiques“, Thomas Oggier, Yannick Dayer et Fabien Clerc, 04/09/2014
2. Page 10: “Ansys tutorial, Für das Analyse-System Steady State Thermal und Komponentensystem Icepak” Prof. Dr. Detlef Redlich, 2011.
3. Page 11: “Ansys tutorial, Für das Analyse-System Steady State Thermal und Komponentensystem Icepak” Prof. Dr. Detlef Redlich, 2011.
4. Page 11: „Systemes Energetiques - Thermodynamique“ Michel Bonvin et Jessen Page, 2015
5. Page 34: “What on Earth” HTTP://WHATONEARTH.OLEHNIELSEN.DK/IMG/SEISMIC_VEL_EARTH.JPG 31.07.15, archive HTTP://ARCHIVE.IS/RBX1K 01.09.15
6. Page 35: Image from „Sismomètre Plan B – A0100“ Christian Cachelin, 25.05.2015, Hes-so Valais-Wallis
7. Page 44: “Modul, Scientific and Production firm” HTTP://HOME.ARCOR.DE/GLAUBE.U/SPF-MODUL/CONSTRUCTION%20OF%20TEM%20N.HTML 02.09.15


Capteurs sismiques
Sheet1
HAUTE ECOLE VALAISANNE
DES 17.01.2015
REV V1.1
1/3 GeophoneAD.SCH
Condensateurs de decouplage ampli-op
C18 10u
C19 10u
C20 10u
C21 10u
C22 10u
C23 10u
+5V
-5V
GND
GEO1+
GEO1-
GEO2+
GEO2-
GEO3+
GEO3-
D1 SMAJ5.0CA-TR
D3 SMAJ5.0CA-TR
D5 SMAJ5.0CA-TR
J5:1 J5:2 J5:3 J5:4
J6:1 J6:2 J6:3 J6:4
J7:1 J7:2 J7:3 J7:4
P1 50k
P2 50k
P3 50k
R1 180
R2 180
R3 180
R7 18k
R8 18k
R9 18k
R10 820
R11 820
R12 820
R17 1k
R18 1k
R22 1k
R25 1k
R28 1k
R31 1k
U4 OPA1632D
U6 OPA1632D
U7 OPA1632D
C10 5n
C13 5n
C14 5n
C15 5n
C16 5n
C17 5n
R19 680k
R20 680k
R23 680k
R24 680k
R29 680k
R30 680k
R16 120k
R21 120k
R26 120k
R27 120k
R32 120k
R33 120k
CONV1+
CONV1-
CONV2+
CONV2-
CONV3+
CONV3-



Capteurs sismiques Sheet2		DES	17.01.2015
		REV	V1.1
HAUTE ECOLE VALAISANNE		2/3	GeophoneAD.SCH



J8
U8
IN
GND
OUT
OUT
ADP3338
+5V
C1
1u
C2
1u
GND
J2
GEO1+
GEO1−
J3
GEO2+
GEO2−
J4
GEO3+
GEO3−
U5
+VIN
−VIN
DC
DC
+VOUT
−VOUT
TMA0505S
C3
100u
C24
100u
−5V
J1
OSCEN
CE1
CE0
SCLK
DOUT/DRDY
MOSI
+3V3
CHSEL1
PCM_D
PCM_C
CHSEL0
RXD
TXD
GPCLK0
SCL
SDA
C27
C25
C28
C29
C26
C30
100n
Condensateurs de decouplage ampli−op
Capteurs sismiques
Sheet3
HAUTE ECOLE VALAISANNE
DES
17.01.2015
REV
V1.1
3/3
GeophoneAD.SCH

HOME ABOUT INVESTOR RELATIONS PRODUCT LINE NEWS CONTACT US EMS

You are here: Home / geospacetechnologies / Geophones GS-11D

Geophones GS-11D

FEBRUARY 7, 2012 BY ADMIN

GS-11D

Rotating Coil Geophone

- Field proven design
- Shock resistant, rotating dual coil construction
- Gold plated contacts for positive electrical connection
- Precision springs, computer designed and matched
- Full one year warranty

The GS-11D is a high output, rotating coil geophone designed and built to withstand
the shocks of rough handling. The precision springs of this field proven geophone are computer designed and matched to optimize performance specifications even under the most extreme conditions.

Gold plated contacts assure positive electrical connections. The Geo Space manufacturing process includes checking all geophone operating parameters with the ATS, an automated computerized test system.

Natural frequencies are 4.5, 8, 10 and 14 Hz, with standard coil resistance of 380 ohms. The PC-21 Land Case is used with the GS-11D geophone.

Cases Available
PC-21 Land Case

Spec Sheet:

GS-11D Specifications

Natural Frequency	4.5 ± .75 Hz	8 ± .75 Hz	10 ± .75 Hz	14 ± .75 Hz
Coil Resistance @ 25°C ± 5%	——380 Ohms ——			
Intrinsic Voltage Sensitivity with 380 Ohm Coil ± 10%	——.81 V/in/sec (.32 V/cm/sec) ——			
Normalized Transduction Constant (V/in/sec)	——042 (sq.root of Rc) ——			
Open Circuit Damping	.34 ± 20%	.39 ± 10%	.32 ± 10%	.23 ± 10%
Damping Constant with 380 Ohm Coil	762	602	482	344
Optional Coil Resistances ± 5%	——4,000 Ohms ——			
Moving Mass ± 5%	23.6 g	16.8 g	16.8 g	16.8 g
Typical Case to Coil Motion P-P	.07 in (.18 cm)	.07 in (.18 cm)	.07 in (.18 cm)	.07 in (.18 cm)
Harmonic Distortion with Driving Velocity of 0.7 in/sec (1.8 cm/sec) P-P	N/S	——0.2% or less —— @ 12 Hz @ 12 Hz @ 12 Hz		
Dimensions				
Height (less terminals*)	———1.32 in (3.35 cm) ———			
Diameter	———1.25 in (3.18 cm) ———			
Weight	———3.9 oz (111 g) ———			

*Terminal height is .135 inches
Specifications are subject to change without notice.

GS-11D Seismic Detector Response Curve
Output vs. Frequency Chart (GS-11D @ 4.5 Hz @ 380 Ohms)

Certificate No.7758

Search by Specific Product

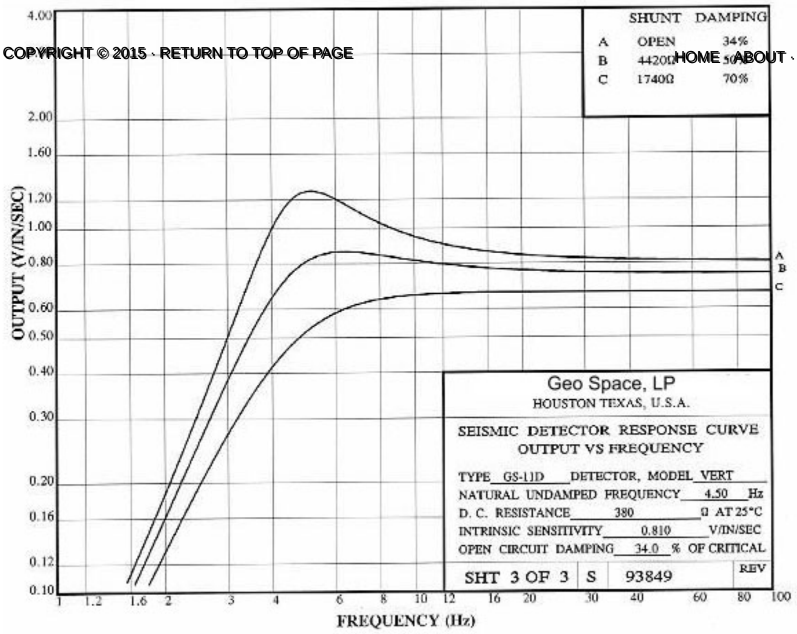
Please Choose

OR

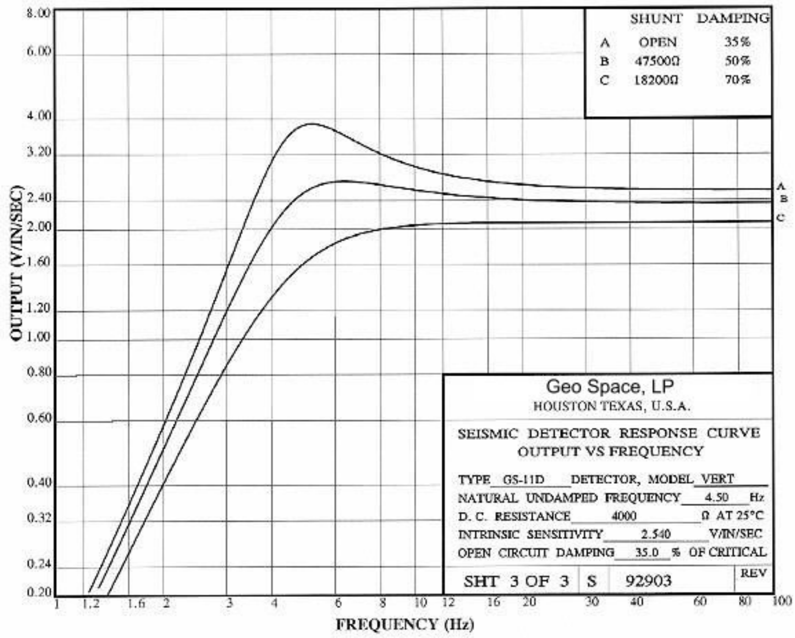
Search By Product or Keyword

Search this website…

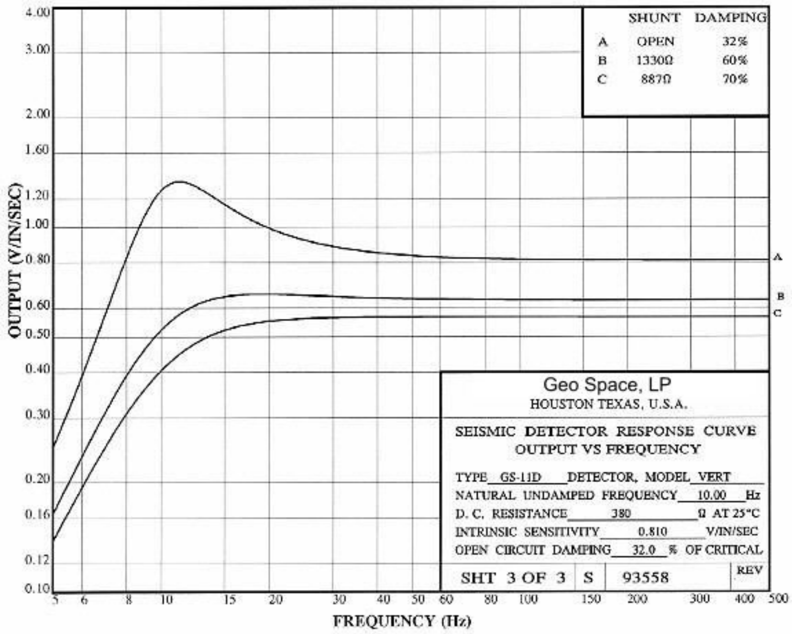
SEARCH



GS-11D Seismic Detector Response Curve
Output vs. Frequency Chart (GS-11D @ 4.5 Hz @ 4000 Ohms)



GS-11D Seismic Detector Response Curve
Output vs. Frequency Chart (GS-11D 10 Hz @ 380 Ohms)



Specifications are subject to change without notice.

For Additional Information, please fill out the form below, and we will be in contact as soon as possible.

Your Name (required)

Your Email (required)

Company Name (required)

Select Your Product Description

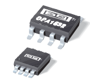
Your Message

Verify the characters in the box below:

YB73

Send

FILED UNDER: GEOSPACETECHNOLOGIES TAGGED WITH: GS-11D



SBOS286 − DECEMBER 2003

High-Perfomance, Fully-Differential AUDIO OP AMP

FEATURES

- SUPERIOR SOUND QUALITY
- ULTRA LOW DISTORTION: 0.000022%
- LOW NOISE: 1.3nV/√Hz
- HIGH SPEED:
  - Slew Rate: 50V/μs
  - Gain Bandwidth: 180MHz
- FULLY DIFFERENTIAL ARCHITECTURE:
  - Balanced Input and Output Converts Single-Ended Input to Balanced Differential Output
- WIDE SUPPLY RANGE: ±2.5V to ±16V
- SHUTDOWN TO CONSERVE POWER

APPLICATIONS

- AUDIO ADC DRIVER
- BALANCED LINE DRIVER
- BALANCED RECEIVER
- ACTIVE FILTER
- PREAMPLIFIER

DESCRIPTION

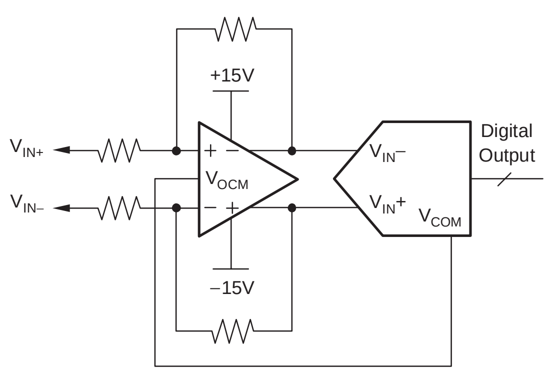
The OPA1632 is a fully-differential amplifier designed for driving high-performance audio analog-to-digital converters (ADCs). It provides the highest audio quality, with very low noise and output drive characteristics optimized for this application. The OPA1632's excellent gain bandwidth of 180MHz and very fast slew rate of 50V/μs produce exceptionally low distortion. Very low input noise of 1.3nV/√Hz further ensures maximum signal-to-noise ratio and dynamic range.

The flexibility of the fully differential architecture allows for easy implementation of a single-ended to fully-differential output conversion. Differential output reduces even-order harmonics and minimizes common-mode noise interference. The OPA1632 provides excellent performance when used to drive high-performance audio ADCs such as the PCM1804. A shutdown feature also enhances the flexibility of this amplifier.

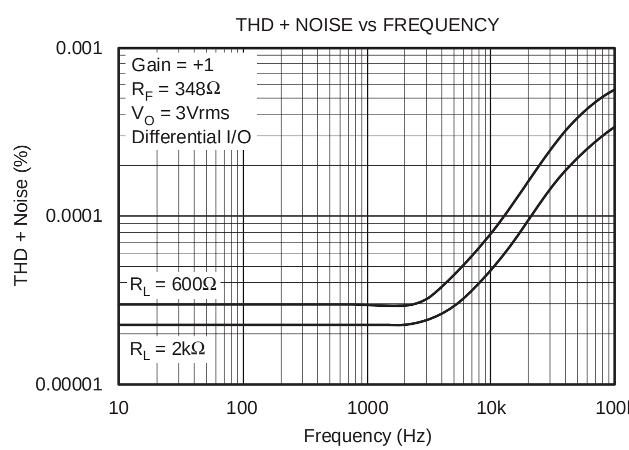
The OPA1632 is available in an SO-8 package and a thermally-enhanced MSOP-8 PowerPAD package.

RELATED DEVICES

OPAx134	High-Performance Audio Amplifiers
OPA627/637	Precision High-Speed DiFET Amplifiers
OPAx227/x228	Low-Noise Bipolar Amplifiers



Typical ADC Circuit



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

PowerPAD is a trademark of Texas Instruments. All other trademarks are the property of their respective owners.

PACKAGE/ORDERING INFORMATION

PRODUCT	PACKAGE-LEAD(1)	PACKAGE DRAWING	SPECIFIED TEMPERATURE RANGE	PACKAGE MARKING	ORDERING NUMBER	TRANSPORT MEDIA, QUANTITY
OPA1632	SO-8	D	−40°C to +85°C	OPA1632	OPA1632D	Rails, 100
					OPA1632DR	Tape and Reel, 2500
	MSOP-8 PowerPAD	DGN	−40°C to +85°C	1632	OPA1632DGN	Rails, 100
					OPA1632DGNR	Tape and Reel, 2500

(1) For the most current specification and package information, refer to our web site at www.ti.com.

ABSOLUTE MAXIMUM RATINGS(1)(2)

over operating free-air temperature range unless otherwise noted.

Supply Voltage, $\pm V_S$	±16.5V
Input Voltage, V_I	$\pm V_S$
Output Current, I_O	150mA
Differential Input Voltage, V_{ID}	±3V
Maximum Junction Temperature, T_J	150°C
Operating Free-Air Temperature Range	−40°C to +85°C
Storage Temperature Range, T_{STG}	−65°C to +150°C
Lead Temperature 1,6mm (1/16th inch) from case for 10 seconds	+300°C
ESD Ratings: Human Body Model	1kV
Charge Device Model	500V
Machine Model	200V

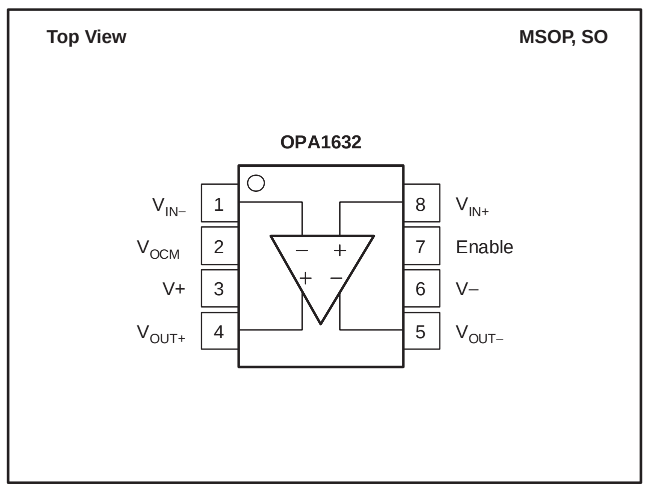
(1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not implied.

(2) The OPA1632 MSOP-8 package version incorporates a PowerPAD on the underside of the chip. This acts as a heatsink and must be connected to a thermally dissipative plane for proper power dissipation. Failure to do so may result in exceeding the maximum junction temperature, which can permanently damage the device. See TI technical brief SLMA002 for more information about using the PowerPAD thermally enhanced package.

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

PIN CONFIGURATION

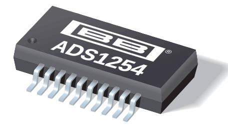


ELECTRICAL CHARACTERISTICS: V_S = ±15V

V_S = ±15V: R_F = 390Ω, R_L = 800Ω, and G = +1, unless otherwise noted.

PARAMETER		CONDITIONS	OPA1632 MIN	OPA1632 TYP	OPA1632 MAX	UNITS
OFFSET VOLTAGE						
Input Offset Voltage				±0.5	±3	mV
vs Temperature	dVos/dT			±5		μV/°C
vs Power Supply, DC	PSRR		316	13		μV/V
INPUT BIAS CURRENT						
Input Bias Current	I_B			2	6	μA
Input Offset Current	I_{OS}			±100	±500	nA
NOISE						
Input Voltage Noise		f = 10 kHz		1.3		$nV/\sqrt{Hz}$
Input Current Noise		f = 10 kHz		0.4		$pA/\sqrt{Hz}$
INPUT VOLTAGE						
Common-Mode Input Range			(V−) + 1.5		(V+) − 1	V
Common-Mode Rejection Ratio, DC			74	90		dB
INPUT IMPEDANCE						
Input Impedance (each input pin)				34 || 4		MΩ || pF
OPEN-LOOP GAIN						
Open-Loop Gain , DC			66	78		dB
FREQUENCY RESPONSE						
Small-Signal Bandwidth		G = +1, R_F= 348Ω		180		MHz
(V_O = 100mV$_{PP}$, Peaking < 0.5 dB)		G = +2, R_F = 602Ω		90		MHz
		G = +5, R_F = 1.5kΩ		36		MHz
		G = +10, R_F = 3.01kΩ		18		MHz
Bandwidth for 0.1dB Flatness		G = +1, V_O = 100mV$_{PP}$		40		MHz
Peaking at a Gain of 1		V_O = 100mV$_{PP}$		0.5		dB
Large-Signal Bandwidth		G = +2, V_O = 20V$_{PP}$		800		kHz
Slew Rate (25% to 75%)		G = +1		50		V/μs
Rise and Fall Time		G = +1, V_O = 5V Step		100		ns
Settling Time to 0.1%		G = +1, V_O = 2V Step		75		ns
0.01%		G = +1, V_O = 2V Step		200		ns
Total Harmonic Distortion + Noise		G = +1, f = 1kHz, V_O = 3Vrms				
Differential Input/Output		R_L = 600Ω		0.0003		%
Differential Input/Output		R_L = 2kΩ		0.000022		%
Single-Ended In/Differential Out		R_L = 600Ω		0.000059		%
Single-Ended In/Differential Out		R_L = 2kΩ		0.000043		%
Intermodulation Distortion		G = +1, SMPTE/DIN, V_O = 2V$_{PP}$				
Differential Input/Output		R_L = 600Ω		0.00008		%
Differential Input/Output		R_L = 2kΩ		0.00005		%
Single-Ended In/Differential Out		R_L = 600Ω		0.0001		%
Single-Ended In/Differential Out		R_L = 2kΩ		0.0007		%
Headroom		THD < 0.01%, R_L = 2kΩ		20.0		V_{PP}
OUTPUT						
Voltage Output Swing		R_L = 2kΩ	(V+) − 1.9		(V−) + 1.9	V
		R_L = 800Ω	(V+) − 4.5		(V−) + 4.5	V
Short-Circuit Current	I_{SC}	Sourcing/Sinking	+50/−60	85		mA
Closed-Loop Output Impedance		G = +1, f = 100kHz		0.3		Ω
POWER-DOWN(1)						
Enable Voltage Threshold				(V−) + 2		V
Disable Voltage Threshold				(V−) + 0.8		V
Shutdown Current		V_{ENABLE} = −15V		0.85	1.5	mA
Turn-On Delay		Time for I_Q to Reach 50%		2		μs
Turn-Off Delay		Time for I_Q to Reach 50%		2		μs
POWER SUPPLY						
Specified Operating Voltage				±15	±16	V
Operating Voltage			±2.5			V
Quiescent Current	I_Q	Per Channel		14	17.1	mA
TEMPERATURE RANGE						
Specified Range			−40		+85	°C
Operating Range			−40		+125	°C
Storage Range			−65		+150	°C
Thermal Resistance	θ_{JA}			200		°C/W

(1) Amplifier has internal 50kΩ pull-up resistor to V_{CC+} pin. This enables the amplifier with no connection to shutdown pin.



SBAS213B – JUNE 2001 – REVISED JUNE 2006

24-Bit, 20kHz, Low Power ANALOG-TO-DIGITAL CONVERTER

FEATURES

- 24 BITS—NO MISSING CODES
- 19 BITS EFFECTIVE RESOLUTION UP TO 20kHz DATA RATE
- LOW NOISE: 1.8ppm
- FOUR DIFFERENTIAL INPUTS
- INL: 15ppm (max)
- EXTERNAL REFERENCE (0.5V to 5V)
- POWER-DOWN MODE
- SYNC MODE
- LOW POWER: 4mW at 20kHz
- SEPARATE DIGITAL INTERFACE SUPPLY 1.8V to 3.6V

APPLICATIONS

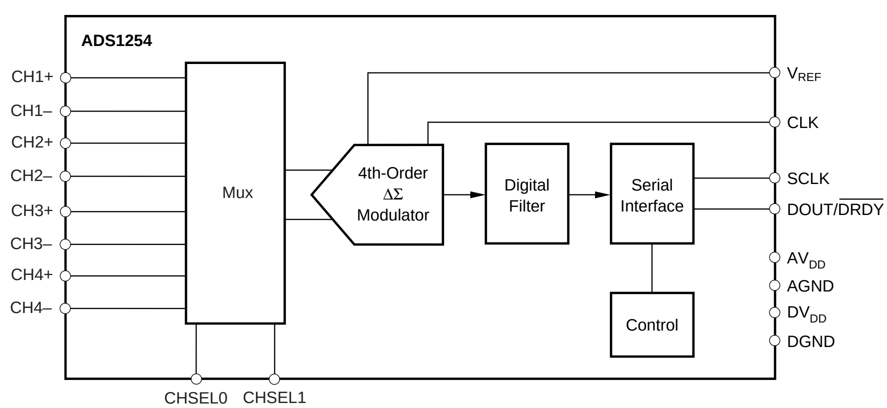
- CARDIAC DIAGNOSTICS
- DIRECT THERMOCOUPLE INTERFACES
- BLOOD ANALYSIS
- INFRARED PYROMETERS
- LIQUID/GAS CHROMATOGRAPHY
- PRECISION PROCESS CONTROL

DESCRIPTION

The ADS1254 is a precision, wide dynamic range, delta-sigma, Analog-to-Digital (A/D) converter with 24-bit resolution. The delta-sigma architecture is used for wide dynamic range and to ensure 24 bits of no missing codes performance. An effective resolution of 19 bits (1.8ppm of rms noise) is achieved for conversion rates up to 20kHz.

The ADS1254 is designed for high-resolution measurement applications in cardiac diagnostics, smart transmitters, industrial process control, weight scales, chromatography, and portable instrumentation. The converter includes a flexible, two-wire synchronous serial interface for low-cost isolation.

The ADS1254 is a multi-channel converter and is offered in an SSOP-20 package.



ABSOLUTE MAXIMUM RATINGS[1]

Analog Input: Current (Momentary)	±100mA
(Continuous)	±10mA
Voltage	GND – 0.3V to V_{DD} + 0.3V
AV_{DD} to AGND	–0.3V to 6V
DV_{DD} to AV_{DD}	–6V to +6V
DV_{DD} to DGND	–0.3V to 6V
V_{REF} Voltage to AGND	–0.3V to V_{DD} + 0.3V
Digital Input Voltage to DGND	–0.3V to V_{DD} + 0.3V
Digital Output Voltage to DGND	–0.3V to V_{DD} + 0.3V
Lead Temperature (soldering, 10s)	+300°C
Power Dissipation (any package)	500mW

NOTE: (1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability.

ELECTROSTATIC DISCHARGE SENSITIVITY

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

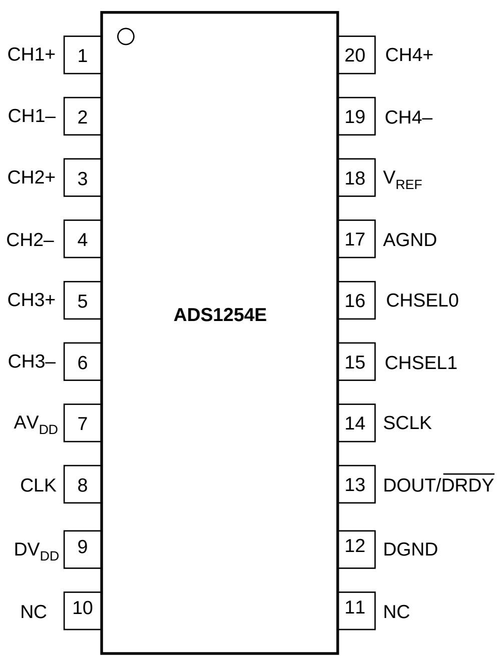
ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

PACKAGE/ORDERING INFORMATION

For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI website at www.ti.com.

PIN CONFIGURATION

Top View **SSOP-20**



PIN DESCRIPTIONS

PIN	NAME	PIN DESCRIPTION
1	CH1+	Analog Input: Positive Input of the Differential Analog Input
2	CH1–	Analog Input: Negative Input of the Differential Analog Input
3	CH2+	Analog Input: Positive Input of the Differential Analog Input
4	CH2–	Analog Input: Negative Input of the Differential Analog Input
5	CH3+	Analog Input: Positive Input of the Differential Analog Input
6	CH3–	Analog Input: Negative Input of the Differential Analog Input
7	AV_{DD}	Input: Analog Power Supply Voltage, +5V
8	CLK	Digital Input: Device System Clock. The system clock is in the form of a CMOS-compatible clock. This is a Schmitt-Trigger input
9	DV_{DD}	Input: Digital Power Supply Voltage
10	NC	No Connection
11	NC	No Connection
12	DGND	Input: Digital Ground
13	DOUT/$\overline{DRDY}$	Digital Output: Serial Data Output/Data Ready. This output indicates that a new output word is available from the ADS1254 data output register. The serial data is clocked out of the serial data output shift register using SCLK.
14	SCLK	Digital Input: Serial Clock. The serial clock is in the form of a CMOS-compatible clock. The serial clock operates independently from the system clock; therefore, it is possible to run SCLK at a higher frequency than CLK. The normal state of SCLK is LOW. Holding SCLK HIGH will either initiate a modulator reset for synchronizing multiple converters or enter power-down mode. This is a Schmitt-Trigger input.
15	CHSEL1	Digital Input: Used to select analog input channel. This is a Schmitt-Trigger Input
16	CHSEL0	Digital Input: Used to select analog input channel. This is a Schmitt-Trigger Input
17	AGND	Input: Analog Ground
18	V_{REF}	Analog Input: Reference Voltage Input
19	CH4–	Analog Input: Negative Input of the Differential Analog Input
20	CH4+	Analog Input: Positive Input of the Differential Analog Input

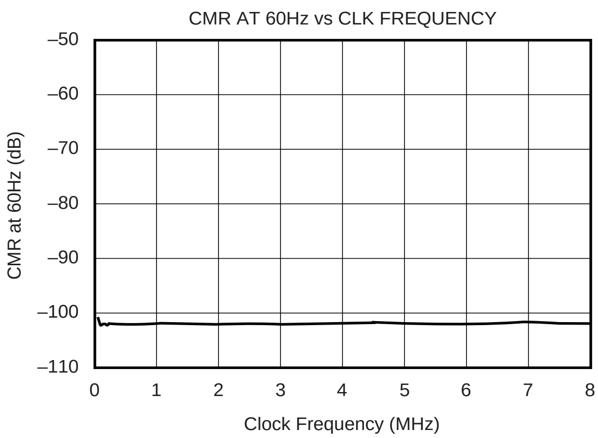
ELECTRICAL CHARACTERISTICS

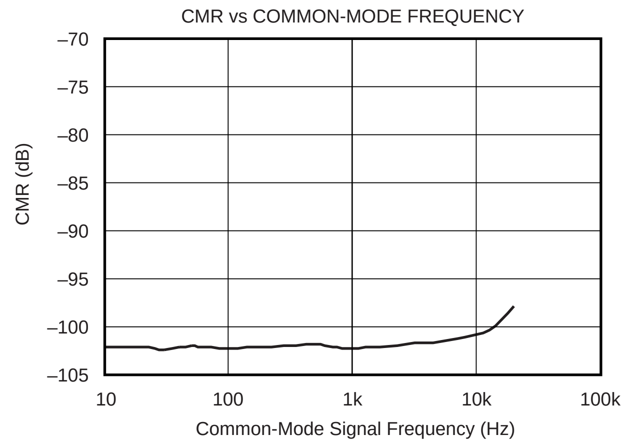
All specifications at T_{MIN} to T_{MAX}, AV_{DD} = +5V, DV_{DD} = +1.8V. CLK = 8MHz, and V_{REF} = 4.096, unless otherwise specified.

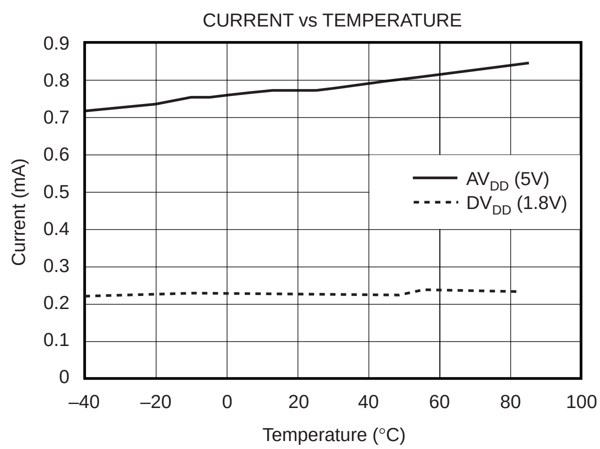
PARAMETER	CONDITIONS	ADS1254E			UNITS
		MIN	TYP	MAX	
ANALOG INPUT					
Input Voltage Range		AGND		$\pm V_{REF}$	V
Input Impedance	CLK = 3,840Hz		260		MΩ
	CLK = 1MHz		1		MΩ
	CLK = 8MHz		125		kΩ
Input Capacitance			6		pF
Input Leakage	At +25°C		5	50	pA
	At T_{MIN} to T_{MAX}			1	nA
DYNAMIC CHARACTERISTICS					
Data Rate				20.8	kHz
Bandwidth	–3dB	4.24			kHz
Serial Clock (SCLK)				8	MHz
System Clock Input (CLK)				8	MHz
ACCURACY					
Integral Non-Linearity[(1)]			±0.0002	±0.0015	% of FSR
THD	1kHz Input; 0.1dB below FS		105		dB
Noise			1.8	2.7	ppm of FSR, rms
Resolution			24		Bits
No Missing Codes			24		Bits
Common-Mode Rejection	60Hz, AC	90	102		dB
Gain Error			0.1	1	% of FSR
Offset Error			±30	±100	ppm of FSR
Gain Sensitivity to V_{REF}			1:1		
Power-Supply Rejection Ratio		70	88		dB
PERFORMANCE OVER TEMPERATURE					
Offset Drift			0.07		ppm/°C
Gain Drift			0.4		ppm/°C
VOLTAGE REFERENCE					
V_{REF}		0.5	4.096	V_{DD}	V
Load Current			32		µA
DIGITAL INPUT/OUTPUT					
Logic Family			CMOS		
Logic Level: V_{IH}		0.65 • DV_{DD}		DV_{DD} + 0.3	V
V_{IL}		–0.3		0.35 • DV_{DD}	V
V_{OH}	I_{OH} = –500µA	DV_{DD} –0.4			V
V_{OL}	I_{OL} = 500µA			0.4	V
Input (SCLK, CLK, CHSEL0, CHSEL1) Hysteresis			0.6		V
Data Format			Offset Binary Two's Complement		
POWER-SUPPLY REQUIREMENTS					
Power Supply Voltage	DV_{DD}	1.8		3.6	VDC
	AV_{DD}	4.75	5	5.25	VDC
Quiescent Current	AV_{DD} = +5V		0.8	1.15	mA
	DV_{DD} = +1.8V		0.2	0.4	mA
Operating Power			4.3	6.5	mW
Power-Down Current			0.4	1	µA
TEMPERATURE RANGE					
Operating		–40		+85	°C
Storage		–60		+150	°C

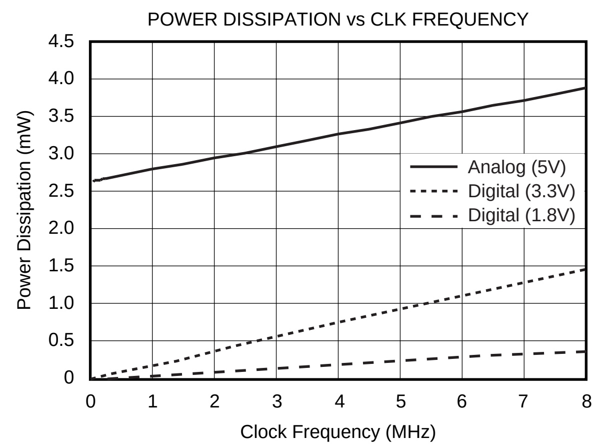
NOTE: (1) Applies to full-differential signals.

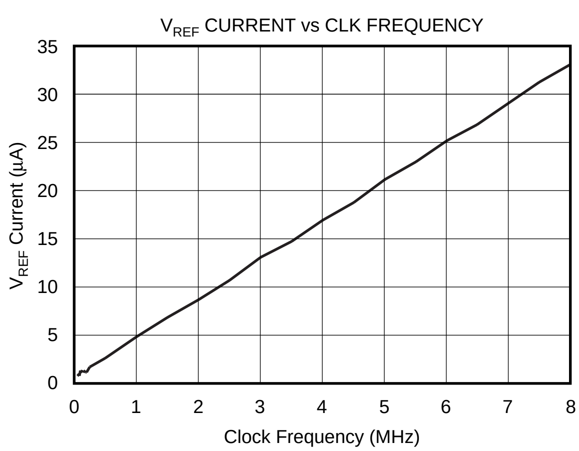
At T_A = +25°C, AV_{DD} = +5V, DV_{DD} = +1.8V, CLK = 8MHz, and V_{REF} = 4.096, unless otherwise specified.

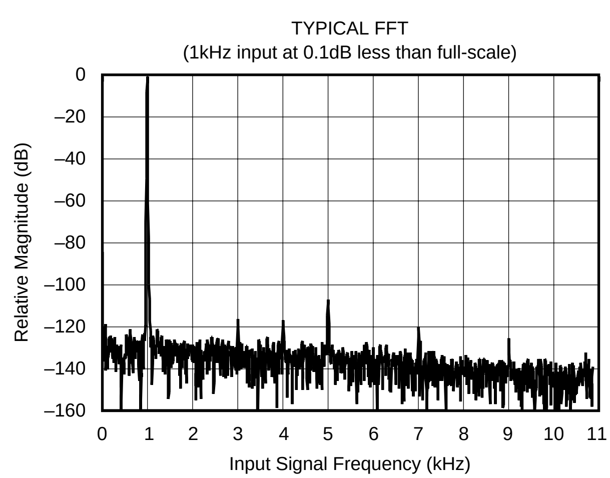












N150 Micro Wireless USB Adapter

TEW-648UBM (V1.0R)

The N150 Micro Wireless USB Adapter (model TEW-648UBM) quickly connects a laptop or desktop computer to a high speed wireless n network.

Enjoy proven wireless n speed and reliability, in a micro design that extends less than three eighths of an inch (9mm) from the edge of a computer.

Connecting to a network is made easy with the external one-touch Wi-Fi Protected Setup (WPS) button. Advanced wireless encryption protects your valuable data. Wi-Fi Multimedia (WMM) Quality of Service (QoS) prioritizes important video, audio, and gaming traffic. Seamlessly stream video, download files, and play games with this ultra compact wireless n adapter.

Features

- 1 x USB 2.0 connector
- Ultra compact form factor
- Wi-Fi compliant with IEEE 802.11n standard
- One-touch wireless connection with external Wi-Fi Protected Setup (WPS) button
- Backwards compatible with IEEE 802.11g and IEEE 802.11b devices
- Maximum reliability, throughput, and connectivity with automatic data rate switching
- Supports 64/128-bit WEP, WPA/WPA2-RADIUS, and WPA-PSK/WPA2-PSK
- Wi-Fi Multimedia (WMM) Quality of Service (QoS) data prioritization
- Easy user setup and intuitive diagnostic utility
- Coverage of up to 30 meters indoor (98feet) and 50 meters outdoor (164 feet) *
- 3-year limited warranty

*Maximum wireless signal rates are referenced from IEEE 802.11 theoretical specifications. Actual data throughput and coverage will vary depending on interference, network traffic, building materials and other conditions.

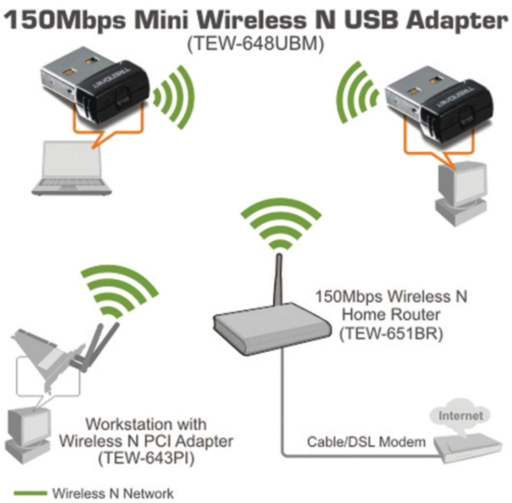
N150 Micro Wireless USB Adapter

TEW-648UBM (V1.0R)

SPECIFICATIONS

Hardware	
Interface	• USB 2.0
Standards	• IEEE 802.11b, IEEE 802.11g, and IEEE 802.11n (draft 2.0)
Button	• WPS button: enables quick wireless connection with WPS function
Power Consumption	• Receive mode: 100mA (max.) • Transmit mode : 210mA (max)
Supported OS	• Windows® 8, 7, Vista, XP • Mac OS® 10.4-10.8
Dimensions (LxWxH)	• 20 x 15 x 7 mm (0.8 x 0.6 x 0.3 in.)
Weight	• 1 g (0.03 oz)
Temperature	• Operating: 0° ~ 40° C (32° ~ 104° F) • Storage: -10° ~ 70° C (14° ~ 158° F)
Humidity	• Max. 95% (non-condensing)
Certifications	• CE, FCC
Wireless	
Modulation	• OFDM, DSSS
Antenna	• Built-in on board antenna
Frequency	• 2.412 ~ 2.484 GHz
Data Rate (auto fallback)	• 802.11b: up to 11Mbps • 802.11g: up to 54Mbps • 802.11n: up to 150Mbps
Output Power	• 802.11b: 14dBm (typical) • 802.11g: 11dBm (typical) • 802.11n: 10dBm (typical)
Receiving Sensitivity	• 802.11b: -84dBm (typical) at 11mpbs • 802.11g: -69dBm (typical) at 54Mbps • 802.11n: -66dBm (typical) at 150Mbps
Encryption	• 64/128-bit WEP, WPA/WPA2-RADIUS, WPA-PSK/WPA2-PSK
Channels	• 1~11 (FCC), 1~13 (ETSI)

NETWORKING SOLUTIONS



PACKAGE CONTENTS

- TEW-648UBM
- CD-ROM (Utility and Driver)
- Multi-Language Quick Installation Guide

RELATED PRODUCTS

TEW-651BR	150Mbps Wireless N Home Router
TEW-650AP	150Mbps Wireless N Access Point
TEW-647GA	Wireless N Gaming Adapter

CONTACT INFORMATION

TRENDnet®
20675 Manhattan Place,Torrance, CA 90501 USA
Tel: 1-310-961-5500
Fax: 1-310-961-5511
Web: www.trendnet.com
Email: sales@trendnet.com
1-888-326-6061

High Accuracy, Ultralow I_Q, 1 A, anyCAP® Low Dropout Regulator

ADP3338

FEATURES

- High accuracy over line and load: ±0.8% @ 25°C, ±1.4% over temperature
- Ultralow dropout voltage: 190 mV (typ) @ 1 A
- Requires only C_O = 1.0 µF for stability
- anyCAP is stable with any type of capacitor (including MLCC)
- Current and thermal limiting
- Low noise
- 2.7 V to 8 V supply range
- −40°C to +85°C ambient temperature range
- SOT-223 package

APPLICATIONS

- Notebook, palmtop computers
- SCSI terminators
- Battery-powered systems
- Bar code scanners
- Camcorders, cameras
- Home entertainment systems
- Networking systems
- DSP/ASIC supplies

FUNCTIONAL BLOCK DIAGRAM

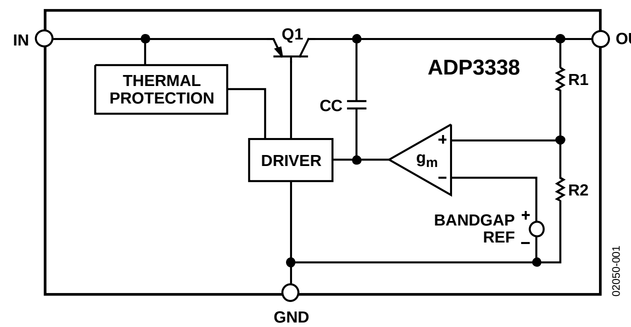


Figure 1.

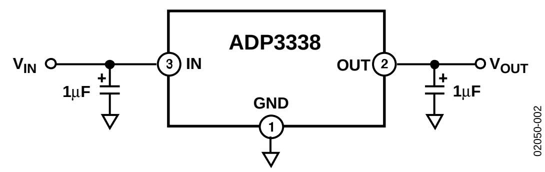


Figure 2. Typical Application Circuit

GENERAL DESCRIPTION

The ADP3338 is a member of the ADP33xx family of precision, low dropout (LDO), anyCAP voltage regulators. The ADP3338 operates with an input voltage range of 2.7 V to 8 V and delivers a load current up to 1 A. The ADP3338 stands out from conventional LDOs with a novel architecture and an enhanced process that offers performance advantages and higher output current than its competition. Its patented design requires only a 1 µF output capacitor for stability. This device is insensitive to output capacitor equivalent series resistance (ESR), and is stable with any good quality capacitor, including ceramic (MLCC) types for space-restricted applications. The ADP3338 achieves exceptional accuracy of ±0.8% at room temperature and ±1.4% over temperature, line, and load variations. The dropout voltage of the ADP3338 is only 190 mV (typical) at 1 A. The device also includes a safety current limit and thermal overload protection. The ADP3338 has ultralow quiescent current: 110 µA (typical) in light load situations.

Rev. B

One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 781.329.4700 **www.analog.com**
Fax: 781.461.3113

TABLE OF CONTENTS

REVISION HISTORY

6/05—Data Sheet Changed from Rev. A to Rev. B

Added Pin Function Descriptions Table 5
Changes to Ordering Guide 13

6/04—Data Sheet Changed from Rev. 0 to Rev. A

Updated Format .... Universal
Changes to Figures 5, 11, 12, 13, 14, 15 6
Updated Outline Dimensions 12
Changes to Ordering Guide 12

6/01—Rev. 0: Initial Version

SPECIFICATIONS

V_{IN} = 6.0 V, C_{IN} = C_{OUT} = 1 μF, T_J = −40°C to +125°C, unless otherwise noted.

Table 1.

Parameter[1, 2, 3]	Symbol	Conditions	Min	Typ	Max	Unit
OUTPUT						
Voltage Accuracy	V_{OUT}	V_{IN} = V_{OUTNOM} + 0.4 V to 8 V, I_L = 0.1 mA to 1 A, T_J = 25°C	−0.8		+0.8	%
		V_{IN} = V_{OUTNOM} + 0.4 V to 8 V, I_L = 0.1 mA to 1 A, T_J = −40°C to +125°C	−1.4		+1.4	%
		V_{IN} = V_{OUTNOM} + 0.4 V to 8 V, I_L = 50 mA to 1 A, T_J = 150°C	−1.6		+1.6	%
Line Regulation		V_{IN} = V_{OUTNOM} + 0.4 V to 8 V, T_J = 25°C		0.04		mV/V
Load Regulation		I_L = 0.1 mA to 1 A, T_J = 25°C		0.006		mV/mA
Dropout Voltage	V_{DROP}	V_{OUT} = 98% of V_{OUTNOM}				
		I_L = 1 A		190	400	mV
		I_L = 500 mA		125	200	mV
		I_L = 100 mA		70	150	mV
Peak Load Current	I_{LDPK}	V_{IN} = V_{OUTNOM} + 1 V		1.6		A
Output Noise	V_{NOISE}	f = 10 Hz to 100 kHz, C_L = 10 μF, I_L = 1 A		95		μV rms
GROUND CURRENT						
In Regulation	I_{GND}	I_L = 1 A		9	30	mA
		I_L = 500 mA		4.5	15	mA
		I_L = 100 mA		0.9	3	mA
		I_L = 0.1 mA		110	190	μA
In Dropout	I_{GND}	V_{IN} = V_{OUTNOM} − 100 mV, I_L = 0.1 mA		190	600	μA

[1] All limits at temperature extremes are guaranteed via correlation using standard statistical quality control (SQC) methods.
[2] Application stable with no load.
[3] V_{IN} = 2.7 V for models with V_{OUTNOM} ≤ 2.2 V.

ABSOLUTE MAXIMUM RATINGS

Unless otherwise specified, all voltages are referenced to GND.

Table 2.

Parameter	Rating
Input Supply Voltage	−0.3 V to +8.5 V
Power Dissipation	Internally limited
Operating Ambient Temperature Range	−40°C to +85°C
Operating Junction Temperature Range	−40°C to +150°C
θ_{JA}	62.3°C/W
θ_{JC}	26.8°C/W
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering 10 sec)	300°C
Vapor Phase (60 sec)	215°C
Infrared (15 sec)	220°C

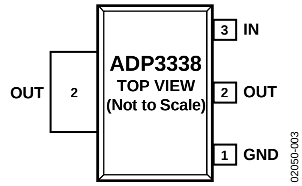
Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Only one absolute maximum rating may be applied at any one time.

ESD CAUTION

ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although this product features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.

PIN CONFIGURATION AND FUNCTION DESCRIPTIONS



NOTE: PIN 2 AND TAB ARE INTERNALLY CONNECTED

Figure 3. Pin Configuration

Table 3. Pin Function Descriptions

Pin No.	Mnemonic	Description
1	GND	Ground Pin.
2	OUT	Regulator Output. Bypass to ground with a 1 μF or larger capacitor.
3	IN	Regulator Input. Bypass to ground with a 1 μF or larger capacitor.

TYPICAL PERFORMANCE CHARACTERISTICS

T_A = 25°C, unless otherwise noted.

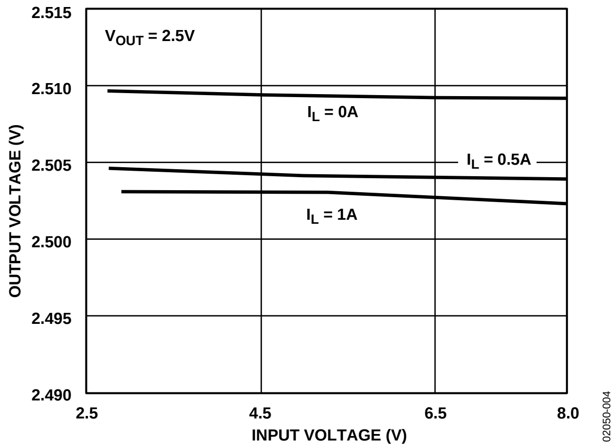


Figure 4. Line Regulation Output Voltage vs. Input Voltage

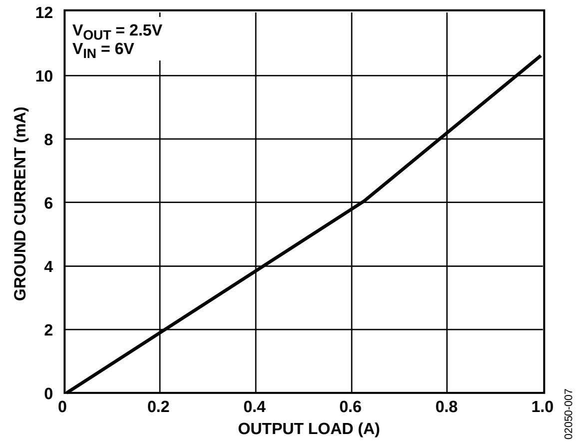


Figure 7. Ground Current vs. Load Current

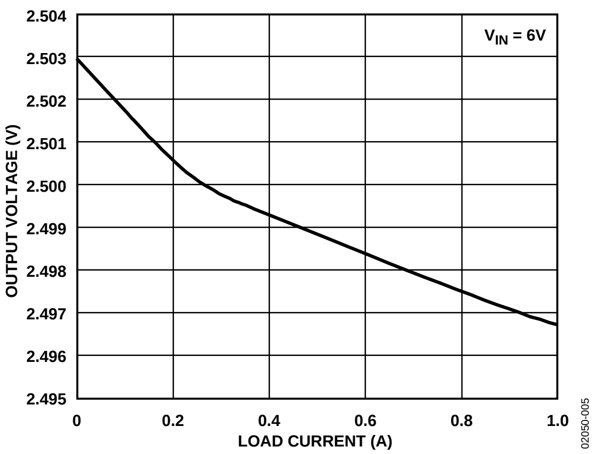


Figure 5. Output Voltage vs. Load Current

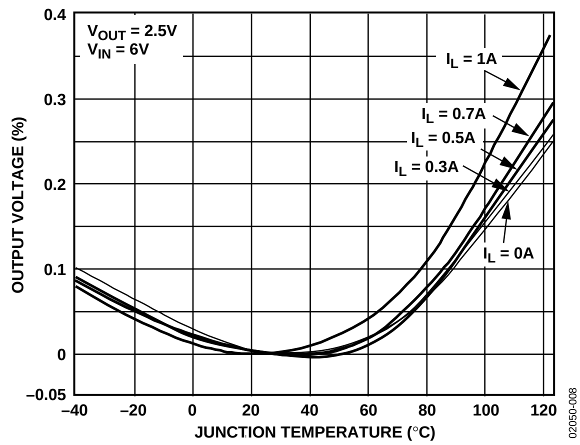


Figure 8. Output Voltage Variation % vs. Junction Temperature

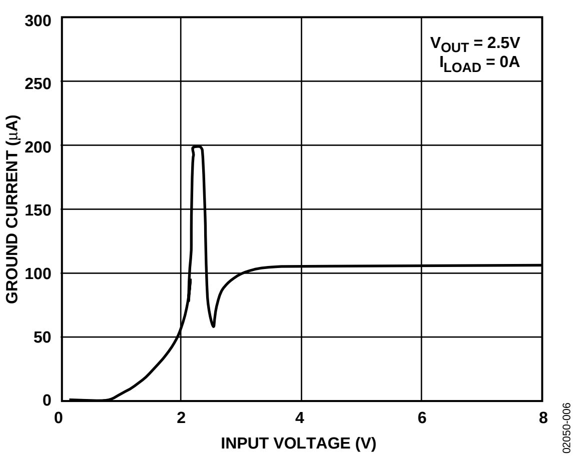


Figure 6. Ground Current vs. Supply Voltage

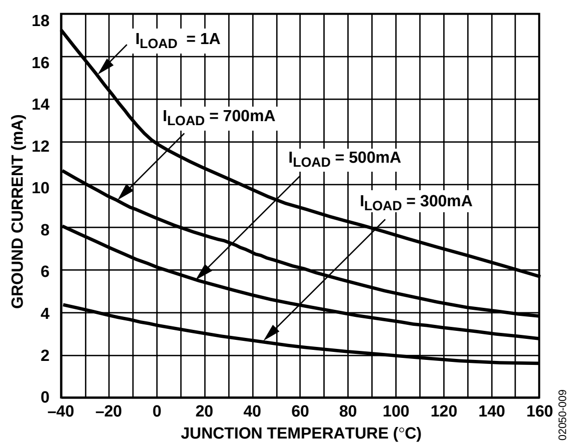


Figure 9. Ground Current vs. Junction Temperature

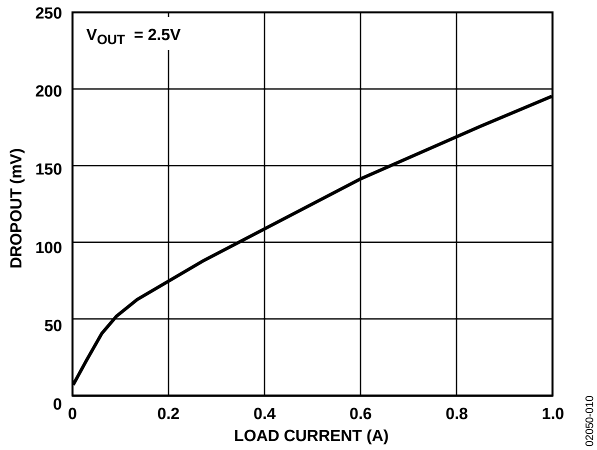


Figure 10. Dropout Voltage vs. Load Current

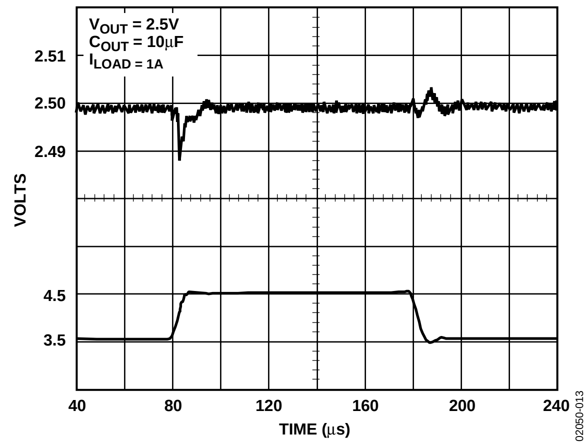


Figure 13. Line Transient Response

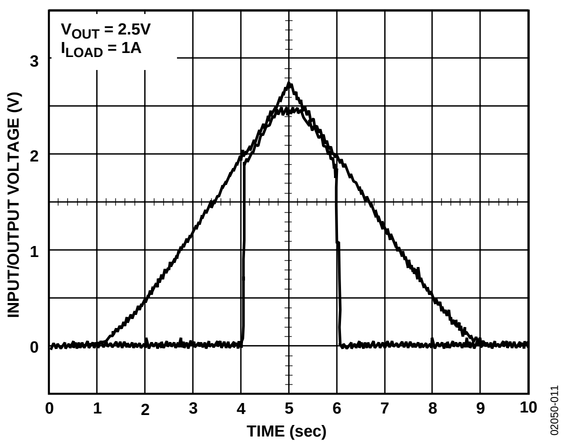


Figure 11. Power-Up/Power-Down

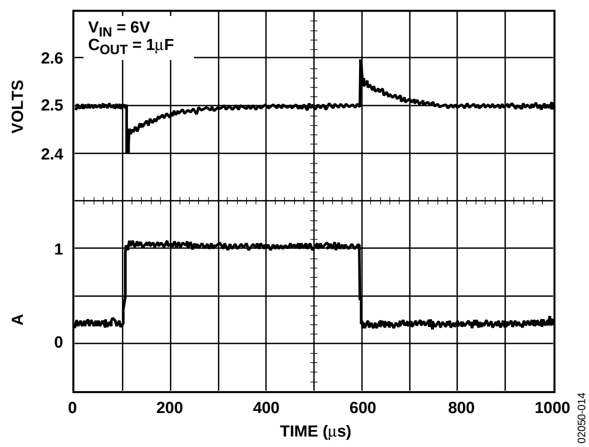


Figure 14. Load Transient Response

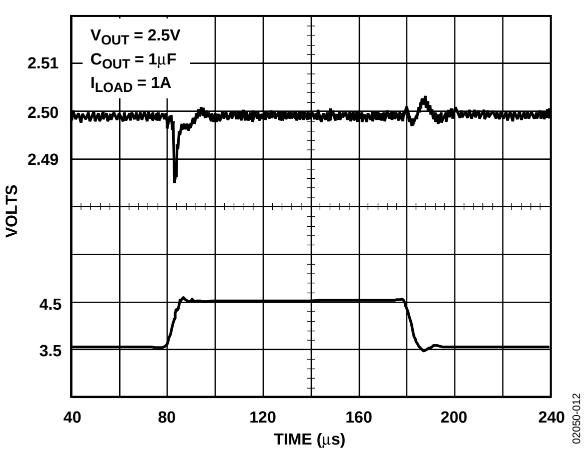


Figure 12. Line Transient Response

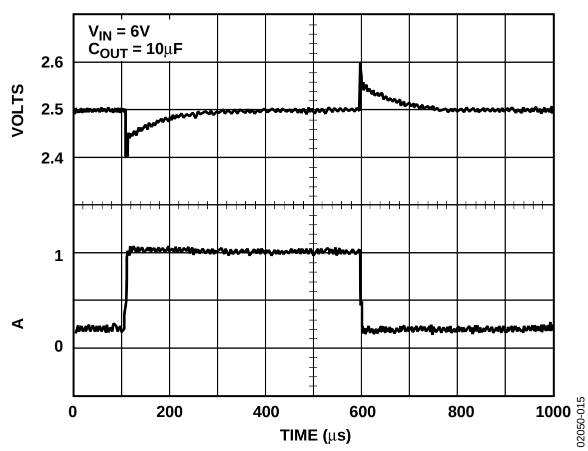


Figure 15. Load Transient Response

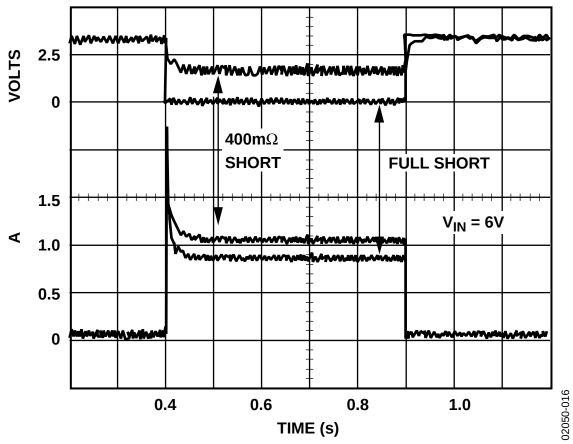


Figure 16. Short-Circuit Current

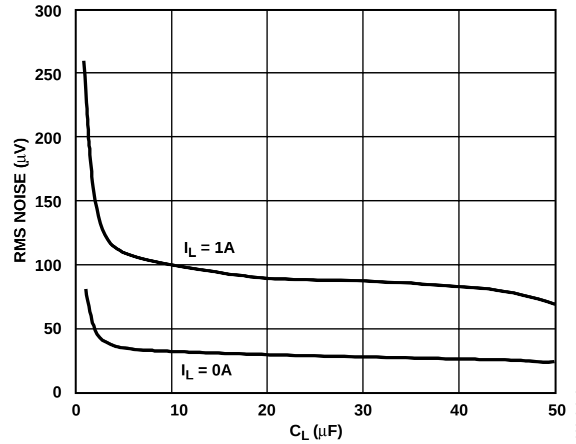


Figure 18. RMS Noise vs. C_L

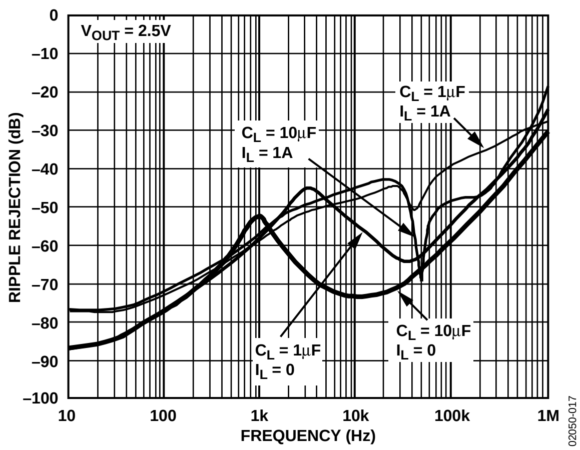


Figure 17. Power Supply Ripple Rejection

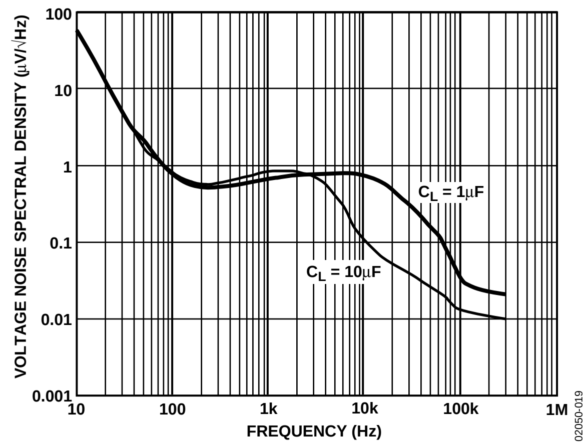


Figure 19. Output Noise Density (10 Hz to 100 kHz)

THEORY OF OPERATION

The ADP3338 anyCAP LDO uses a single control loop for regulation and reference functions. The output voltage is sensed by a resistive voltage divider, consisting of R1 and R2, which is varied to provide the available output voltage option. Feedback is taken from this network by way of a series diode (D1) and a second resistor divider (R3 and R4) to the input of an amplifier.

A very high gain error amplifier is used to control this loop. The amplifier is constructed in such a way that equilibrium produces a large, temperature-proportional input offset voltage that is repeatable and very well controlled. The temperature-proportional offset voltage is combined with the complementary diode voltage to form a virtual band gap voltage that is implicit in the network, although it never appears explicitly in the circuit. Ultimately, this patented design makes it possible to control the loop with only one amplifier. This technique also improves the noise characteristics of the amplifier by providing more flexibility on the trade off of noise sources that leads to a low noise design.

The R1, R2 divider is chosen in the same ratio as the band gap voltage to the output voltage. Although the R1, R2 resistor divider is loaded by Diode D1 and a second divider consisting of R3 and R4, the values can be chosen to produce a temperature-stable output. This unique arrangement specifically corrects for the loading of the divider, thus avoiding the error resulting from base current loading in conventional circuits.

The patented amplifier controls a new and unique noninverting driver that drives the pass transistor, Q1. The use of this special noninverting driver enables the frequency compensation to include the load capacitor in a pole-splitting arrangement to achieve reduced sensitivity to the value, type, and ESR of the load capacitance.

Most LDOs place very strict requirements on the range of ESR values for the output capacitor because they are difficult to stabilize due to the uncertainty of load capacitance and resistance. Moreover, the ESR value required to keep conventional LDOs stable changes depending on load and temperature. These ESR limitations make designing with LDOs more difficult because of their unclear specifications and extreme variations over temperature.

With the ADP3338 anyCAP LDO, this is no longer true. It can be used with virtually any good quality capacitor, with no constraint on the minimum ESR. This innovative design provides circuit stability with just a small 1 µF capacitor on the output. Additional advantages of the pole-splitting scheme include superior line noise rejection and very high regulator gain to achieve excellent line and load regulation. An impressive ±1.4% accuracy is guaranteed over line, load, and temperature.

Additional features of the circuit include current limit and thermal shutdown.

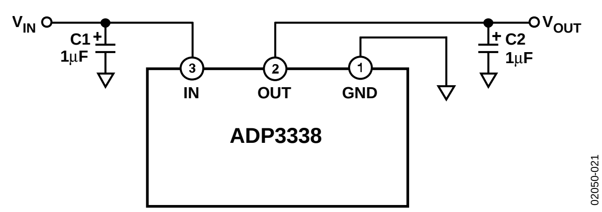


Figure 20. Typical Application Circuit

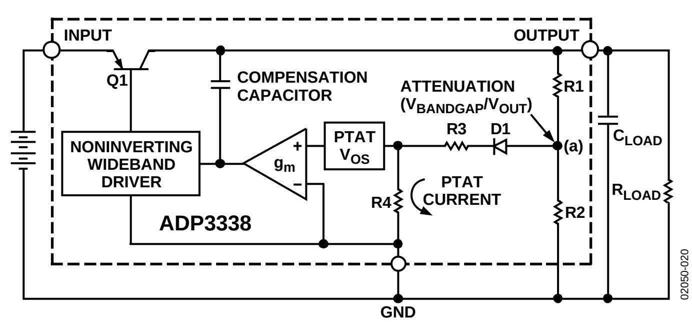


Figure 21. Functional Block Diagram

APPLICATION INFORMATION

CAPACITOR SELECTION

Output Capacitor

The stability and transient response of the LDO is a function of the output capacitor. The ADP3338 is stable with a wide range of capacitor values, types, and ESR (anyCAP). A capacitor as low as 1 μF is the only requirement for stability. A higher capacitance may be necessary if high output current surges are anticipated, or if the output capacitor cannot be located near the output and ground pins. The ADP3338 is stable with extremely low ESR capacitors (ESR ≈ 0) such as multilayer ceramic capacitors (MLCC) or OSCON. Note that the effective capacitance of some capacitor types falls below the minimum over temperature or with dc voltage.

Input Capacitor

An input bypass capacitor is not strictly required, but is recommended in any application involving long input wires or high source impedance. Connecting a 1 μF capacitor from the input to ground reduces the sensitivity of the circuit to PC board layout and input transients. If a larger output capacitor is necessary, a larger value input capacitor is recommended.

OUTPUT CURRENT LIMIT

The ADP3338 is short-circuit protected by limiting the pass transistor's base drive current. The maximum output current is limited to approximately 2 A (see Figure 16).

THERMAL OVERLOAD PROTECTION

The ADP3338 is protected against damage due to excessive power dissipation by its thermal overload protection circuit. Thermal protection limits the die temperature to a maximum of 160°C. Under extreme conditions, such as high ambient temperature and power dissipation where the die temperature starts to rise above 160°C, the output current is reduced until the die temperature has dropped to a safe level.

Current and thermal limit protections are intended to protect the device against accidental overload conditions. For normal operation, externally limit the power dissipation of the device so the junction temperature does not exceed 150°C.

CALCULATING POWER DISSIPATION

Device power dissipation is calculated as

$$P_D = (V_{IN} - V_{OUT}) \times I_{LOAD} + (V_{IN} \times I_{GND})$$

Where I_{LOAD} and I_{GND} are load current and ground current, and V_{IN} and V_{OUT} are the input and output voltages, respectively. Assuming the worst-case operating conditions are I_{LOAD} = 1.0 A, I_{GND} = 10 mA, V_{IN} = 3.3 V, and V_{OUT} = 2.5 V, the device power dissipation is

$$P_D = (3.3\text{ V} - 2.5\text{ V}) \times 1000\text{ mA} + (3.3\text{ V} \times 10\text{ mA}) = 833\text{ mW}$$

So, for a junction temperature of 125°C and a maximum ambient temperature of 85°C, the required thermal resistance from junction to ambient is

$$\theta_{JA} = \frac{125°\text{C} - 85°\text{C}}{0.833\text{ W}} = 48°\text{C/W}$$

PRINTED CIRCUIT BOARD LAYOUT CONSIDERATIONS

The thermal resistance, θ_{JA}, of the SOT-223 is determined by the sum of the junction-to-case and the case-to-ambient thermal resistances. The junction-to-case thermal resistance, θ_{JC}, is determined by the package design and is specified at 26.8°C/W. However, the case-to-ambient thermal resistance is determined by the printed circuit board design.

As shown in Figure 22, the amount of copper to which the ADP3338 is mounted affects thermal performance. When mounted to the minimal pads of 2 oz. copper, as shown in Figure 22 (a), θ_{JA} is 126.6°C/W. Adding a small copper pad under the ADP3338, as shown in Figure 22 (b), reduces the θ_{JA} to 102.9°C/W. Increasing the copper pad to one square inch, as shown in Figure 22 (c), reduces the θ_{JA} even further to 52.8°C/W.

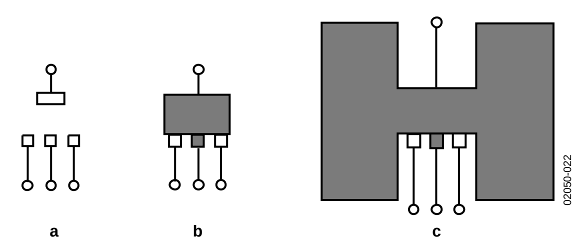
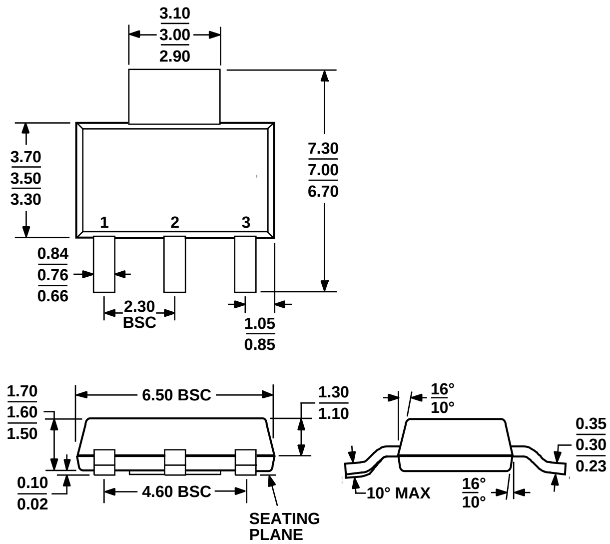


Figure 22. PCB Layouts

Use the following general guidelines when designing printed circuit boards:

- Keep the output capacitor as close as possible to the output and ground pins.
- Keep the input capacitor as close as possible to the input and ground pins.
- Specify thick copper and use wide traces for optimum heat transfer. PC board traces with larger cross sectional areas remove more heat from the ADP3338.
- Decrease thermal resistance by adding a copper pad under the ADP3338, as shown in Figure 22 (b).
- Use the adjacent area to the ADP3338 to add more copper around it. Connecting the copper area to the output of the ADP3338, as shown in Figure 22 (c), is best, but thermal performance will be improved even if it is connected to other signals.
- Use additional copper layers or planes to reduce the thermal resistance. Again, connecting the other layers to the output of the ADP3338 is best, but is not necessary. When connecting the output pad to other layers, use multiple vias.

OUTLINE DIMENSIONS



COMPLIANT TO JEDEC STANDARDS TO-261-AA

Figure 23. 3-Lead Small Outline Transistor Package [SOT-223] (KC-3)
Dimensions shown in millimeters

ORDERING GUIDE

Model	Temperature Range	Output Voltage (V)	Package Option	Package Description
ADP3338AKC-1.5-RL	–40°C to +85°C	1.5	KC-3	3-Lead SOT-223
ADP3338AKC-1.5-RL7	–40°C to +85°C	1.5	KC-3	3-Lead SOT-223
ADP3338AKCZ-1.5-RL[1]	–40°C to +85°C	1.5	KC-3	3-Lead SOT-223
ADP3338AKCZ-1.5-RL7[1]	–40°C to +85°C	1.5	KC-3	3-Lead SOT-223
ADP3338AKC-1.8-RL	–40°C to +85°C	1.8	KC-3	3-Lead SOT-223
ADP3338AKC-1.8-RL7	–40°C to +85°C	1.8	KC-3	3-Lead SOT-223
ADP3338AKCZ-1.8-RL[1]	–40°C to +85°C	1.8	KC-3	3-Lead SOT-223
ADP3338AKCZ-1.8-R7[1]	–40°C to +85°C	1.8	KC-3	3-Lead SOT-223
ADP3338AKC-2.5-RL	–40°C to +85°C	2.5	KC-3	3-Lead SOT-223
ADP3338AKC-2.5-RL7	–40°C to +85°C	2.5	KC-3	3-Lead SOT-223
ADP3338AKCZ-2.5-RL[1]	–40°C to +85°C	2.5	KC-3	3-Lead SOT-223
ADP3338AKCZ-2.5RL7[1]	–40°C to +85°C	2.5	KC-3	3-Lead SOT-223
ADP3338AKC-2.85-RL	–40°C to +85°C	2.85	KC-3	3-Lead SOT-223
ADP3338AKC-2.85-RL7	–40°C to +85°C	2.85	KC-3	3-Lead SOT-223
ADP3338AKCZ-2.85R7[1]	–40°C to +85°C	2.85	KC-3	3-Lead SOT-223
ADP3338AKC-3-RL	–40°C to +85°C	3.0	KC-3	3-Lead SOT-223
ADP3338AKC-3-RL7	–40°C to +85°C	3.0	KC-3	3-Lead SOT-223
ADP3338AKCZ-3-RL7[1]	–40°C to +85°C	3.0	KC-3	3-Lead SOT-223
ADP3338AKC-3.3-RL	–40°C to +85°C	3.3	KC-3	3-Lead SOT-223
ADP3338AKC-3.3-RL7	–40°C to +85°C	3.3	KC-3	3-Lead SOT-223
ADP3338AKCZ-3.3-RL[1]	–40°C to +85°C	3.3	KC-3	3-Lead SOT-223
ADP3338AKCZ-3.3RL7[1]	–40°C to +85°C	3.3	KC-3	3-Lead SOT-223
ADP3338AKC-5-REEL	–40°C to +85°C	5	KC-3	3-Lead SOT-223
ADP3338AKC-5-REEL7	–40°C to +85°C	5	KC-3	3-Lead SOT-223
ADP3338AKCZ-5-REEL[1]	–40°C to +85°C	5	KC-3	3-Lead SOT-223
ADP3338AKCZ-5-R7[1]	–40°C to +85°C	5	KC-3	3-Lead SOT-223

[1] Z = Pb-free part.

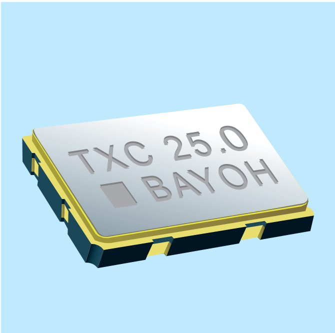
NOTES

NOTES

NOTES

C02050–0–6/05(B)

5 x 3.2 mm SMD CMOS CXO 7C SERIES



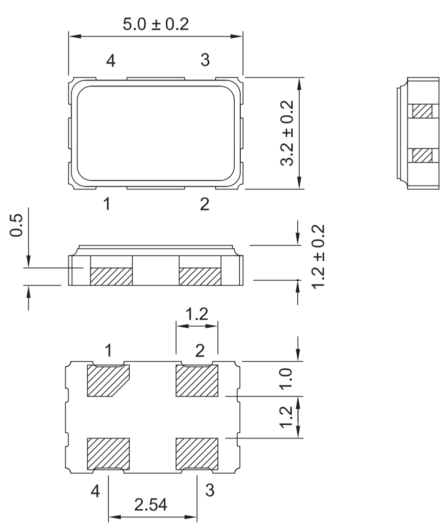
Features

- > Ultra small SMD seam sealed clock crystal oscillator units.
- > High precision characteristic covering up to wide frequency range.
- > Designed for automatic mounting and reflow soldering.
- > Optionable stand-by function for output: Tri-state output.
- > Supply voltage range : 1.8 V ~ 5.0 V
- > High stability, low jitter, low power consumption.
- > Main application : wireless communication set, PDA, and DSC.
- > RoHS Compliant / Pb Free.

Electrical Specifications

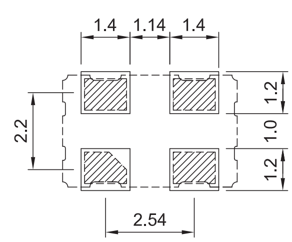
Item / Type	7C		
Output Type	CMOS		
Output Load	15 pF	15 pF , 30 pF	15 pF , 50 pF
Oscillation Mode	Fundamental / 3rd Overtone		
Supply Voltage	1.8 V	2.5 V , 2.8 V , 3.3 V	5 V
Frequency Range	1 ~ 150 MHz		
Frequency Stability	± 50 ppm (-10 ~ + 70 °C), or specify		
Operating Temperature Range	- 40 ~ + 85 °C		
Storage Temperature Range	- 55 ~ + 125 °C		
Voltage Vol (Max.) / Voh (Min.)	0.1 VDD / 0.9 VDD		
Rise (Tr) / Fall (Tf) Time	10 ns Max.		
Supply Current	20 mA Max.	30 mA Max.	45 mA Max.
Symmetry	40 ~ 60 %		
Start-up Time	10 ms Max		
Phase Jitter (12 KHz ~ 20 MHz)	1 ps Max		
Aging (at 25 °C)	± 3 ppm / year Max.		

Dimensions



PAD FUNCTION:
1:ENABLE CONTROL
2:GND
3:OUT
4:VDD

Suggested Layout



Units:mm

Remark : Specification subject to change without prior notice. Please confirm with our sales.

OMNI-2400

OMNI-2400
15 Hz
2400 Ω
OMNI

Omni-Directional Geophone

Features

- Unique omni-directional geophone design provides ideal vector fidelity response
- High output sensitivity (1.32 volt/in/sec)
- 200 ^{0}C temperature rating
- Ideal for multi-component, high resolution seismic and micro-seismic data recording and monitoring

The OMNI Series geophone provides a unique in-axis sensitivity regardless of tilt angle in space. Each OMNI element has identical sensitivity, impedance, phase, frequency response, and harmonic distortion specifications, providing ideal vector fidelity response. The mathematical precision of the resulting measurements significantly improves the discrimination of plane wave measurements at the detector.

DESCRIPTION	SPECIFICATION	TOLERANCE
OPTIMUM ORIENTATION	OMNI	
OPERATIONAL RANGE	0° TO 180°	
NATURAL FREQUENCY (Fn)		
@ OPTIMUM ORIENTATION	15 Hz	± 5 %
@ OPERATIONAL RANGE	15 Hz	-5% to +15%
CLEAN BAND PASS (SPURIOUS RESPONSE)	> 365 Hz	
DC RESISTANCE	2400 ohms	± 5%
INTRINSIC VOLTAGE SENSITIVITY (G)		
@ OPTIMUM ORIENTATION	1.32 V/in./sec, 0.520 V/cm/sec	± 5 %
@ OPERATIONAL RANGE	1.32 V/in./sec, 0.520 V/cm/sec	-15% to + 5%
OPEN CIRCUIT DAMPING (B_o)		
@ OPTIMUM ORIENTATION	.57	± 15 %
@ OPERATIONAL RANGE	.57	-20% to +10%
MOVING MASS (M)	7.8 gr	± 5 %
HARMONIC DISTORTION	@ 15 Hz WITH DRIVING VELOCITY OF .7 in/sec (1.8 cm/sec) P-P	
@ OPTIMUM ORIENTATION	< .20 %	
@ OPERATIONAL RANGE	< .75 %	
DAMPING CONSTANT (B_cR_t)	2066	
STORAGE TEMPERATURE	- 40 to +100 °C	
OPERATING TEMPERATURE	- 40 to +200 °C	
DIMENSIONS		
WEIGHT	1.52 oz., 44 gr	
DIAMETER	0.875 in., 2.22 cm	
HEIGHT	1.035 in., 2.63 cm	

7007 Pinemont Drive • Houston, Texas 77040 USA
www.geospace.com
Tel: 713.986.4444 • Fax: 713.986.4445

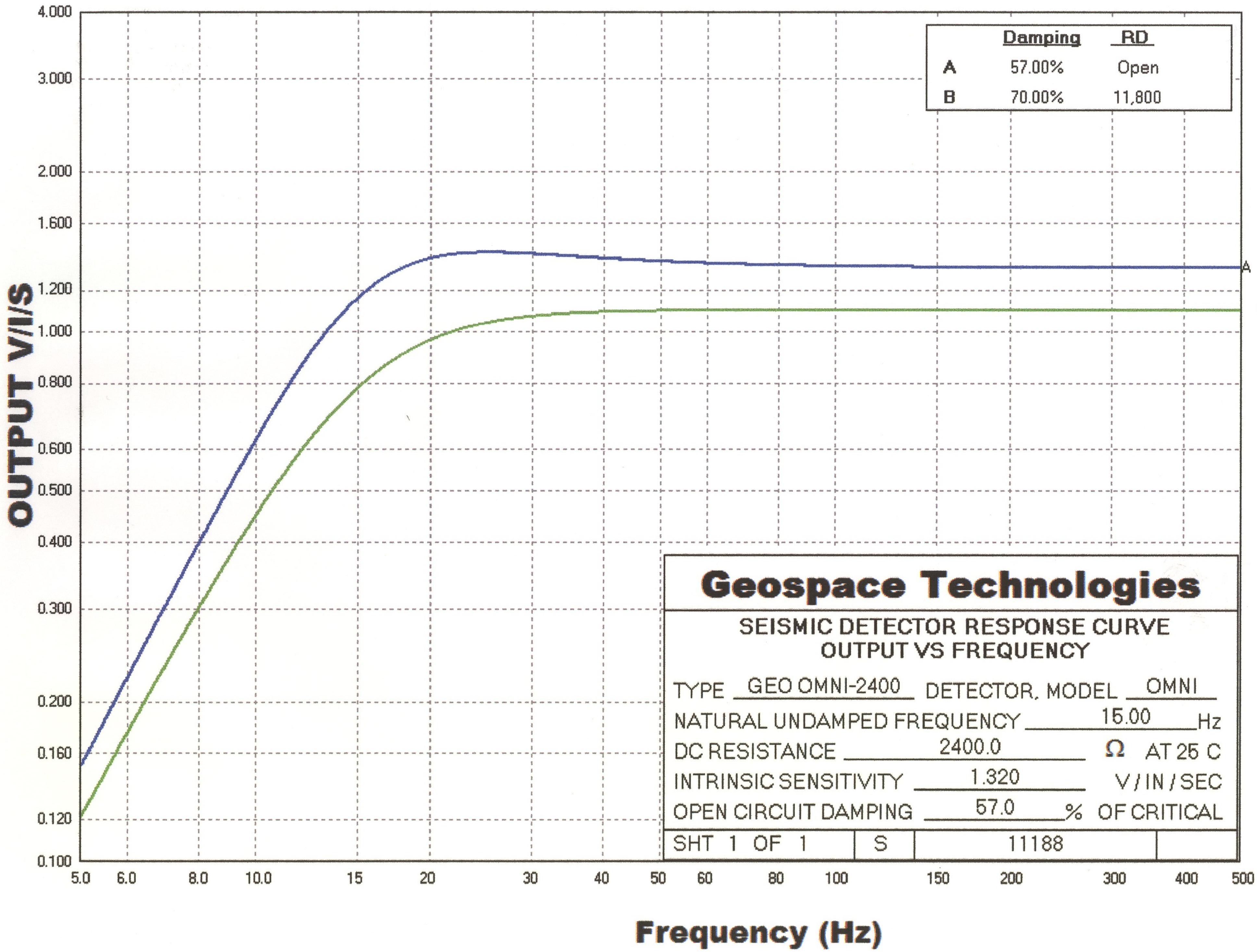
Regional Offices

Geospace Technologies, Canada
2735 - 37^{th} Avenue N.E.
Calgary, Alberta, Canada T1Y 5R8
403 250-9600

Geospace Technologies, Eurasia
Kirovogradskaya, 36
Ufa, Baskortostan, Russia 450001
011 (7) 3472 25 39 73

Geospace Technologies, China
Room 700, 7th Floor, Lido Office Tower, Lido Place
Jichang Road, Jiang Tai Road, Beijing, 100004, P.R.China
011 (86) 10 6437 8768

Geospace Engineering Resources International (GERI), UK
F3 Bramingham Business Park, Enterprise Way, Luton
Bedfordshire LU3 4BU, England
011 44 (0) 7775 688 467



Damping RD
A 57.00% Open
B 70.00% 11,800
Geospace Technologies
SEISMIC DETECTOR RESPONSE CURVE
OUTPUT VS FREQUENCY
TYPE GEO OMNI-2400 DETECTOR, MODEL OMNI
NATURAL UNDAMPED FREQUENCY 15.00 Hz
DC RESISTANCE 2400.0 Ω AT 25 C
INTRINSIC SENSITIVITY 1.320 V / IN / SEC
OPEN CIRCUIT DAMPING 57.0 % OF CRITICAL
SHT 1 OF 1
S
11188
A
B
OUTPUT V/I/S
4.000
3.000
2.000
1.600
1.200
1.000
0.800
0.600
0.500
0.400
0.300
0.200
0.160
0.120
0.100
5.0 6.0 8.0 10.0 15 20 30 40 50 60 80 100 150 200 300 400 500
Frequency (Hz)

Geophones SMC-1850

FEBRUARY 6, 2012 BY ADMIN

SMC-1850

High Temperature Geophone

>All units tested at 200° C
>Ideal for VSP, tri-axial and gimbal downhole operations
>Full one year warranty
>Small size, high output
>Patented PCB header
>100% burn-in of basic units

The SMC-1850 High Temperature Geophone has been tested at 200°C for more than 300 hours with no loss in performance specifications. Its design structure and super strength magnetic field makes the output of this small geophone equal to or greater than the output of larger units. Rotating dual coil construction withstands severe shocks and rough handling. The patented PCB header provides easy and reliable electrical connections.

Spec Sheet:

SMC-1850 Specifications

Natural Frequency (Fn) ± 5%	10.0 Hz	14.0 Hz	15.0 Hz	30.0 Hz
Operating Position	Vert – Horz	Vert – Horz	Vert – Horz	Vert – Horz
Maximum Tilt Within Specifications	20° – 5°	30° – 10°	0° – 180°	0° – 180°
Coil Resistance ± 5%	1850 ohms			
Intrinsic Sensitivity ± 5%	.402 V/cm/sec (1.02 V/in/sec)			
Total Harmonic Distortion	Less than 1% at 12 Hz or natural frequency whichever is larger.			
Temperature Limits	-40°F to 392°F (-40°C to 200°C)			
Maximum Coil Excursion	0.12 in P-P (3.0 mm P-P)			
Suspended Mass	0.23 oz. (6.6 g)			

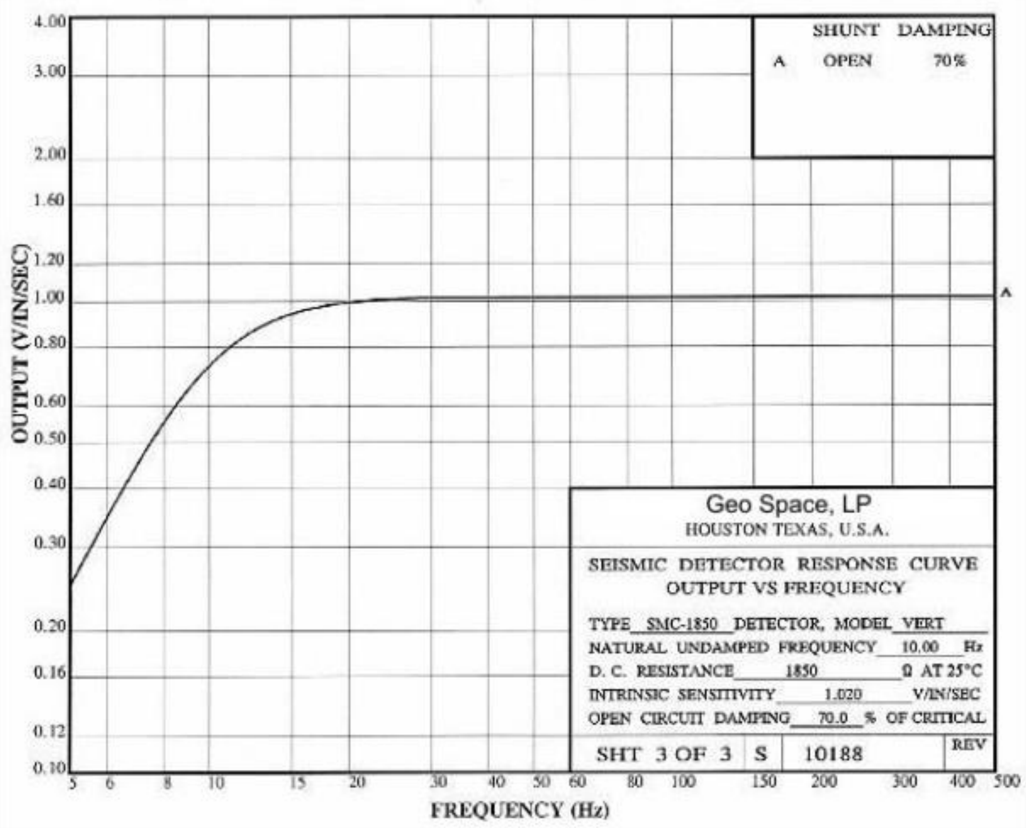
Dimensions

Diameter:	0.875 in (22.2 mm)
Height:	1.04 in (26.4mm)
Weight:	1.52 oz. (43g)

Note: For testing on SMT-200 Geophone Tester, the frequency, resistance and damping tolerances entered must be 1% greater than the published specification above. Sensitivity tolerance entered must be 2% greater than the published specification.

All specifications apply to measurements made after a heat cycle of 200°C and after unit returns to room temperature (25°C). Units will operate at larger tilt angles, but performance will not necessarily meet specifications. Note: The SMC-1850 is NOT hermetically sealed.

SMC-1850 @ 10 Hz



Specifications are subject to change without notice.

High Temperature, Low Power Operational Amplifier

Data Sheet **AD8634**

FEATURES

Extreme high temperature operation
- **−40°C to +210°C, FLATPACK package**
- **−40°C to +175°C, SOIC package**

Rail-to-rail output
Low power: 1.3 mA maximum
Gain bandwidth product: 9.7 MHz typical at $A_V = 100$
Low offset voltage: 250 μV maximum
Unity-gain stable
High slew rate: 5.0 V/μs typical at 210°C
Low noise: 4.2 nV/√Hz typical at 1 kHz and 210°C

APPLICATIONS

Downhole drilling and instrumentation
Avionics
Heavy industrial
High temperature environments

PIN CONFIGURATION

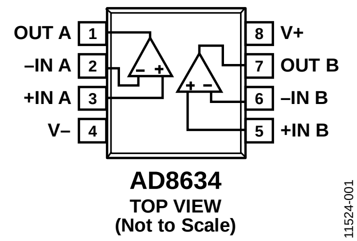


Figure 1. SOIC and FLATPACK Pinout

GENERAL DESCRIPTION

The AD8634 is a precision, 9.7 MHz bandwidth, dual amplifier that features rail-to-rail outputs. The AD8634 is guaranteed to operate from 3 V to 30 V (or from ±1.5 V to ±15 V) and at very high temperatures.

The AD8634 is well suited for applications that require both ac and dc precision performance. The combination of wide bandwidth, low noise, and precision makes the AD8634 useful in a wide variety of applications, including filters and interfacing with a variety of sensors.

This dual-channel op amp is offered in an 8-lead SOIC package with an operating temperature range of −40°C to +175°C. It is also available in an 8-lead ceramic flat package (FLATPACK) with an operating temperature range of −40°C to +210°C. Both packages are designed for robustness at extreme temperatures and are qualified for up to 1000 hours of operation at the maximum temperature rating.

The AD8634 is a member of a growing series of high temperature qualified products offered by Analog Devices, Inc. For a complete selection table of available high temperature products, see the high temperature product list and qualification data available at http://www.analog.com/hightemp.

Rev. A **Document Feedback**

One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 781.329.4700
Technical Support **www.analog.com**

TABLE OF CONTENTS

REVISION HISTORY

7/14—Rev. 0 to Rev. A

Changes to Unity-Gain Crossover Parameter, Table 1 and −3 dB Closed-Loop Bandwidth Parameter, Table 1 ... 3
Changes to Unity-Gain Crossover Parameter, Table 2 and −3 dB Closed-Loop Bandwidth Parameter, Table 2 ... 4

7/13—Revision 0: Initial Version

SPECIFICATIONS

ELECTRICAL CHARACTERISTICS, V_{SY} = ±15.0 V

V_{SY} = ±15.0 V, V_{CM} = 0 V, $T_{MIN} \le T_A \le T_{MAX}$, unless otherwise noted.

Table 1.

Parameter	Symbol	Test Conditions/ Comments	SOIC Package −40°C ≤ T_A ≤ +175°C Min	Typ	Max	FLATPACK Package −40°C ≤ T_A ≤ +210°C Min	Typ	Max	Unit
INPUT CHARACTERISTICS									
Offset Voltage	V_{OS}				250			250	µV
Offset Voltage Drift	$\Delta V_{OS}/\Delta T$			0.35			0.35		µV/°C
Offset Voltage Matching		$T_A = T_{MAX}$			150			150	µV
Input Bias Current	I_B		−200	−45	+200	−200	−40	+200	nA
Input Offset Current	I_{OS}				30			30	nA
Input Voltage Range	V_{IN}		−14.7		+14.7	−14.5		+14.5	V
Common-Mode Rejection Ratio	CMRR	V_{CM} = −14.0 V to +14.0 V	105	120		100	115		dB
Large Signal Voltage Gain	A_{VO}	−13.5 V ≤ V_{OUT} ≤ +13.5 V, R_L = 2 kΩ	104	112		100	108		dB
Input Impedance									
Differential				53‖1.1			53‖1.1		kΩ‖pF
Common-Mode				1.1‖2.5			1.1‖2.5		GΩ‖pF
OUTPUT CHARACTERISTICS									
Output Voltage High	V_{OH}	R_L = 10 kΩ to V_{CM}	14.8	14.90		14.8	14.90		V
		R_L = 2 kΩ to V_{CM}	14.0	14.5		14.0	14.5		V
		R_L = 2 kΩ to V_{CM}, $T_A = T_{MAX}$	14.60	14.75		14.60	14.75		V
Output Voltage Low	V_{OL}	R_L = 10 kΩ to V_{CM}		−14.95	−14.8		−14.95	−14.8	V
		R_L = 2 kΩ to V_{CM}		−14.8	−14.70		−14.75	−14.65	V
		R_L = 2 kΩ to V_{CM}, $T_A = T_{MAX}$			−14.70			−14.65	V
Short-Circuit Current	I_{SC}	V_{OUT} = 0 V, $T_A = T_{MAX}$		+100/−20			+105/−18		mA
POWER SUPPLY									
Power Supply Rejection Ratio	PSRR	V_{SY} = ±2 V to ±18 V	105	115		103	113		dB
Supply Current per Amplifier	I_{SY}	I_{OUT} = 0 mA, $T_A = T_{MAX}$		1.0	1.2		1.1	1.3	mA
DYNAMIC PERFORMANCE									
Slew Rate	SR	R_L = 2 kΩ	3.6	4.9		3.6	5.0		V/µs
Gain Bandwidth Product	GBP	V_{IN} = 5 mV p-p, R_L = 10 kΩ, A_V = 100		9.7			9.7		MHz
Unity-Gain Crossover	UGC	V_{IN} = 5 mV p-p, R_L = 10 kΩ, A_V = 1		7.0			7.0		MHz
−3 dB Closed-Loop Bandwidth	−3 dB	V_{IN} = 5 mV p-p, A_V = 1		11.0			11.0		MHz
Phase Margin	ΦM			84			82		Degrees
NOISE PERFORMANCE									
Voltage Noise	e_n p-p	0.1 Hz to 10 Hz		0.13			0.13		µV p-p
Voltage Noise Density	e_n	f = 1 kHz		4.2			4.2		nV/√Hz
Current Noise Density	i_n			0.6			0.6		pA/√Hz

ELECTRICAL CHARACTERISTICS, V_{SY} = 3.0 V

V_{SY} = 3.0 V, V_{CM} = 1.5 V, V_{OUT} = 1.5 V, $T_{MIN} \le T_A \le T_{MAX}$, unless otherwise noted.

Table 2.

Parameter	Symbol	Test Conditions/ Comments	SOIC Package −40°C ≤ T_A ≤ +175°C			FLATPACK Package −40°C ≤ T_A ≤ +210°C			Unit
			Min	Typ	Max	Min	Typ	Max	
INPUT CHARACTERISTICS									
Offset Voltage	V_{OS}				250			250	µV
Offset Voltage Drift	$\Delta V_{OS}/\Delta T$			0.35			0.35		µV/°C
Offset Voltage Matching		$T_A = T_{MAX}$			150			150	µV
Input Bias Current	I_B		−200	−45	+200	−200	−40	+200	nA
Input Offset Current	I_{OS}				30			30	nA
Input Voltage Range	V_{IN}		0.3		2.7	0.5		2.5	V
Common-Mode Rejection Ratio	CMRR	V_{CM} = 0.3 V to 2.7 V	60	65		55	60		dB
Large Signal Voltage Gain	A_{VO}	0.5 V ≤ V_{OUT} ≤ 2.5 V, R_L = 2 kΩ	104	112		100	108		dB
Input Impedance									
Differential				53‖1.1			53‖1.1		kΩ‖pF
Common-Mode				2.8‖2.5			2.8‖2.5		GΩ‖pF
OUTPUT CHARACTERISTICS									
Output Voltage High	V_{OH}	R_L = 10 kΩ to V_{CM}	2.8	2.90		2.8	2.90		V
		R_L = 2 kΩ to V_{CM}	2.0	2.5		2.0	2.5		V
		R_L = 2 kΩ to V_{CM}, $T_A = T_{MAX}$	2.60	2.75		2.60	2.75		V
Output Voltage Low	V_{OL}	R_L = 10 kΩ to V_{CM}		50	200		50	200	mV
		R_L = 2 kΩ to V_{CM}		200	300		250	350	mV
		R_L = 2 kΩ to V_{CM}, $T_A = T_{MAX}$			300			350	mV
Short-Circuit Current	I_{SC}	V_{OUT} = 0 V, $T_A = T_{MAX}$		+65/−13			+70/−11		mA
POWER SUPPLY									
Power Supply Rejection Ratio	PSRR	V_{SY} = ±1.25 V to ±1.75 V	97	102		95	100		dB
Supply Current per Amplifier	I_{SY}	I_{OUT} = 0 mA, $T_A = T_{MAX}$		0.9	1.1		1.0	1.2	mA
DYNAMIC PERFORMANCE									
Slew Rate	SR	R_L = 2 kΩ	3.5	4.9		3.5	5.0		V/µs
Gain Bandwidth Product	GBP	V_{IN} = 5 mV p-p, R_L = 10 kΩ, A_V = 100		9.7			9.7		MHz
Unity-Gain Crossover	UGC	V_{IN} = 5 mV p-p, R_L = 10 kΩ, A_V = 1		7.0			7.0		MHz
−3 dB Closed-Loop Bandwidth	−3 dB	V_{IN} = 5 mV p-p, A_V = 1		11.0			11.0		MHz
Phase Margin	ΦM			84			82		Degrees
NOISE PERFORMANCE									
Voltage Noise	e_n p-p	0.1 Hz to 10 Hz		0.13			0.13		µV p-p
Voltage Noise Density	e_n	f = 1 kHz		4.2			4.2		nV/√Hz
Current Noise Density	i_n			0.6			0.6		pA/√Hz

1 nV/√Hz Low Noise 210°C Instrumentation Amplifier

Data Sheet **AD8229**

FEATURES

Designed and guaranteed for 210°C operation
Low noise
- **1 nV/√Hz input noise**
- **45 nV/√Hz output noise**

High CMRR
- **126 dB CMRR (minimum), G = 100**
- **80 dB CMRR (minimum) to 5 kHz, G = 1**

Excellent ac specifications
- **15 MHz bandwidth (G = 1)**
- **1.2 MHz bandwidth (G = 100)**
- **22 V/μs slew rate**
- **THD: −130 dBc (1 kHz, G = 1)**

Versatile
- **±4 V to ±17 V dual supply**
- **Gain set with single resistor (G = 1 to 1000)**
- **Specified temperature range**
  - **−40°C to +210°C, SBDIP package**
  - **−40°C to +175°C, SOIC package**

APPLICATIONS

Down-hole instrumentation
Harsh environment data acquisition
Exhaust gas measurements
Vibration analysis

FUNCTIONAL BLOCK DIAGRAM

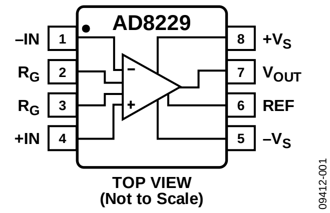


Figure 1.

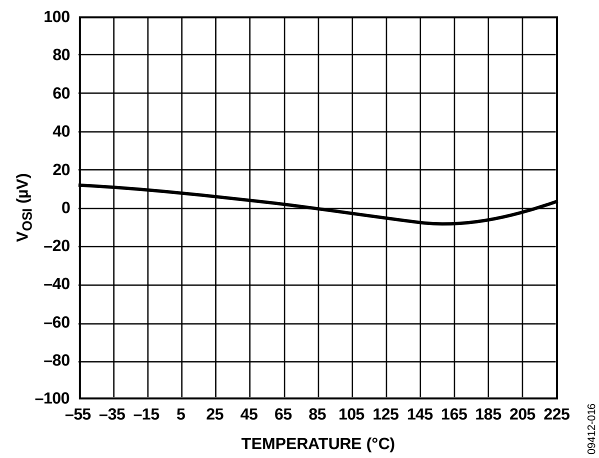


Figure 2. Typical Input Offset vs. Temperature (G = 100)

GENERAL DESCRIPTION

The AD8229 is an ultralow noise instrumentation amplifier designed for measuring small signals in the presence of large common-mode voltages and high temperatures.

The AD8229 has been designed for high temperature operation. The process is dielectrically isolated to avoid leakage currents at high temperatures. The design architecture was chosen to compensate for the low V_{BE} voltages at high temperatures.

The AD8229 excels at measuring tiny signals. It delivers industry leading 1 nV/√Hz input noise performance. The high CMRR of the AD8229 prevents unwanted signals from corrupting the acquisition. The CMRR increases as the gain increases, offering high rejection when it is most needed.

The AD8229 is one of the fastest instrumentation amplifiers available. Its current feedback architecture provides high bandwidth at high gain, for example, 1.2 MHz at G = 100. The design includes circuitry to improve settling time after large input voltage transients. The AD8229 was designed for excellent distortion performance, allowing use in demanding applications such as vibration analysis.

Gain is set from 1 to 1000 with a single resistor. A reference pin allows the user to offset the output voltage. This feature can be useful when interfacing with analog-to-digital converters.

For the most demanding applications, the AD8229 is available in an 8-lead side-brazed ceramic dual in-line package (SBDIP). For space-constrained applications, the AD8229 is available in an 8-lead plastic standard small outline package (SOIC).

Rev. B

One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 781.329.4700 **www.analog.com**
Fax: 781.461.3113

TABLE OF CONTENTS

REVISION HISTORY

2/12—Rev. A to Rev. B

Added 8-Lead SOIC ... Universal
Changes to Features Section and General Description Section ... 1
Changes to Table 1 ... 3
Changes to Table 2, Thermal Resistance Section, and Table 3 ... 6
Updated Outline Dimensions ... 21
Changes to Ordering Guide ... 21

9/11—Rev. 0 to Rev. A

Changes to Features Section and General Description Section ... 1
Changes to Table 2 ... 6
Added Predicted Lifetime vs. Operating Temperature Section and Figure 3; Renumbered Sequentially ... 6
Changes to Figure 18 and Figure 19 ... 10
Changes to Figure 24 to Figure 28 ... 11
Changes to Figure 29 and Figure 30 ... 12
Changes to Figure 48 ... 15
Changes to Figure 56 ... 17
Changes to Power Supplies Section ... 18

1/11—Revision 0: Initial Version

SPECIFICATIONS

+V_S = 15 V, −V_S = −15 V, V_{REF} = 0 V, T_A = 25°C, G = 1, R_L = 10 kΩ, unless otherwise noted.

Table 1.

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
COMMON-MODE REJECTION RATIO (CMRR)					
CMRR DC to 60 Hz with 1 kΩ Source Imbalance	V_{CM} = ±10 V				
G = 1		86			dB
Temperature Drift	T_A = −40°C to +210°C			300	nV/V/°C
G = 10		106			dB
Temperature Drift	T_A = −40°C to +210°C			30	nV/V/°C
G = 100		126			dB
Temperature Drift	T_A = −40°C to +210°C			3	nV/V/°C
G = 1000	T_A = −40°C to +210°C	134			dB
CMRR at 5 kHz	V_{CM} = ±10 V				
G = 1		80			dB
G = 10		90			dB
G = 100		90			dB
G = 1000		90			dB
VOLTAGE NOISE	V_{IN}+, V_{IN}− = 0 V				
Spectral Density[1]: 1 kHz					
Input Voltage Noise, e_{ni}			1	1.1	nV/√Hz
Output Voltage Noise, e_{no}			45	50	nV/√Hz
Peak to Peak: 0.1 Hz to 10 Hz					
G = 1			2		μV p-p
G = 1000			100		nV p-p
CURRENT NOISE					
Spectral Density: 1 kHz			1.5		pA/√Hz
Peak to Peak: 0.1 Hz to 10 Hz			100		pA p-p
VOLTAGE OFFSET	V_{OS} = V_{OSI} + V_{OSO}/G				
Input Offset, V_{OSI}				100	μV
Average TC	T_A = −40°C to +210°C		0.1	1	μV/°C
Output Offset, V_{OSO}				1000	μV
Average TC	T_A = −40°C to +210°C		3	10	μV/°C
Offset RTI vs. Supply (PSR)	V_S = ±5 V to ±15 V				
G = 1	T_A = −40°C to +210°C	86			dB
G = 10	T_A = −40°C to +210°C	106			dB
G = 100	T_A = −40°C to +210°C	126			dB
G = 1000	T_A = −40°C to +210°C	130			dB
INPUT CURRENT					
Input Bias Current				70	nA
High Temperature	T_A = 210°C			200	nA
Input Offset Current				35	nA
High Temperature	T_A = 210°C			50	nA

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
DYNAMIC RESPONSE					
Small Signal Bandwidth −3 dB					
G = 1			15		MHz
G = 10			4		MHz
G = 100			1.2		MHz
G = 1000			0.15		MHz
Settling Time 0.01%	10 V step				
G = 1			0.75		μs
G = 10			0.65		μs
G = 100			0.85		μs
G = 1000			5		μs
Settling Time 0.001%	10 V step				
G = 1			0.9		μs
G = 10			0.9		μs
G = 100			1.2		μs
G = 1000			7		μs
Slew Rate					
G = 1 to 100			22		V/μs
THD (FIRST FIVE HARMONICS)	f = 1 kHz, R_L = 2 kΩ, V_{OUT} = 10 V p-p				
G = 1			−130		dBc
G = 10			−116		dBc
G = 100			−113		dBc
G = 1000			−111		dBc
THD + Noise	f = 1 kHz, R_L = 2 kΩ, V_{OUT} = 10 V p-p, G = 100		0.0005		%
GAIN[2]	G = 1 + (6 kΩ/R_G)				
Gain Range		1		1000	V/V
Gain Error	V_{OUT} = ±10 V				
G = 1			0.01	0.03	%
G = 10			0.05	0.3	%
G = 100			0.05	0.3	%
G = 1000			0.1	0.3	%
Gain Nonlinearity	V_{OUT} = −10 V to +10 V				
G = 1 to 1000	R_L = 10 kΩ		2		ppm
Gain vs. Temperature					
G = 1	T_A = −40°C to +210°C		2	5	ppm/°C
G > 10	T_A = −40°C to +210°C			−100	ppm/°C
INPUT					
Impedance (Pin to Ground)[3]			1.5||3		GΩ||pF
Input Operating Voltage Range[4]	V_S = ±5 V to ±18 V for dual supplies	$-V_S + 2.8$		$+V_S - 2.5$	V
Over Temperature	T_A = −40°C to +210°C	$-V_S + 2.8$		$+V_S - 2.5$	V
OUTPUT					
Output Swing, R_L = 2 kΩ		$-V_S + 1.9$		$+V_S - 1.5$	V
High Temperature, SBDIP package	T_A = 210°C	$-V_S + 1.1$		$+V_S - 1.1$	V
High Temperature, SOIC package	T_A = 175°C	$-V_S + 1.2$		$+V_S - 1.1$	V
Output Swing, R_L = 10 kΩ		$-V_S + 1.8$		$+V_S - 1.2$	V
High Temperature, SBDIP package	T_A = 210°C	$-V_S + 1.1$		$+V_S - 1.1$	V
High Temperature, SOIC package	T_A = 175°C	$-V_S + 1.2$		$+V_S - 1.1$	V
Short-Circuit Current			35		mA

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
REFERENCE INPUT					
R_{IN}			10		kΩ
I_{IN}	$V_{IN}+$, $V_{IN}- = 0$ V		70		µA
Voltage Range		$-V_S$		$+V_S$	V
Reference Gain to Output			1		V/V
Reference Gain Error			0.01		%
POWER SUPPLY					
Operating Range		±4		±17	V
Quiescent Current			6.7	7	mA
High Temperature, SBDIP package	$T_A = 210°C$			12	mA
High Temperature, SOIC package	$T_A = 175°C$			11	mA
TEMPERATURE RANGE					
For Specified Performance[5]					
SBDIP package		−40		+210	°C
SOIC package		−40		+175	°C

[1] Total Voltage Noise = $\sqrt{(e_{ni}^2 + (e_{no}/G)^2) + e_{RG}^2}$. See the Theory of Operation section for more information.
[2] These specifications do not include the tolerance of the external gain setting resistor, R_G. For G>1, R_G errors should be added to the specifications given in this table.
[3] Differential and common-mode input impedance can be calculated from the pin impedance: $Z_{DIFF} = 2(Z_{PIN})$; $Z_{CM} = Z_{PIN}/2$.
[4] Input voltage range of the AD8229 input stage only. The input range can depend on the common-mode voltage, differential voltage, gain, and reference voltage. See the Input Voltage Range section for more details.
[5] For the guaranteed operation time at the maximum specified temperature, refer to the Predicted Lifetime vs. Operating Temperature section.

INA12x-HT Precision, Low-Power Instrumentation Amplifiers

1 Features

- Low Offset Voltage: 25 uV Typical
- Low Input Bias Current: 50 nA Typical (1)
- High CMR: 95 dB Typical(1)
- Inputs Protected to ±40 V
- Wide Supply Range: ±2.25 V to ±18 V
- Low Quiescent Current: 2 mA Typical(1)

2 Applications

- Bridge Amplifiers
- Thermocouple Amplifiers
- RTD Sensor Amplifiers
- Medical Instrumentation
- Data Acquisition
- Supports Extreme Temperature Applications:
  - Controlled Baseline
  - One Assembly/Test Site
  - One Fabrication Site
  - Available in Extreme Temperature Ranges (–55°C to 210°C) (2)
  - Extended Product Life Cycle
  - Extended Product-Change Notification
  - Product Traceability

(1) Typical values for 210°C application.
(2) Custom temperature ranges available.

3 Description

The INA128-HT and INA129-HT are low-power, general-purpose instrumentation amplifiers offering excellent accuracy. The versatile three-operational-amplifier design and small size make them ideal for a wide range of applications. Current-feedback input circuitry provides wide bandwidth even at high gain. A single external resistor sets any gain from 1 to 10000. The INA128-HT provides an industry-standard gain equation; the INA129-HT gain equation is compatible with the AD620.

The INA128-HT and INA129-HT are laser trimmed for very low offset voltage (25 μV Typ) and high common-mode rejection (93 dB at G ≥ 100). These devices operate with power supplies as low as ±2.25 V, and quiescent current of 2 mA, typically. Internal input protection can withstand up to ±40 V without damage.

Texas Instruments' high-temperature products use highly optimized silicon (die) solutions with design and process enhancements to maximize performance over extended temperatures.

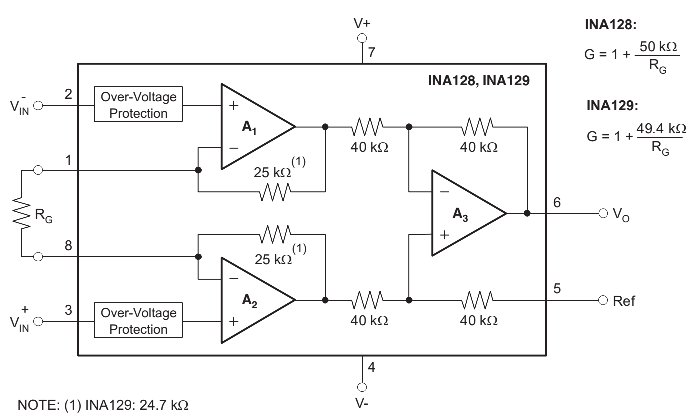
The INA129-HT is available in 8-pin ceramic DIP and 8-pin ceramic surface-mount packages, specified for the –55°C to 210°C temperature range. The INA128-HT is available in an 8-pin SOIC-8 surface-mount package, specified for the –55°C to 175°C temperature range.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
INA128-HT	SOIC (8)	4.90 mm × 3.91 mm
INA129-HT	CFP (8)	6.90 mm × 5.65 mm
	CDIP SB (8)	11.81 mm × 7.49 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

4 Simplified Schematic



NOTE: (1) INA129: 24.7 kΩ

7.6 Electrical Characteristics: INA129-HT

over operating free-air temperature range (unless otherwise noted)

PARAMETER	TEST CONDITIONS	T_A = –55°C to +125°C			T_A = 210°C(1)			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
INPUT								
OFFSET VOLTAGE, RTI								
Initial	T_A = 25°C		±25 ±100/G	±125 ±1000/G				µV
vs temperature	T_A = T_{MIN} to T_{MAX}		±0.2 ±5/G	±1 ±20/G		±1 ±850/G		µV/°C
vs power supply	V_S = ±2.25 V to ±18 V		±0.2 ±20/G	±2 ±200/G		±20 ±1000/G		µV/V
Long-term stability			±1 ±3/G			±1 ±3/G		µV/mo
Impedance, differential			10^{10} || 2			10^{10} || 2		Ω || pF
Common mode			10^{11}||9			10^{11}||9		Ω || pF
Common mode voltage range(2)	V_O = 0 V	(V+) − 2	(V+) − 1.4		(V+) − 2	(V+) − 1.4		V
		(V−) + 2	(V−) + 1.7		(V−) + 2	(V−) + 1.7		V
Safe input voltage				±40			±40	V
Common-mode rejection	V_{CM} = ±13 V, ΔR_S = 1 kΩ							
	G = 1	58	86			53		dB
	G = 10	78	106			69		dB
	G = 100	99	125			89		dB
	G = 1000	113	130			95		dB
CURRENT								
Bias current			±2	±10		±50		nA
vs temperature			±30			±600		pA/°C
Offset Current			±1	±10		±50		nA
vs temperature			±30			±600		pA/°C
NOISE								
Noise voltage, RTI	G = 1000, R_S = 0 Ω							
f = 10 Hz			10			25		nV/√Hz
f = 100 Hz			8			20		nV/√Hz
f = 1 kHz			8			20		nV/√Hz
f_B = 0.1 Hz to 10 Hz			0.2			2		μV_{PP}
Noise current								
f = 10 Hz			0.9					pA/√Hz
f = 1 kHz			0.3					pA/√Hz
f_B = 0.1 Hz to 10 Hz			30					pA_{PP}

(1) Minimum and maximum parameters are characterized for operation at T_A = 210°C, but may not be production tested at that temperature. Production test limits with statistical guardbands are used to ensure high temperature performance.
(2) Input common-mode range varies with output voltage — see typical curves.

Electrical Characteristics: INA129-HT (continued)

over operating free-air temperature range (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A = –55°C to +125°C			T_A = 210°C[1]			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
GAIN									
Gain equation				1 + (49.4 kΩ/R_G)			1 + (49.4 kΩ/R_G)		V/V
Range of gain			1		10000	1		10000	V/V
Gain error		G = 1		±0.01%	±0.1%		±1.1%		
		G = 10		±0.02%	±0.5%		±2.6%		
		G = 100		±0.05%	±0.7%		±13.5%		
		G = 1000		±0.5%	±2.5%		±65.5%		
Gain vs temperature[3]		G = 1		±1	±10		±100		ppm/°C
49.4-kΩ resistance[3][4]				±25	±100		±100		ppm/°C
Nonlinearity		V_O = ±13.6 V, G = 1		±0.0001	±0.001		±0.1		% of FSR
		G = 10		±0.0003	±0.002		±0.2		
		G = 100		±0.0005	±0.002		±0.7		
		G = 1000		±0.001	See [5]		±2.4	See [5]	
OUTPUT									
Voltage	Positive	R_L = 10kΩ	(V+) − 1.4	(V+) − 0.9		(V+) − 1.4	(V+) − 0.9		V
	Negative	R_L = 10kΩ	(V−) + 1.4	(V−) + 0.8		(V−) + 1.4	(V−) + 0.8		
Load capacitance stability				1000			1000		pF
Short-curcuit current				+6/−15			+12/−5		mA
FREQUENCY RESPONSE									
Bandwidth, −3 dB		G = 1		1300			850		kHz
		G = 10		700			400		
		G = 100		200			50		
		G = 1000		20			7.5		
Slew rate		V_O = ±10 V, G = 10		4			4		V/µs
Settling time, 0.01%		G = 1		7			10		µs
		G = 10		7			10		
		G = 100		9			30		
		G = 1000		80			150		
Overload recovery		50% overdrive		4			4		µs
POWER SUPPLY									
Voltage range			±2.25	±15	±18	±2.25	±15	±18	V
Current, total		V_{IN} = 0 V		±0.7	±1		±2		mA
TEMPERATURE RANGE									
Specification			−55		+125			210	°C
Operating			−55		+125			210	°C

(3) Specified by wafer test.
(4) Temperature coefficient of the 49.4-kΩ term in the gain equation.
(5) Nonlinearity measurements in G = 1000 are dominated by noise. Typical nonlinearity is ±0.001%.

OCTAL SIMULTANEOUS-SAMPLING 24-BIT ANALOG-TO-DIGITAL CONVERTER

Check for Samples: ADS1278-HT

FEATURES

- **Simultaneously Measure Eight Channels**
- **Up to 128-kSPS Data Rate**
- **AC Performance:**
  62-kHz Bandwidth
  111-dB SNR (High-Resolution Mode)
  –108-dB THD
- **DC Accuracy:**
  0.8-µV/°C Offset Drift
  1.3-ppm/°C Gain Drift
- **Selectable Operating Modes:**
  High-Speed: 128 kSPS, 106 dB SNR
  High-Resolution: 52 kSPS, 111 dB SNR
  Low-Power: 52 kSPS, 31 mW/ch
  Low-Speed: 10 kSPS, 7 mW/ch
- **Linear Phase Digital Filter**
- **SPI™ or Frame-Sync Serial Interface**
- **Low Sampling Aperture Error**
- **Modulator Output Option (digital filter bypass)**
- **Analog Supply: 5 V**
- **Digital Core: 1.8 V**
- **I/O Supply: 1.8 V to 3.3 V**
- **Currently Available in an HTQFP-64 PowerPAD™ package, an 84-Pin HFQ Package and a KGD Chiptray Option**

SUPPORTS EXTREME TEMPERATURE APPLICATIONS

- **Controlled Baseline**
- **One Assembly/Test Site**
- **One Fabrication Site**
- **Available in Extreme (–55°C/210°C) Temperature Range** [(1)]
- **Extended Product Life Cycle**
- **Extended Product-Change Notification**
- **Product Traceability**
- **Texas Instruments High Temperature Products Utilize Highly Optimized Silicon (Die) Solutions With Dsign and Process Enhancements to Maximize Performance Over Extended Temperatures**

(1) Custom temperature ranges available

APPLICATIONS

- **Down-Hole Drilling**
- **High Temperature Environments**
- **Vibration/Modal Analysis**
- **Multi-Channel Data Acquisition**
- **Acoustics/Dynamic Strain Gauges**
- **Pressure Sensors**

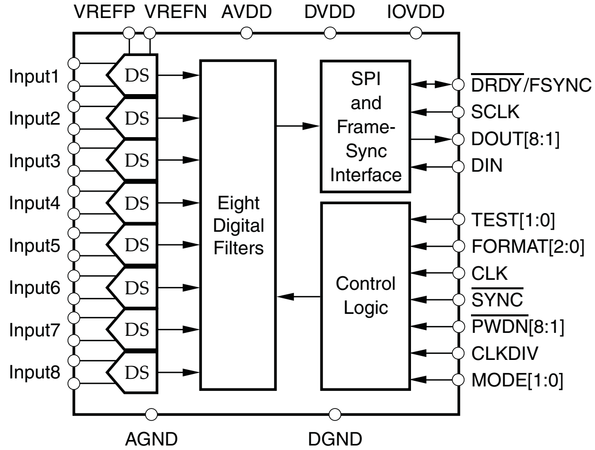
DESCRIPTION

Based on the single-channel ADS1271, the ADS1278 (octal) is a 24-bit, delta-sigma (ΔΣ) analog-to-digital converter (ADC) with data rates up to 128 k samples per second (SPS), allowing simultaneous sampling of eight channels.

Traditionally, industrial delta-sigma ADCs offering good drift performance use digital filters with large passband droop. As a result, they have limited signal bandwidth and are mostly suited for dc measurements. High-resolution ADCs in audio applications offer larger usable bandwidths, but the offset and drift specifications are significantly weaker than respective industrial counterparts. The ADS1278 combines these types of converters, allowing high-precision industrial measurement with excellent dc and ac specifications.

The high-order, chopper-stabilized modulator achieves very low drift with low in-band noise. The onboard decimation filter suppresses modulator and signal out-of-band noise. These ADCs provide a usable signal bandwidth up to 90% of the Nyquist rate with less than 0.005 dB of ripple.

Four operating modes allow for optimization of speed, resolution, and power. All operations are controlled directly by pins; there are no registers to program. The device is fully specified over the extended industrial range (–55°C to 210°C) and is available in an HTQFP-64 PowerPAD package (-55°C to 175°C), an 84-pin HFQ package and a KGD chiptray option.



ADS1278

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

Table 1. ORDERING INFORMATION(1)

T_A	PACKAGE	ORDERABLE PART NUMBER
–55°C to 175°C	PAP	ADS1278HPAP
–55°C to 210°C	HFQ	ADS1278SHFQ
	HKP	ADS1278SHKP
	CHIPTRAY (bare die)	ADS1278SKGDA

(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI Web site at www.ti.com.

ELECTRICAL CHARACTERISTICS

All specifications at $T_A = T_J$ = –55°C to 210°C, AVDD = 5 V, DVDD = 1.8 V, IOVDD = 3.3 V, f_{CLK} = 27 MHz, VREFP = 2.5 V, VREFN = 0 V, and all channels active, unless otherwise noted.

PARAMETER		TEST CONDITIONS	T_A = –55°C to 125°C MIN	TYP	MAX	T_A = 210°C[1] MIN	TYP	MAX	UNIT
Analog Inputs									
Full-scale input voltage (FSR[2])		V_{IN} = (AINP – AINN)		$\pm V_{REF}$			$\pm V_{REF}$		V
Absolute input voltage		AINP or AINN to AGND	AGND – 0.1		AVDD + 0.1	AGND – 0.1		AVDD + 0.1	V
Common-mode input voltage (V_{CM})		V_{CM} = (AINP + AINN)/2		2.5			2.5		V
Differential input impedance	High-Speed mode			14			14		kΩ
	High-Resolution mode			14			14		kΩ
	Low-Power mode			28			28		kΩ
	Low-Speed mode			140			140		kΩ
DC Performance									
Resolution		No missing codes	24						Bits
Data rate (f_{DATA})	High-Speed mode	f_{CLK} = 32.768MHz[3]		128,000			128,000		SPS
		f_{CLK} = 27MHz		105,469			105,469		SPS[4]
	High-Resolution mode			52,734			52,734		SPS
	Low-Power mode			52,734			52,734		SPS
	Low-Speed mode			10,547			10,547		SPS
Integral nonlinearity (INL)[5]		Differential input, V_{CM} = 2.5V		±0.0003	±0.0012			±0.0014	% FSR[2]
Offset error				0.25	2			2	mV
Offset drift				0.8					µV/°C
Gain error				0.1	0.5			0.5	% FSR
Gain drift				1.3					ppm/°C
Noise	High-Speed mode	Shorted input		8.5	21			21	µV, rms
	High-Resolution mode	Shorted input		5.5	13			13	µV, rms
	Low-Power mode	Shorted input		8.5	21			21	µV, rms
	Low-Speed mode	Shorted input		8.0	21			21	µV, rms
Common-mode rejection		f_{CM} = 60Hz	90	108		90			dB
Power-supply rejection	AVDD	f_{PS} = 60Hz		80			80		dB
	DVDD			85			85		dB
	IOVDD			105			102		dB
V_{COM} output voltage		No load		AVDD/2			AVDD/2		V
AC Performance									
Crosstalk		f = 1kHz, –0.5dBFS[6]		–107					dB
Signal-to-noise ratio (SNR)[7] (unweighted)	High-Speed mode		98	106		96			dB
	High-Resolution mode	V_{REF} = 2.5V	101	110		101			dB
		V_{REF} = 3V		111					dB
	Low-Power mode		98	106		97			dB
	Low-Speed mode		98	107		98			dB
Total harmonic distortion (THD)[8]		V_{IN} = 1kHz, –0.5dBFS		–108	–96			-96	dB
Spurious-free dynamic range				109					dB
Passband ripple				±0.005					dB

(1) Minimum and maximum parameters are characterized for operation at T_A = 175°C but may not be production tested at that temperature. Production test limits with statistical guardbands are used to ensure high temperature performance.
(2) FSR = full-scale range = $2V_{REF}$.
(3) f_{CLK} = 32.768MHz max for High-Speed mode, and 27MHz max for all other modes. When f_{CLK} > 27MHz, operation is limited to Frame-Sync mode and $V_{REF} \leq 2.6V$.
(4) SPS = samples per second.
(5) Best fit method.
(6) Worst-case channel crosstalk between one or more channels.
(7) Minimum SNR is ensured by the limit of the *DC noise* specification.
(8) THD includes the first nine harmonics of the input signal; Low-Speed mode includes the first five harmonics.

ELECTRICAL CHARACTERISTICS (continued)

All specifications at T_A = T_J = –55°C to 210°C, AVDD = 5 V, DVDD = 1.8 V, IOVDD = 3.3 V, f_{CLK} = 27 MHz, VREFP = 2.5 V, VREFN = 0 V, and all channels active, unless otherwise noted.

PARAMETER		TEST CONDITIONS	T_A = –55°C to 125°C			T_A = 210°C (1)			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Passband				0.453 f_{DATA}					Hz
–3dB Bandwidth				0.49 f_{DATA}					Hz
Stop band attenuation	High-Resolution mode		95						dB
	All other modes		100						
Stop band	High-Resolution mode		0.547 f_{DATA}		127.453 f_{DATA}				Hz
	All other modes		0.547 f_{DATA}		63.453 f_{DATA}				Hz
Group delay	High-Resolution mode			39/f_{DATA}					s
	All other modes			38/f_{DATA}					s
Settling time (latency)	High-Resolution mode	Complete settling		78/f_{DATA}					s
	All other modes	Complete settling		76/f_{DATA}					s
Voltage Reference Inputs									
Reference input voltage (V_{REF}) (V_{REF} = VREFP – VREFN)		f_{CLK} = 27MHz	0.5	2.5	3.1	0.5	2.5	3.1	V
		f_{CLK} = 32.768MHz (3)	0.5	2.5	2.6	0.5	2.5	2.6	V
Negative reference input (VREFN)			AGND – 0.1		AGND + 0.1	AGND – 0.1		AGND + 0.1	V
Positive reference input (VREFP)			VREFN + 0.5		AVDD + 0.1	VREFN + 0.5		AVDD + 0.1	V
Reference Input impedance	High-Speed mode			0.65			0.65		kΩ
	High-Resolution mode			0.65			0.65		kΩ
	Low-Power mode			1.3			1.3		kΩ
	Low-Speed mode			6.5			6.5		kΩ
Digital Input/Output (IOVDD = 1.8V to 3.6V)									
V_{IH}			0.7 IOVDD		IOVDD	0.7 IOVDD		IOVDD	V
V_{IL}			DGND		0.3 IOVDD	DGND		0.3 IOVDD	V
V_{OH}		I_{OH} = 4mA	0.8 IOVDD		IOVDD	0.8 IOVDD		IOVDD	V
V_{OL}		I_{OL} = 4mA	DGND		0.2 IOVDD	DGND		0.2 IOVDD	V
Input leakage		0 < $V_{IN\ DIGITAL}$ < IOVDD			±10				µA
Master clock rate (f_{CLK})		High-Speed mode (9)	0.1		32.768	0.1		32.768	MHz
		Other modes	0.1		27	0.1		27	MHz
Power Supply									
AVDD			4.75	5	5.25	4.75	5	5.25	V
DVDD			1.65	1.8	1.95	1.65	1.8	1.95	V
IOVDD			1.65		3.6	1.65		3.6	V
Power-down current	AVDD			1	10		65		µA
	DVDD			1	50		200		µA
	IOVDD			1	11		25		µA
AVDD current	High-Speed mode			97	145		135	185	mA
	High-Resolution mode			97	145		135	185	mA
	Low-Power mode			44	64		60	84	mA
	Low-Speed mode			9	14		12	22	mA

(9) f_{CLK} = 32.768MHz max for High-Speed mode, and 27MHz max for all other modes. When f_{CLK} > 27MHz, operation is limited to Frame-Sync mode and V_{REF} ≤ 2.6V.

ELECTRICAL CHARACTERISTICS (continued)

All specifications at $T_A = T_J$ = –55°C to 210°C, AVDD = 5 V, DVDD = 1.8 V, IOVDD = 3.3 V, f_{CLK} = 27 MHz, VREFP = 2.5 V, VREFN = 0 V, and all channels active, unless otherwise noted.

PARAMETER		TEST CONDITIONS	T_A = –55°C to 125°C			T_A = 210°C[(1)]			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
DVDD current	High-Speed mode			23	30		24	31	mA
	High-Resolution mode			16	20		17	20	mA
	Low-Power mode			12	17		13	17	mA
	Low-Speed mode			2.5	4.5		3	5	mA
IOVDD current	High-Speed mode			0.25	1		0.3	1.15	mA
	High-Resolution mode			0.125	0.6		0.2	0.75	mA
	Low-Power mode			0.125	0.6		0.2	0.75	mA
	Low-Speed mode			0.035	0.3		0.1	0.45	mA
Power dissipation	High-Speed mode			530	785			985	mW
	High-Resolution mode			515	765			985	mW
	Low-Power mode			245	355			455	mW
	Low-Speed mode			50	80			120	mW

SM470R1B1M-HT 16-/32-Bit RISC Flash Microcontroller

1 Device Overview

1.1 Features

- High-Performance Static CMOS Technology
- SM470R1x 16-/32-Bit RISC Core (ARM7TDMI™)
  - 60-MHz System Clock (Pipeline Mode)
  - Independent 16-/32-Bit Instruction Set
  - Open Architecture With Third-Party Support
  - Built-In Debug Module
- Integrated Memory
  - 1MB Program Flash
    - Two Banks With 16 Contiguous Sectors
  - 64KB Static RAM (SRAM)
  - Memory Security Module (MSM)
  - JTAG Security Module
- Operating Features
  - Low-Power Modes: STANDBY and HALT
  - Industrial Temperature Range
- 470+ System Module
  - 32-Bit Address Space Decoding
  - Bus Supervision for Memory/Peripherals
  - Digital Watchdog (DWD) Timer
  - Analog Watchdog (AWD) Timer
  - Enhanced Real-Time Interrupt (RTI)
  - Interrupt Expansion Module (IEM)
  - System Integrity and Failure Detection
  - ICE Breaker
- Direct Memory Access (DMA) Controller
  - 32 Control Packets and 16 Channels
- Zero-Pin Phase-Locked Loop (ZPLL)-Based Clock Module With Prescaler
  - Multiply-by-4 or -8 Internal ZPLL Option
  - ZPLL Bypass Mode
- Twelve Communication Interfaces:
  - Two Serial Peripheral Interfaces (SPIs)
  - 255 Programmable Baud Rates
  - Three Serial Communication Interfaces (SCIs)
    - 2^{24} Selectable Baud Rates
    - Asynchronous/Isosynchronous Modes
  - Two High-End CAN Controllers (HECC)
    - 32-Mailbox Capacity
    - Fully Compliant With CAN Protocol, Version 2.0B
  - Five Inter-Integrated Circuit (I^2C) Modules
    - Multi-Master and Slave Interfaces
    - Up to 400 Kbps (Fast Mode)
    - 7- and 10-Bit Address Capability
- High-End Timer Lite (HET)
  - 12 Programmable I/O Channels:
    - 12 High-Resolution Pins
  - High-Resolution Share Feature (XOR)
  - High-End Timer RAM
    - 64-Instruction Capacity
- External Clock Prescale (ECP) Module
  - Programmable Low-Frequency External Clock (CLK)
- 12-Channel, 10-Bit Multi-Buffered ADC (MibADC)
  - 64-Word FIFO Buffer
  - Single- or Continuous-Conversion Modes
  - 1.55-µs Minimum Sample and Conversion Time
  - Calibration Mode and Self-Test Features
- Flexible Interrupt Handling
- Expansion Bus Module (EBM)
  - Supports 8- and 16-Bit Expansion Bus Memory Interface Mappings
  - 42 I/O Expansion Bus Pins
- 46 Dedicated General-Purpose I/O (GIO) Pins and 47 Additional Peripheral I/Os
- Sixteen External Interrupts
- On-Chip Scan-Base Emulation Logic, IEEE Standard 1149.1 (1) (JTAG) Test-Access Port
- Available in KGD, HFQ, HKP, and PGE Packages

(1) The test-access port is compatible with the IEEE Standard 1149.1-1990, IEEE Standard Test-Access Port and Boundary Scan Architecture specification. Boundary scan is not supported on this device.

International
IOR Rectifier

HTA-SERIES

HIGH TEMPERATURE DC-DC CONVERTER

185°C, 200V Input, Single/Dual Output

HTA

Description

The HTA Series of DC-DC converters is a family of 20W, single and dual output, high reliability devices designed to operate in extremely high temperature environments such as those encountered in oil exploration applications. Features include small size, low weight and high tolerance to environmental stresses such as wide temperature extremes, severe shock and vibration. All internal components are derated to meet the intended operating environment. Documentation including electrical stress and thermal analysis are available.

The converters incorporate a fixed frequency single forward topology with magnetic feedback and internal EMI filter. All models include an external inhibit port and have an adjustable output voltage. They are enclosed in a hermetic 3.805" x 1.5" x 0.430" AlSi package and weigh less than 70grams. The package utilizes rugged ceramic feed-thru copper core pins and is sealed using parallel seam welding.

Full environmental screening includes temperature cycling, constant acceleration, fine and gross leak, and burn-in. Non-screened versions of the HTA converters are available for system development purposes. Variations in electrical specifications and screening to meet custom requirements can be accommodated.

Features

- 150 to 250V DC Input Range
- Up to 20W Output Power
- Single and Dual Output Models Include 3.3, 5, 12, 15, ±5, ±12 and ±15V
- Internal EMI Filter
- Magnetically Coupled Feedback
- High Efficiency - to 76%
- -35°C to +185°C Operating Case Temperature Range
- 10MΩ @ 500V DC Isolation
- Under-Voltage Lockout
- Short Circuit and Overload Protection
- Output Over Voltage Limiter
- Adjustable Output Voltage
- Synchronization Input and Output
- External Inhibit
- Low Weight, < 70grams

Applications

- Down Hole Exploration Tools

Circuit Description

The HTA Series of converters utilize a single-ended forward topology with resonant reset. The nominal switching frequency is 550kHz. Electrical isolation and tight output regulation are achieved through the use of a magnetically coupled feedback.

Output current is limited under any load fault condition to approximately 125% of rated load at maximum operating case temperature. An overload condition causes the converter output to behave like a constant current source with the output voltage dropping below nominal. The converter will resume normal operation when the load current is reduced below the current limit point. This protects the converter from both overload and short circuit conditions.

The current limit point exhibits a slightly negative temperature coefficient to reduce the possibility of thermal runaway.

An external Inhibit port is provided to control converter operation. The converter's operation is inhibited when this pin is pulled low. It is designed to be driven by an open collector logic device. The pin may be left open for normal operation and has a nominal open circuit voltage of 4.0V with respect to the Input Return (pin 2).

The output voltage of all models can be adjusted using a single external resistor.

Absolute Maximum Ratings		Maximum Operating Conditions	
Input voltage range	-0.5V_{DC} to +300V_{DC}	Input voltage range	150V_{DC} to 250V_{DC}
Output power	Internally limited	Output power	0 to Max. Rated
Lead temperature	+300°C for 10 seconds	Operating temperature	-35°C to +185°C
Operating case temperature	-35°C to +185°C		
Storage temperature	-55°C to +185°C		

Electrical Performance Characteristics

Parameter	Group A Subgroup	Conditions -35°C ≤ T_C ≤ +185°C V_{IN} = 200V_{DC} ± 5%, C_L = 0 unless otherwise specified	Limits Min	Limits Nom	Limits Max	Unit
Input Voltage			150	200	250	V
Output voltage (V_{OUT})						V
HTA2003R3S	1	I_{OUT} = 100% rated load Note 4	3.25	3.30	3.35	
HTA20005S	1		4.95	5.00	5.05	
HTA20012S	1		11.88	12.00	12.12	
HTA20015S	1		14.85	15.00	15.15	
HTA20005D	1		±4.95	±5.00	±5.05	
HTA20012D	1		±11.88	±12.00	±12.12	
HTA20015D	1		±14.85	±15.00	±15.15	
HTA20003R3S	2,3	I_{OUT} = 100% rated load Note 4	3.20		3.40	
HTA20005S	2,3		4.85		5.15	
HTA20012S	2,3		11.64		12.36	
HTA20015S	2,3		14.55		15.45	
HTA20005D	2,3		±4.85		±5.15	
HTA20012D	2,3		±11.64		±12.36	
HTA20015D	2,3		±14.55		±15.45	
Output power (P_{OUT})	1,2,3	V_{IN} = 150, 200, 250 Volts, Note 2	0		20	W
Output current (I_{OUT})	1,2,3	V_{IN} = 150, 200, 250 Volts, Note 2				A
HTA20003R3S			0		6.10	
HTA20005S			0		4.00	
HTA20012S			0		1.67	
HTA20015S			0		1.33	
HTA20005D		Either Output, Note 3	0		3.20	
HTA20012D		Either Output, Note 3	0		1.34	
HTA20015D		Either Output, Note 3	0		1.06	
Line regulation (VR_{LINE})	1,2,3	V_{IN} = 150, 200, 250 Volts I_{OUT} = 10%, 50%, 100% rated, Note 4	-0.5		+0.5	%
Load regulation (VR_{LOAD})	1,2,3	I_{OUT} = 10%, 50%, 100% rated, Note 4 V_{IN} = 150, 200, 250 Volts	-1.0		+1.0	%
Cross regulation (VR_{CROSS})	1,2,3	V_{IN} = 150, 200, 250 Volts, Note 5				%
HTA20005D		Positive Output	-1.0		+1.0	
		Negative Output	-10		+10	
HTA20012D HTA20015D		Positive Output	-1.0		+1.0	
		Negative Output	-5.0		+5.0	

For Notes to Electrical Performance Characteristics, refer to page 5

Electrical Performance Characteristics (continued)

Parameter	Group A Subgroup	Conditions $-35°C \le T_C \le +185°C$ $V_{IN} = 200V_{DC} \pm 5\%$, $C_L = 0$ unless otherwise specified	Limits Min	Nom	Max	Unit
Input current, no load (I_{IN})						
HTA20003R3S HTA20005S HTA20012S HTA20015S HTA20005D HTA20012D HTA20015D	1,3	I_{OUT} = 0, Pin 4 open			20	mA
HTA20003R3S HTA20005S HTA20012S HTA20015S HTA20005D HTA20012D HTA20015D	2	I_{OUT} = 0, Pin 4 open			30	mA
Input current inhibited	1,2,3	Pin 4 shorted to pin 2			5.0	mA
Output ripple (V_{RIP})						
HTA20003R3S HTA20005S HTA20012S HTA20015S HTA20005D HTA20012D HTA20015D	1,3	V_{IN} = 150, 200, 250 Volts I_{OUT} = 100% rated load Notes 4, 6			50 50 70 80 80 80 80	mV p-p
HTA20003R3S HTA20005S HTA20012S HTA20015S HTA20005D HTA20012D HTA20015D	2	V_{IN} = 150, 200, 250 Volts I_{OUT} = 100% rated load Notes 4, 6			25 25 35 40 40 40 40	mV p-p
Switching frequency (f_S)	1,2,3	Sync. Input (Pin 4) open	500	550	650	kHz
Efficiency (E_{FF})						
HTA20003R3S HTA20005S HTA20012S HTA20015S HTA20005D HTA20012D HTA20015D	1	I_{OUT} = 100% rated load Note 4	65 71 71 71 70 69 69	68 74 74 74 73 72 72		
HTA20003R3S HTA20005S HTA20012S HTA20015S HTA20005D HTA20012D HTA20015D	2	I_{OUT} = 100% rated load Note 4	65 69 71 71 68 68 68			%
HTA20003R3S HTA20005S HTA20012S HTA20015S HTA20005D HTA20012D HTA20015D	3	I_{OUT} = 100% rated load Note 4	65 70 70 70 68 68 68			

For Notes to Electrical Performance Characteristics, refer to page 5

Electrical Performance Characteristics (continued)

Parameter	Group A Subgroup	Conditions $-35°C \le T_C \le +185°C$ $V_{IN} = 200V_{DC} \pm 5\%$, $C_L = 0$ unless otherwise specified	Limits Min	Nom	Max	Unit
Under Voltage Released/Lockout Turn-on (input voltage rising) Turn-off (input voltage decreasing)	1,2,3 1,2,3	No load, Full load Notes 1, 4	 119		146	V
Synchronization Frequency Range Pulse Amplitude, High Pulse Amplitude, Low Pulse Rise Time Pulse Duty Cycle	1,2,3 1,2,3 1,2,3	Note 1	550 4.0 -0.5 20		650 10 0.8 100 80	kHz V V ns %
Transient Recovery Specification		Notes 4, 10, 11, 12				
Transient Load Response Half to Full Load	4,5,6	Overshoot Recovery Time			10 300	% µs
Transient Load Response Full to Half Load	4,5,6	Overshoot Recovery Time			10 450	% µs
Transient Load Response 10% to Half Load	4,5,6	Overshoot Recovery Time			15 300	% µs
Transient Load Response Half to 10% Load	4,5,6	Overshoot Recovery Time (For 3.3S & 05S) Recovery Time (For All other Models)			15 650 450	% µs µs
Enable Input (Inhibit Function) open circuit voltage drive current (sink) voltage range	1,2,3	Note 1	3.0 -0.5		5.0 100 50	V µA V
Current Limit Point Expressed as a percentage of full rated load current	1 2 3	V_{OUT} = 90% of Nominal, Note 4	115 105 130		175 150 220	%
Power dissipation, load fault (P_D)	1,2,3	Short Circuit, Overload, Note 8			30	W
Turn-on Response Overshoot (V_{OS}) Turn-on Delay (T_{DLY})	4,5,6	Min. Load, Full Load Notes 4, 9	 2.0		10 200	% ms
Capacitive Load (C_L) HTA20003R3S HTA20005S HTA20012S HTA20015S HTA20005D HTA20012D HTA20015D	1	I_{OUT} = 100% rated load No effect on DC performance Notes 1, 4, 7 Each output on duals			2200 1000 180 120 500 90 60	µF
Line Rejection	1	MIL-STD-461, CS101 30Hz to 50kHz, Notes 1, 4	40	50		dB
Isolation	1	Input to Output or Any Pin to Case except pin 3, test @ $500V_{DC}$	100			MΩ
Device Weight					70	g

For Notes to Electrical Performance Characteristics, refer to page 5

International
IOR Rectifier
AN INFINEON TECHNOLOGIES COMPANY

PD-97825

HIGH TEMPERATURE HYBRID DC-DC CONVERTER

HTB28XXS

185°C, 5W, 28V Input, Single Output

Description

The HTB28XXS Series is a hybrid, hermetically sealed, single output 5W DC-DC converter designed to operate in high temperature up to 185°C and shock and vibration environments such as those encountered in oil exploration applications. Features include small size, 1" width and low weight. All internal components are specifically selected to meet the intended operating environment. Documentation, including electrical stress and thermal analysis, is available to customers.

The HTB28XXS Series of DC-DC converters use flyback topology, operating at a nominal frequency of 550 kHz. High input to output galvanic isolation is achieved through the use of transformers in the power and feedback paths. The advanced feedback design provides fast loop response for superior line and load transient characteristics and offers greater reliability than converters incorporating optical feedback circuits.

These converters are designed to meet full performance over a 17 to 34 volts input range and provide output power of up to 5 watts. An inhibit pin allows to shut the converter down or enable it.

Output current is limited under any load fault condition to approximately 180% of rated value. An overload condition causes the converter output to limit current. The converter will remain in current limit mode until the load current is reduced below the overcurrent limit, at which time it will resume normal operation. This protects the converter as well as load from both overload and short circuit conditions.

The converters are enclosed in a 1.0"W x 0.41"H x 2.82"L flanged package excluding mounting tabs and I/O pins and weigh less than 44 grams. The cold rolled steel (CRS) package utilizes rugged ceramic feed-thru copper core pins and is sealed with parallel seam welding.

Full environmental screening includes temperature cycling, constant acceleration, fine and gross leak testing and burn-in as per Device Screening table. Variations in electrical specifications and screening to meet custom requirements may be accommodated.
.

HTB

Features

- Case Operating Temperatures: -35°C to +185°C
- Life > 1200 hours @ +185°C
- Up to 5W Output Power
- Wide Input Voltage Range: 17 to 34 Volts
- Single Outputs: 3.3V, 5V, 12V and15V
- Minimum Efficiency 69%
- Low Inhibit Current (less than 3.5mA)
- External Inhibit / Enable
- Short Circuit and Overload Protection
- Under-Voltage Lockout Protection
- Industry Standard Pin-out
- Compact Flanged Package: 1.0"W x 0.41"H x 2.82"L
- Parallel Seam Welded Steel Package

Applications

- Down Hole Exploration Tools

Absolute Maximum Ratings		Maximum Operating Conditions	
Input voltage range	-0.5VDC to 40VDC	Input voltage range	17VDC to 34VDC
Output power	Internally limited	Output power	0 to Max. Rated
Lead temperature	+300°C for 10 sec	Case Operating temperature	-35°C to +185°C
Storage temperature	-45°C to +125°C		

Note: Storage at high temperature will effect life.

Electrical Performance Characteristics

TEST	Conditions -35° ≤ T_C ≤ +185°C V_{IN} = 28V_{DC} ±5% C_L = 0 unless otherwise specified	Subgroup [10]	HTB2803R3S Preliminary		HTB2805S		HTB2812S Preliminary		HTB2815S Preliminary		
			Min	Max	Min	Max	Min	Max	Min	Max	Unit
Output voltage	I_{OUT} = 100% I_{MAX}	1	3.26	3.34	4.95	5.05	11.88	12.12	14.85	15.15	V
		2, 3	3.2	3.4	4.85	5.15	11.64	12.24	14.55	15.30	
Output current [1]	V_{IN} = 17, 28, and 34 V_{DC}	1, 2, 3		1.51 5.0		1.0		0.416		0.333	A
Output power	V_{IN} = 17, 28, and 34 V_{DC}	1, 2, 3		5.0		5.0		5.0		5.0	W
Output ripple voltage [2]	V_{IN} = 17, 28 and 34 V_{DC} I_{OUT} = I_{MAX}	1		50		50		50		50	mV PP
		2, 3		50		50		50		50	
Input Under Voltage	Turn-on (rising), I_{OUT} = 0	1,2,3	12	15	12	15	12	15	12	15	V
	Turn off (decreasing), I_{OUT} = 0	1,2,3	12	14	12	14	12	14	12	14	
	Hysteresis	1,2	0.7		0.7		0.7		0.7		V
		3	0.4		0.4		0.4		0.4		
Line regulation	V_{IN} = 17, 28, and 34 V_{DC} I_{OUT} = 0, 50%, 100% I_{MAX}	1, 2, 3	-0.5	+0.5	-0.5	+0.5	-0.5	+0.5	-0.5	+0.5	%
Load regulation	V_{IN} = 17, 28, and 34 V_{DC} I_{OUT} = 0, 50%, 100% I_{MAX}	1, 2, 3	-2.0	+2.0	-1.0	+1.0	-1.0	+1.0	-1.0	+1.0	%
Input current	I_{OUT} = 0	1, 2, 3		15		15		20		20	mA
	I_{OUT} = 0 (inhibited)			3.5		3.5		3.5		3.5	
Input ripple current [2]	I_{OUT} = I_{MAX}	1, 3		100		100		100		100	mA PP
		2		150		150		150		150	
Efficiency	I_{OUT} = I_{MAX}	1, 3	69		69		75		75		%
		2	69		70		71		71		
Current Limit Point Expressed as a percentage of full rated output power	V_{OUT} = 90% of nominal	1, 2, 3		180		180		180		180	%
Isolation	V_{TEST} 500 V_{DC}, T_c= 25°C Input to output or any pin to case	1	100		100		100		100		MΩ
Capacitive load [3, 4,10]	No effect on DC performance, T_C = 25°C I_{OUT} = I_{MAX}	4		1000		1000		300		300	µF
Power dissipation, load fault	Overload [5]	1, 2, 3		5.0		5.0		5.0		5.0	W
	Short circuit			2.5		3.0		2.5		2.5	
Switching frequency [4]	I_{OUT} = I_{MAX}	4, 5, 6	500	600	500	600	500	600	500	600	kHz

For Notes to Electrical Performance Characteristics, refer to page 4

LOW NOISE, VERY LOW DRIFT, PRECISION VOLTAGE REFERENCE

Check for Samples: REF5025-HT

FEATURES

- **Low Temperature Drift: 40 ppm/°C**
- **Low Noise: 3 μV$_{PP}$/V**
- **High Output Current: ±7 mA**

APPLICATIONS

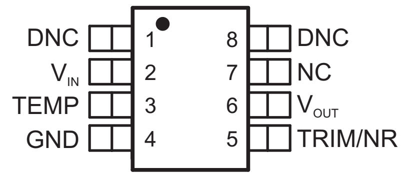
- **Down-Hole Drilling**
- **High Temperature Environments**

SUPPORTS EXTREME TEMPERATURE APPLICATIONS

- **Controlled Baseline**
- **One Assembly/Test Site**
- **One Fabrication Site**
- **Available in Extreme (–55°C/210°C) Temperature Range** (1)
- **Extended Product Life Cycle**
- **Extended Product-Change Notification**
- **Product Traceability**
- **Texas Instruments high temperature products utilize highly optimized silicon (die) solutions with design and process enhancements to maximize performance over extended temperatures.**

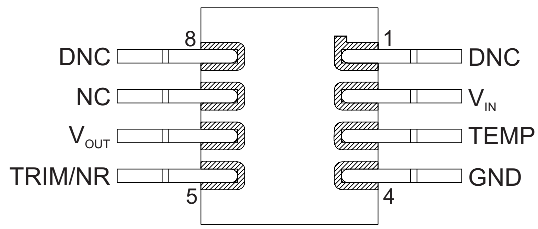
(1) Custom temperature ranges available

HKJ PACKAGE (TOP VIEW)



DNC = Do not connect
NC = No internal connection

HKQ PACKAGE (TOP VIEW)



HKQ as formed or HKJ mounted dead bug

DESCRIPTION

The REF5025 is a low-noise, low-drift, very high precision voltage reference. This reference is capable of both sinking and sourcing, and is very robust with regard to line and load changes.

Temperature drift (40 ppm/°C) from –55°C to 210°C is achieved using proprietary design techniques. These features combined with very low noise make the REF5025 ideal for use in down-hole drilling applications.

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

BARE DIE INFORMATION

DIE THICKNESS	BACKSIDE FINISH	BACKSIDE POTENTIAL	BOND PAD METALLIZATION COMPOSITION	BOND PAD THICKNESS
15 mils.	Silicon with backgrind	GND	Al-Cu (0.5%)	598 nm

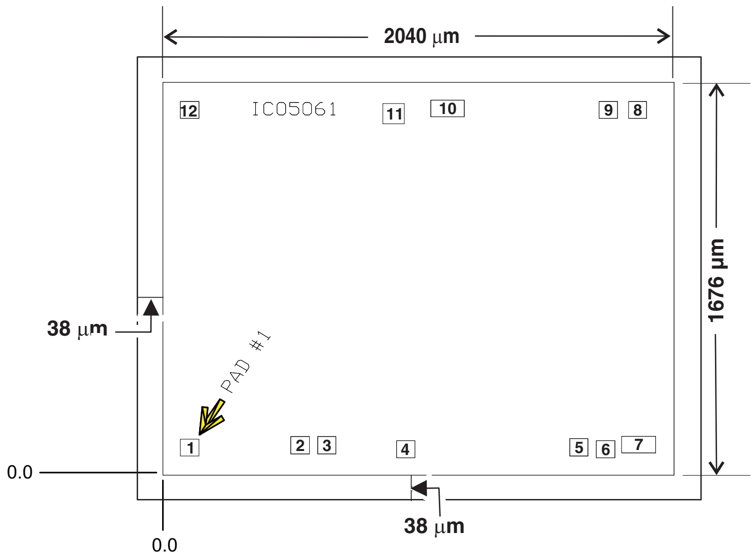


Table 1. Bond Pad Coordinates in Microns

DISCRIPTION	PAD NUMBER	X min	Y min	X max	Y max
NC	1	35.45	46.55	111.45	122.55
NC	2	496.75	56.55	572.75	132.55
VIN	3	607.45	56.55	683.45	132.55
NC	4	937.9	39.4	1013.9	115.4
TEMP	5	1660.1	47.2	1736.1	123.2
GND	6	1770.9	38.85	1847.05	115
GND	7	1877.1	59.6	2016.8	135.6
TRIM/NR	8	1904.65	1553.4	1980.65	1629.4
NC	9	1782.15	1553.4	1858.15	1629.4
VOUT	10	1080.2	1559.85	1219.9	1636
VOUT	11	880.25	1543.55	956.25	1619.55
NC	12	35.45	1553.45	111.45	1629.45

ORDERING INFORMATION(1)

T_A	PACKAGE	ORDERABLE PART NUMBER	TOP-SIDE MARKING
–55°C to 210°C	KGD (bare die)	REF5025SKGD1	NA
		REF5025SKGD2	
	HKJ	REF5025SHKJ	REF5025SHKJ
	HKQ	REF5025SHKQ	REF5025SHKQ

(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at www.ti.com.

3.3-V RS-485 TRANSCEIVER

Check for Samples: SN65HVD11-HT

FEATURES

- **Operates With a 3.3-V Supply**
- **Bus-Pin ESD Protection Exceeds 16-kV Human-Body Model (HBM)**
- **1/8 Unit-Load Option Available (up to 256 Nodes on Bus)**
- **Optional Driver Output Transition Times for Signaling Rates (1) of 1 Mbps, 10 Mbps, and 32 Mbps**
- **Based on ANSI TIA/EIA-485-A**
- **Bus-Pin Short Circuit Protection From –7 V to 12 V**
- **Open-Circuit, Idle-Bus, and Shorted-Bus Fail-Safe Receiver**
- **Glitch-Free Power-Up and Power-Down Protection for Hot-Plugging Applications**
- **SN75176 Footprint**

APPLICATIONS

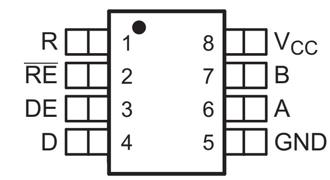
- **Down-Hole Drilling**
- **High Temperature Environments**
- **Digital Motor Controls**
- **Utility Meters**
- **Chassis-to-Chassis Interconnects**
- **Electronic Security Stations**
- **Industrial Process Control**
- **Building Automation**
- **Point-of-Sale (POS) Terminals and Networks**

(1) The signaling rate of a line is the number of voltage transitions that are made per second expressed in the units bits per second (bps).

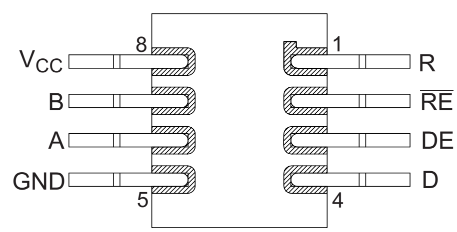
SUPPORTS EXTREME TEMPERATURE APPLICATIONS

- **Controlled Baseline**
- **One Assembly/Test Site**
- **One Fabrication Site**
- **Available in Extreme (–55°C/210°C) Temperature Range (2)**
- **Extended Product Life Cycle**
- **Extended Product-Change Notification**
- **Product Traceability**
- **Texas Instruments' high temperature products utilize highly optimized silicon (die) solutions with design and process enhancements to maximize performance over extended temperatures.**

D, JD OR HKJ PACKAGE (TOP VIEW)



HKQ PACKAGE (TOP VIEW)



HKQ as formed or HKJ mounted dead bug

(2) Custom temperature ranges available

DESCRIPTION/ORDERING INFORMATION

The SN65HVD11 combines a 3-state differential line driver and differential input line receiver that operates with a single 3.3-V power supply. It is designed for balanced transmission lines and meets or exceeds ANSI TIA/EIA-485-A and ISO 8482:1993, with the exception that the thermal shutdown is removed. This differential bus transceiver is a monolithic integrated circuit designed for bidirectional data communication on multipoint bus-transmission lines. The driver and receiver have active-high and active-low enables, respectively, that can be externally connected together to function as direction control.

The driver differential outputs and receiver differential inputs connect internally to form a differential input/ output (I/O) bus port that is designed to offer minimum loading to the bus when the driver is disabled or V_{CC} = 0.

Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.