Converting Data

Converting Data - Overview

- You now have voltage data for each sensor.
- The next step is figuring out how to convert the voltages into useful units.
- Each type of sensor comes with a detailed datasheet filled with useful information, including how to convert the data.
- The datasheets for all the sensors are in the manual.
- If you are interested, the datasheets for the other integrated circuits used on the payload are available on the DVD.

Converting Data - Process

- **All the sensors are proportional to the actual value, but have an offset – that is, you can use a linear equation to convert from units to voltage.**

- **Each sensor can be characterized by its sensitivity and its zero output offset: V_{OUT} = sensitivity * X + offset, where X is data in the appropriate units for the sensor in question.**

- **We want the converted data X in terms of V_{OUT}, so we solve the equation for X as follows:**

  V_{OUT} = sensitivity * X + offset

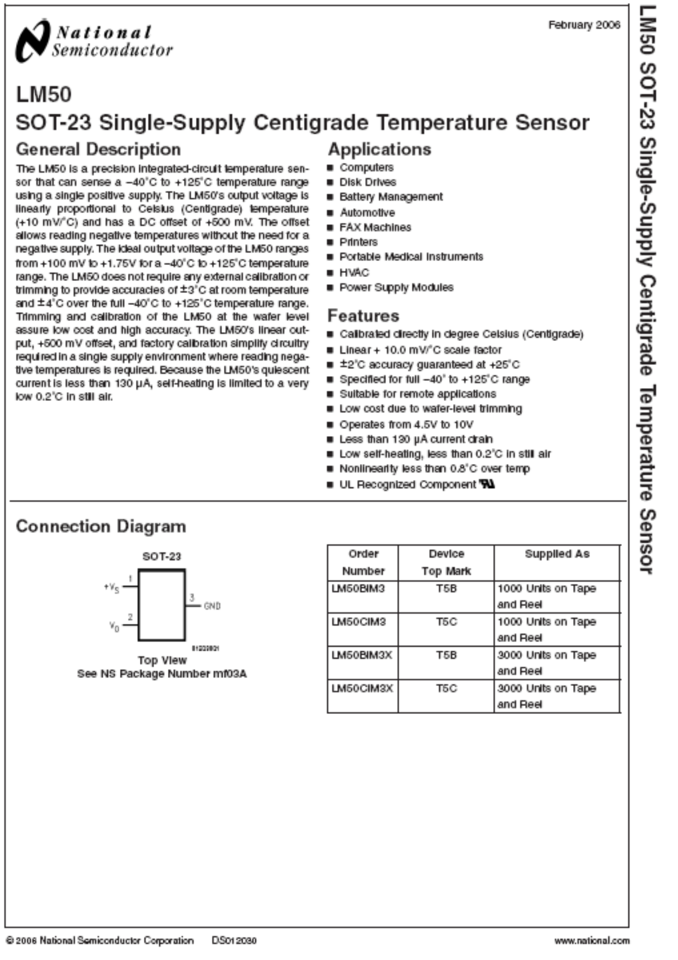
  V_{OUT} - offset = sensitivity * X

  (V_{OUT} - offset) / sensitivity = X

  X = (1/sensitivity) * VOUT – (offset/sensitivity)

Converting Data – Temperature Sensor 1

- **Open the datasheet for the LM50c temperature sensor.**
- **The front page gives an overview of the sensor. Scan through the datasheet to see what other information it has, including detailed electronic and mechanical information.**



National Semiconductor

February 2006

LM50 SOT-23 Single-Supply Centigrade Temperature Sensor

LM50
SOT-23 Single-Supply Centigrade Temperature Sensor

General Description

The LM50 is a precision integrated-circuit temperature sensor that can sense a −40˚C to +125˚C temperature range using a single positive supply. The LM50's output voltage is linearly proportional to Celsius (Centigrade) temperature (+10 mV/˚C) and has a DC offset of +500 mV. The offset allows reading negative temperatures without the need for a negative supply. The ideal output voltage of the LM50 ranges from +100 mV to +1.75V for a −40˚C to +125˚C temperature range. The LM50 does not require any external calibration or trimming to provide accuracies of ±3˚C at room temperature and ±4˚C over the full −40˚C to +125˚C temperature range. Trimming and calibration of the LM50 at the wafer level assure low cost and high accuracy. The LM50's linear output, +500 mV offset, and factory calibration simplify circuitry required in a single supply environment where reading negative temperatures is required. Because the LM50's quiescent current is less than 130 µA, self-heating is limited to a very low 0.2˚C in still air.

Applications

- Computers
- Disk Drives
- Battery Management
- Automotive
- FAX Machines
- Printers
- Portable Medical Instruments
- HVAC
- Power Supply Modules

Features

- Calibrated directly in degree Celsius (Centigrade)
- Linear + 10.0 mV/˚C scale factor
- ±2˚C accuracy guaranteed at +25˚C
- Specified for full −40˚ to +125˚C range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 4.5V to 10V
- Less than 130 µA current drain
- Low self-heating, less than 0.2˚C in still air
- Nonlinearity less than 0.8˚C over temp
- UL Recognized Component

Connection Diagram

SOT-23

+V_S 1, V_O 2, 3 GND

Top View
See NS Package Number mf03A

Order Number	Device Top Mark	Supplied As
LM50BIM3	T5B	1000 Units on Tape and Reel
LM50CIM3	T5C	1000 Units on Tape and Reel
LM50BIM3X	T5B	3000 Units on Tape and Reel
LM50CIM3X	T5C	3000 Units on Tape and Reel

Converting Data – Temperature Sensor 2

- Scroll down to page 2, where you will see the image below, along with an equation which gives output voltage in terms of temperature: V_{OUT} = 10mV/ °C * Temp °C + 500mV
- Notice that the sensitivity of the device is 10mV/C, while the zero temperature offset is 500mV.

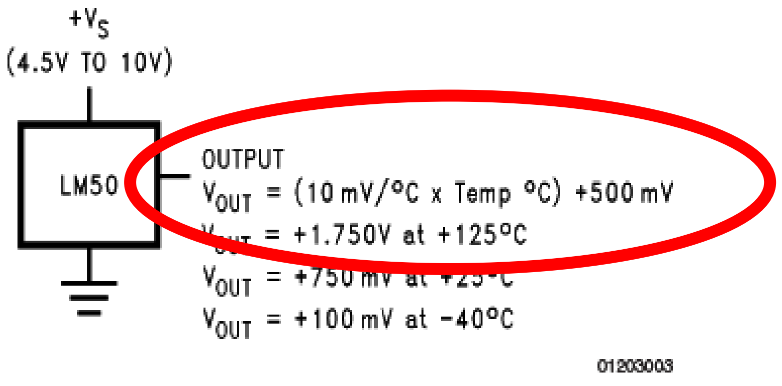


FIGURE 1. Full-Range Centigrade Temperature Sensor (−40˚C to +125˚C)

Converting Data – Temperature Sensor 3

- **Solve the equation for temperature in terms of voltage. Be careful of units. The final equation should use volts rather than millivolts.**

  1.) $1000\ mV = 1\ V$

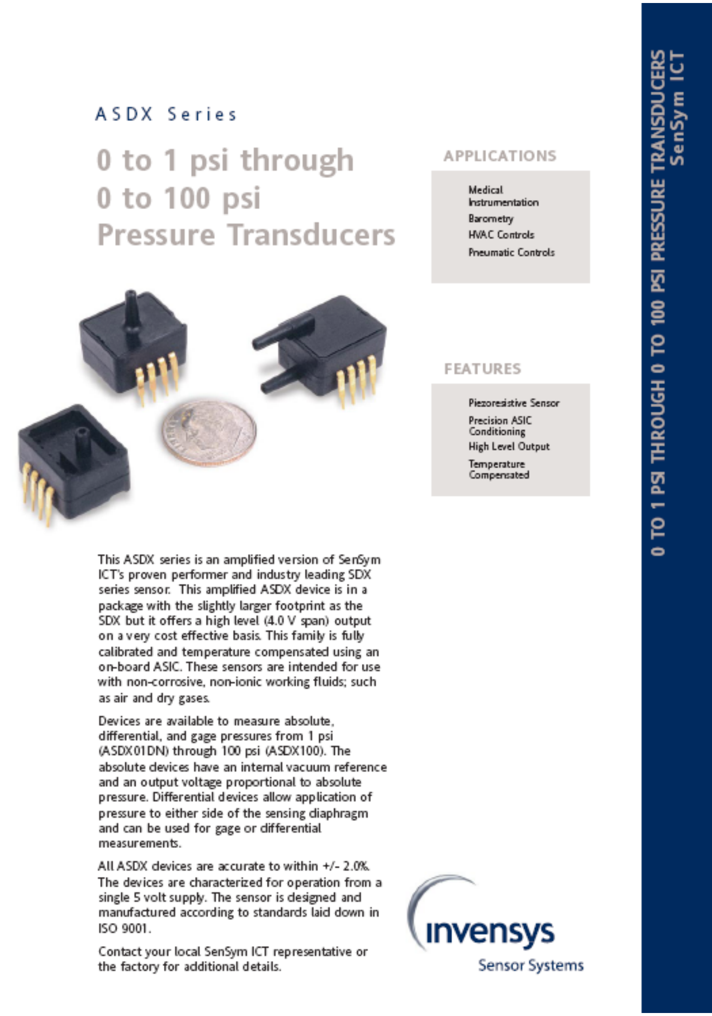
  2.) $\therefore\ V_{OUT} = 0.01\ V/\ °C * Temp\ °C + 0.5\ V$

  3.) $Temp\ °C/\ (V\ /\ 100\ °C) = V_{OUT} - 0.5\ V$

  4.) $Temp\ °C = 100*(°C\ /\ V)*\ V_{OUT} - 50\ °C$

Converting Data – Pressure Sensor 1

- Open the datasheet for the ASDX015 pressure sensor.
- Notice that unlike the temperature sensor, this datasheet is for a whole series of pressure sensors.
- We use the ASDX015, which can measure pressures between 0PSI and 15PSI.



ASDX Series

0 to 1 psi through 0 to 100 psi Pressure Transducers

APPLICATIONS

Medical Instrumentation
Barometry
HVAC Controls
Pneumatic Controls

FEATURES

Piezoresistive Sensor
Precision ASIC Conditioning
High Level Output
Temperature Compensated

This ASDX series is an amplified version of SenSym ICT's proven performer and industry leading SDX series sensor. This amplified ASDX device is in a package with the slightly larger footprint as the SDX but it offers a high level (4.0 V span) output on a very cost effective basis. This family is fully calibrated and temperature compensated using an on-board ASIC. These sensors are intended for use with non-corrosive, non-ionic working fluids; such as air and dry gases.

Devices are available to measure absolute, differential, and gage pressures from 1 psi (ASDX01DN) through 100 psi (ASDX100). The absolute devices have an internal vacuum reference and an output voltage proportional to absolute pressure. Differential devices allow application of pressure to either side of the sensing diaphragm and can be used for gage or differential measurements.

All ASDX devices are accurate to within +/- 2.0%. The devices are characterized for operation from a single 5 volt supply. The sensor is designed and manufactured according to standards laid down in ISO 9001.

Contact your local SenSym ICT representative or the factory for additional details.

invensys Sensor Systems

0 TO 1 PSI THROUGH 0 TO 100 PSI PRESSURE TRANSDUCERS
SenSym ICT

Converting Data – Pressure Sensor 2

PRESSURE RANGE SPECIFICATIONS

SenSym Part No.	Pressure Range	Burst Pressure[5]	Sensitivity
ASDX001	0 – 1 PSI	20 PSI	4.00 V/PSI
ASDX005	0 – 5 PSI	20 PSI	0.80 V/PSI
ASDX015	0 – 15 PSI	30 PSI	0.267 V/PSI
ASDX030	0 – 30 PSI	60 PSI	0.133 V/PSI
ASDX100	0 – 100 PSI	150 PSI	0.040 V/PSI

PERFORMANCE CHARACTERISTICS[1]

Characteristic	Symbol	Min	Typ	Max	Units
Zero Pressure Offset	Voff	0.420	0.500	0.580	V
Full Scale Span[2]	Vfss		4.00		V
Output at FS Pressure	Vfso	4.420	4.500	4.580	V
Accuracy[3]	–	–	–	±2.0	%Vfss
Response Time[4]		–	8	–	ms
Quantization Step[6]		–	3	–	mV

- **Scroll down to page 3, where you will see these tables.**
- **Locate the sensitivity and zero pressure offset of the ASDX015**

$$V_{OUT} = 0.267*(V/PSI)*Press. + 0.5\ V$$

Converting Data – Pressure Sensor 3

- Solve the equation for pressure in terms of voltage.

1.) $V_{OUT} = 0.267*(V/PSI)*Press. + 0.5\ V$

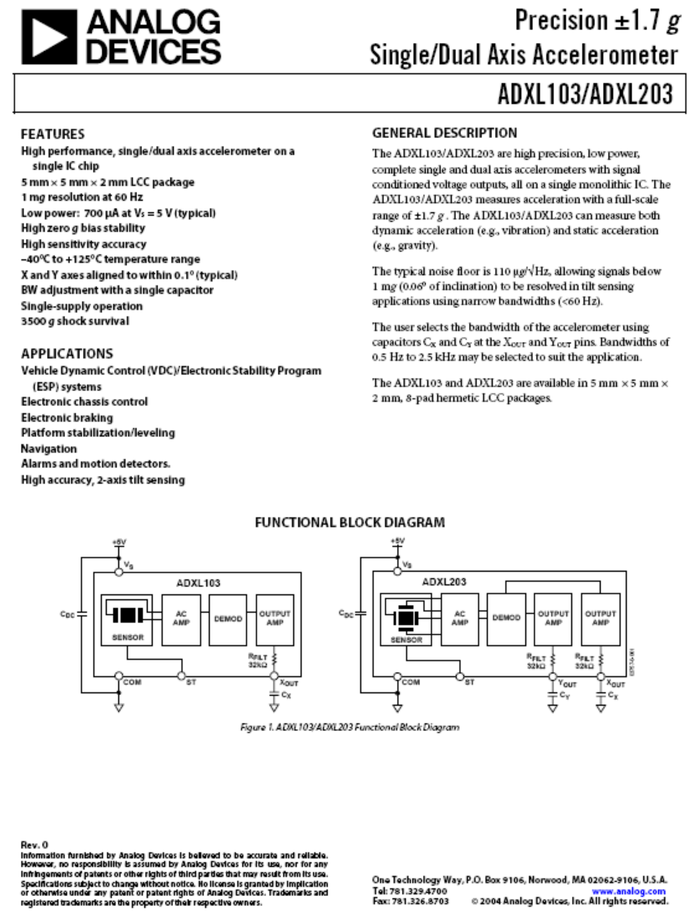
2.) $V_{OUT} - 0.5\ V = 0.267*(V/PSI)*Press.$

3.) $Pressure = 3.75*(PSI/V)*V_{OUT} - 1.87\ PSI$

Converting Data – Low Range Accelerometers 1

- **Open the datasheet for the ADXL103/ADXL203 single/dual axis precision (low range) accelerometers.**

- **Notice the functional block diagram on the front page. Block diagrams are useful for understanding the basics behind a system without the overwhelming detail of a full schematic.**


ANALOG DEVICES

Precision ±1.7 *g*
Single/Dual Axis Accelerometer

ADXL103/ADXL203

FEATURES

High performance, single/dual axis accelerometer on a single IC chip
5 mm × 5 mm × 2 mm LCC package
1 m*g* resolution at 60 Hz
Low power: 700 µA at V_S = 5 V (typical)
High zero *g* bias stability
High sensitivity accuracy
–40°C to +125°C temperature range
X and Y axes aligned to within 0.1° (typical)
BW adjustment with a single capacitor
Single-supply operation
3500 *g* shock survival

APPLICATIONS

Vehicle Dynamic Control (VDC)/Electronic Stability Program (ESP) systems
Electronic chassis control
Electronic braking
Platform stabilization/leveling
Navigation
Alarms and motion detectors.
High accuracy, 2-axis tilt sensing

GENERAL DESCRIPTION

The ADXL103/ADXL203 are high precision, low power, complete single and dual axis accelerometers with signal conditioned voltage outputs, all on a single monolithic IC. The ADXL103/ADXL203 measures acceleration with a full-scale range of ±1.7 *g*. The ADXL103/ADXL203 can measure both dynamic acceleration (e.g., vibration) and static acceleration (e.g., gravity).

The typical noise floor is 110 µ*g*/√Hz, allowing signals below 1 m*g* (0.06° of inclination) to be resolved in tilt sensing applications using narrow bandwidths (<60 Hz).

The user selects the bandwidth of the accelerometer using capacitors C_X and C_Y at the X_{OUT} and Y_{OUT} pins. Bandwidths of 0.5 Hz to 2.5 kHz may be selected to suit the application.

The ADXL103 and ADXL203 are available in 5 mm × 5 mm × 2 mm, 8-pad hermetic LCC packages.

FUNCTIONAL BLOCK DIAGRAM

Figure 1. ADXL103/ADXL203 Functional Block Diagram

Rev. 0

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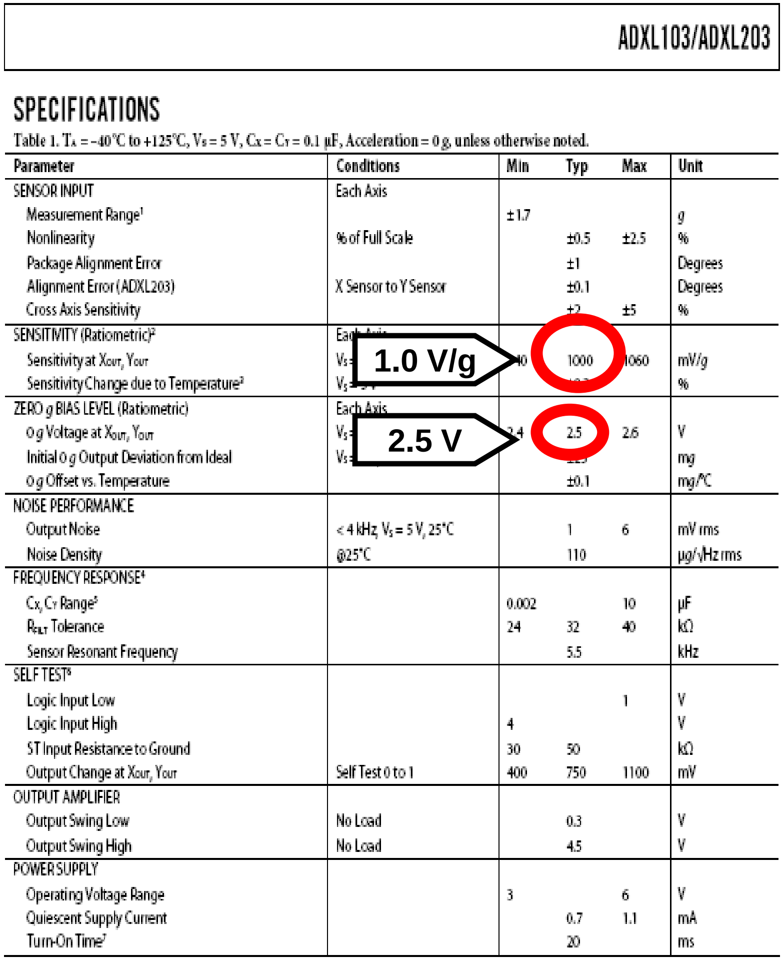
Converting Data – Low Range Accelerometers 2



ADXL103/ADXL203

SPECIFICATIONS

Table 1. T_A = −40°C to +125°C, V_S = 5 V, C_X = C_Y = 0.1 µF, Acceleration = 0 *g*, unless otherwise noted.

Parameter	Conditions	Min	Typ	Max	Unit
SENSOR INPUT	Each Axis				
Measurement Range[1]		±1.7			*g*
Nonlinearity	% of Full Scale		±0.5	±2.5	%
Package Alignment Error			±1		Degrees
Alignment Error (ADXL203)	X Sensor to Y Sensor		±0.1		Degrees
Cross Axis Sensitivity			±2	±5	%
SENSITIVITY (Ratiometric)[2]	Each Axis				
Sensitivity at X_{OUT}, Y_{OUT}	V_S = [illegible]	[illegible]	1000	[illegible]	mV/*g*
Sensitivity Change due to Temperature[3]	V_S = [illegible]		[illegible]		%
ZERO *g* BIAS LEVEL (Ratiometric)	Each Axis				
0 *g* Voltage at X_{OUT}, Y_{OUT}	V_S = [illegible]	[illegible]	2.5	2.6	V
Initial 0 *g* Output Deviation from Ideal	V_S = [illegible]		[illegible]		m*g*
0 *g* Offset vs. Temperature			±0.1		m*g*/°C
NOISE PERFORMANCE					
Output Noise	< 4 kHz, V_S = 5 V, 25°C		1	6	mV rms
Noise Density	@25°C		110		µ*g*/√Hz rms
FREQUENCY RESPONSE[4]					
C_X, C_Y Range[5]		0.002		10	µF
R_{FILT} Tolerance		24	32	40	kΩ
Sensor Resonant Frequency			5.5		kHz
SELF TEST[6]					
Logic Input Low				1	V
Logic Input High		4			V
ST Input Resistance to Ground		30	50		kΩ
Output Change at X_{OUT}, Y_{OUT}	Self Test 0 to 1	400	750	1100	mV
OUTPUT AMPLIFIER					
Output Swing Low	No Load		0.3		V
Output Swing High	No Load		4.5		V
POWER SUPPLY					
Operating Voltage Range		3		6	V
Quiescent Supply Current			0.7	1.1	mA
Turn-On Time[7]			20		ms

- **Scroll down to the specifications table on page 3.**

- **Locate the sensitivity and the 0g offset, which is called the "0g Voltage at X_{OUT}, Y_{OUT}" in this datasheet.**

$$V_{OUT} = 1*(V/g)*acc. + 2.5\ V$$

Converting Data – Pressure Sensor 3

- Solve the equation for g's in terms of voltage.

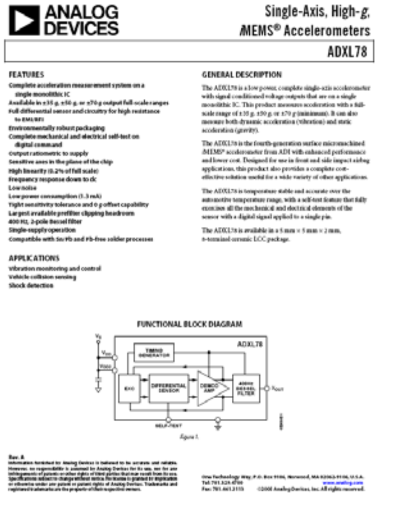
1.) $V_{OUT} = 1*(V/g)*acc. + 2.5\ V$

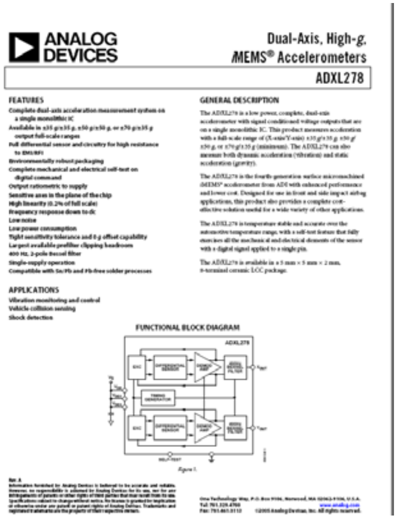
2.) $V_{OUT} - 2.5\ V = (V/g)*acc.$

3.) $Acceleration = V_{OUT}*g - 2.5*g$

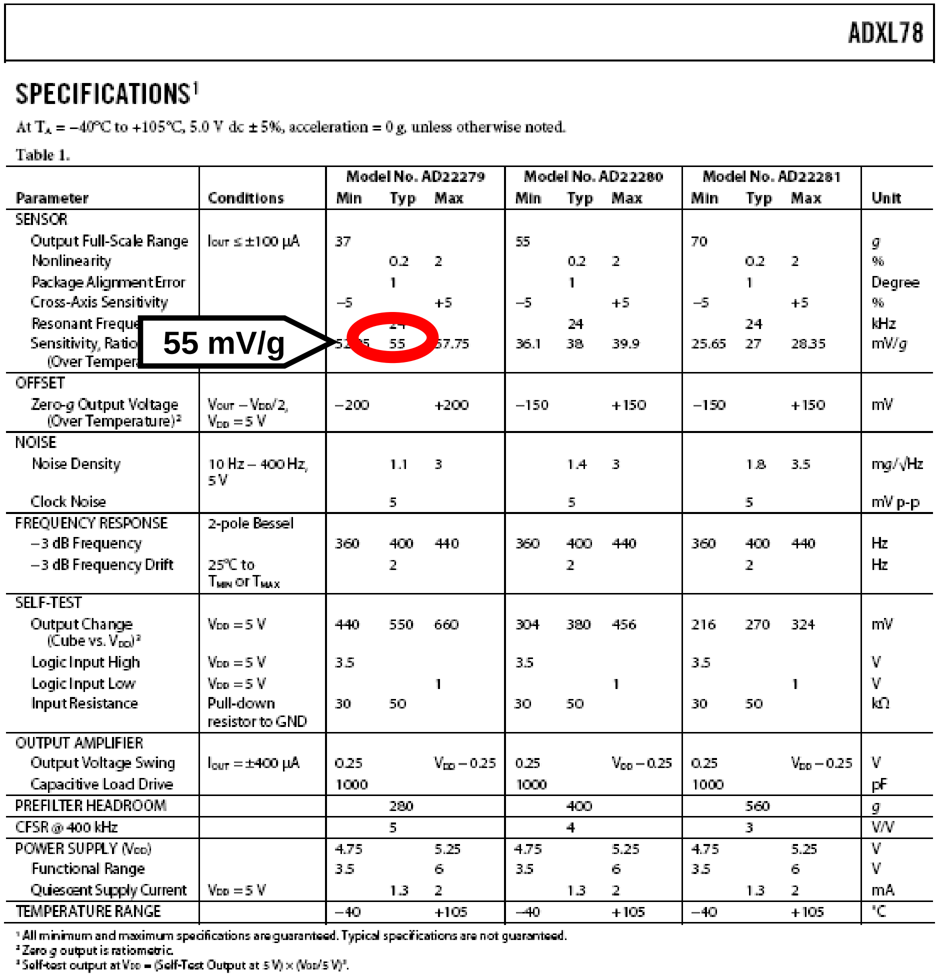
Converting Data – High Range Accelerometers 1

- Open the datasheets for the ADXL78 single axis high range accelerometer and the ADXL278 dual axis high range accelerometer.
- Notice that they are almost identical. If you want, you can look at a few pages to confirm that.
- The conversion is the same, so we will just use the ADXL78 datasheet. Again, you can cross-check with the ADXL278 datasheet to be sure.





Converting Data – High Range Accelerometers 2



ADXL78

SPECIFICATIONS[1]

At T_A = −40°C to +105°C, 5.0 V dc ± 5%, acceleration = 0 *g*, unless otherwise noted.

Table 1.

Parameter	Conditions	Model No. AD22279 Min	Typ	Max	Model No. AD22280 Min	Typ	Max	Model No. AD22281 Min	Typ	Max	Unit
SENSOR											
Output Full-Scale Range	$I_{OUT} \leq \pm 100$ μA	37			55			70			*g*
Nonlinearity			0.2	2		0.2	2		0.2	2	%
Package Alignment Error			1			1			1		Degree
Cross-Axis Sensitivity		−5		+5	−5		+5	−5		+5	%
Resonant Freque			[illegible]			24			24		kHz
Sensitivity, Ratio (Over Temper		[illegible]	55	57.75	36.1	38	39.9	25.65	27	28.35	mV/*g*
OFFSET											
Zero-*g* Output Voltage (Over Temperature)[2]	$V_{OUT} - V_{DD}/2$, V_{DD} = 5 V	−200		+200	−150		+150	−150		+150	mV
NOISE											
Noise Density	10 Hz – 400 Hz, 5 V		1.1	3		1.4	3		1.8	3.5	mg/√Hz
Clock Noise			5			5			5		mV p-p
FREQUENCY RESPONSE	2-pole Bessel										
−3 dB Frequency		360	400	440	360	400	440	360	400	440	Hz
−3 dB Frequency Drift	25°C to T_{MIN} or T_{MAX}		2			2			2		Hz
SELF-TEST											
Output Change (Cube vs. V_{DD})[3]	V_{DD} = 5 V	440	550	660	304	380	456	216	270	324	mV
Logic Input High	V_{DD} = 5 V	3.5			3.5			3.5			V
Logic Input Low	V_{DD} = 5 V			1			1			1	V
Input Resistance	Pull-down resistor to GND	30	50		30	50		30	50		kΩ
OUTPUT AMPLIFIER											
Output Voltage Swing	I_{OUT} = ±400 μA	0.25		$V_{DD} - 0.25$	0.25		$V_{DD} - 0.25$	0.25		$V_{DD} - 0.25$	V
Capacitive Load Drive		1000			1000			1000			pF
PREFILTER HEADROOM			280			400			560		*g*
CFSR @ 400 kHz			5			4			3		V/V
POWER SUPPLY (V_{DD})		4.75		5.25	4.75		5.25	4.75		5.25	V
Functional Range		3.5		6	3.5		6	3.5		6	V
Quiescent Supply Current	V_{DD} = 5 V		1.3	2		1.3	2		1.3	2	mA
TEMPERATURE RANGE		−40		+105	−40		+105	−40		+105	°C

[1] All minimum and maximum specifications are guaranteed. Typical specifications are not guaranteed.
[2] Zero *g* output is ratiometric.
[3] Self-test output at V_{DD} = (Self-Test Output at 5 V) × (V_{DD}/5 V)^2.

- Scroll down to the specifications table on page 3.
- We use the AD22279.
- Find the sensitivity, which determines how the output voltage changes based on acceleration.
- For some reason, the zero-g offset is omitted from this page.

Converting Data – High Range Accelerometers 3

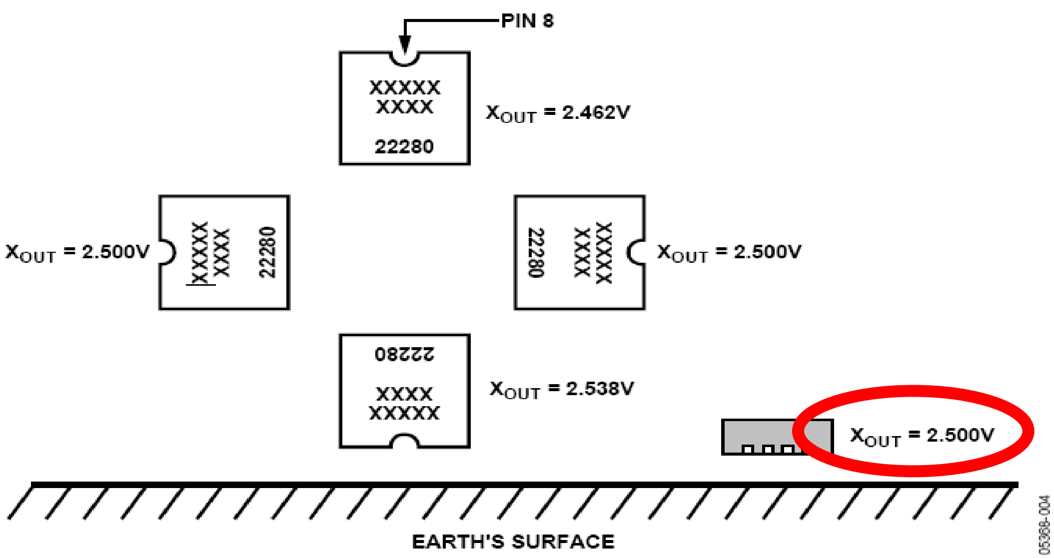


Figure 4. Output Response vs. Orientation

- **Scroll down to this chart on page 6. It shows the theory of how the accelerometers work.**

- **It also shows the output voltage at 0g (the zero-g offset)**

$$V_{OUT} = 55*(mV/g)*acc. + 2.5\ V$$

Converting Data – Temperature Sensor 3

- Solve the equation for acceleration in terms of voltage. Be careful of units. The final equation should use volts rather than millivolts.

1.) $1000 \text{ mV} = 1 \text{ V}$

2.) $\therefore V_{OUT} = 0.055*(V/g)*acc. + 2.5 \text{ V}$

3.) $V_{OUT} – 2.5 \text{ V} = 0.055*(V/g)*acc.$

4.) $\text{Acceleration} = 18.18*(g/V)*V_{OUT} – 45.45 \text{ g}$