SEN-30103-XX: Quad-Channel Analog Thermocouple Amplifier Breakout

playingwithfusion.com

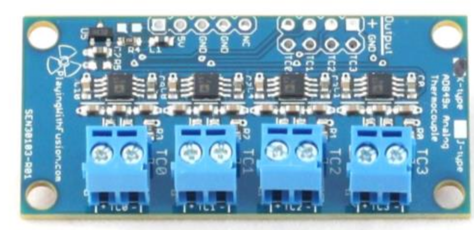
Overview

SEN-30103 is a quad (four) channel analog thermocouple amplifier based on the AD849x series of ICs from Analog Devices. Supply voltage is externally supplied to give the user control of the output and measurement range based on the type of device being used to read the output (keep reading for details on this). SEN-30103 is available for both J-type and K-type thermocouples. Sub-variants are also available to offset the output voltage to enable negative temperature readings to include the entire standard operating range of both J- and K-type thermocouples.

Features

- Output is 5mV/°C (0.005V / °C), with offset options available for negative temperature readings
- Available for J and K type thermocouples Cold-junction compensated
- Wide supply voltage range from 3V - 18V, to be selected based on user needs
- SEN-30103-X1 options enable full negative range measurement range, dependent on positive supply voltage
- SEN-30103-X0 options handle positive temperature range only
- ±3°C initial accuracy
- Ttc = Vout / 0.005 °C (X0 options)
- Ttc = (Vout-1.245)/0.005 °C (X1 options)
- Screw terminals for thermocouple lead inputs
- Pin header matching Arduino R3 power and analog header layout for power and voltage outputs
- RoHS Compliant
- Small 2.54cm x 5.27cm (1.0” x 2.075”) form factor
- 4 mounting holes sized for M3 or 4-40 screws
- SEN-30103 comes with screw terminals installed

Applications



- Automotive data acquisition (exhaust, coolant, brakes, etc)
- Industrial instrumentation
- Oven temperature measurements
- Home brew setups
- Celsius thermometer
- Full range of hobby projects
  - Arduino thermocouple interface with analog header
  - Build a reflow oven or kegerator!

Description

The SEN-30103-(K0/K1/J0/J1) lineup are analog thermocouple amplifier devices based on the AD849x (AD8494, AD8495) series from Analog Devices. These quad-channel thermocouple breakout boards convert very low voltage signals from K and J-type thermocouples to a highly-linear, 0.005V/°C output with 0V or 1.245V offset (0°C = 0V or 1.245V output) that is cold-junction compensated. The output signal can be read by a multitude of standard measurement devices, including digital multimeters, data acquisition systems or an analog input on an Arduino. Available devices

Table 1: SEN-30103 Standard Options

PWF Part No.	TC Type	Optimized Temperature Range: Ambient/PCB Temp	Optimized Temperature Range: Measurement (Hot) Junction	Negative Temperature Handling
SEN-30103-J0	J	0°C to 50°C	Positive J type range	No
SEN-30103-J1	J	0°C to 50°C	Full J type range	Yes
SEN-30103-K0	K	0°C to 50°C	Positive K type range	No
SEN-30103-K1	K	0°C to 50°C	Full K type range	Yes

*sensors optimized for ambient environments from 25-100°C available upon request

are listed in Table 1 below.

Analog filtering is included to remove unwanted EMI on the input stage of the conditioner.

Common mode filtering with a cutoff frequency of 1 kHz is included, as well as 50 Hz differential signal filtering. Included in the input stage is a 1 MΩ resistor that is connected to the negative input line. This results in open-input detection capability. When a thermocouple isn't present (or a wire has broken), the amplifier saturates its output to the supply voltage. This can be used to identify this type of fault.

Application & Guide
SEN-30103 is designed for flexible, low-cost integration into existing measurement systems. The simplest of these is the Arduino application. Specifically, SEN-30103 power supply and analog outputs are spaced to plug straight into Arduino supply and analog headers using a male pin header. It is also possible to use the SEN-30103 with a breadboard or point-to-point wiring.

As previously discussed, the standard output signal range is from 0V to the input supply voltage, which is directly used to power the amplifiers. Table 2 below shows typical power supply and offset operations and their corresponding measurement range.

Table 2: SEN-30103 Typical Applications

	Supply Voltage	Temperature Range
SEN-30103-X0	3.3V	0°C - 660°C
SEN-30103-X1	5V	MIN°C - 751°C
SEN-30103-X0	5V	0°C - 1000°C
SEN-30103-X0	10V	0°C - MAX°C
SEN-30103-X1	10V	-MIN°C - MAX°C

Note 1: MIN temperature range of K-type TC = ~-260°C, J-type TC = ~-180°C
Note 2: MAX temperature range of K-type TC = ~1380°C, J-type TC = ~1200°C

Ranges shown were chosen to represent typical 3.3V, 5V, and 10V measurement systems. It can be seen that even a 3.3V system can be used for measurements typical of ovens and many industrial processes. Typical 5V systems (such as an Arduino) can be used to achieve a 0°C - 1000°C measurement range, which covers most automotive temperature needs (coolant, oil, exhaust). Offset devices should be selected any time negative temperatures need to be measured. A 10V measurement system would be required to read the full thermocouple range of either a J-type or K-type thermocouple.

Performance Characteristics
The SEN-30103-XX devices are designed to output a highly linear signal based on an input from J-Type or K-Type thermocouples. This is accomplished by the integration of an operational amplifier and cold-junction compensation within the AD849x series ICs. As a result, the output of the SEN-30103-XX can be approximated as linear over a specified window, with degradation of the estimate outside of this window. See Table 3 for an overview of linearization based on thermocouple type.

Table 3: Sensor Temperature Linearization

PWF Part No.	Thermocouple Type	Measurement (hot) Junction Temperature Ranges: +/- 2°C linearity, no correction	Measurement (hot) Junction Temperature Ranges: Correction tables applied
SEN-30103-J0	J	0°C to 95°C	Full J type range
SEN-30103-J1	J	-35°C to 95°C	Full J type range
SEN-30103-K0	K	0°C to 400°C	Full K type range
SEN-30103-K1	K	-25°C to 400°C	Full K type range

Keeping this in mind, the end user may either accept the nonlinearity, or apply one of two methods to handle the output voltage from the sensors. The method chosen will depend on linearity accuracy requirements as well as the required operational range of the input signal. Absolute accuracy is separate from the linearity accuracy, which can be found in Tables 5.

In one application example, if a +/- 2°C linearity accuracy is acceptable and the sensing application will stay within the windows shown in Table 3, temperature conversion is straightforward and calculated based on output voltage with the formulas:

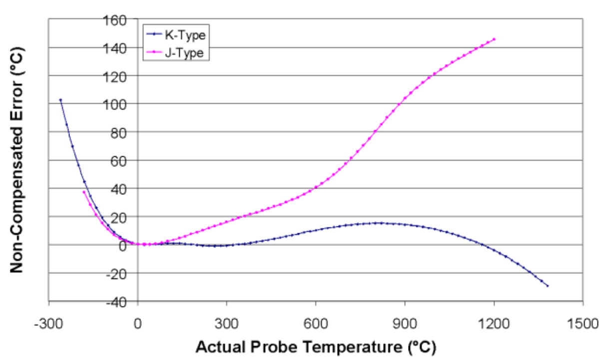
Ttc (X1 variants) = ((Vout – 1.245V) / 0.005)°C

Ttc (X0 variants) = Vout / 0.005°C

These formulas apply for both J-Type and K-type sensors. They are also fitting for applications with less stringent linearity accuracy requirements and wider operating ranges. See Figure 1 for temperature error across the input temperature operating range due to thermocouple nonlinearity.

If linearity accuracy provided by the formula in the previous example is not acceptable, there is an alternative method that corrects for linearity error. Specifically, correction tables can be used to correct the high-order non-linearity across the sensor's operating range. See Tables 5 and 6 for this information for the X0 and X1 variants, respectively (calculated based on Analog Devices AN-1087). This correction is directly related to the high-order response characteristics of the respective thermocouples. It can be noted that K-type thermocouples exhibit far greater linearity in the positive temperature range than J-type thermocouples, with less than 20°C temperature error beyond 1200°C even without correction.

Figure 1: Temperature Error vs Probe Temperature



Common Issues & Resolution

- Thermocouple measurement is noisy or inconsistent due
  - Most often seen with grounded thermocouples causing common-mode voltage handling issues
  - Switch to ungrounded thermocouples, if possible
  - "Paint" bare thermocouple ends with varnish to electrically insulate
  - Consider FDQ-10001 if grounded thermocouples are required
- Measurement system lacks resolution needed
  - Oversample and average results
  - Consider using digital thermocouple interfaces, outlined below
  - Contact us for application guidance
- Power supply needs are causing issues
  - Consider SEN-30101 or FDQ-10001 with integrated power supplies

Table 4: Operating Characteristics

Parameter	Rating
Supply Voltage (operational)	2.7V to 36V
Supply Voltage (maximum)	36V
Reverse Supply Protection	none
Output Short-to-Ground Duration	Indefinite
Absolute Accuracy (initial)	3°C
Optimal Operating Temperature	0°C to 50°C
Safe Operating Temperature	-25°C to 85°C
Storage Temperature	-40°C to 125°C

Ordering Options & Related Parts

SEN-30103-J0: Quad J-type (AD8494) Breakout, no offset
SEN-30103-K0: Quad K-type (AD8495) Breakout, no offset
SEN-30103-J1: Quad J-type (AD8494) Breakout, 1.245V offset, negative temp
SEN-30103-K1: Quad K-type (AD8495) Breakout, 1.245V offset, negative temp
SEN-30101**:** Quad analog thermocouple conditioner, integrated power supply
FDQ-10001: Eight-channel, highly integrated analog thermocouple module

SEN-30007: Quad MAX31856 thermocouple interface, SPI, Arduino Shield
SEN-30008: Quad MAX31856 thermocouple breakout, SPI
SEN-30011: Quad MCP9601, Qwiic I2C interface, multiple thermocouple options
SEN-30202: Dual MAX31865 RTD, SPI

Table 5: Correction Tables for SEN-30103-X0 (no offset) Thermocouple Sensors

Measurement Junction Temperature (°C)	Ideal Output (V)	Actual Output (V)	
	SEN30103-K0 SEN30103-J0	SEN30103-K0 K-Type	SEN301013-J0 J-Type
0	0	0.003	0.002
20	0.1	0.1	0.1
25	0.125	0.125	0.125
40	0.2	0.2	0.201
60	0.3	0.301	0.303
80	0.4	0.402	0.406
100	0.5	0.504	0.511
120	0.6	0.605	0.617
140	0.7	0.705	0.723
160	0.8	0.803	0.829
180	0.9	0.901	0.937
200	1	0.999	1.044
220	1.1	1.097	1.151
240	1.2	1.196	1.259
260	1.3	1.295	1.366
280	1.4	1.396	1.473
300	1.5	1.497	1.58
320	1.6	1.599	1.687
340	1.7	1.701	1.794
360	1.8	1.803	1.901
380	1.9	1.906	2.008
400	2	2.01	2.114
420	2.1	2.113	2.221
440	2.2	2.217	2.328
460	2.3	2.321	2.435
480	2.4	2.425	2.542
500	2.5	2.529	2.65
520	2.6	2.634	2.759
540	2.7	2.738	2.868
560	2.8	2.843	2.979
580	2.9	2.947	3.09
600	3	3.051	3.203
620	3.1	3.155	3.316
640	3.2	3.259	3.431
660	3.3	3.362	3.548
680	3.4	3.465	3.666
700	3.5	3.568	3.786
720	3.6	3.67	3.906
740	3.7	3.772	4.029
760	3.8	3.874	4.152
780	3.9	3.975	4.276
800	4	4.076	4.401

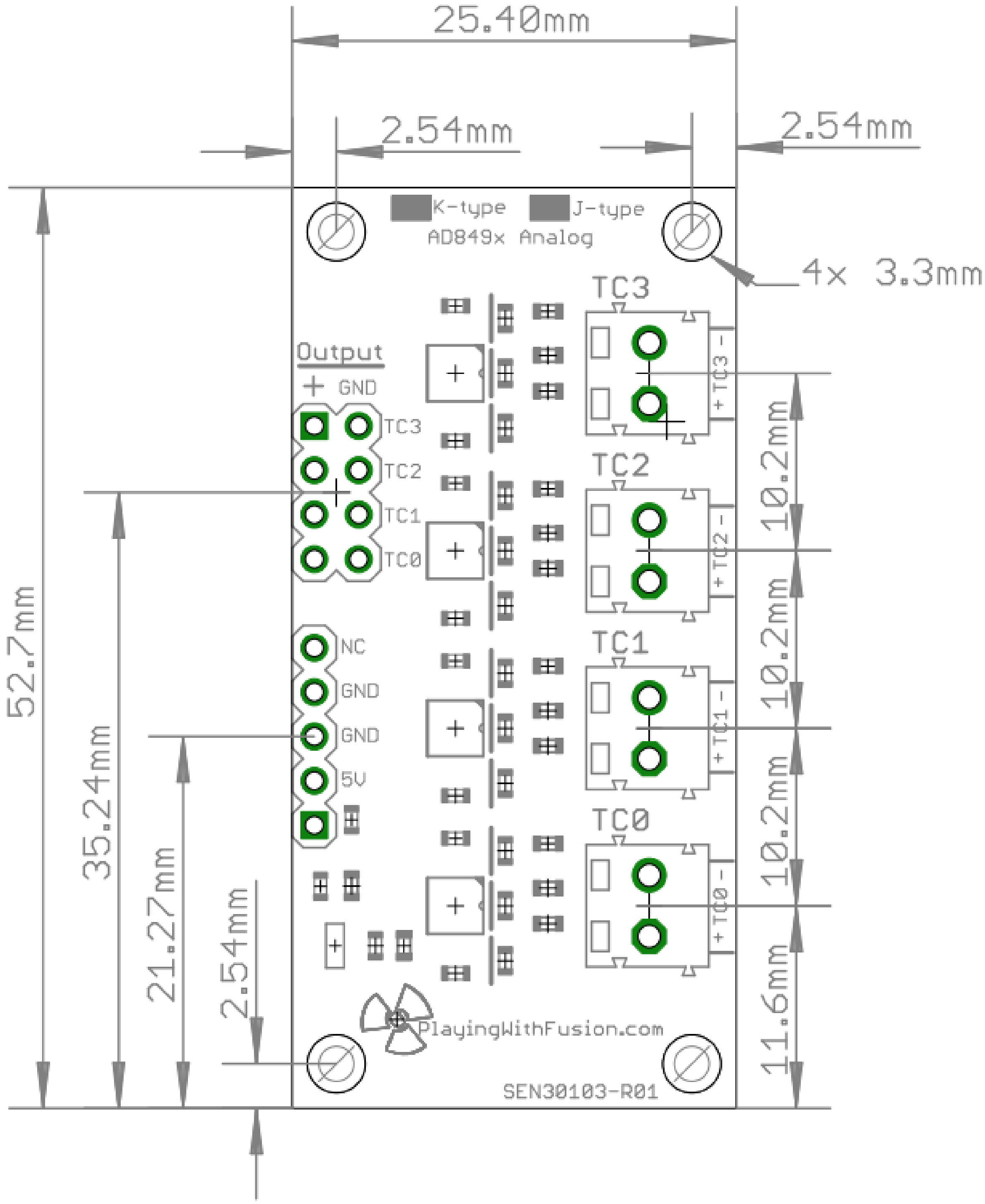
Measurement Junction Temperature (°C)	Ideal Output (V)	Actual Output (V)	
	SEN30103-K0 SEN30103-J0	SEN30103-K0 K-Type	SEN301013-J0 J-Type
820	4.1	4.176	4.526
840	4.2	4.275	4.65
860	4.3	4.374	4.774
880	4.4	4.473	4.897
900	4.5	4.571	5.018
920	4.6	4.669	5.138
940	4.7	4.766	5.257
960	4.8	4.863	5.374
980	4.9	4.959	5.49
1000	5	5.055	5.606
1020	5.1	5.15	5.72
1040	5.2	5.245	5.833
1060	5.3	5.339	5.946
1080	5.4	5.432	6.058
1100	5.5	5.525	6.17
1120	5.6	5.617	6.282
1140	5.7	5.709	6.394
1160	5.8	5.8	6.505
1180	5.9	5.891	6.616
1200	6	5.98	6.727
1220	6.1	6.069	
1240	6.2	6.158	
1260	6.3	6.245	
1280	6.4	6.332	
1300	6.5	6.418	
1320	6.6	6.503	
1340	6.7	6.587	
1360	6.8	6.671	
1380	6.9	6.754	

Table 6: Correction Tables for SEN-30103-X1 (offset) Thermocouple Sensors

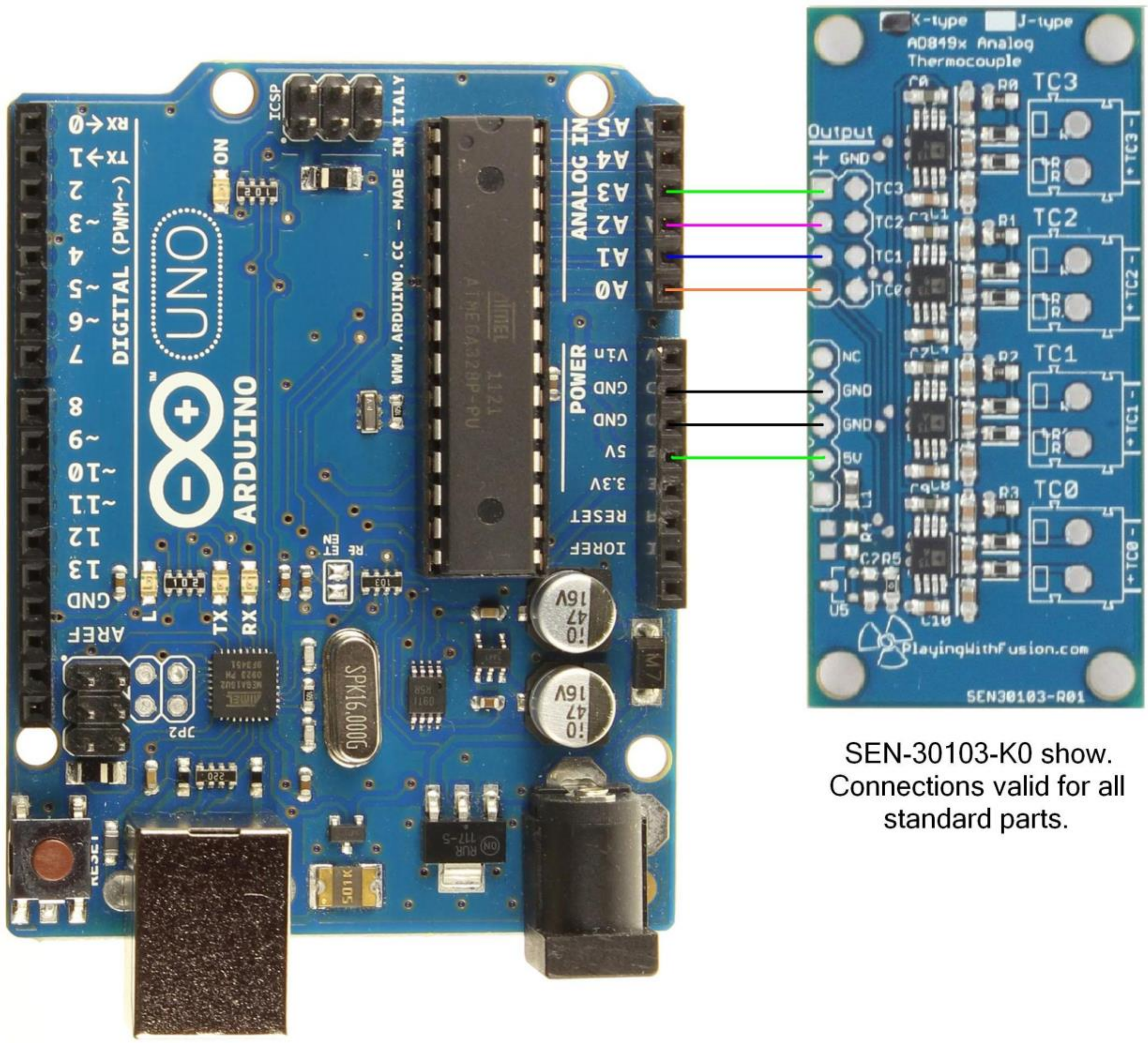
Measurement Junction Temperature (°C)	Ideal Output (V)	Actual Output (V)	
	SEN30103-K1 SEN30103-J1	SEN30103-K1 K-Type	SEN301013-J1 J-Type
-260	-0.055	0.459	
-240	0.045	0.471	
-220	0.145	0.494	
-200	0.245	0.526	
-180	0.345	0.568	0.531
-160	0.445	0.618	0.587
-140	0.545	0.676	0.651
-120	0.645	0.741	0.722
-100	0.745	0.813	0.799
-80	0.845	0.89	0.88
-60	0.945	0.973	0.967
-40	1.045	1.061	1.057
-20	1.145	1.152	1.15
0	1.245	1.248	1.247
20	1.345	1.345	1.345
25	1.37	1.37	1.37
40	1.445	1.445	1.446
60	1.545	1.546	1.548
80	1.645	1.647	1.651
100	1.745	1.749	1.756
120	1.845	1.85	1.862
140	1.945	1.95	1.968
160	2.045	2.048	2.074
180	2.145	2.146	2.182
200	2.245	2.244	2.289
220	2.345	2.342	2.396
240	2.445	2.441	2.504
260	2.545	2.54	2.611
280	2.645	2.641	2.718
300	2.745	2.742	2.825
320	2.845	2.844	2.932
340	2.945	2.946	3.039
360	3.045	3.048	3.146
380	3.145	3.151	3.253
400	3.245	3.255	3.359
420	3.345	3.358	3.466
440	3.445	3.462	3.573
460	3.545	3.566	3.68
480	3.645	3.67	3.787
500	3.745	3.774	3.895
520	3.845	3.879	4.004
540	3.945	3.983	4.113

Measurement Junction Temperature (°C)	Ideal Output (V)	Actual Output (V)	
	SEN30103-K1 SEN30103-J1	SEN30103-K1 K-Type	SEN301013-J1 J-Type
560	4.045	4.088	4.224
580	4.145	4.192	4.335
600	4.245	4.296	4.448
620	4.345	4.4	4.561
640	4.445	4.504	4.676
660	4.545	4.607	4.793
680	4.645	4.71	4.911
700	4.745	4.813	5.031
720	4.845	4.915	5.151
740	4.945	5.017	5.274
760	5.045	5.119	5.397
780	5.145	5.22	5.521
800	5.245	5.321	5.646
820	5.345	5.421	5.771
840	5.445	5.52	5.895
860	5.545	5.619	6.019
880	5.645	5.718	6.142
900	5.745	5.816	6.263
920	5.845	5.914	6.383
940	5.945	6.011	6.502
960	6.045	6.108	6.619
980	6.145	6.204	6.735
1000	6.245	6.3	6.851
1020	6.345	6.395	6.965
1040	6.445	6.49	7.078
1060	6.545	6.584	7.191
1080	6.645	6.677	7.303
1100	6.745	6.77	7.415
1120	6.845	6.862	7.527
1140	6.945	6.954	7.639
1160	7.045	7.045	7.75
1180	7.145	7.136	7.861
1200	7.245	7.225	7.972
1220	7.345	7.314	
1240	7.445	7.403	
1260	7.545	7.49	
1280	7.645	7.577	
1300	7.745	7.663	
1320	7.845	7.748	
1340	7.945	7.832	
1360	8.045	7.916	
1380	8.145	7.999	

Appendix 1: Mechanical Drawing



Appendix 2: Application Information:
Arduino Header Connections



SEN-30103-K0 show. Connections valid for all standard parts.