TekBot Design Review
A Proposal For…

DSP Temperature Sensor

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Theory of Operation

The DSP Temperature sensor uses a 10K thermistor and a 10K resistor to create a voltage divider circuit. As the atmospheric temperature changes, the thermistor's resistance changes, and so does the voltage across it. This voltage can then be picked up by the analog to digital converter (ADC) on the DSP or AVR board. Since this voltage is proportional to the temperature, a student or other user can then analyze the signal in software to determine the temperature.

Environmental Constraints

- User Group
  The ideal group of users for this circuit are OSU students, as well as anyone who will use the TekBot AVR or DSP boards.

- Cost
  Since it has been understood from the beginning that this circuit would be included in a larger sensor circuit, costs for auxiliary parts such as power supply, headers, etc. have not been included. Thus only the cost for parts are examined:

Parts List & Cost		
Sym	Part ID	Digikey
R1	10K Ω	.01
T1	10K Ω	.40
	Subtotal:	$.41

- How Should It Be Used?
  This circuit is ideally powered by a regulated +5 volts, and outputs an analog signal between +5v and ground. This low current signal should then be connected to the input of an ADC.

- How Could It Be Abused?
  Since this circuit is so simple and rugged, it would be hard to abuse. However, the thermistor is only rated for 500mW maximum dissipation. At 5v, it is only dissipating 625uW.

  In order to dummy-proof this circuit, it may be a wise idea to include a diode in series with the output voltage. This would protect against a user mistakenly connecting the output to power and frying the thermistor.

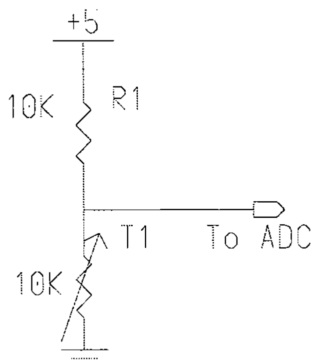
- Manufacturing
  The thermistor described in this document is available as a thru-hole component resembling a small, ceramic capacitor. It has two leads, spaced .1" apart. In manufacturing the PCB, this needs to be kept in mind.

- Marketing
  Since this part is not reliant on any donations from other companies, it is fully capable of being marketed to the public for a profit.

Circuit Characteristics

- Power Source
  As stated earlier, this circuit is designed for a regulated +5v supply. However, any reasonable voltage can power this circuit as long as the ADC this circuit is connected and properly calibrated.

- Schematic and Circuit Description



The two resistive components, R1 and T1, form a resistance ladder. The resistance of T1 decreases as temperature increases, and thus changes the voltage across it. This signal is then picked up by an ADC in order to be analyzed in software.

At 5v operation and 25 degrees Celsius, T1 = 10K Ohms, this circuit draws 250uA, and dissipates 1.25mW.

Analysis

- Worst Case Circuit
  According to the datasheet, this part is guaranteed to be within ± 3%. However, just to be thorough, we assumed a worst case of ± 5%. Tables 1-3 display the results of the worst case analysis done on this circuit. See Appendix A for the hand written analysis.

Table 1 - Resistances at Temperatures Worst Case Analysis was Analyzed

Temperature (°C)	Ideal Resistance	-5%	+5%
25	10K	9.5K	10.5K
0	32.56K	30932	34188
100	677.3	643.4	711.2

Table 2 - Electrical Characteristics of T1 at Worst Case

T_1 Value	Volts	Current	Watts Dissipated
9.5 K	2.44	256 u,	625 u
10.5 K	2.56	244 u	625 u
34.188 K	3.87	113 u	438 u
30.932 K	3.78	122 u	462 u
711.2 K	332 m	467 u	155 u
643.4 K	302 m	470 u	142 u

Table 3 - Electrical Characteristics of R1 at Worst Case

T_1 Value	Volts	Current	Watts Dissipated
9.5 K	2.56	256 u	657 u
10.5 K	2.44	244 u	595 u
34.188 K	1.13	113 u	128 u
30.932 K	1.22	122 u	149 u
711.2 K	4.67	467 u	2.18 u
643.4 K	4.70	470 u	2.21 m

- Over Voltage
  Trying to stay reasonable, this circuit has been analyzed and found to work properly at a 24v power supply is the full range of temperatures specified in the data sheet, and analyzed in the worst case analysis (0-100 °C). The limiting factor at high voltages is R1 being able to handle the power dissipation.

- Power Dissipation
  Tables 4 and 5 show the circuit and component power dissipation at both the maximum worst case power dissipation of T1 (Table 4) and the maximum worst case power dissipation of R1 (Table 5)

Table 4 - Circuit Dissipation at T1 Max Worse Case Power Dissipation

	Watts
T1	625 u
R1	657 u
Total	1.282 m

Table 5 - Circuit Dissipation at R1 Max Worst Case Power Dissipation

	Watts
T1	142 u
R1	2.21 m
Total	2.352 m

Operation

This section describes important information for interfacing the temperature circuit to an ADC. Table 6 displays the resistance vs. temperature information as given on the datasheet. The equations in Equations 1 can be used to calculate the temperature or resistance. The variable 'T' in both equations are in Kelvin's. F means degrees in Fahrenheit. R is in Ohms, not K-Ohms.

Table 6 - Thermistor Resistance vs. Temperature

°C	R (K)
-40	332.1
-35	240
-30	175.2
-25	129.3
-20	96.36
-15	72.5

°C	R (K)
-10	55.05
-5	42.16
0	32.56
5	25.34
10	19.87
15	15.7

°C	R (K)
20	12.49
25	10
30	8.059
35	6.535
40	5.33
45	4.372

°C	R (K)
50	3.606
55	2.989
60	2.49
65	2.084
70	1.753
75	1.481

°C	R (K)
80	1.256
85	1.07
90	0.9154
95	0.786
100	0.6773
105	0.5858

°C	R (K)
110	0.5083
115	0.4426
120	0.3866
125	0.3387
130	0.2977
135	0.2624

°C	R (K)
145	0.2055
150	0.1826

Equations 1 - Resistance and Temperature Equations for T1

$$R(T) = 10000 * e^{-14.6337 + \frac{4791.842}{T} - \frac{115334}{T^2} - \frac{3730535}{T^3}}$$

$$T(R) = (3.354016 + 2.569355 * \ln(\frac{R}{10000}) + 2.626311 * \ln(\frac{R}{10000})^2 + .675278 * \ln(\frac{R}{10000})^3)^{-1}$$

$$F = \frac{9}{5} * (T - 273.15) + 32$$

Conclusion

As stated earlier, this document makes no effort to estimate the cost of time, PCB manufacture, or other costs since this circuit will be part of a much larger one. Also, I feel the need to point out that while I was able to get the function R(T) to work, I couldn't seem to see a correlation between the output of T(R) and what I was expecting. More work needs to be done in analyzing this function so that the temperature can be extracted in software.

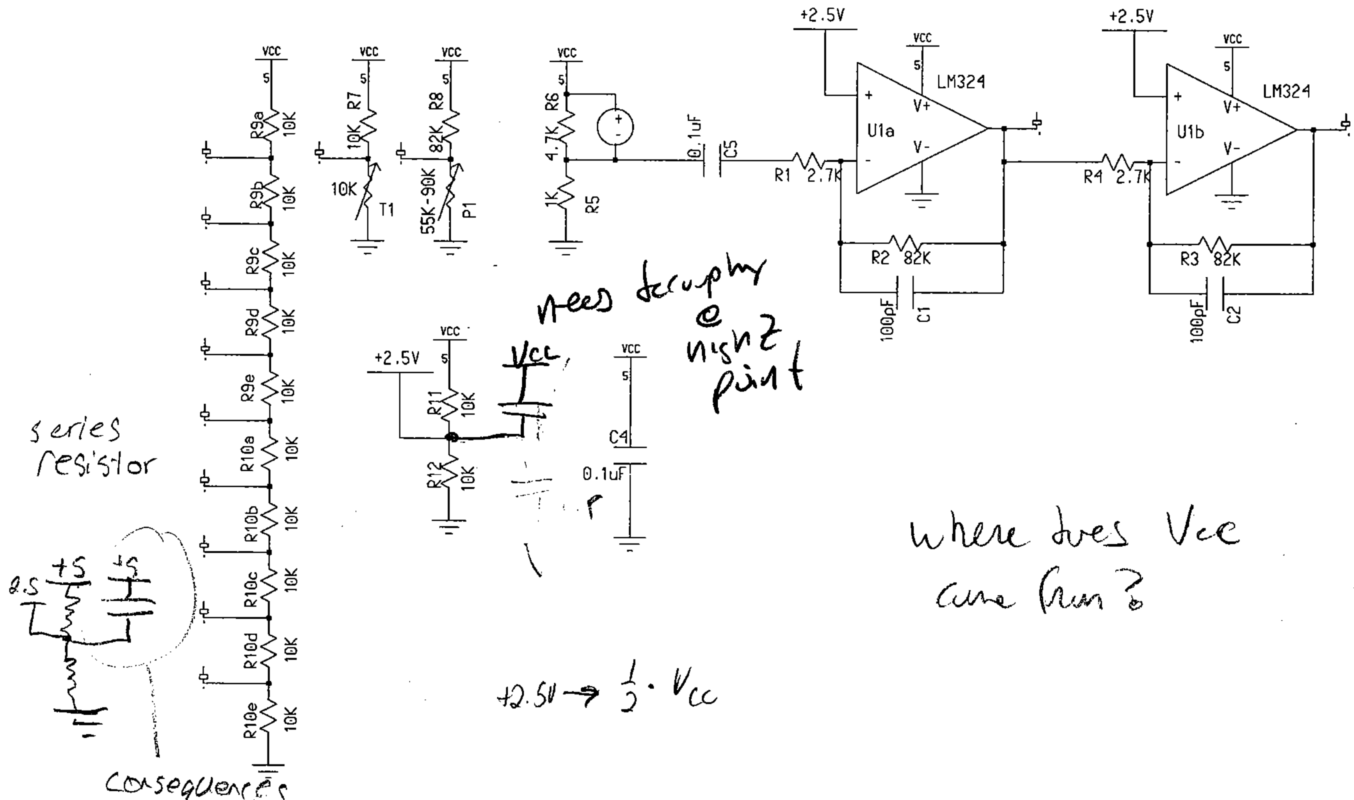
DSP Sensor Board

Construction Guide

Theory of Operation

The DSP Sensor board contains environmental sensors that pick up temperature, light, and sound and output them in the form of an analog signal which can then be processed by the DSP board, AVR board, or other ADC (Analog to Digital Converter).

Schematic



series resistor

consequences

needs decoupling @ right point

Vcc

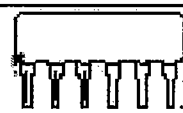
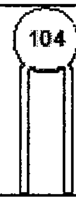
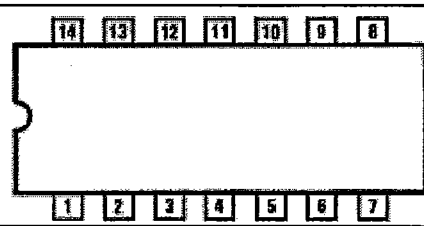
+2.5V → $\frac{1}{2} \cdot V_{cc}$

where does Vcc come from?

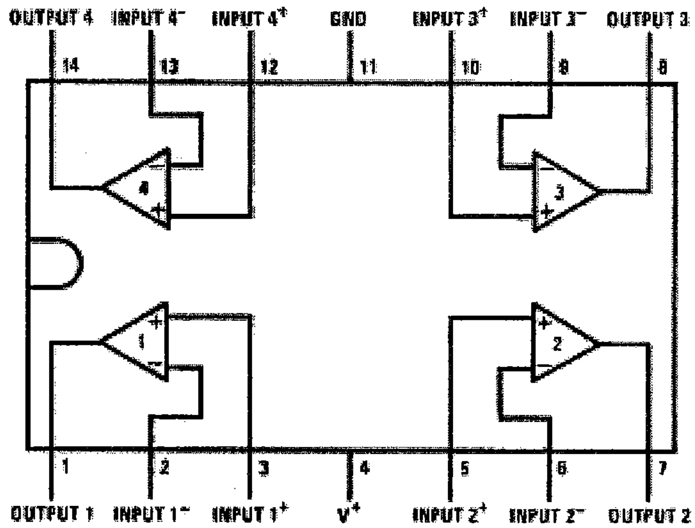
Circuit Description

The resistor ladder created by R9 and R10 allow high and low reference voltages for an ADC. Temperature sensor T1, and light sensor P1, are matched with resistor values to create a varying voltage as the environment changes. The output of microphone, M1, is sent through two Op-Amps to amplify the signal. The Op-Amps also act as low-pass filters with a cut-off frequency of 19.4Khz in order to remove any high frequency noise that may be picked up. All these analog signals can then be interfaced to via the protoboard area.

Parts List

Sym	Value	Markings
R1,R4	2.7K W	Red, Purple, Red
R2, R3, R8	82K W	Grey, Red, Orange
R5	1K W	Brown, Black, Orange
R6	4.7K W	Yellow, Purple, Red
R7, R11, R12	10K W	Brown, Black, Orange
R9, R10	10K W SIP	
C4,C5	.1 uF	
C1,C2	100 pF	
T1	BC1470	
P1	55K-90K Photoresistor	
U1	LM324	

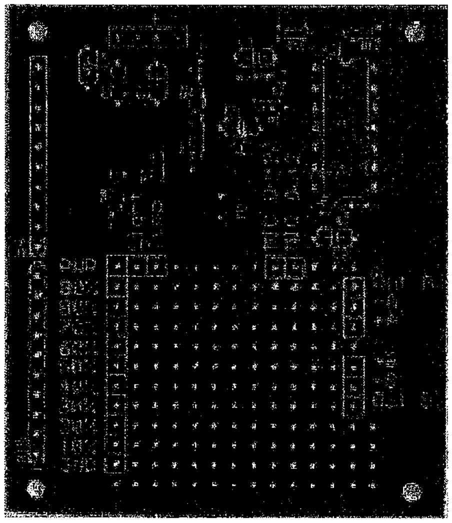
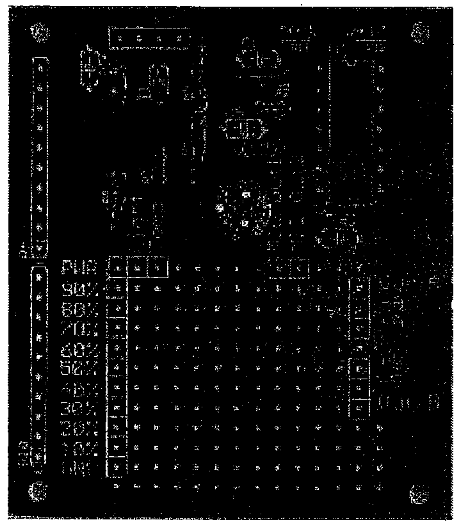
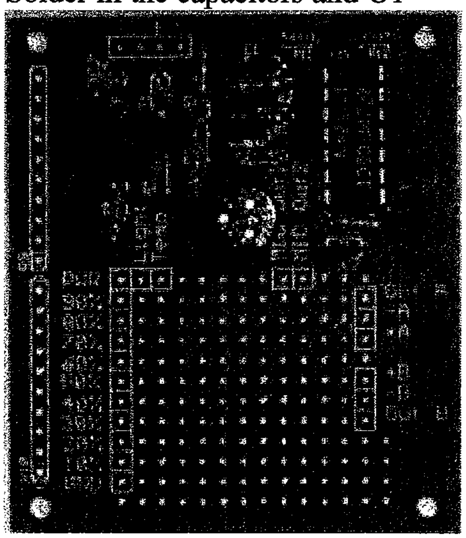
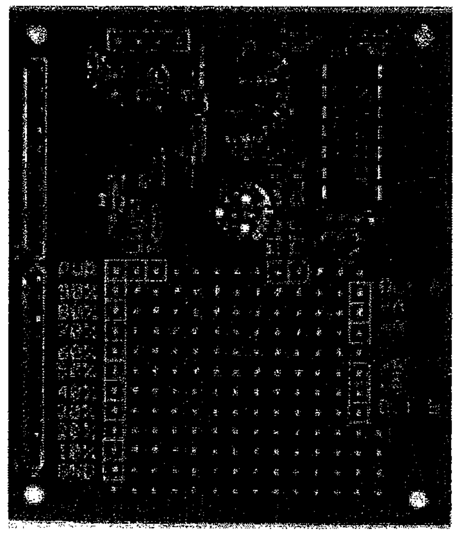
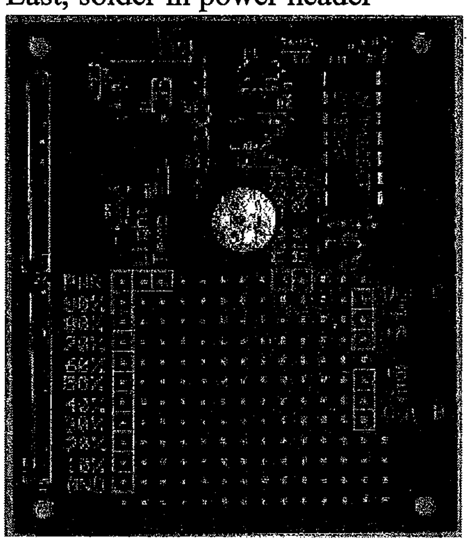
LM324 Pin out:



Construction:

Soldering the board is done from smallest to biggest (height-wise). Soldering parts on the board will be done in the following order:

Soldering Order:
Resistors
Chip
IR Sensor
Capacitor
Potentiometer
Headers

1. First solder on the resistors: 	2. Solder on the sensors 
3. Solder in the capacitors and U1 	4. Solder in R9 and R10 
5. Last, solder in power header 	

Testing

Light

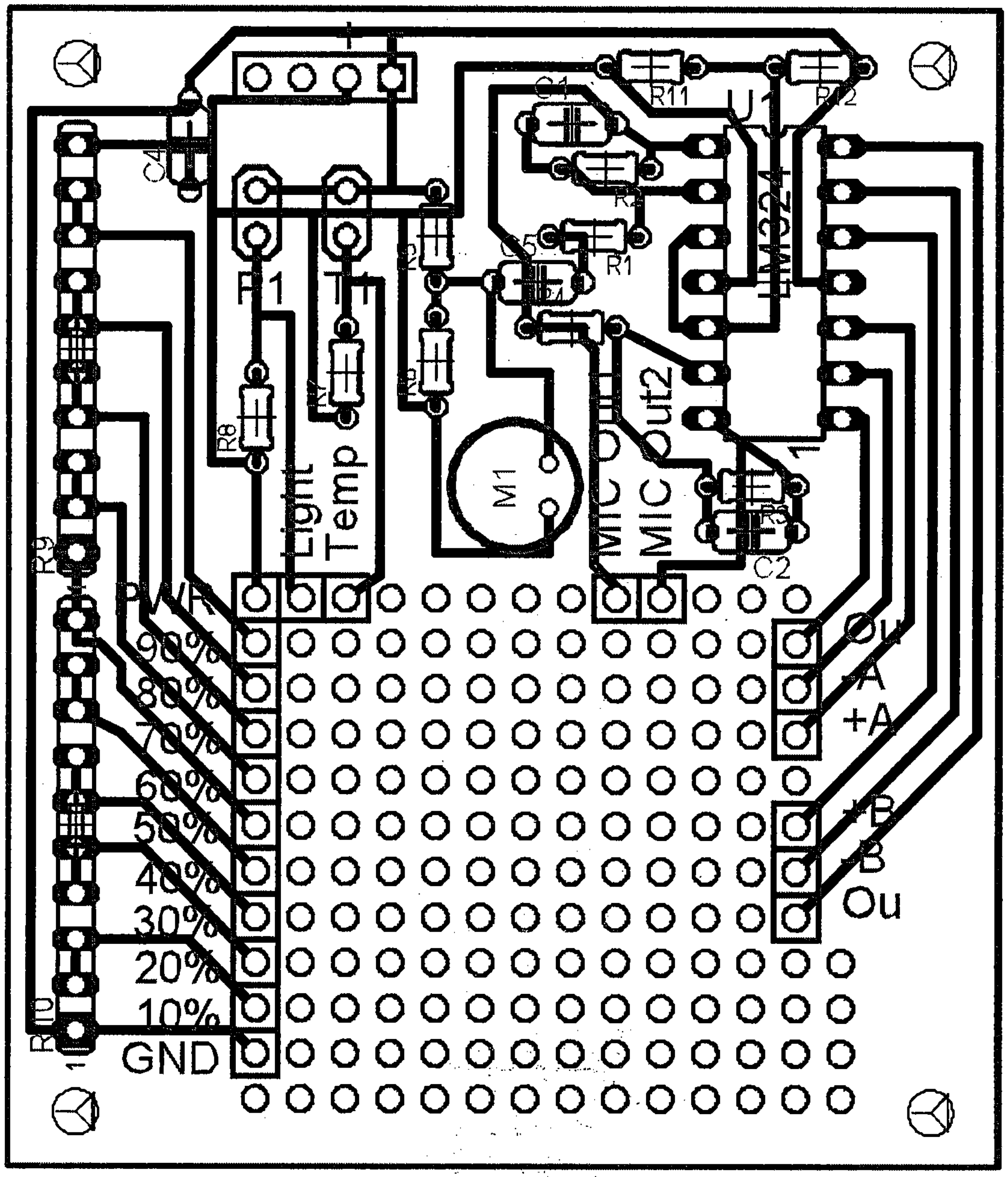
1. Put a DMM into the voltage setting and connect it to the light sensor output.
2. Vary the light hitting the sensor by shading with your hand.
3. Notice the voltage displayed by the DMM. It should vary proportionally. If not, check your connection.

Temperature

1. Put a DMM into the voltage setting and connect it to the temperature sensor output.
2. Hold the temperature sensor between two fingers.
3. Notice the voltage displayed by the DMM. It should change as the temperature on the sensor approaches your body temperature. If not, check your connection.

Microphone

1. Connect the microphone output labeled 'Mic Out 2' to an oscilloscope.
2. Set the vertical display to 500mV/div.
3. Lean in close, and speak into the microphone. You should notice a signal generated proportionally to your speaking.



8/26/2003 02:10:44p f=2.50 C:/Program Files/EAGLE-4.09r2/projects/TekBot.DSP/dsp_sensor2.brd