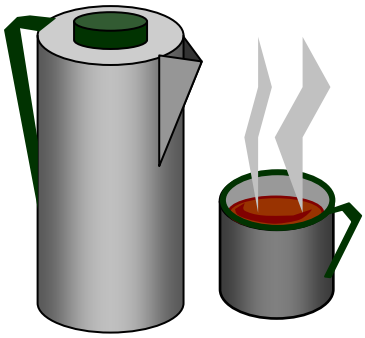
PROJECT: Thermal Detection

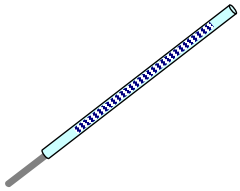


Level 2 - Exercises 1 to 5
Level 3 - Exercises 6 to 9

This project explores measuring temperature, interpreting information and basic input output logic.

This project incorporates the use of the PicPatch[08] microcontroller circuit board.

Materials: Thermometer, cup of hot water and an Electric jug.



Objective:

Temperature can be detected and measured using a device called a Negative Temperature Coefficient Resistor (NTC). This technology is used in many applications of which this project will explore just a few examples.

Scope:

Detection

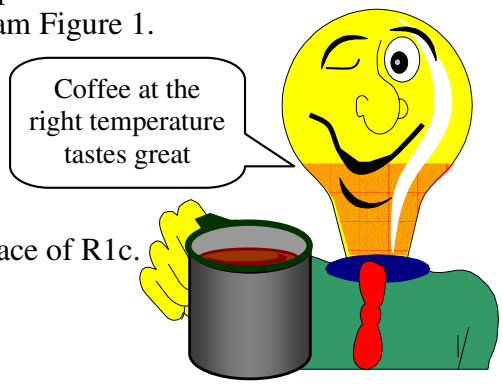
Using the NTC in a resistor divider network we can use Kirchhoff's first Law to obtain a voltage which we can use to measure the level of temperature sensed by the NTC.

Indication

Sound and Light can be used as a basic means to indicate the presence of heat variation. This can be done by either making a Piezo beeper disk produce an audible tone, or use an array of Light Emitting Diodes (LEDs) to display a temperature bar graph.

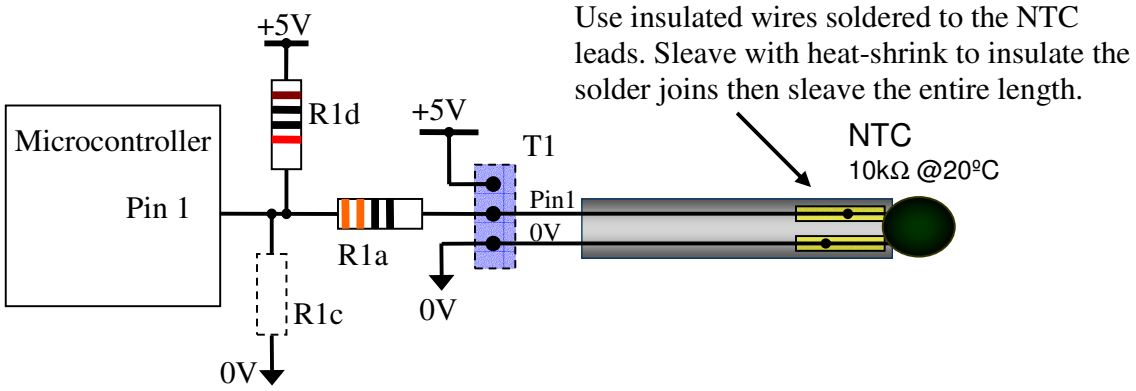
Connection Diagrams

The microcontroller driver circuit requires the following components fitted onto the PicPatch[08] as illustrated in the thermal detection circuit diagram Figure 1.



R1a = 330Ω (330 ohm) Resistor,
R1d = 10kΩ (10k ohm) Resistor (The pull-up resistor),
R1b and R1c leave vacant.
*Option – For a very long cable run fit a 10nF capacitor in place of R1c.
A 10kΩ NTC connected to T1 0V and Pin1.

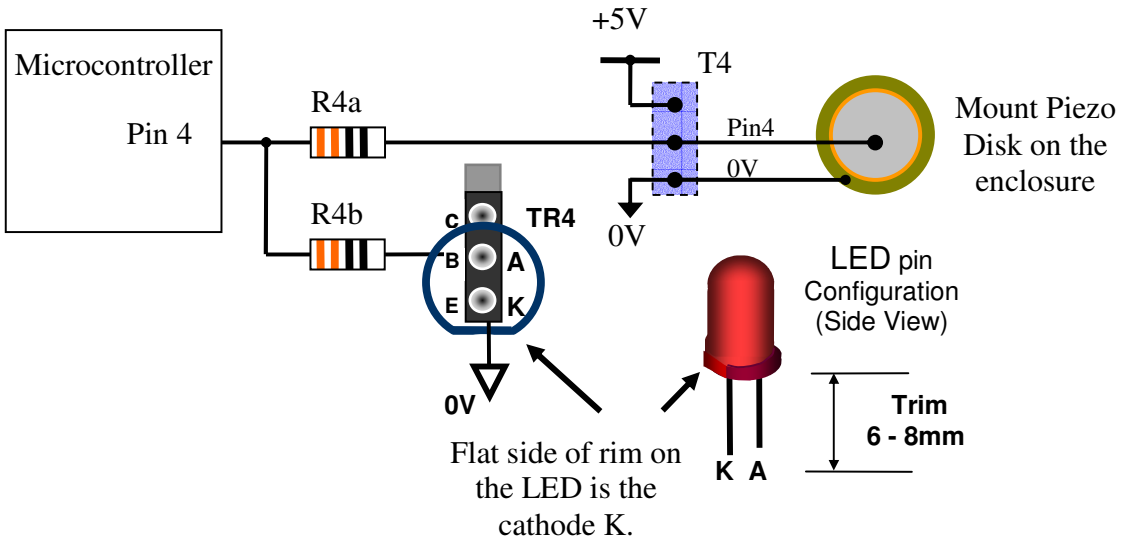
FIGURE 1. Thermal detection circuit.



The beeper circuit requires the following components fitted;

R4a = 330Ω Resistor,
R4b = 330Ω Resistor,
TR4 = Fit an LED into TR4 SIL socket as illustrated in Figure 2.
The Piezo disk connects to T4 terminal Pin 4 and 0V as illustrated.
The Piezo beeper disk must be fixed on a firm surface for it to produce a sound.
You may wish to use double sided sticky tape or blue-tac.

FIGURE 2. Beeper driver circuit.



PROGRAM 1.

The “Hot Coffee” test program.
To test if the cup of coffee is hot, dip the NTC into the hot water for a little while.
If the temperature is hot the beeper sound constantly.

```
'Hot Coffee program 1
 Input 1                          'Make Port Pin 1 an input
 Loop:                            'Note – the sense level will depend on battery voltage.
      Sound 4, (110, 10)          'Make a tone on Port Pin 4
      If Pin1 = 0 then Loop       'If Pin 1 is pulled low by the heated NTC then don't pause
      Pause 500                   'Wait 0.5 seconds
      Goto Loop                   'and repeat the exercise
```

Exercise.

1. Describe some practical applications and people who could benefit from this technology?

2. Present another idea of how to detect and indicate the temperature electronically?

3. Name some common domestic appliances that would use this technology?

PROGRAM 2.

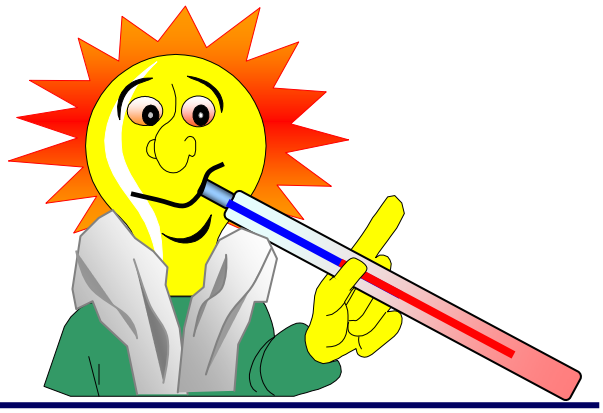
This program reads an analogue level in proportion to the conductivity of the NTC.
The beeper will sound more frequently as the temperature of the NTC is increased.

'Temperature beeper program 2.

```
 Loop:                            'Note - Picaxe08 (b2 = 0 to 160), Picaxe08M (b2 = 0 to 255)
      Readadc 1, b2               'Read the value at Pin 1 into register b2
      W0 = b2 * 5                 'Multiply the analogue value by 5
      Pause W0                    'and wait accordingly in milliseconds
      Sound 4, (110, 10)          'Make a tone on Port Pin 4
      Goto Loop                   'and repeat the exercise
```

4. Explain two practical applications how this tecnology could be used in the food industry and the programs required?

5. Write a program using only one sound command line so that every half second the beeper sounds either one of three different tones for when the coffee is hot, warm or cold.



Exercises for Level 3.

Materials: Thermometer, cup of hot water and an Electric jug.

6. Develop a program to signal to the computer the temperature level from 20ºC to 50ºC using the Debug command to display the value in Register W0. There are two methods you can use for this program which is by calculation or using a lookup table.

Note: To view W0 in the Debug window click on "Word" mode.
For the Picaxe 08 the value b2 for Readadc will only register a maximum value of 160.

Hints: Design a program first using the Debug command to check that the temperatures listed in Table 1 give an approximate value for that listed for b2.

TABLE 1. Value of B2 vs Temperature using Picaxe 08.

ºC	18	20	23	27	31	35	40	45	50	56	63	70	82	95
b2	160	149	139	128	117	107	96	85	75	64	53	43	32	21

For the calculation method follow these steps.

Subtract b2 from 255 to get the inverse value proportional to temperature and put into W0 register.
Multiply this value by 100 and then divde the result by a constant K.
K is calculated by getting the value for b2 for 20ºC and subtracting this from the value for 63ºC.
Divide this result by the temperature delta value (subtracting 63ºC - 20ºC), then multiply this value by 100.
Now that you have the same scale the next step is to compensate for offset.

This is calculated by finding the mid point value for b2 which is 41ºC and b2 = 101.

1.
2. 255 - 101 = 154 @ 41ºC ‘Subtract b2 from 255
3. 154 x 100 / K = 69 ‘Multiply the result by 100 and divide by the constant K,
4. 69 – 41 = 28 ‘Subtract this value from 41ºC to find the offset value.

The program therefore should reflect the formula : W0 = 255 – b2 x 100 / 223 – 28

For the Lookup table method use Table 1 as an example.

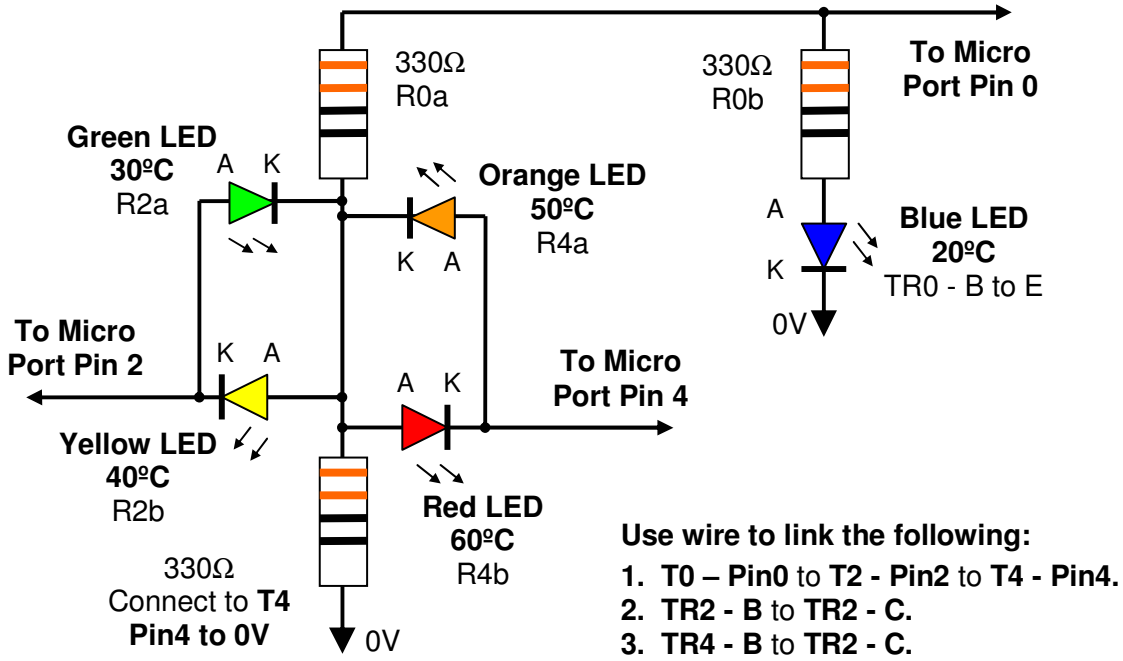
If you are using the Picaxe08M the program can use interpolation to calculate values between those listed in Table 1.

Design Project.

7. Present an idea of how this technology in question 6 or 8 could be implemented in a practical device as a hand held instrument. Provide detailed drawings of the circuit diagram , circuit board, enclosure, battery compartment and digital display.
Keep in mind the ergonomics and features that may help the user, e.g. belt or pocket clip etc.

Advance Exercise.

8. Design an LED Bar-Graph Thermometer.
   Insert 4x LEDs back to back in place of R2a, R2b, R4a, R4b.
   Refer to Figure 2 for the LED K and A lead orientation. Using coloured LEDs is optional.
   Arrange Port Pins 0, 2 and 4 to drive an array of 5 LEDs that illuminate for every 10ºC ranging from 20ºC to 60ºC using the software comands DATA, DIRS and PINS.



Note:

Using the copper wire provided in the PicPatch kit, link the points listed in the above table.
Port Pin 0 must be set high to provide the positive supply for LEDs R2b and R4b.
The Blue LED in this circuit will glow whenever the temperaturte is above 20ºC.

Conclusion:

9. Report on the possibilities using this technology and problems that could be experienced. Explain the linearity error by plotting a graph of temperature vs b2 using Table 1 and suggest possible solutions to overcome this problem in your conclusion.

Tutor Information

This project demonstrates Kirchhoff's first law to calculate the voltage of a resistor divider.
The value of NTC resistance is proportional to the voltage that appears at Pin 1.
However the NTC does not give a linear resistance verse temperature over the full scale 0 to 100ºC.

If a voltage at Pin 1 is the same as the supply voltage, +5Vrail, the full-scale analogue value b2 will register 255 for the Picaxe 08M. For the Picaxe 08 the value for b2 will stop at 160, 62.7% of the +5V rail voltage.

If the resistance of the NTC is 9.7kΩ, the voltage at Pin 1 will be half of the supply voltage.
⇒ (Rntc + R1a) / (Rntc + R1a + R1d) x Vsupply.
⇒ (9.7k + 330) / (9.7k + 330 + 10k) x 4.5V = 2.25V approximately.

The value for b2 will register approximately 127 for Picaxe 08M and 117 to 127 for the Picaxe 08.

Note: You will be able to measure this voltage reasonably accurately with a multimeter as the internal resistance inside the multimeter across the test leads will not greatly influence the circuit resistance.

Answers.

1. A Mother who wishes to know the approximate temperature of her baby's bottle or a blind person who does not want to risk touching very hot water and would like to now the approximate temperature of a cup of coffee or tea or the bath water etc.

2. Sense temperature with thermocouple wire, Semiconductor sensor and display it on a LCD display. A bimetallic strip can also be used activate a switch to turn on and off an indicator lamp or alarm.

3. Refrigerator, Oven, Cook Pot, Air conditioning unit, Dish washer, Washing machine.

4. 4.1. To control temperature for food display cabinets, cool stores and bakery ovens etc.
The software would switch on and off a compressor or heating element to regulate the temperature.

4.2. Sound an alarm when the temperature has failed to meet the required temperature, such as a cool store.
The software activates an alarm if the temperature fails to reach the required threshold.

5. Three step tone thermometer program.

```
Loop:  b2 = 100              'Set Tone to lowest pitch. (Use Table 1.)
       Pause 500             'Wait 500 milliseconds (0.5 seconds)
       Readadc 1, b1         'Read the analogue value at Pin 1 into the Temperature register
       IF b1 >64 Then Tone1      'If the temperature is greater than  56ºC then hot
       IF b1 >96   Then Tone2    'If the temperature is greater than  40ºC then warm
       Tone3: b2 = 110           'Set tone to warm ready to
       Tone2: b2 = b2 + 10       'increase tone to next level,
       Tone1: Sound 4, (b2,10)   'sound tone on output pin 4,
       Goto Loop                 'and repeat the exercise
```

6. 6.1. The first step program to display the value of Pin 1 recorded into register b2;

```
Loop:  Pause 100             'Wait 100 milliseconds
       Readadc 1,b2          'Read the analogue value at Pin 1 into the Temperature register
       Debug b2              'Display the value of b2 register
       Goto Loop             'and repeat the exercise
```

6.2. By Calculation the program is suitable for the Picaxe08;

```
Loop:  Pause 100             'Wait 100 milliseconds
       Readadc 1,b2          'Read the analogue value at Pin 1 into the Temperature register
       b2 = 255 - b2         'calculate the inverse value in proportion to temperature
       W0 = b2 * 100 / 223   'multiply this value by 100 to divide by 223 (W0/2.23)
       W0 = W0 – 28          'subtract the offset value to align with the temperature scale
       DEBUG W0              'Display the value of W0 register, the approximate temperature.
       Goto Loop             'and repeat the exercise
```

6.3. By Look-up table using Picaxe08;

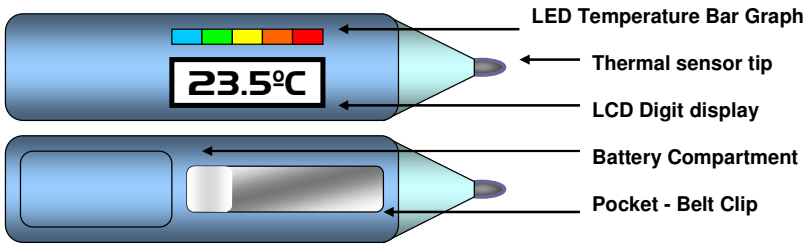
```
Loop: Pause 100                  'Wait 100 milliseconds
      Readadc 1,b2               'Read the analogue value at Pin 1 into register b2

                                 'Find pointer no. for b2
      Lookdown b2,(160,149,139,128,117,107,96,85,75,64,53,43,32,21), b1

                                 'Get equivalent temperture
      Lookup  b1,   (18,  20,  23,  27,  31,  35,  40,45,50,56,63,70,82,95), b2

      Debug b2                   'Display the value of b2, the approximate temperature
      Goto Loop                  'and repeat the exercise
```

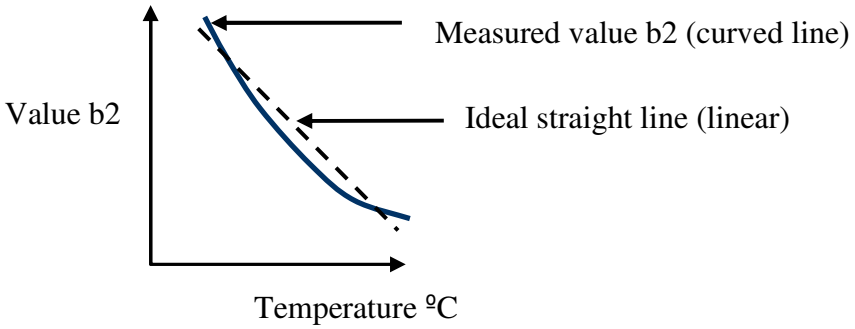
7. The handheld thermometer instrument.



8. LED Bar-Graph Thermometer program by calculation.

```
        Data 0, (53,75,96,117,149)     '5 temperature levels for 63, 50, 40, 31, 20ºC respectively
                                       'Port Pins %xxx43210.
        Data 5,   (%00010001, %00010001, %00000101, %00000101, %00000001)
                                       'Port Pins %xxx43210.
        Data 10 , (%00000001, %00010001, %00000001, %00000101, %00000001)
Loop:   Pause 200                      'Pause 0.2 seconds
        Readadc 1, b1          'Read the analogue value at Pin 1 into the Temperature register
        For b0 = 0 to 5        'Scan values in data table. A lookup comand can be used aswell.
        Read b0, b2                    'Read the next value b2 for comparison with b1
        If  b1 <= b2 then LEDon        'If the temperature is above b2 then turn on appropriate LED
        Next                           'otherwise continue onto the next value for comparison
        Let Dirs = %00000000           'If level registered < 20ºC then clear port direction registers
        Let Pins = %00000000           'If level registered < 20ºC the reset port pins low
        Pulsout 0, 2000        'Momentary flash blue LED to indicate power is on.
        Goto Loop              'and repeat the exercise
LEDon:  b1 = b0 + 5            'set topoint to the data for the LED pin settings.
        Read b1, b2            'Read in the pin settings. A lookup comand can be used aswell.
        Let Dirs = b2          'Set the ports with the pin direction, Input or Outputs
        b1 = b0 + 10           'set topoint to the data for the LED pin settings.
        Read b1, b2            'Read in the pin settings. A lookup comand can be used aswell.
        Let Pins = b2          'Set the appropriate pins high or low
        Goto Loop              'and repeat the exercise.
```

9. This technology is widely used in the medical, food, science and industry, etc. The NTC non-linear characters causes inaccuracy so it is better to use a lookup table to calculate the reference for actual temperature verses NTC resistance.



Graph of Table 1.

The reading as measured on Pin 1 gives the curved non-linear line, the straight line is the ideal linear reference. Such programs typically use a lookup table for equivalent temperature values listed for b2, with temperature divisions of 10ºC or less ranging from -10ºC to 120ºC. For values between these divisions intepolation is used to calculate the difference between adjacent temperature divisions.

The Picaxe08 has a low resolution analogue input for Pin1, so the temperature results will only be an approximation.