Application of Thermistors

- Physics review – electricity
- Basic circuits
- Ohm's Law
- Thermistor properties / circuits
- Laboratory information

Current and Voltage

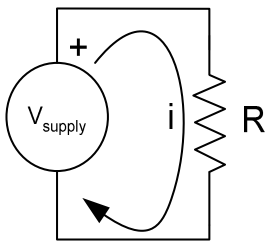
- Current:
  - Flow of electrons
    - The quantity of electrons per unit time flowing through a conducting medium
    - Units of Amperes (A), abbreviated “amps“ or fundamentally coulombs per second (coulomb=6.03×10^{23} electrons)
- Voltage:
  - Electromotive force (EMF)
    - A potential or “tension” between two points of a conducting medium that can drive the flow of electrons through the medium expressed as work per number of electrons
    - Analogous to pressure in a fluid that can drive flow of fluid through a pipe
    - Units of Volts (V) or fundamentally joules per coulomb, the energy (potential) per unit of electrons.

Power dissipation

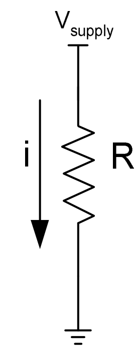
- Power
  - Electromotive Force times quantity of electrons moved per unit time
    - Work done per unit time
    - Voltage X Current
      - [Joules/Coulomb] x [Columbs/second] = [Joule/second] = Watts
    - Units of Watts

Current flow in circuits

- Schematic with a voltage source supplying a potential to a resistive load (R) with a current (i).



- An abbreviated schematic showing the source and indicating the return to source is ground referenced.

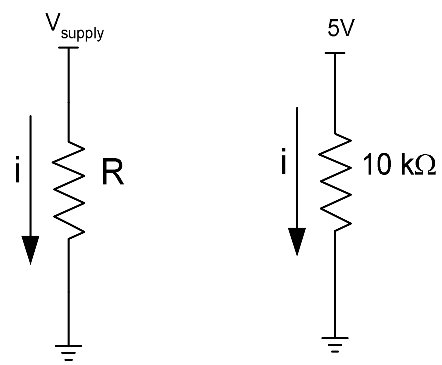


Resistors and Ohms Law

- Property of a resistor – Flow of current is proportional to voltage (or vice versa). The proportionality constant is known as resistance: $v = Ri$

- For the following circuit:

$$V_{\text{supply}} = Ri$$



- Resistance has units of Ohms (Ω)
  - (fundamentally, volts per amp)
- The current could be computed in the circuit above given V_{supply} and R: i = 5V / 10,000Ω = 0.0005 V = 0.5 mV

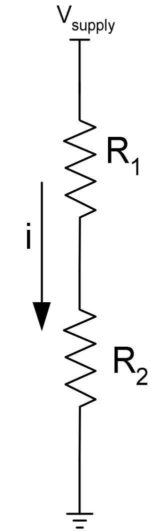
Circuit computations

- For a more complex circuit (half bridge)
  - The current (i) must be the same for both resistors (no other path) $i = i_{R_1} = i_{R_2}$ (1)
  - The supply voltage dropped across both resistors must be the sum of the voltage across R_1 and R_2

$$V_{\text{supply}} = V_{R_1} + V_{R_2} \quad (2)$$

  - We can compute the voltage across R_2, (V_{R_2}) as a function of V_{supply} and the resistances by using Ohm's law:
  - From (2) $V_{\text{supply}} = R_1 i + R_2 i = [R_1 + R_2] i$ $\qquad i = \dfrac{V_{\text{supply}}}{[R_1 + R_2]}$
  - From (1) $i = \dfrac{V_{R_2}}{R_2}$

$$\frac{V_{R_2}}{R_2} = \frac{V_{\text{supply}}}{[R_1 + R_2]} \qquad V_{R_2} = V_{\text{supply}} \frac{R_2}{[R_1 + R_2]}$$



Thermistors - characteristics

- Read Thermometrics handout.
- Thermistor is a resistor where resistance is strongly a function of temperature
- Important characteristics
  - Mass – larger masses = slower response
  - Temperature coefficient
    - NTC – Resistance decreases with temperature
      - Exponential relationship between temperature and resistance

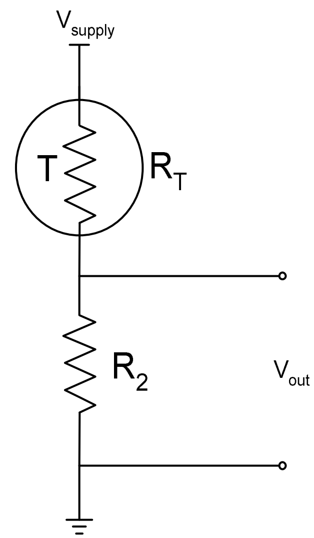
$$R_T = R_{T_0} e^{\left[\frac{\beta(T_0 - T)}{T_0 T}\right]}$$

    - PTC – Resistance increases with temperature
  - Packaging
  - Temperature range

Thermistor circuits for temperature measurement

- Half bridge (voltage divider)

$$V_{\text{out}} = V_{\text{supply}} \frac{R_2}{[R_T + R_2]}$$



- For a NTC thermistor:

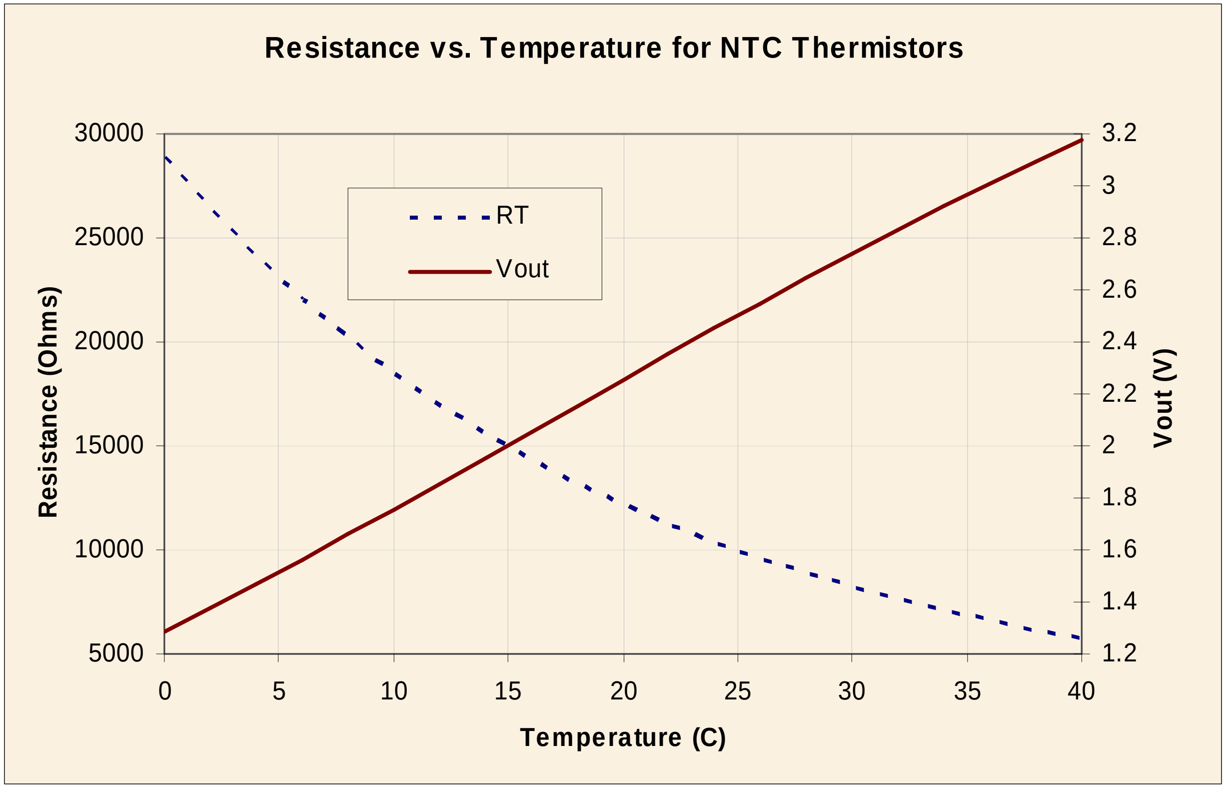
Variable	Symbol	Direction
Temperature	T	Increase
Thermistor resistance	R_T	Decrease
Voltage out	V_{out}	Increase

- Design issue: select V_{supply} so that self-heating is insignificant
  - Does R_T heat up due to resistive power dissipation? (P=VI)

Theoretical Performance of Voltage Divider Circuit

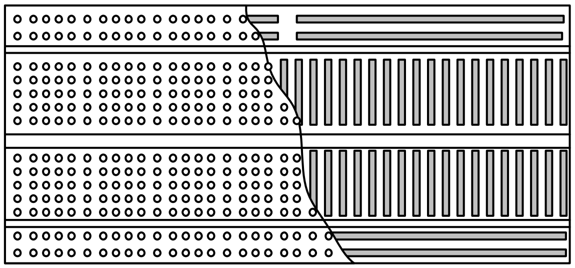
R_{T0}	T_0	β	$R_{\_2}$	V_{supply}
10000	25	3450	10000	5

T	R_T	Vout
0	28868.95	1.286374
2	26333.94	1.376124
4	24053.43	1.468281
6	21998.96	1.562551
8	20145.56	1.658619
10	18471.27	1.756156
12	16956.77	1.854822
14	15585.01	1.954269
16	14340.97	2.05415
18	13211.32	2.154121
20	12184.3	2.253847
22	11249.45	2.353002
24	10397.5	2.451281
26	9620.204	2.548394
28	8910.211	2.644074
30	8260.974	2.73808
32	7666.646	2.830192
34	7122.002	2.920219
36	6622.364	3.007996
38	6163.541	3.093382
40	5741.773	3.176262

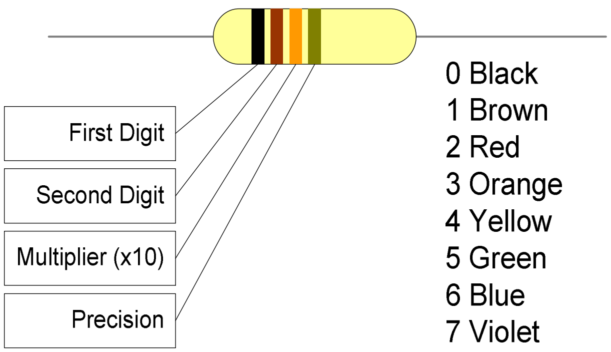


Information for the laboratory

- Prototype board internal connections



- Resistor color codes



0 Black
1 Brown
2 Red
3 Orange
4 Yellow
5 Green
6 Blue
7 Violet
8 Grey
9 White
5% Gold
10% Silver