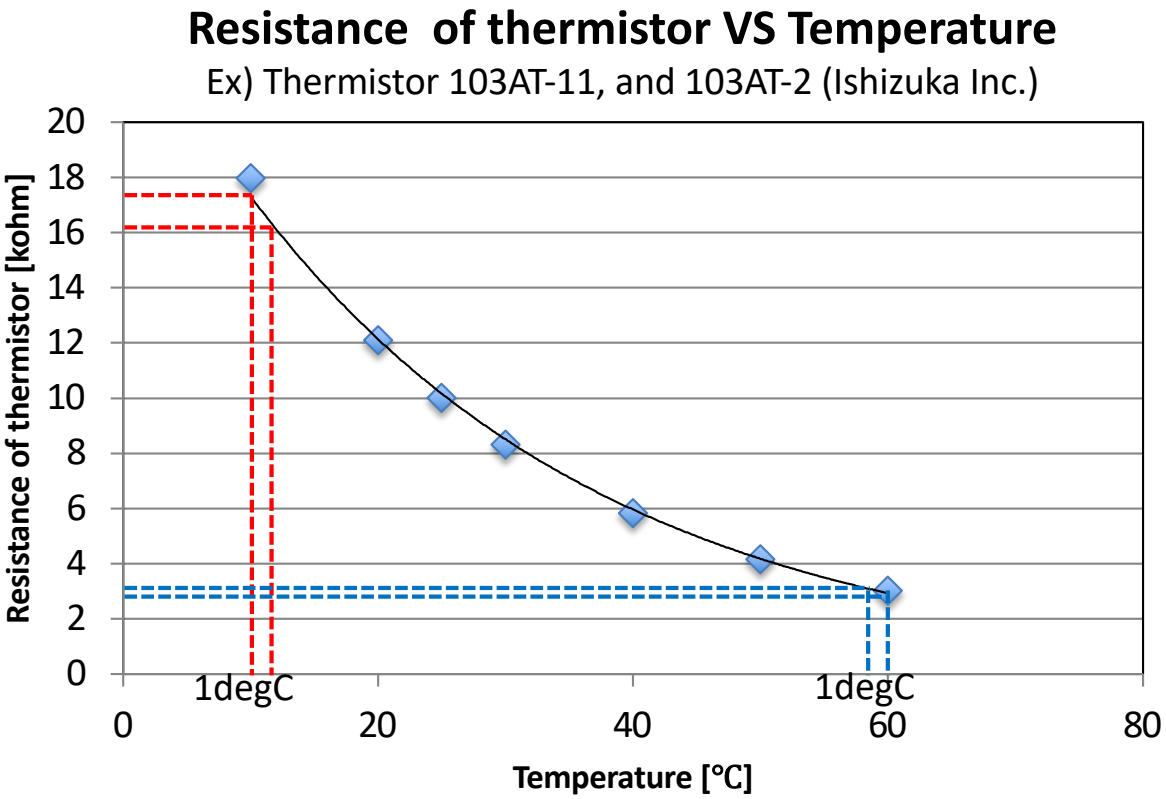
Exercise for Design of Measurement Circuit

- For Thermistor -

Sensor used in this exercise
- Temperature sensor “Thermistor” -

- The resistor with sensitivity for temperature.
  => Output of the sensor is resistance.
  => The resistance should be changed into voltage.
- The response property (relation between temperature and resistance) is non-linear.



Temperature[°C]	Resistance [kΩ]
10	17.96
20	12.09
25	10.00
30	8.313
40	5.827
50	4.160
60	3.020

Relationship between temperature and sensor resistance of thermistor

$$R_S = R_0 \cdot exp\left\{B\left(\frac{1}{T_S} - \frac{1}{T_0}\right)\right\}$$

T_0: Standard temperature.
In the case of this time, T_0 = 25 + 273.15 [K].

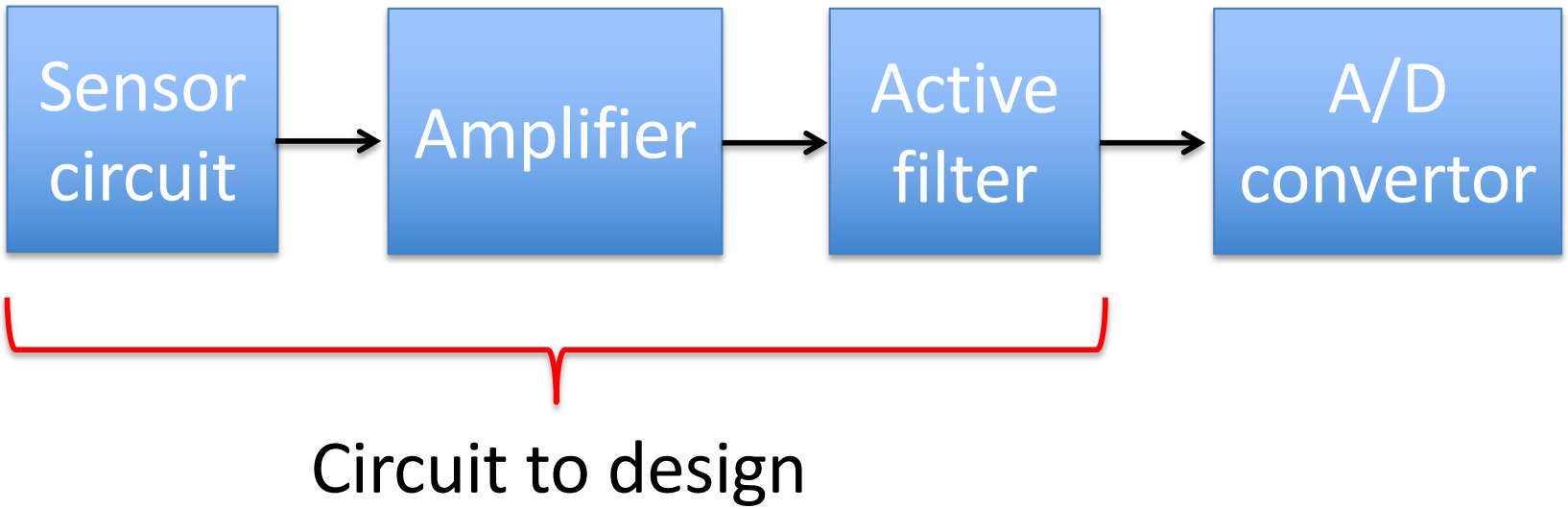
R_0: Standard resistance value of sensor at standard temperature.
In the case of this time, R_0 = 10x10^3[Ω]=10[kΩ].

B: B constant of thermistor. This value is related with sensitivity to temperature of Thermistor. In the case of this time, B=3435[K].

T_S: Measurement temperature. Unit is [K].

R_S: Resistance value of sensor at temperature Ts. Unit is [Ω].

Block diagram of measurement circuit
And
Indication of the part you design



Resistor circuit for resistor type sensor

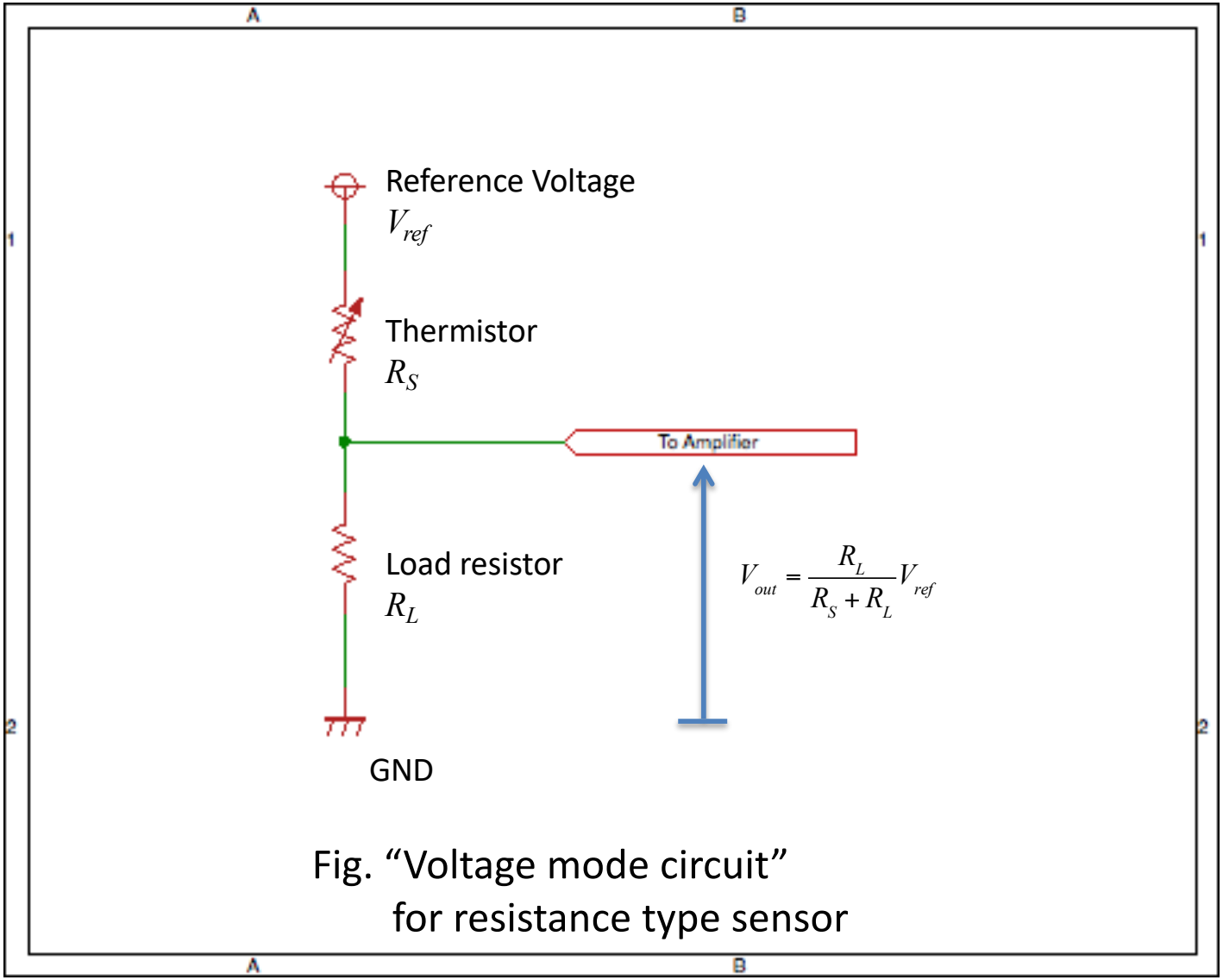
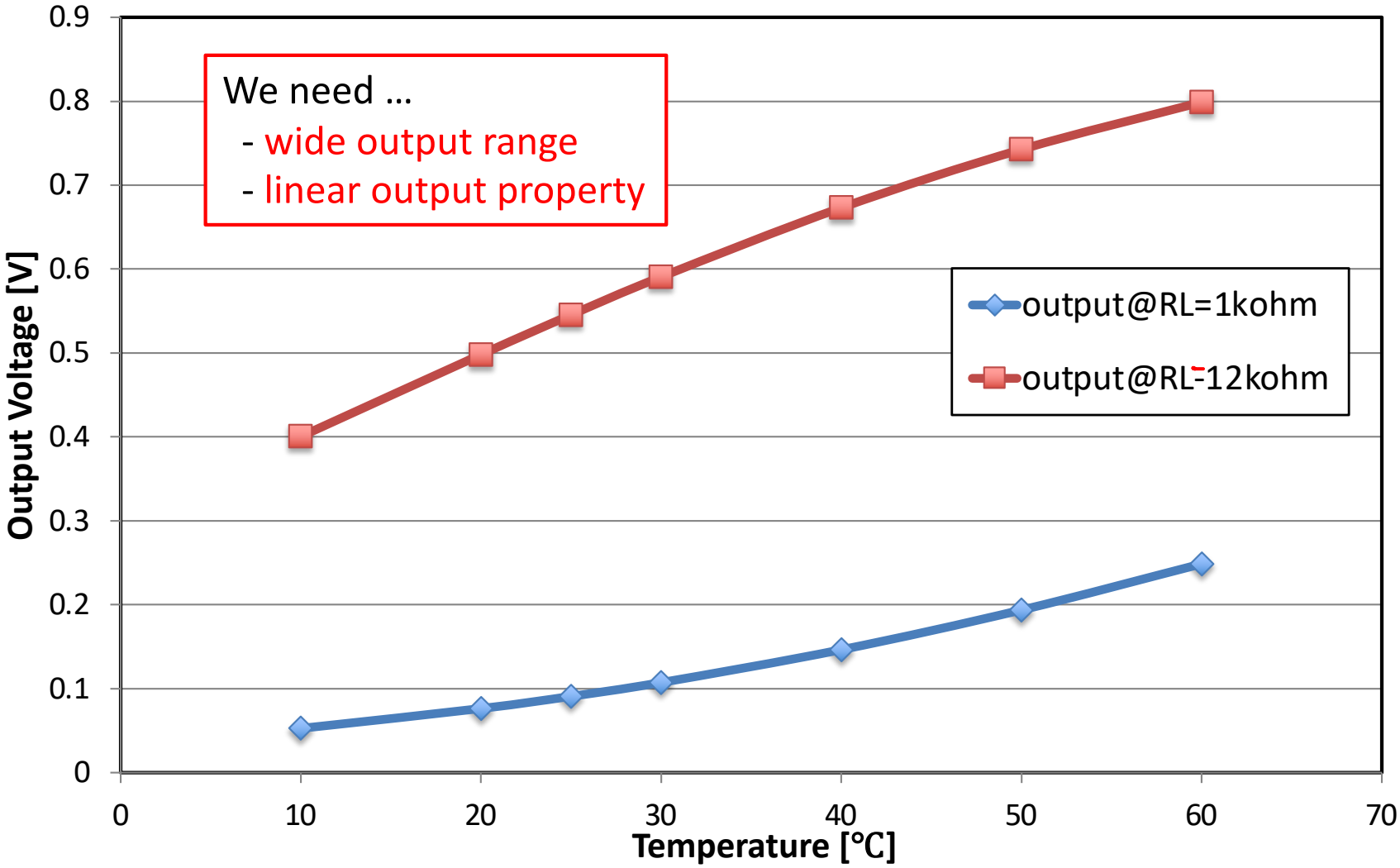
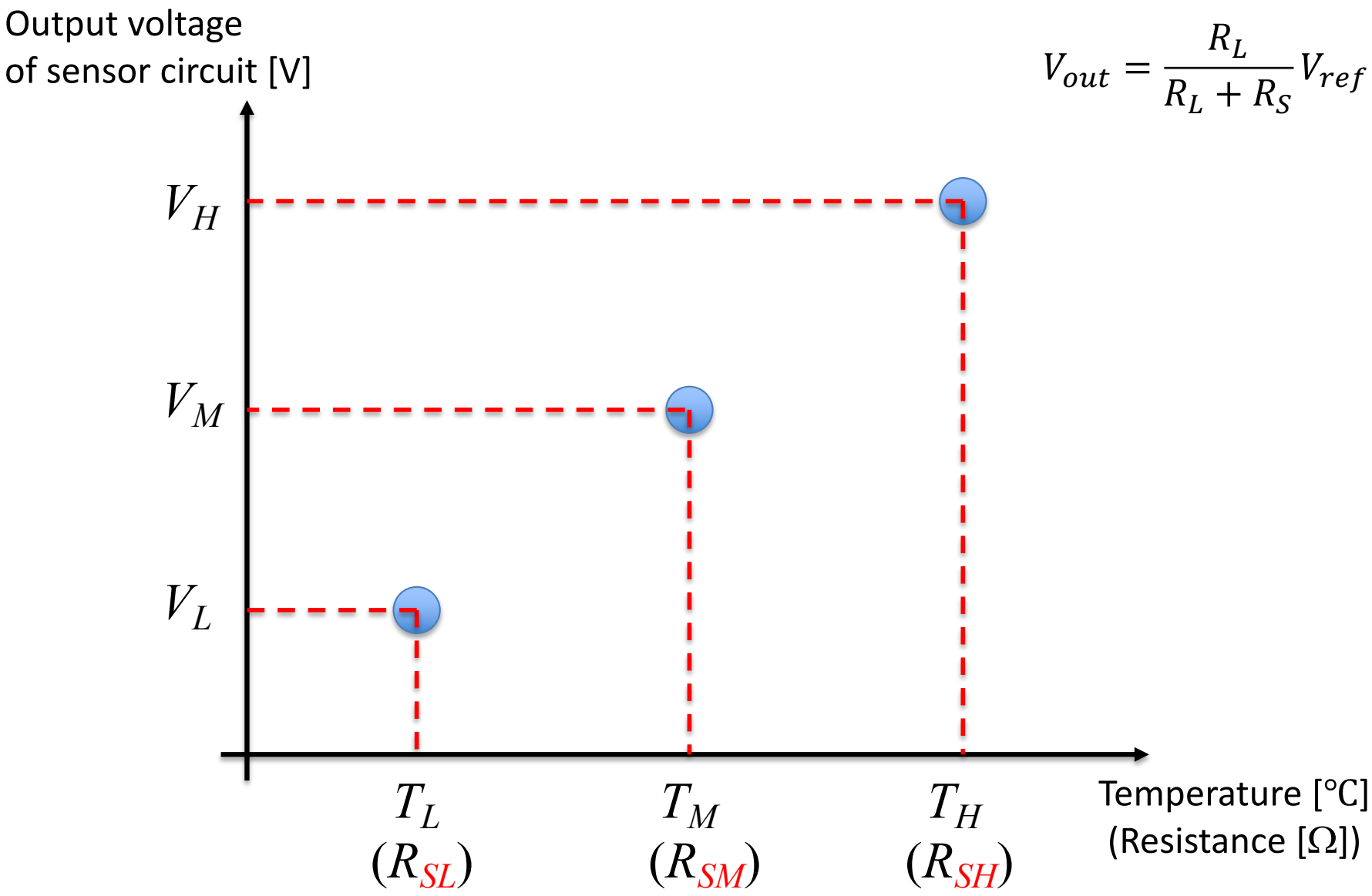


Fig. “Voltage mode circuit”
for resistance type sensor

Calculated sensor output using load resistor



How to design of load resistor R_L



Sensor circuit output for temperature

Temperature[℃]	Output [V]@RL=
10	
20	
25	
30	
40	
50	
60	

Specification of measurement circuits in this exercise

- Measurement temperature range: 10 ～ 60 [℃]

- Sensor driving voltage V_{ref} is 1 [V].

- Condition of A/D conversion:
  - 16bit successive approximation method
  - Input voltage range is 0 ～ 10V.
    => Up to 9[V] to prevent over input for A/D converter.
  - Sampling frequency is 100Hz.

- Required filter's attenuation slope: 40[dB/dec]

Design step of measurement circuit in this exercise

Step 1: Design of load resistor in voltage mode circuit

=> The load resistance should be chosen for the following characteristics.
- Wide range output voltage over measurement temperature range.
- Linearity of output characteristics in measurement temperature range

Step 2: Design of filter circuit and checking its amplification gain

=> The filter should be designed for the followings.
- Cutoff frequency to protect the sampling theorem
- Order of filter to realize required attenuation slope

Step 3: Design of amplifier circuit

=> The amplifier should be designed for the followings.
- High input impedance compared with output impedance of signal source
- The gain should be designed to set the maximum output voltage to about 9 V.
- The gain must be designed in consideration of the gain of above active filter.

Available parts for circuit design

- Thermistor : 103AT-2, 103AT-11, 103JT (Ishiduka inc.)
- OP-Amp. : LM358N (two OP-Amps in an IC)
- Carbon film resistor in E24 series
- Multilayer ceramic capacitor in E6 series

Values in E24 and E6 series

1.0	1.1	1.2	1.3	**1.5**	1.6	1.8	2.0	**2.2**	2.4	2.7	3.0
3.3	3.6	3.9	4.3	**4.7**	5.1	5.6	6.2	**6.8**	7.5	8.2	9.1

Overall contents of this exercise

Circuit design

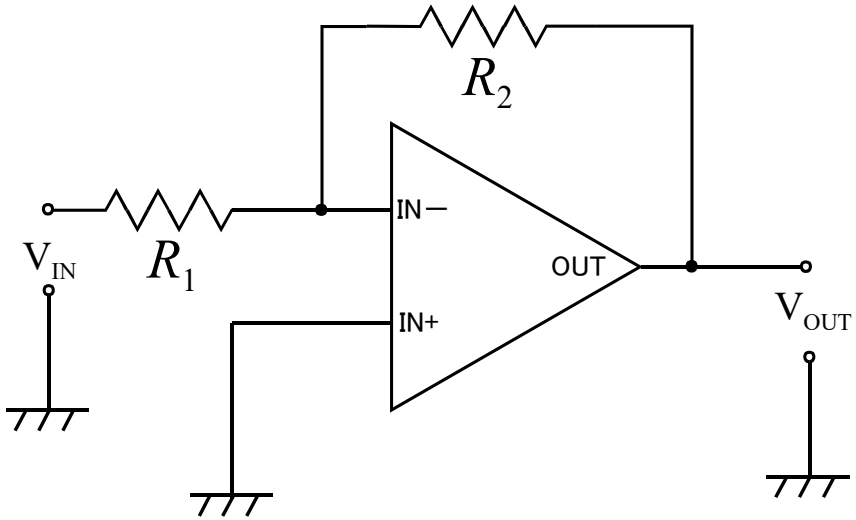
Checking the operation of the circuit you designed by Circuit simulator

How to deal with measured data

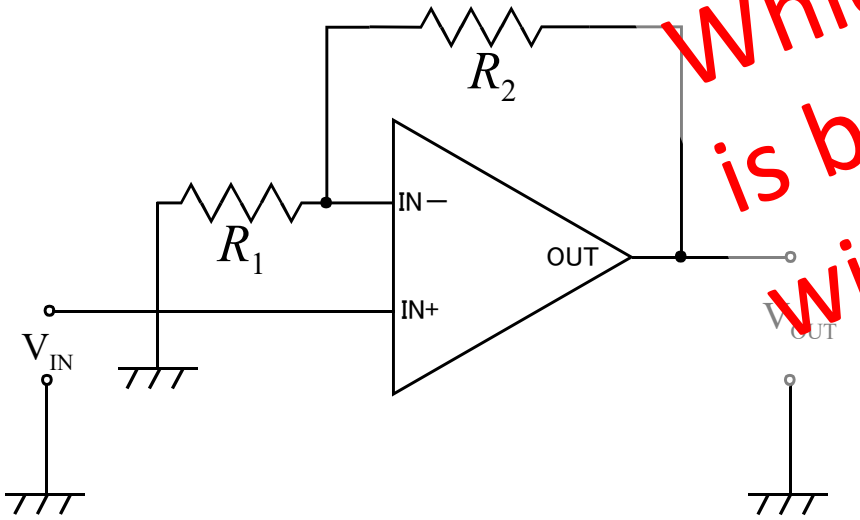
Analysis of measured data

* Making and submission of the report for this exercise will be after the analysis.

Basic amplifier using OP-Amp.



Inverting amplifier



Non-inverting amplifier

- Inverting amplifier
  - Signal inputs to Inverting input terminal “IN-”
  - Output signal has 180° phase difference to input signal.
  - Input impedance is not high (almost R_1).
- Non-inverting amplifier
  - Signal inputs non-inverting terminal “IN+”
  - Output signal is co-phase with input signal
  - Input impedance is high. (Important!!!)

Which amplifier circuit is best for first connection with sensor circuit?

Measurement circuit