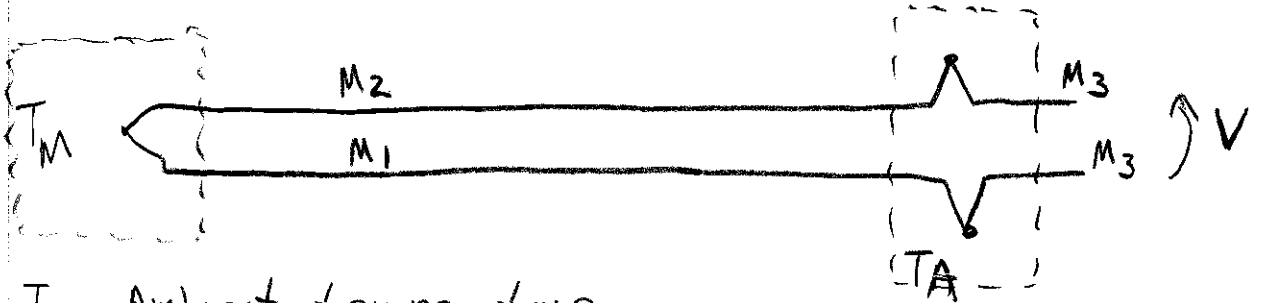
Thermocouple Algebra

k_{21} is the thermocouple contant (in Volts/°C) for a thermocouple made of metals 1 & 2.

There is no way to directly measure the voltage across a thermocouple since any connection to make the measurement introduces two more thermocouples. On paper it looks like we can.

Note that the k_{21} constant varies with temperature. We will ignore this effect in solving thermocouple problems to keep the algebra linear. The main point is to understand the concepts.

Here is a basic thermocouple problem. The solution shown is the approach to take for all thermocouple problems.



T_A = Ambient temperature
T_M = Temperature we are measuring
M_1, M_2, M_3 = Metal 1, Metal 2, Metal 3
↑
Typically Copper

Step 1: Write an equation for the voltages around the loop.

$$V = T_A(k_{13}) + T_m(k_{21}) + T_A(k_{32})$$

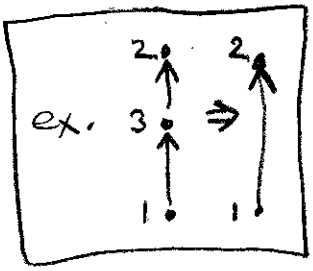
Step 2: Combine terms and put <u>Tm</u> term first

$$V = T_m(k_{21}) + T_A(k_{13} + k_{32})$$

Step 3: Re-arrange terms so we can eliminate the third metal

$$V = T_m(k_{21}) + T_A(k_{13} \quad k_{32})$$

$$V = T_m(k_{21}) + T_A(k_{12})$$



Step 4: Swap metals and change sign to make all k terms the same.

$$V = T_m(k_{21}) - T_A(k_{21})$$

Step 5: Combine terms to obtain the desired form

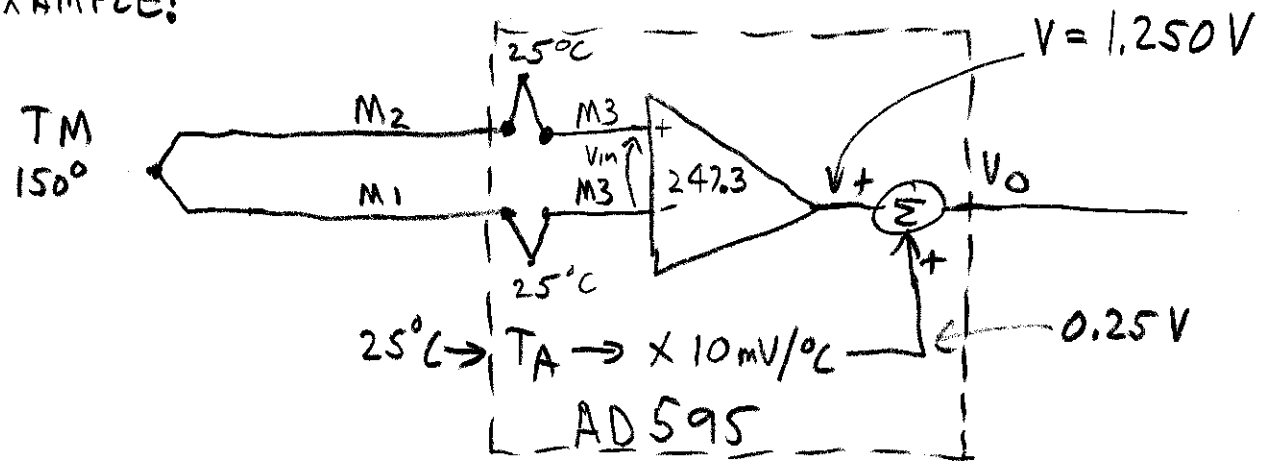
$$V = (T_m - T_A)\,k_{21}$$

Note that the measurement is <u>always</u> relative to ambient.

THERMOCOUPLE PROBLEMS

IN THE FOLLOWING PROBLEMS THE MEASUREMENT THERMOCOUPLE IS TYPE K ($40.44\mu V/^\circ C$). THE THERMOCOUPLE CONDITIONER IS AN AD595 WHICH HAS A GAIN OF 247.3 (FOR 10mV/°C OUTPUT) AND ADDS A VOLTAGE TO THE OUTPUT OF THE AMBIENT TEMPERATURE OF THE AD595 MULTIPLIED BY 10 mV/°C — THIS IS CALLED AMBIENT COMPENSATION. FOR EACH PROBLEM, COMPUTE THE OUTPUT VOLTAGE OF THE AD595 AND THE APPARENT TEMPERTURE OF T_M. DOES THIS AGREE WITH THE ACTUAL TEMPERTURE OF T_M?

EXAMPLE:

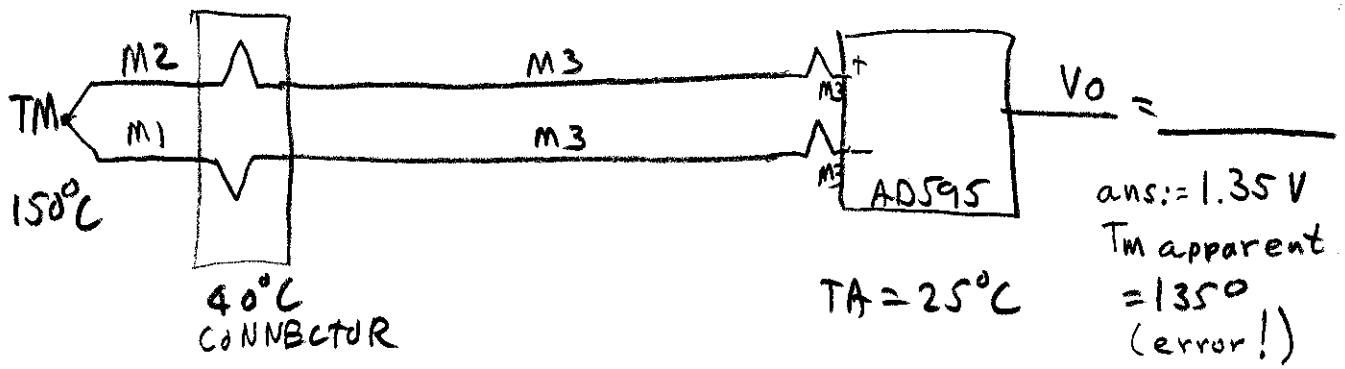


$V_{in} = T_A K_{13} + T_M K_{21} + T_A K_{32} = (T_M - T_A) K_{21}$ $\quad [K_{21} = 40.44\mu V/^\circ C]$

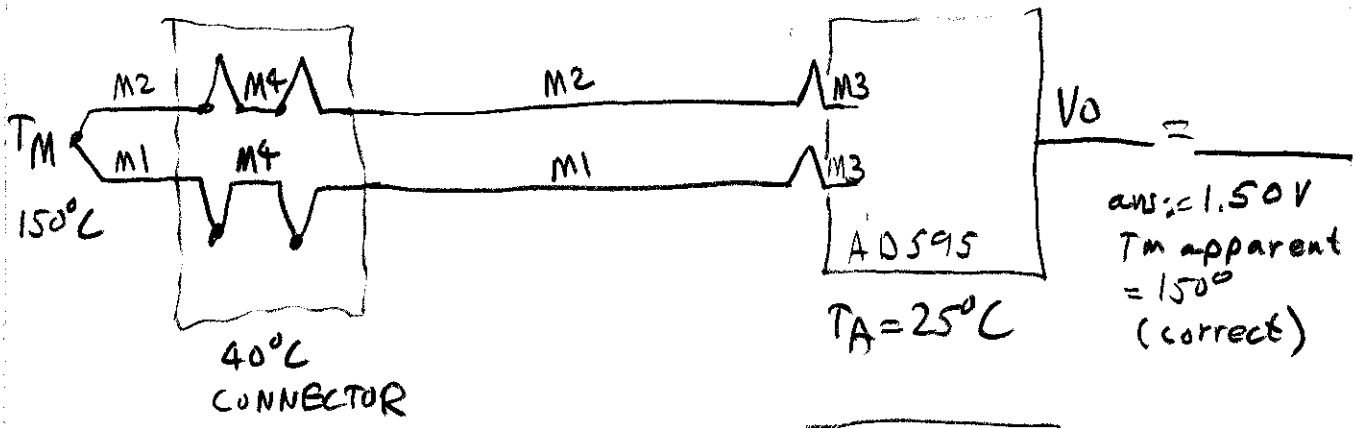
$V_{in} = (150 - 25)\,40.44\mu V \approx 5.055\ mV$

$V = V_{in} * 247.3 = 1.250\ V$

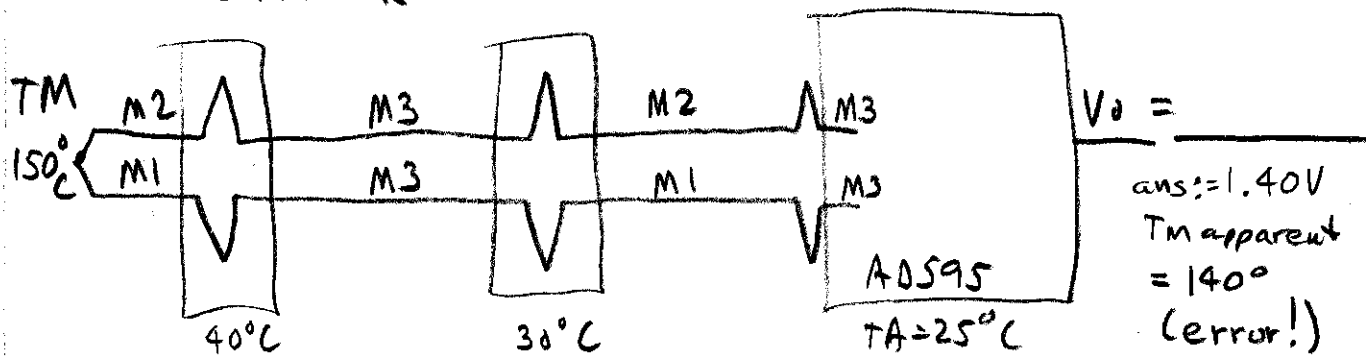
$V_O = V + 0.25 = \underline{\underline{1.50V}}$ THUS $T_M = 150^\circ C$



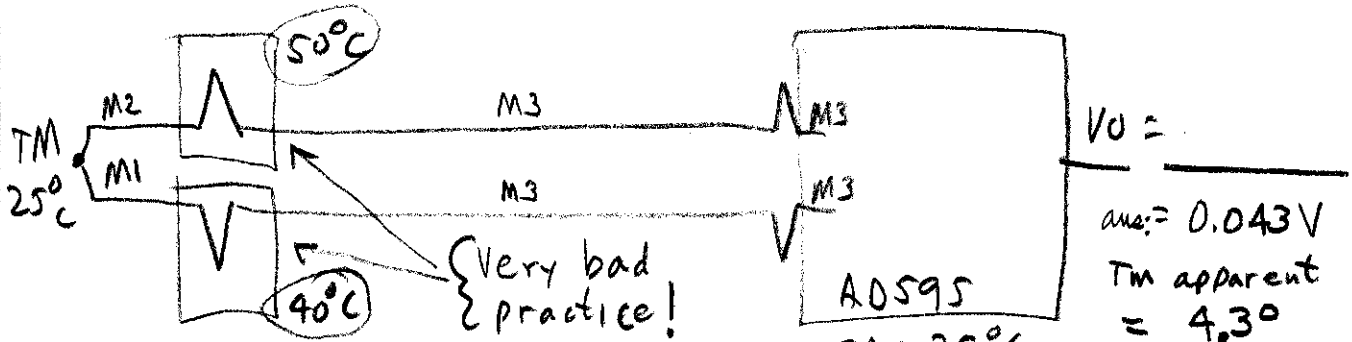
ans: = 1.35 V
Tm apparent
= 135°
(error!)



ans: = 1.50 V
Tm apparent
= 150°
(correct)



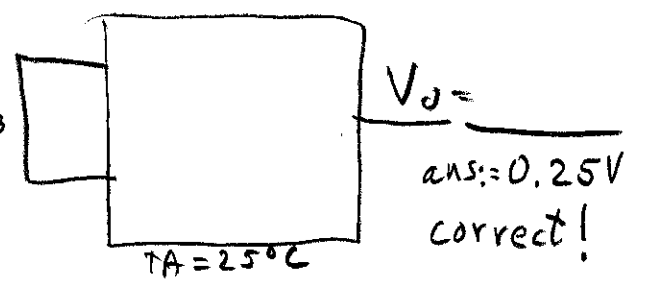
ans: = 1.40 V
Tm apparent
= 140°
(error!)



USE $K_{32} = -23\,\mu V/°C$

ans: = 0.043 V
Tm apparent
= 4.3°
(error!)

short connected
across input
(thermometer mode)



ans: = 0.25 V
correct!