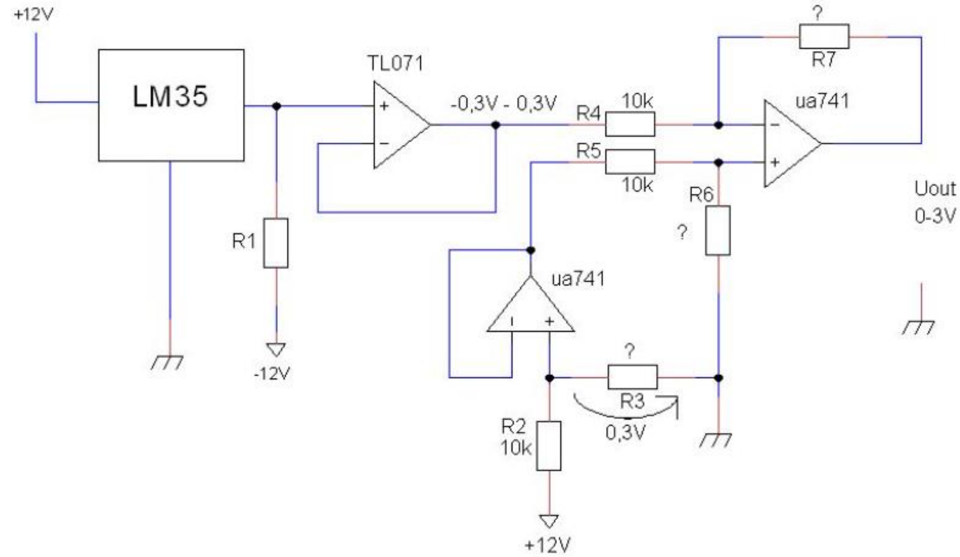
Design Analog signal processing

In this task, one will design temperature sensor circuit, buffer circuit and differential amplifier circuit. The differential amplifier will be used to gain input voltage (-0.3V to 0.3V) to wanted level as in figure.

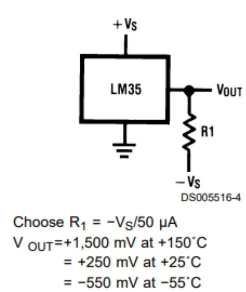


Analog signal processing circuit diagram

The sensor LM35 output voltage will change -0.3V to +0.3V when environment temperature changes from -30 Celsius to +30 Celsius.

We need to calculate the value of resistances:

Calculation of resistance R_1



Full-range centigrade temperature sensor

From the datasheet of LM35, we have the equation of R_1 as following:

$$R_1 = \frac{-V_s}{50\mu A} = \frac{12V}{50 \times 10^{-6} A} = 240000\Omega = 240k\Omega$$

Calculation of R_3:

We have:

$$I_2 = \frac{12 - 0.3}{10000} = 1.17 \times 10^{-3} A$$

And because $I_3 = I_2$, so that we can calculate R_3 as follow:

$$R_3 = \frac{U_3}{I_3} = \frac{0.3V}{1.17 \times 10^{-3} A} = 256{,}41\Omega$$

Calculation of R_6 and R_7:

Because there is differential amplifier, so that:

$$R_6 = R_7$$

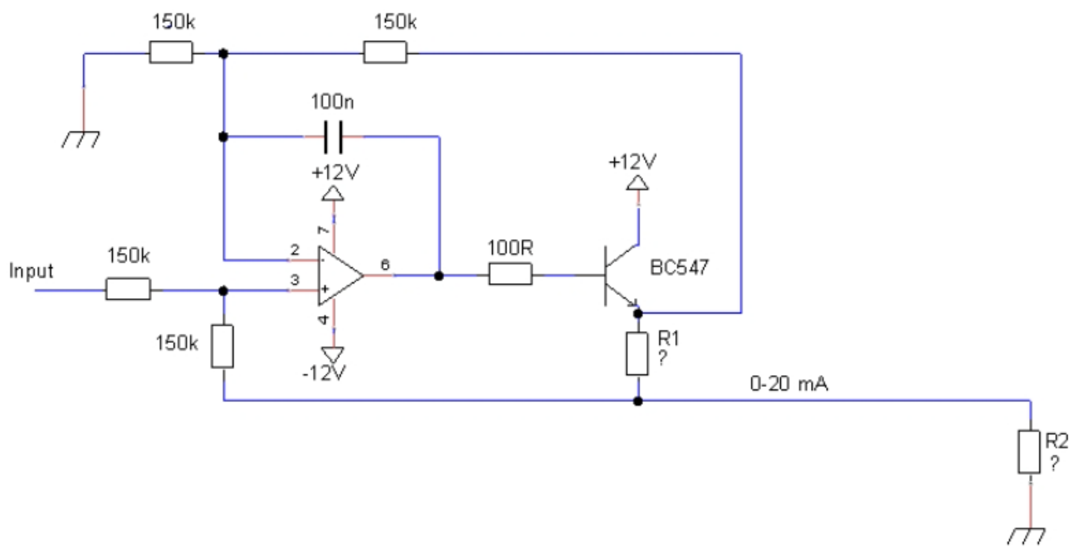
$$\text{and } U_{out} = \frac{-R_7}{R_4} \times (U_{1a} - U_{1b})$$

Indeed, we have that when the range is from -300mV to 300mV, the output should become 3V to 0V. So, we have the equation of R_7 as follow:

$$R_7 = R_6 = U_{out} \times \frac{-R_4}{(-0.3 - 0.3)} = 3 \times \frac{-10000\Omega}{-0.6} = 50k\Omega$$

Design communication processing

Transmitter



we have created an analog signal which depends on environment temperature (record through LM35), and the output voltage of the previous circuit is changing from 3V to 0V when the temperature is changing from -30 Celsius to +30 Celsius, respectively. And in this task, we will calculate the resistors so that we can have 0-20mA current through R_1 when input voltage varies 0-3V DC.

Because when current 20mA flows in circuit the resistor R_2 must have 5V over it, so we have equation to calculate R_2 as follow:

$$R_2 = \frac{5V}{20mA} = \frac{5V}{20 \times 10^{-3}A} = 250\Omega$$

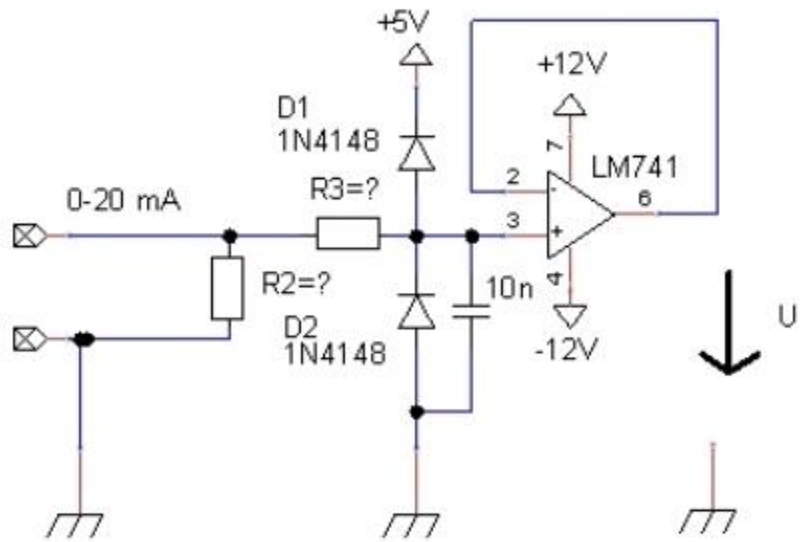
From the circuit schematic, the input voltage varies from 0-3V, as the same result, the voltage through the resistor R1 is also varies from 0-3V, we have the equation to calculate R1 following:

$$R_1 = \frac{3V}{20mA} = 150\Omega$$

The reason why we are using the current as analog signal instead of using voltage is because we can transfer the signal more far away consider of there will be much less signal loss on the way transfer.

Since the equation of resistor of the cable is $R = \rho\frac{l}{A}$, which ρ is a constant number depends on material of cable, and l is the length of cable, A is the area of cross section. By calculation, it is easy to see that, by normal cable, we can transfer the signal in a very long cable without the fear of losing the signal.

Transmitter

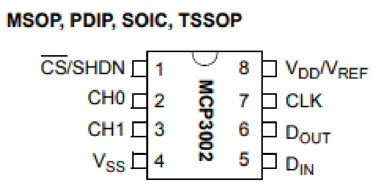


The R_2 in this diagram is also the same R_2 resistor in the transmitter diagram. In this receiver circuit, we will need to calculate the resistor of R_3. If there is an input signal which contains 8kV ESD discharge voltage, and we do not want to have the current through D1 or D2 during this ESD event is bigger than 0.8A, so the resistor R_3 needed to be calculated as following:

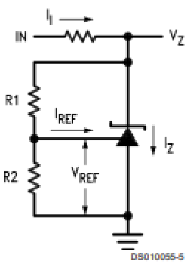
$$R_3 = \frac{U_{ESD}}{I_{ESD}} = \frac{8kV - 12V}{0.8A} = 10k\Omega$$

Analog to digital conversion

we will connect our analog signal (varies from 0-5V) and convert it into digital signal by using MCP3002. In the datasheet of MCP3002, the Vdd (reference voltage) should be 5V as condition. To achieve that, we need a reference chip LM431.



Pin of the ADC



Circuit for Zener

First step, we need to build a feeder circuit for the LM431 (as shown in the right-hand side figure). The output voltage through this adjustable Zener shunt regulator will be V_z and is the reference voltage for out ADC. V_{in} will be the same as input voltage +12V for amplifier we were using. Now, we will need to calculate the resistor R which has I_I going through, and R_2 when we give the value of $R_1 = 10k\Omega$.

To calculate R, we have the following equation:

$$R = \frac{V_{in} - V_z}{I_I} = \frac{12V - 5V}{10mA} = 700\Omega$$

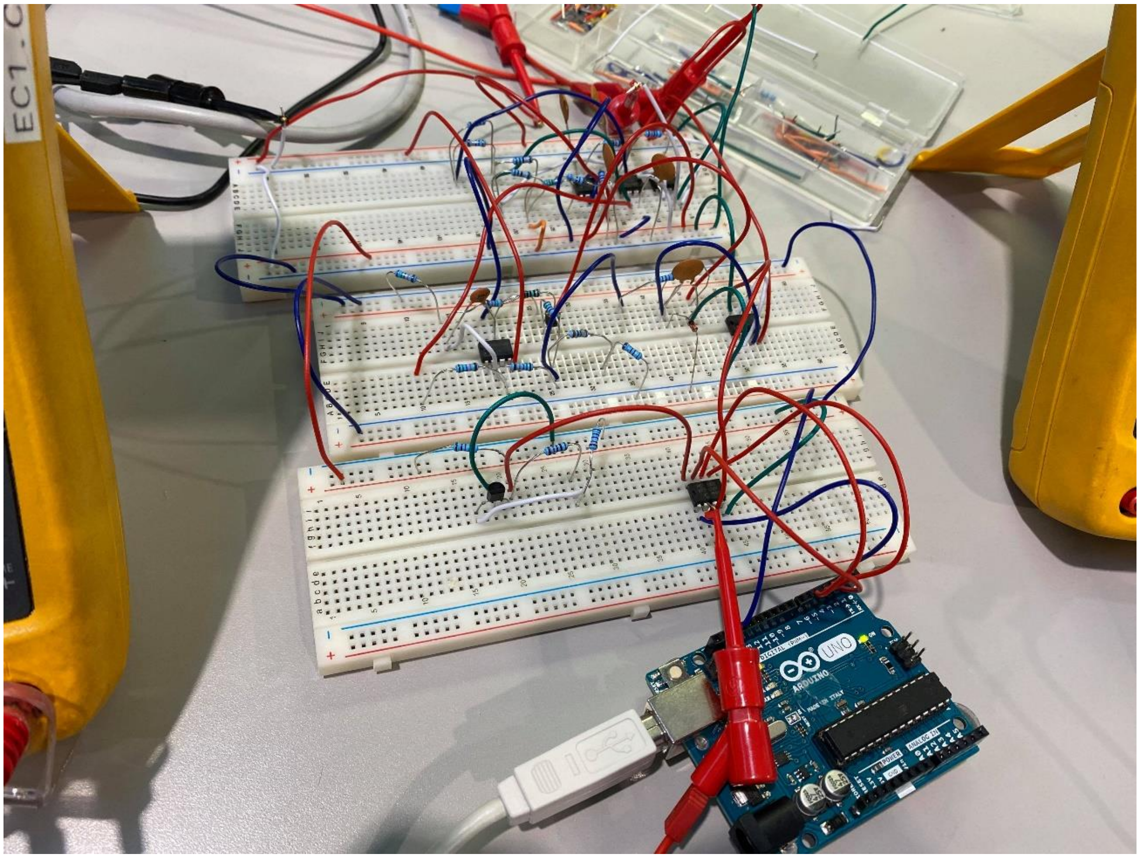
Also, from the datasheet of LM431, we have $V_{ref} = 2.5V$ and $I_{ref} = 2\mu A$ (both typical values) and the equation as follow:

$$V_z = V_{ref} \times \left(1 + \frac{R_1}{R_2}\right) + I_{ref} \times R_1$$

$$\Leftrightarrow 5V = 2.5V \times \left(1 + \frac{10k\Omega}{R_2}\right) + 2\mu A \times 10k\Omega$$

$$\Leftrightarrow R_2 = 10k\Omega$$

So, from the calculated value of R and R_2, we can build the analog to digital conversion circuit in bread board as follow: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