EE 438

DESIGN WITH INTEGRATED CIRCUITS

TERM PROJECT

DIGITAL THERMOMETER

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I. Objective:

In this project we designed a system which samples the temperature, monitores it on display and whenever the temperature is outside a predefined range, drives LEDs. With this aim, we defined these specifications :

- The circuit should generate an appropriate signals when temperature exceeds 40°C or goes below 20°C.
- The circuit should hinder signal chattering around this threshold signals.
- Signals generated at these threshold values should be different.

So our design includes precision centigrade temperature sensor, comparator circuits with schmitt triger actions which drive LEDs at the threshold levels, amplifier stages and a digital to analog converter to display the temperature with seven segment displayers.

II. Design and Implementation Details:

Precision Centigrade Temperature Sensor

LM35 which gives 10mV output voltage per centigrade has been used for temperature sensing.

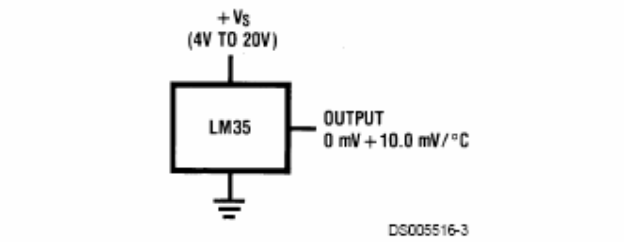


FIGURE 1. Basic Centigrade Temperature Sensor
(+2°C to +150°C)

Amplifier Stages:

To meet the design criteria, two comparator circuits with schmitt-trigger action are designed to realize a window detector. At the upper limit, higher and lower threshold values are 42°C and 38°C respectively. At the lower limit, higher and lower threshold values are 22°C and 18°C respectively. For proper signal generation, a non-inverting schmitt-trigger (Fig. 9.23 in the textbook) at the upper limit and an inverting schmitt-trigger (Fig. 9.22 in the textbook) at the lower limit are preferred. Both circuits operate with a single 5V power supply.

For the schnmitt-trigger circuits to function properly, realistic threshold values had to be chosen. Since the thermocouplers (LM35) output changes only 10mV per °C, proper amplification was necessary. We decided to amplify the LM35 output signal to 3.5 Volts when the temperature equals the corresponding limit value for each schmitt-trigger circuit.

At 20°C, V_{LM35} = 200mV→ A_{LOW} = 3.5 / 0.2 V = 17.5 V/V

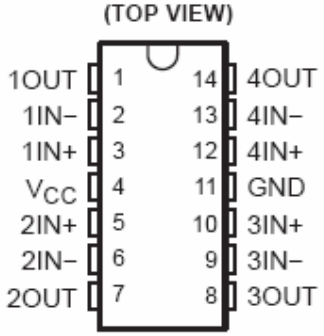
At 40°C, V_{LM35} = 400mV→ A_{HIGH} = 3.5 / 0.4 V = 8.75 V/V

Non-inverting amplifiers (Fig. 1.7 in the textbook) are used fo amplification with the following resistor values:

Lower Limit Amplifier: R1 = 1 kΩ, R2 = 16.5 kΩ (A = 1+(16.5/1)) = 17.5 V/V

Upper Limit Amplifier: R1 = 1.02 kΩ, R2 = 7.87 kΩ (A = 8.72 V/V) (all wirh 1% tolerance)

For both circuits LM324 op-amps with V^+=6V and V^-=0V are used to allow V_{OH} to rise above 4V so that V_{TH} of the following schmitt-trigger circuits can be exceeded.



LM324

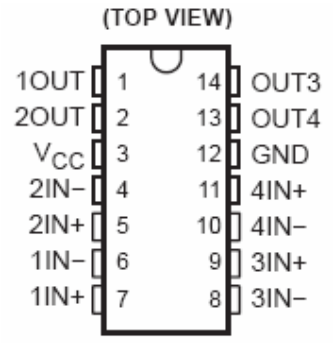
Comparator Circuits with Schmitt Triger Actions

±2°C around the limiting values for schmitt-trigger action correspond to ±0.2V around 3.5V for V_{TH} and V_{TL}.

The following resistor values are used for the Lower Limit Schmitt-Trigger circuit to obtain V_{TH} = 3.7V and V_{TL} = 3.3V:
R1 = 60.4k, R2 = 22.1k, R3 = 100k, R4 = 5k (all with 1% tolerance)(see Fig.9.22 on page 419 for the circuit diagram, design formulas are on the same page-9.13)

The following resistor values are used for the Upper Limit Schmitt-Trigger circuit to obtain V_{TH} = 3.7V and V_{TL} = 3.3V:
R1 = 10.2k, R2 = 4.64k, R3 = 4.87k, R4 = 69.8k, R5 = 5k (all with 1% tolerance) (see Fig.9.23 on page 420 for the circuit diagram, design formula is on the same page-9.14)

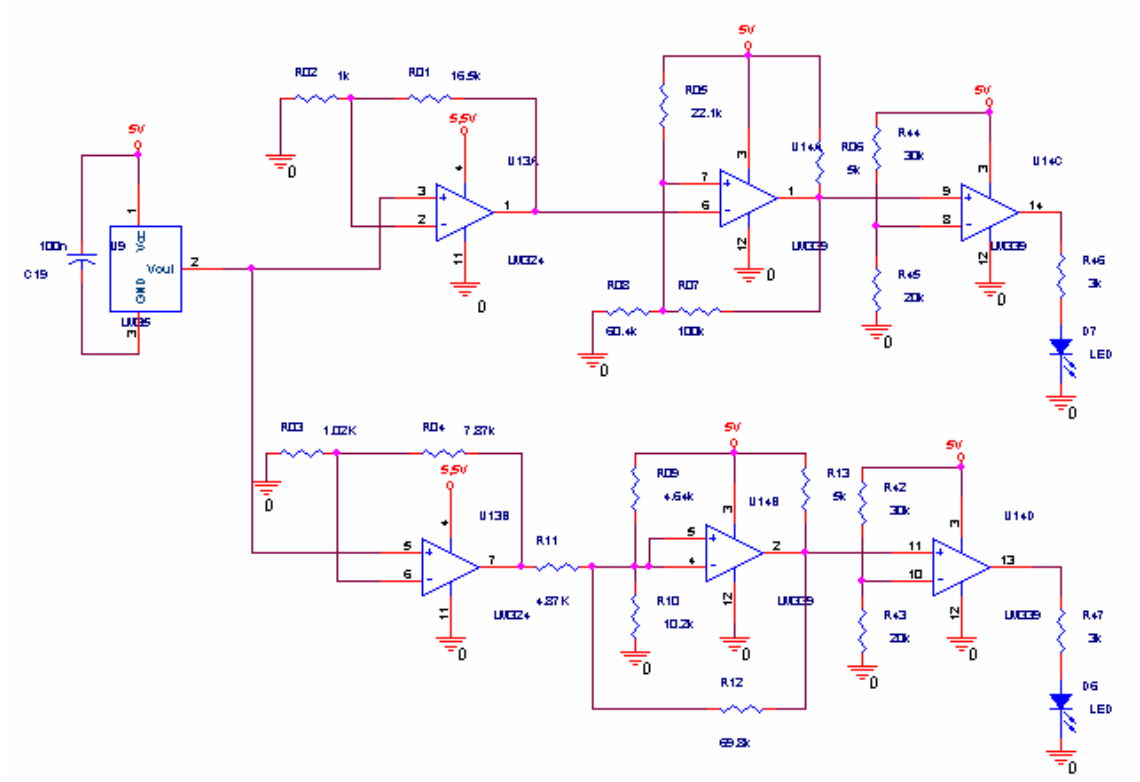
For both circuits LM339 comparators with V^+=5V and V^-=0V are used.



LM339

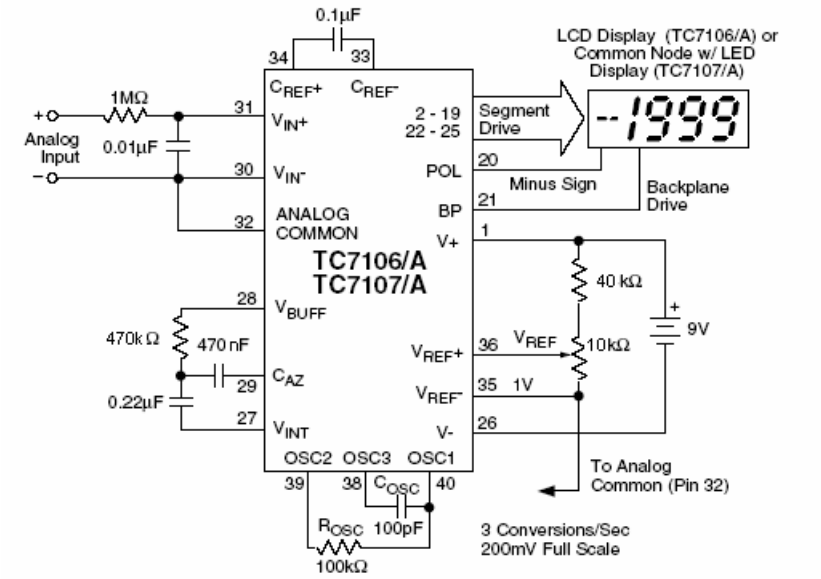
Comparator outputs are passed again through LM339 op-amps with V_T=2V to prevent loading, since the resistor values for schmit-triggers are calculated without any load. (The remaining 2 op-amps in a single LM339 IC are used for this last stage) In fact these comparator circuits act as buffers to drive LEDs which are driven with 3kΩ pull-up resistors conected to the 5V power supply.

Our design to drive LEDs outside of the threshold values is shown below:

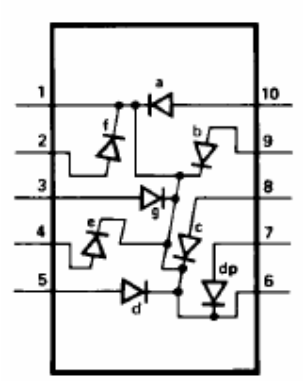


Analog to Digital Conversion and Monitoring the Temperature

We used ICL7107 analog to digital converter which drives directly LED display. We implemented the circuit seen below for 2V full scale range and 3 samples per second.

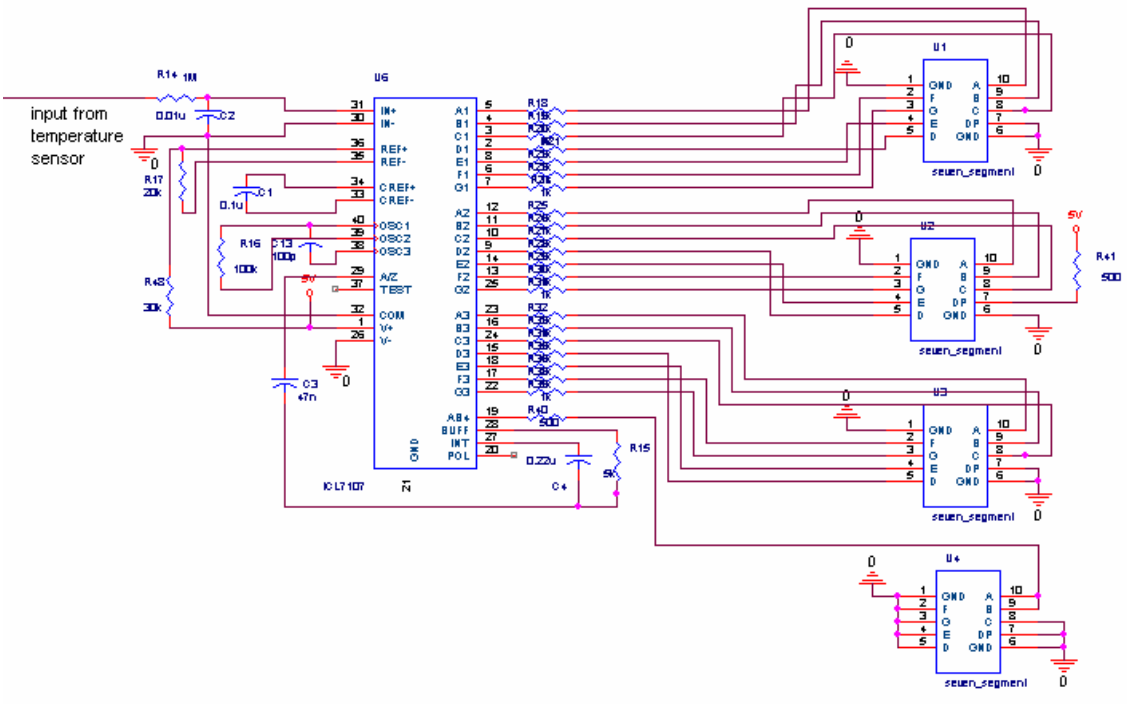


In order to monitor the digital output, HSDP-3603 common anode seven segment displays can be used. But unfortunately we had common cathode displays seen below:



HSDP-3603

Our design for this part of the project is shown below,



We implemented the circuit on the breadboard. The circuit is working well and we observed expected outputs.