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ELECTRONIC THERMOSTAT

Digital System Design

School of Technology

CONTENTS

1 ABSTRACT

In this course, we learn about the mechanism of electronic components for both analog and digital and how they can be connected and communicated to microcontrollers. We also have a chance to develop and build a small microcontroller-based system, which is a electronic thermostat in this case.

2 INTRODUCTION

We perform this laboratory report in order to record our work process during the whole course and to understand more about the concept of electronic components and how to use them to build a system. This report also resumes our total 112h work load during the course. The contents include our understanding of electronic design and mechanism of electronics components. Digital systems simulation, operations of electrical components embedded to a microcontroller, Printed Circuit Board design methods and manufacturing. EMC-interferences and testing, robust design.

3 PRE-DESIGN

3.1 Device description

As requirements, the product has to manage the property monitoring and control. The product will be used in small summer cottage or middle size summer cottage. The designed device is consumer product and it can be used for other small buildings monitoring as well. The marketing area for the product is world-wide. The product contains a temperature measurement system which can be used to measure temperature at distance of 100 meters (wireless communication cannot be used because of steel walls between measurement point and the main device).

3.2 Functional Requirements

3.2.1 Temperature Measurement

Several requirements have to be reached when implementing temperature measurement part inside products

1. The ambient of temperature is by 0.5 ° C accuracy
2. Measurement range should be at least -30 + 30 ° C
3. Measured temperature is constantly informed in device screen.

3.2.2 Communication

When implementing the communication part of device, we should also consider these conditions

1. The transmitter is capable of transferring temperature information at least 100 meters.
2. Environment contains sensors are equipped with transmitter.
3. Main unit contains intelligence and sensor inputs.
4. Transmitter does not use expensive components.
5. Communication can be used in environment which contains electromagnetic interference (communication should not get interfered because of dynamic 10 V/m electric field).

3.2.3 Heat Control

Heat control is also a necessary part of system and should meet some requirements

1. System is capable to control up to five radiators and each radiator contains three different size heat resistors.
2. Each resistor can be controlled separately and each radiator contains its own control relays.
3. User can adjust desired temperature by using keyboard (0.5° C accuracy).
4. Temperature control must take place in one second response time.

3.2.4 Antitheft Alarm System

The system is capable to maximum eight events at the same time (doors, windows or other hatches). In addition it is possible to connect five motion detectors and five smoke alarms to the system. The motion detectors and the smoke detectors will provide an alarm (binary information). The system should inform alarms by siren and flashing lights. The basic system does not need to be a remote controlled, but remote controller feature should be taken into account because of the device future generations.

It is possible to turn off the alarm system from its own keyboard. The password needed when user wants to turn off the alarm system. The alarm system should contain a delay function which means that the alarm is given after 15/30 seconds from sensor event. Delayed alarm should be informed with buzzer.

3.2.5 Temperature Registration

The functionality of temperature registration also needed to be ensured

1. Device is capable to collect measured data
2. Memory data should be big enough for one week data quantity
3. User can browse measured results in device screen or results can be sent via serial communication to personal computer
4. Measured values should be kept in the memory during power failure at least five hours

5. User can change the sampling rate of measurement values.

3.2.6 Interfaces requirements

1. Device should contain a keyboard which can be used to set value for temperature control. The keyboard can be used to feed password. The device should contain a display to show temperature values
2. The device can be controlled from personal computer which uses RS-232 communication between device and personal computer.
3. The device collects measured data and counts every single day minimum temperature, maximum temperature and average temperature
4. The device can be programmed via serial communication and the data can downloaded to personal computer via serial communication. Serial communication settings are fixed so settings not need to be changed

3.2.7 Other requirements

- Accuracy of measurement 0.5 °C
- Range of measurement. -30 °C ... +30 °C
- Response time for control 1 s
- Responding to the alarm 0.5 s
- Easy to use and no special skills needed from user.
- Must be protected against power failure. The device is able to be in idle state for at least five hours.
- Device parameters can be changed from device keyboard and from personal computer
- The device operating temperature range should be -40 °C ... 50 °C and environment relative humidity < 90%.

3.2.8 Design Restrictions

- The device should be small as possible
- Only GCC C-compiler allowed when developing the software.
- The power consumption should be as small as possible.

3.3 Block diagram of the device

Base on requirement description, we came up with the system component structure under block diagram. The block diagram can be seen under figure 1 below.

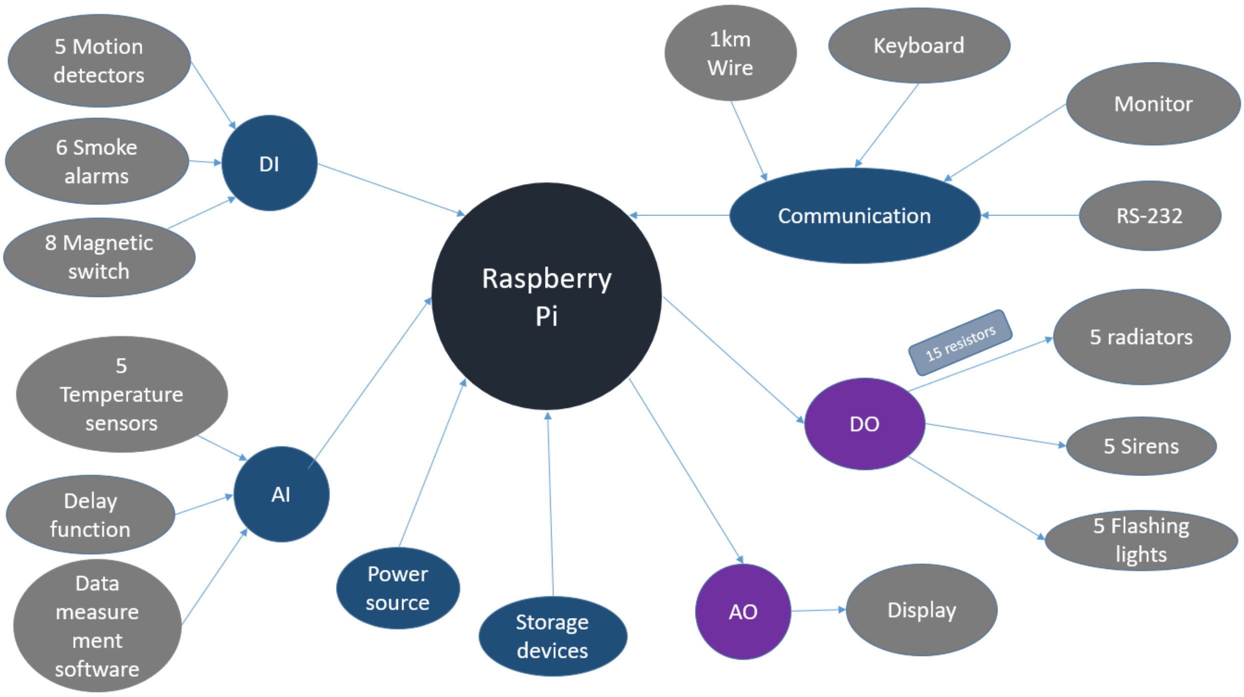


Figure 1. Block diagram that describe structure of device

Inside this block diagram, we use Raspberry Pi as a middle device that receives every input and sends out data as an output in the system. Any devices or components which is connected to Raspberry Pi as an input will have blue color, outputs are purple and outer devices will have gray color. As we defined color of different components in this way, it is easier for us to look at and build system later on.

For example, Digital Input (DI) is connected as an input device to Raspberry Pi (because it has blue color) and there are three other components also connected as inputs of DI which are: 5 motion detectors, 6 smoke alarms and 8 magnetic switches. For another example, Analog Output (AO) is connected as an output to Raspberry Pi (because it is purple) and it has other devices to connected to as its output which is Display (Display analog statistics on user device). Or simply, we just need to take a look on the arrow direction.

3.4 Device features

3.4.1 Manufacturing price

Base on the block diagram that has been defined on previous part, we will consider about device features and price for a completed device.

Components price estimate table								
ID	Name	Product code	Manufacture	Price	Quantity	Total Price	Reference	Note
1	Motion Detector	ZRE200GE	Zilog	1.96	5	9.8	Digikey	
2	Smoke Alarm	MAX30105EFD	Maxim Intergrated	3.83	6	22.98	mouser.fi	
3	Magnetic Switch	BU0009SUF08	Directed Electronics	7.41	8	59.28	amazon	
4	Temperature Sensor	BCB00SP	Melexis	10.23	5	51.15	mouser.fi	minus 40 to 88 Celcius degree
5	1km Wire	THHN	Henan Jinsui		1	0.00031	alibaba	1.55/5000m
6	RS 323	FBA_EL-PN-47307034	SF Cable	4.49	1	4.49	amazon	
7	Resistor	BONENS	Chengdu	0.1	15	1.5	alibaba	
8	Keyboard	DV7-6000	Shenzen Sistel	7.65	1	7.65	alibaba	
9	Monitor	1597-1576-ND	Seeed Technology	21	1	21	mouser.fi	
10	Radiators	F75Z8005JA	HENG AN	10	5	50	alibaba	
11	Sirens	HTK411	Yueqing Height Electrical	3	5	15	alibaba	
12	Flashing Lights	BL1175	Saip/Saipwell	3	5	15	alibaba	
13	Storage Device (HD)	RMU-1306	Shenzen Ruitek	1.5	1	1.5		
14	Raspberry Pi 3	358-RPI3-MODBP-POE	Power Management IC	21.82	1	21.82	mouser.fi	
	TOTAL COST					281.17031		

Figure 2. Component Price Estimated Table.

We have made several researches on some popular websites which sells electronic components and picked up the most suitable price and components for our digital system. The component features, quantities and prices after being filtered can be displayed on figure 2 above.

According to our research, the whole system cost will be approximately in 281 Dollar (which is around 240 Euro). The estimated duration to manufacture and finish this system will range from 50 to 100 hours with 2-3 people work together. Base on Finnish work labor statistics, it costs around 10-15 Euro to hire a person to work in 1 hour. To sum up, base on our research about devices features and prices as well as work labor statistics, we come up with the total price below

$$Maximum\ Manufacturing\ Cost = Components + Manufacturing\ Costs$$

$$Maximum\ Manufacturing\ Cost = \ 281 + 100\ \times\ 3 = 581\ Euro$$

So, the maximum manufacturing cost for this digital system can be reach to 581 Euro as the highest peak.

With each system, we estimated profit for company is about 100-150 Euro. So, the total cost that customer may have pay for this can be calculated as

$$Total\ Cost = Maximum\ Manufacturing\ Cost + Company\ Profit$$

$$Total\ Cost = 581 + 150 = 731\ Euro$$

Base on the result, the total amount that customers need to pay for the whole system is estimated as 731 Euro for each.

3.4.2 Accuracy of measurement

The temperature sensor which was chosen on previous part ranges from -40 to 80 degree of Celsius with accuracy value is 0.5 °C. It has a larger range than requirements (which ranges from -30 °C to 30 °C)

So, with this temperature sensor, the smallest measurable change in temperature with this temperature sensor is 0.5 °C. And the minimum operating temperature is -40 °C and the highest one is 80 °C.

3.5 Different communication methods

The comparison between different communication methods can be seen under the table below, based on several factors : Distance between transmitter and receiver, external factor communication, price, advantages and disadvantages.

Almost price statistics were taken from amazon so that we can have a fair comparison when comparing the price among devices.

	Distance	External factor communication	Price	Advantages	Disadvantages
Current loop	600m	For serial communication, a current interface that uses current instead of voltage for signaling. Current loops	100-150 USD	Long distance and noise immune transmission of data	No mechanical or electrical standard

		can be used over moderately long distances			
RS232	50ft	Serial communication, used to connecting computer and its peripheral devices to allow serial data exchange between them.	14.95 USD	RS232 interface is supported in many compatible legacy devices due to its simplicity It supports long distances and with error correction capabilities. Low cost and immune to noise	It is not suitable for chip to chip or chip to sensor device communications. Supports lower speed for long distances. RS232 interface requires separate transceiver chips which will add cost to the system. It is unbalanced transmission.
RS485	4000ft	Star and ring topologies are not recommended because of signal reflections or excessively low or high termination impedance. If a star configuration is unavoidable, special RS-485 repeaters are available which bidirectionally listen for data on each span and then retransmit the data onto all other spans.	15.95 USD	Immune to noise.	It supports single master and multiple slaves.
RS232VSCurrent loop	500ft	can accept loop currents of either 20mA or 60mA and convert them to RS-232 data.	82 EUR	Provide better protection against the electrical interference generated by the air	

		suited to protecting data communication being carried out in environments where the terminating equipment has high voltage sources.		conditioning unit, it can accept loop currents of either 20mA or 60mA and convert them to RS-232 data.	
CAN BUS		communicate with each other in applications without a host computer	14.55 USD	Supports distributed real-time control with a very high level of security. Provide feature improves the network reliability and transmission efficiency	It is likely to have undesirable interactions between nodes. CAN driver must produce at least 1.5V across typical 60 Ohm. Network should be wired in topology which limits stubs as much as possible.
MOD BUS		communication among many devices connected to the same network, for example, a system that measures temperature and humidity and communicates the results to a computer.	49.99 USD	offers flexibility of type of data that can be communicated to other devices. Data transfer designed for industrial applications Moves raw bits or words without placing restrictions on vendors	No standard method for a node to find the description of a data object, i.e. finding a register value represents a temperature between 30° and 175°. No security against unauthorized commands or interception of data Transmissions must be contiguous which limits the types of remote communications devices to those that can buffer data

					to avoid gaps in the transmission.

Table 1. Comparison between different communication method

According to our research, the cheapest solution to transfer can be found are RS232VSCurrent loop and RS232, with the price is approximately 15 Euro.

4 ANALOG SIGNAL PROCESSING

4.1 Design

In this part, we will design temperature sensor circuit, buffer circuit and differential amplifier circuit. Sensor LM35 output voltage will change -0.3V to +0.3V when environment temperature changes -30 C to +30 C. The differential amplifier will be used to gain input voltage (-0.3V to 0.3V) to wanted level (0V-3V) as we can see under figure 3 below.

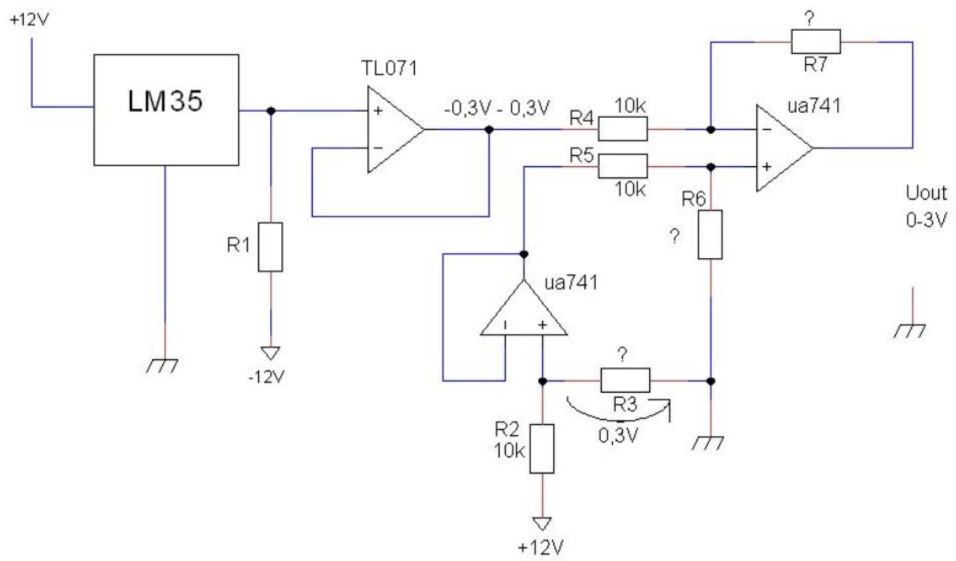


Figure 3. Differential amplifier circuit

The calculation process for two unknown components can be described below.

- **R1**

  We will first start with R1

$$R1 = -\frac{V2}{50uA} = \frac{12}{50uA} = 240k$$

- **R3**

  According to the voltage divider equation, we have

$$\frac{U3}{R3} = \frac{U2}{R2}$$

We also have $U3 = 0.3V, U2 = 12 - 0.3 = 11.7V$

$$\frac{U3}{U2} = \frac{R3}{R2} = \frac{1}{39}$$

$$R3 = \frac{1}{39} \times R2 = \frac{1}{39} \times 10000 = 256.41$$

- **R6, R7**

  According to differential amplifier equation, we have : $R6 = R7$

  $$Vout = \frac{R7}{R5}(Va - Vb)$$

  We also have : $Vout = 3V$

  $$R7 = -\frac{Vout\ R5}{Va - Vb} = -\frac{3\ \times 10k}{(-0.3 - 0.3)} = 50k$$

  So, in this case: $R6 = R7 = 50k$

4.2 Simulation

After calculating unknown component values, we have the LTSpice simulation as can be seen under figure below. In this simulation, we measured and plotted the diagram of I1 and V1

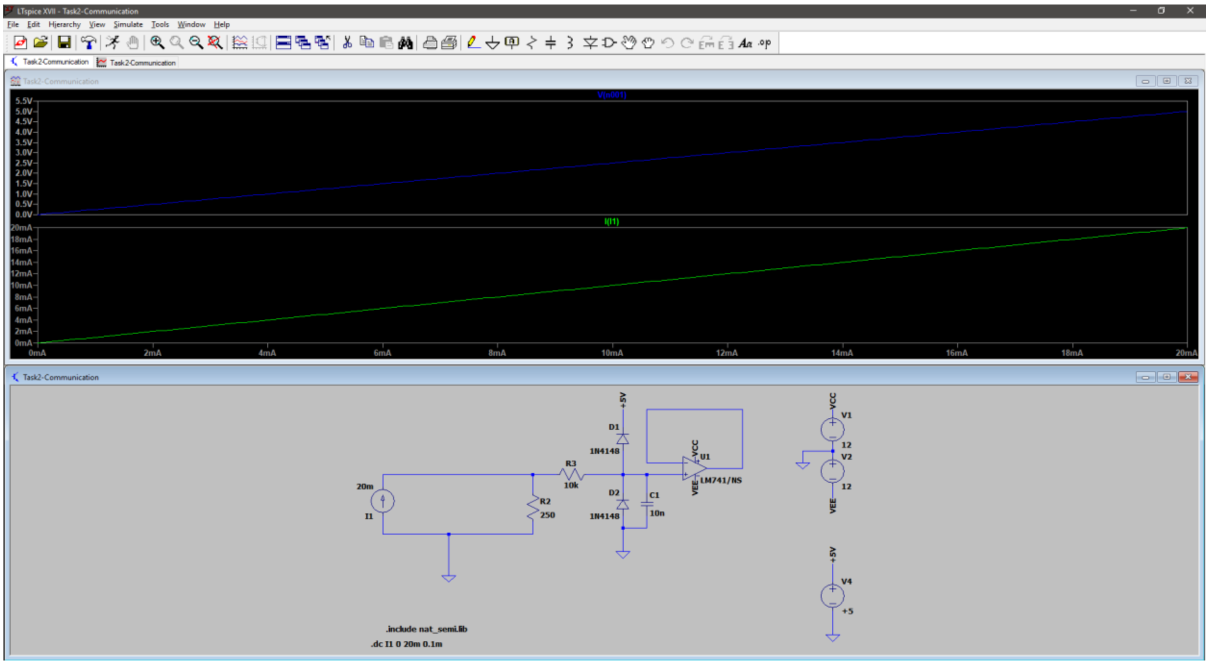


Figure 3. Simulation using LTSpice.

We can see that the two diagrams are corresponding to each other.

- V1 ranges from 0V to 5.5V
- I1 ranges from 0A to 20mA

With V1 = 0V, we have I1 = 0A as a corresponding value

With V1 = 5.5V, we have I1 = 20mA as a corresponding value.

4.3 Circuit testing and verification in breadboard

The breadboard general schematic can be found under figure 4 below.

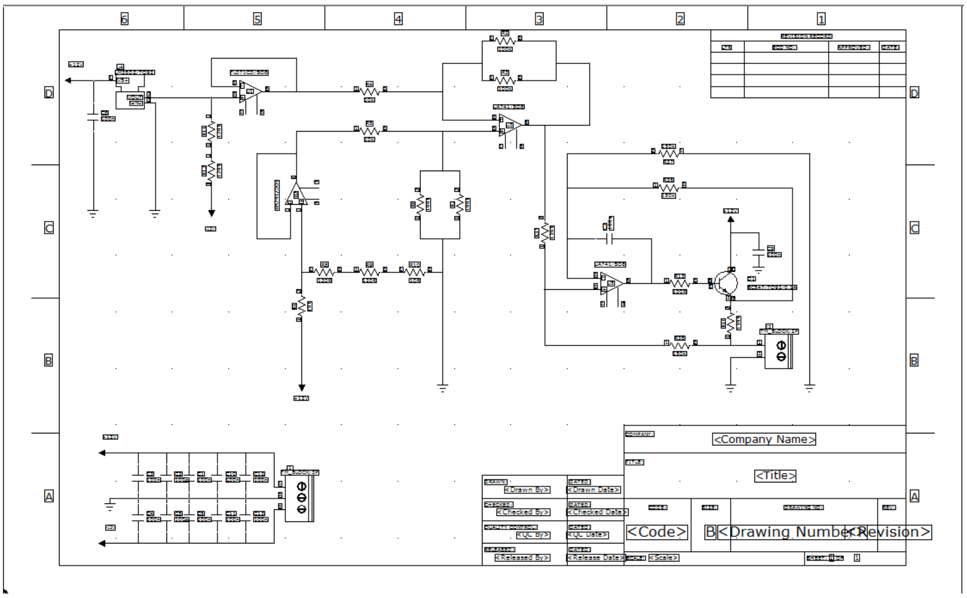


Figure 4. Bread board schematic

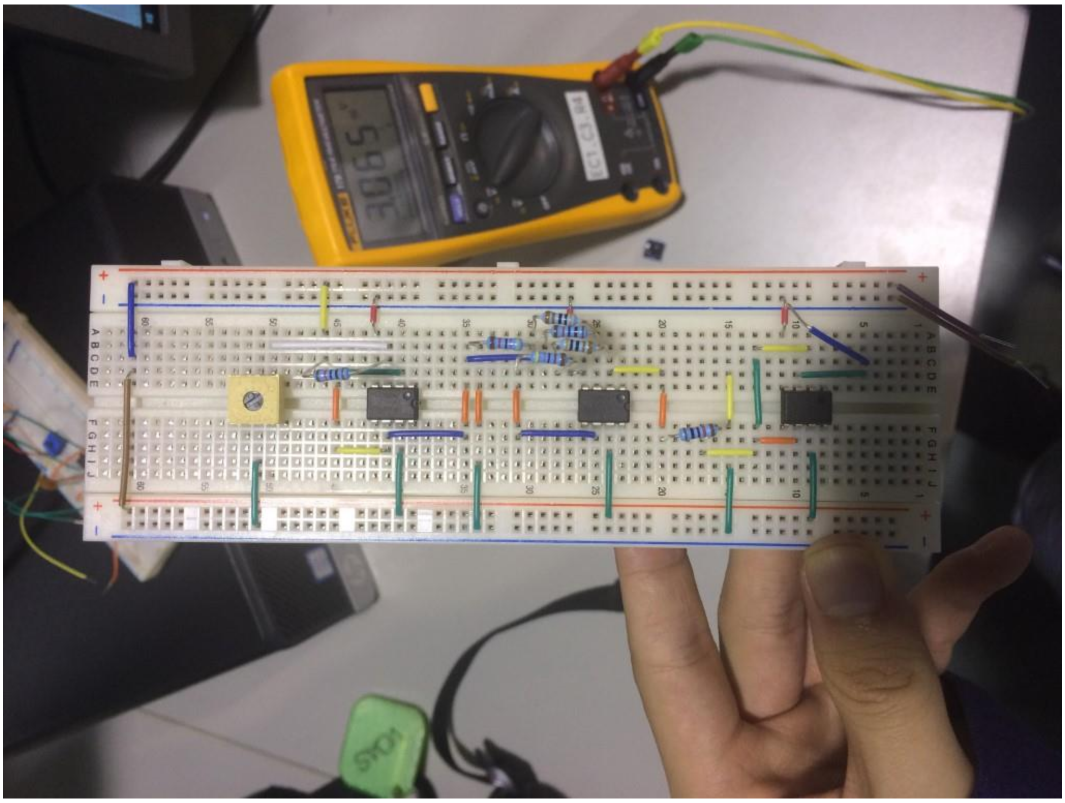
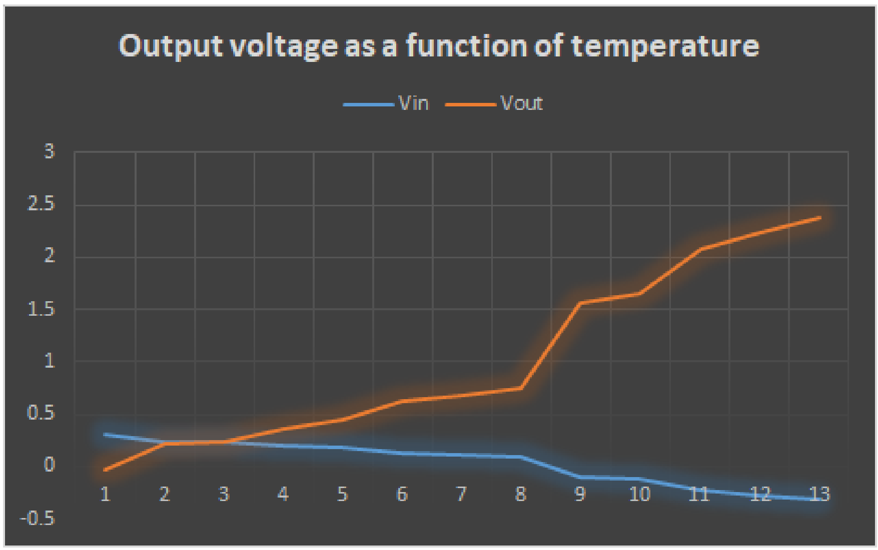


Figure 5. Bread board circuit

After finishing the circuit on breadboard, we did some measurement with input voltage (Vin) and output voltage (Vout). Hence, we came up with the statistics can be seen under figure 5 below.

From statistics gain from table, we can plot the diagram with two separated lines: the blue line represents Vin while orange line represents Vout. The Vout line graph increases while in the same time, Vin line graph is quiet decreasing by time.



Vin	Vout
0.3	-0.324
0.241	-0.025
0.237	-0.002
0.203	0.166
0.181	0.266
0.135	0.493
0.121	0.566
0.103	0.654
-0.101	1.673
-0.121	1.775
-0.23	2.313
-0.268	2.502
-0.304	2.679

Figure 5. Output Voltage as a function of temperature diagrams and statistics

4.4 Electronic thermostat design for radiation

In this task, we simulate our circuit design of amplifier comparator with hysteresis which can be used as an electronic thermostat. LM35 is used to measure the environment temperature and operational amplifier controls the relay output.

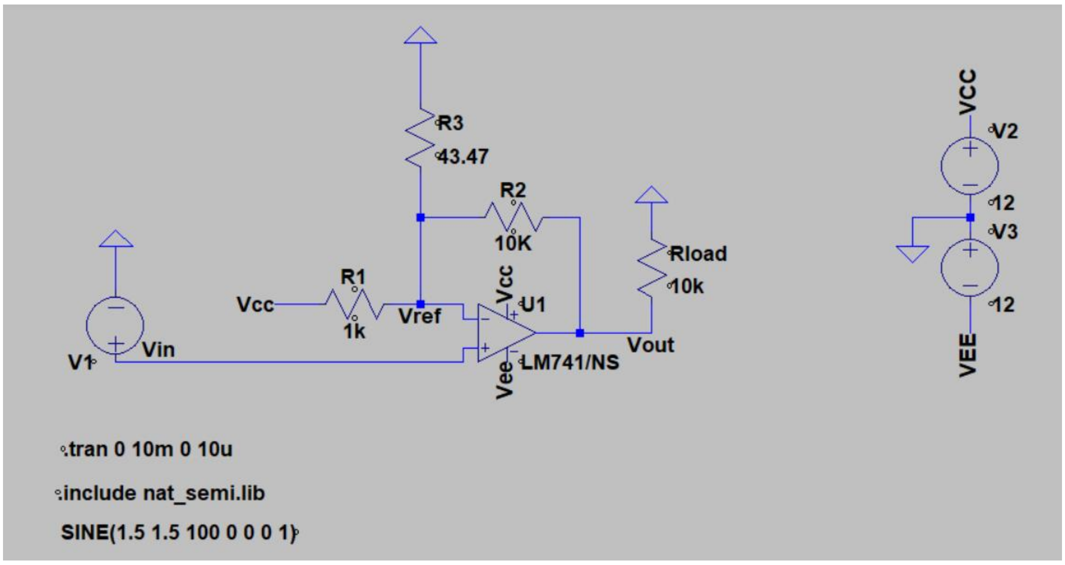


Figure 5. Electronic thermostat using LTSpice

The circuit plotting diagram can be seen under figure 6 below with three lines represent for three variables : V out, V in and V ref

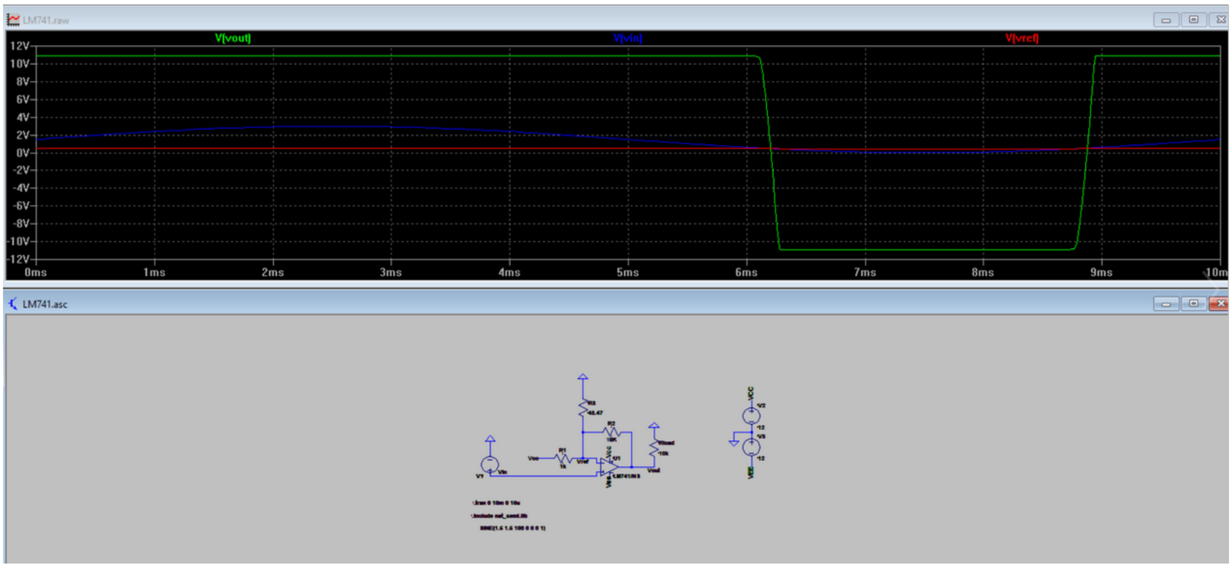


Figure 5. Electronic thermostat plotting diagram using LTSpice

5 COMMUNICATION

5.1 Transmitter

5.1.1 Design and calculation

In the previous part, we have designed and simulated temperature sensor circuit, buffer circuit and a differential amplifier circuit. The solution is also tested and verified in bread board.

In this part, we continue to build the remain part of system, transmitter. To simply understand, the output of previous system is designed as an input for this system. We have done the first part, now we continue moving on to next part. The circuit can be seen under figure 7 below

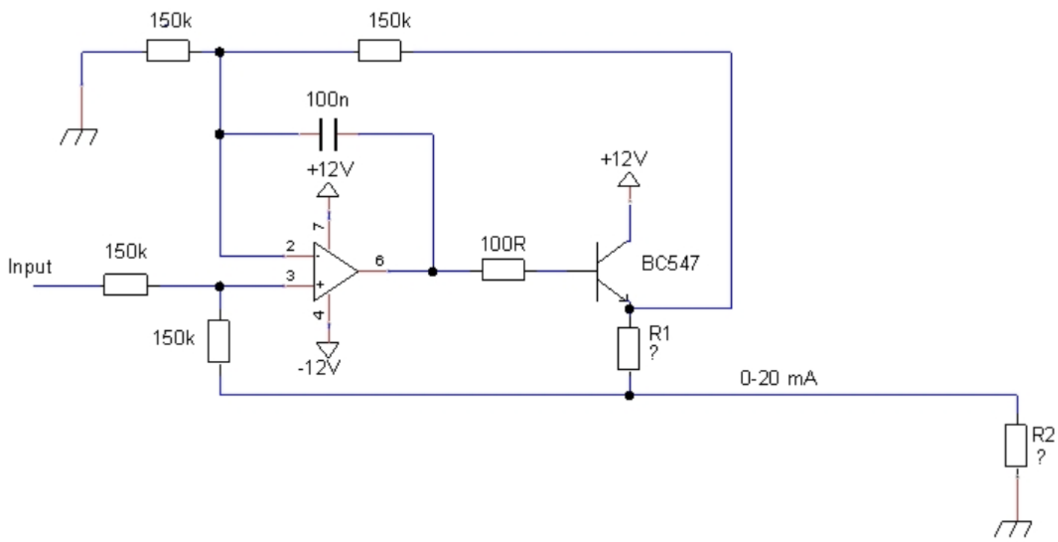


Figure 7. Communication Transmitter

- The **BC548** is a general-purpose NPN bipolar junction transition commonly used in European and American electronic equipment. It is notably often the first type of bipolar transistor hobbyists encounter and is often featured in designs in hobby electronics magazines where a general-purpose transistor is required. The BC548 is low in cost and widely available.
- An **LM741** operational amplifier is a DC-coupled high gain electronic voltage amplifier. It has only one op-amp inside. An operational amplifier

IC is used as a comparator which compares the two signal, the inverting and non-inverting signal. The main function of this IC is to do mathematical operation in various circuits. Op-amps have large gain and usually used as Voltage Amplifier. The LM741 can operate with a single or dual power supply voltage.

- In order to have 0-20 mA current through R1 when input voltage varies 0-3 V DC and current 20 mA flows in circuit the resistor R2 must have 5V over it, the value of R1 and R2 should be

$$R1 = \frac{Vin}{I} = \frac{3V}{20mA} = 150\Omega$$

$$R2 = \frac{V2}{I} = \frac{5V}{20mA} = 250\ \Omega$$

5.1.2 Simulation

Base on the obtained result on previous part, we come up with this circuit simulation on LTSpice. As can be seen on plotting area under figure 8 below, two values have been simulated. We can easily see that :

- With I = 0A, the corresponding value of V = 0V
- With I = 20mA, the corresponding value V = 5V

These simulation are exactly the same with requirements on design part.

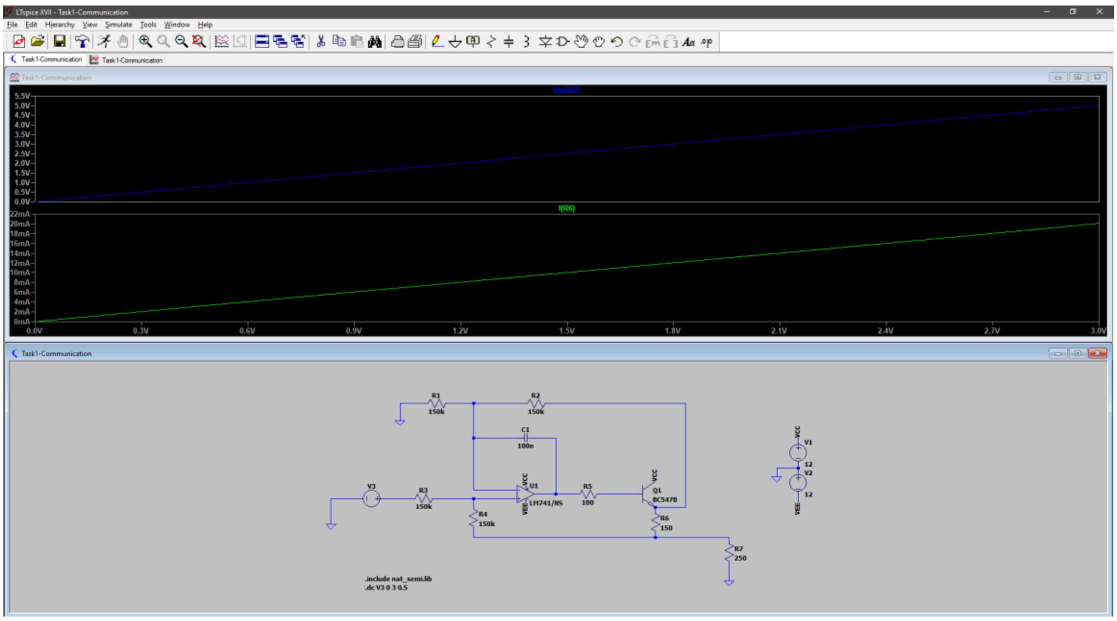


Figure 8. Communication Transmitter Simulation

5.1.3 Breadboard circuit testing and verification

The bread board implemented on circuit can be seen on figure 9 below. At this point, we are testing and verifying this circuit using multimeters.

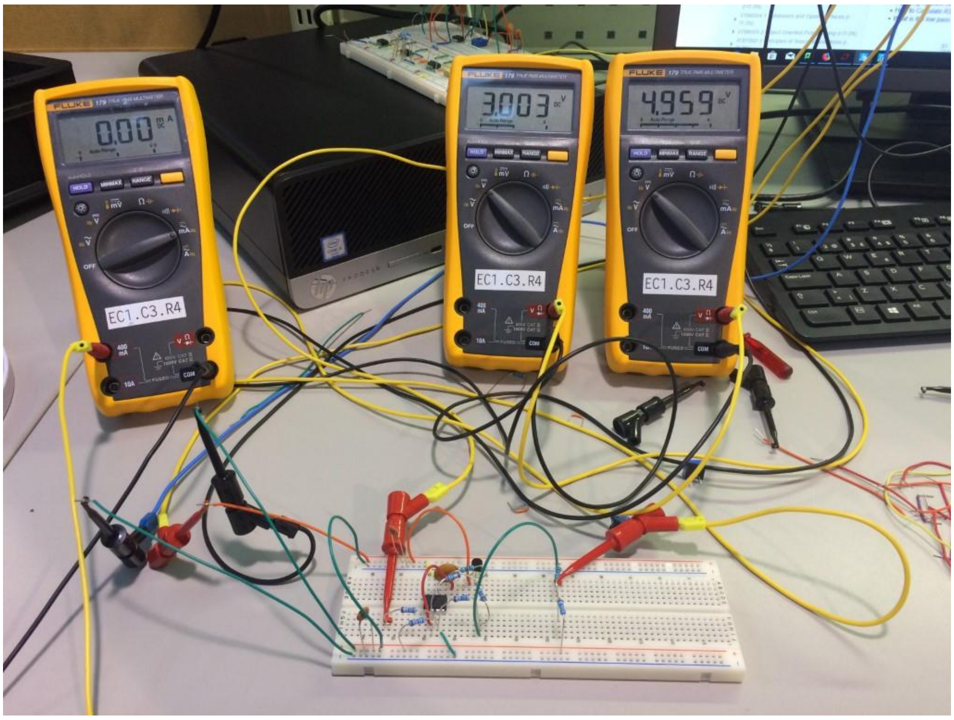


Figure 9. Communication Transmitter Circuit

After finishing the circuit on breadboard, we did some measurement with input voltage (Vin) and output voltage (Vout). Hence, we came up with the statistics can be seen under figure 10 below.

From statistics gain from table, we can plot the diagram with two separated lines: the blue line represents Vin while orange line represents Vout. Both line graphs have the same trend which are decreasing.

Vin	Vout
3	4.95
2.83	4.69
2.34	3.86
1.91	3.16
1.6	2.66
1.17	1.93
0.73	1.21
0.47	0.78
0.15	0.25
0.02	0.04

Figure 10. Communication Transmitter Diagram and Statistics

5.2 Receiver

5.2.1 Design and Calculation

The design of receiver can bee seen under figure 11 below.

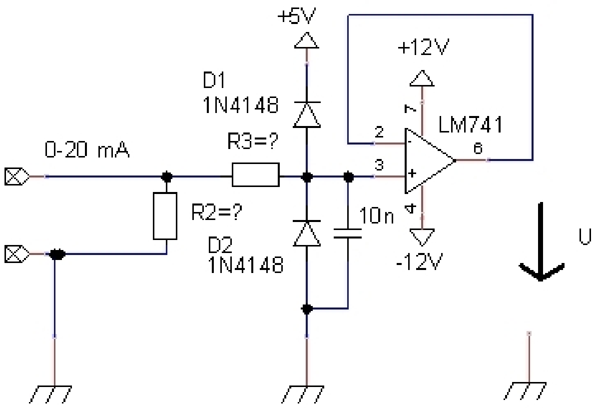


Figure 11. Communication Receiver Circuit

In order to have input signal contains 8 kV ESD discharge voltage and that current during this ESD event through D1 or D2 is 0.8A, we should have value of R2 and R3 as below

$$R2 = \frac{Vin}{I} = \frac{5V}{20mA} = 250\Omega$$

$$R3 = \frac{V3}{I3} = \frac{8000V}{0.8A} = 10000\ \Omega$$

The low pass filter cut-off frequency is

$$f = \frac{1}{2\pi RC} = \frac{1}{2\pi \times 10000 \times 10 \times 10^{-9}} = 1600\ Hz$$

5.2.2 Communication Receiver Simulation

Base on the obtained result on previous part, we come up with this circuit simulation on LTSpice. As can be seen on plotting area under figure 8 below, two values have been simulated. We can easily see that :

- With I = 0A, the corresponding value of V = 0V
- With I = 20mA, the corresponding value V = 5V

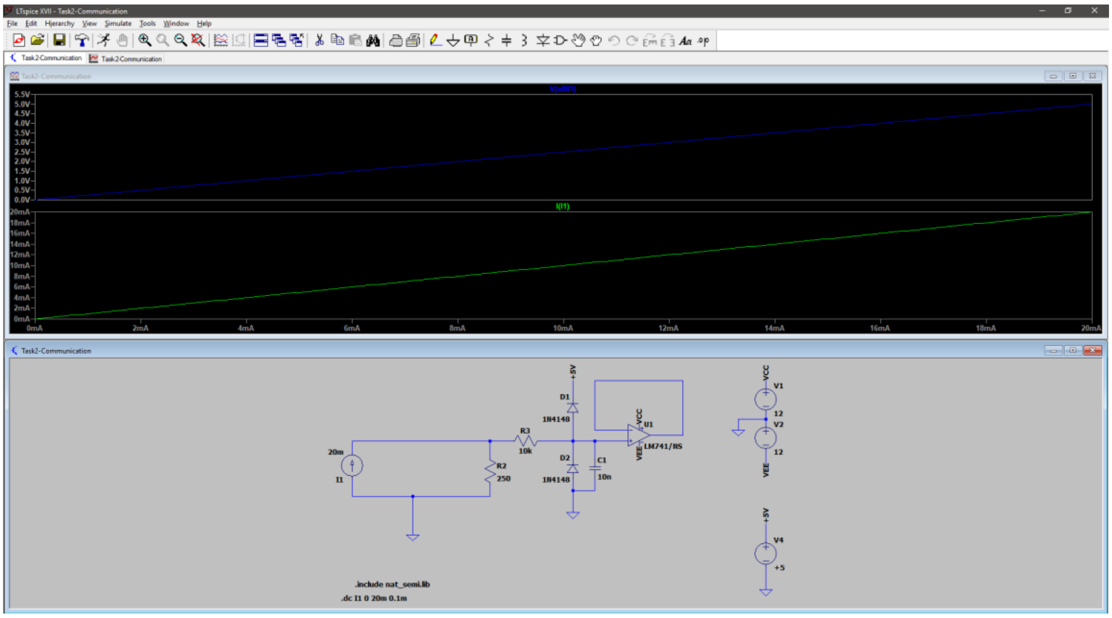


Figure 12. Communication Receiver Simulation

5.3 Test system in bread board

The receiver circuit bread board after being implemented can be seen as in the Figure 13 below. In this testing, we replace LM35 by DC-power supply and adjust -

0.3V to +0.3V using 0.1V steps. Measure current from current loop and measure receiver output voltage.

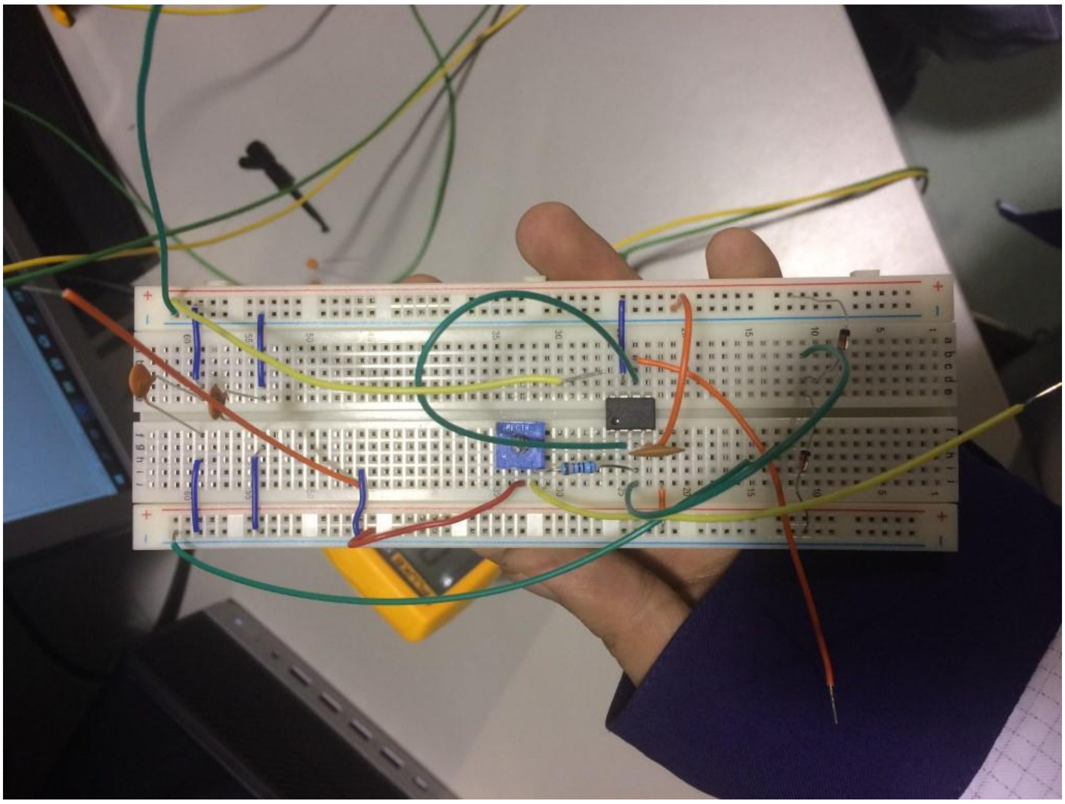
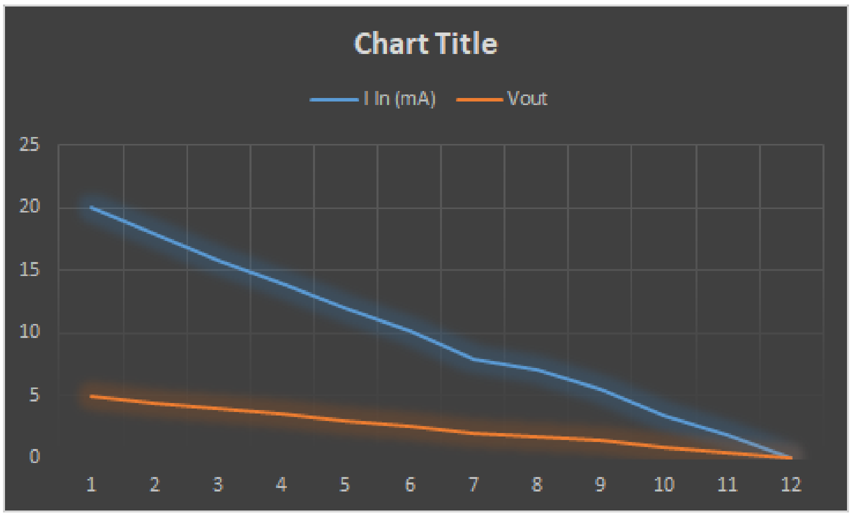


Figure 12. Communication Receiver Bread Board Circuit

After that, we did some measurement with input current (I in) and output voltage (V out) of the receiver. Hence, we came up with the statistics can be seen under figure 11 below. From statistics gain from table, we can plot the diagram with two separated lines: the blue line represents Iin while orange line represents V out.



I In (mA)	Vout
20.05	4.96
17.88	4.42
15.79	3.9
14.05	3.47
12.02	2.97
10.21	2.52
7.95	1.964
7.03	1.73
5.56	1.37
3.38	0.84
1.87	0.46
0.03	0.008

Figure 13. Communication Receiver Diagram and Statistics

6 ANALOG TO DIGITAL CONVESION

6.1 Design

The different between MCP3002 and ADC0832 chips is described as

- MCP3002 is a 10-bit Analog-to-Digital Converter (ADC) combines high performance and low power consumption in a small package, making it ideal for embedded control applications. MCP3002 features 200k samples/second, 2 input channels, low power consumption (5nA typical standby, 520µA typical active), and is available in 8-pin PDIP, SOIC and TSSOP packages.
- ADC0832 is an 8-bit successive approximation A/D converter with a serial I/O and configurable input multiplexers with up to 8 channels. The 2-, 4- or 8-channel multiplexers are software configured for single-ended or differential inputs as well as channel assignment.

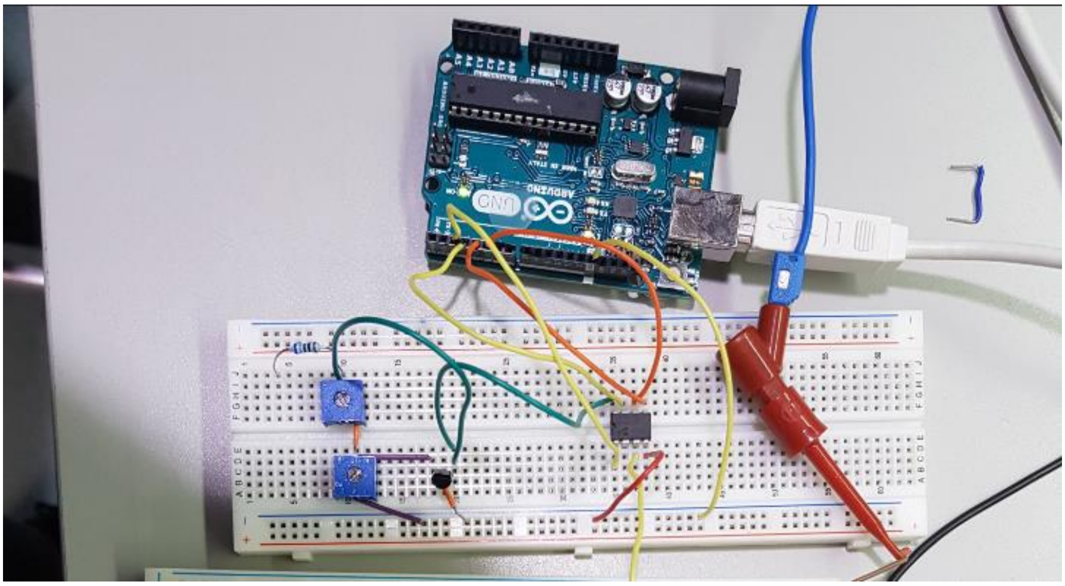


Figure 14. Circuit for the ADC use to measure temperature

6.2 PADs Simulation

In this section, we design circuit for the ADC so that we can use it to measure temperature with temperature information comes from receiver circuit. The receiver circuit output is 0V to 5V. In this section, we use reference chip LM431.

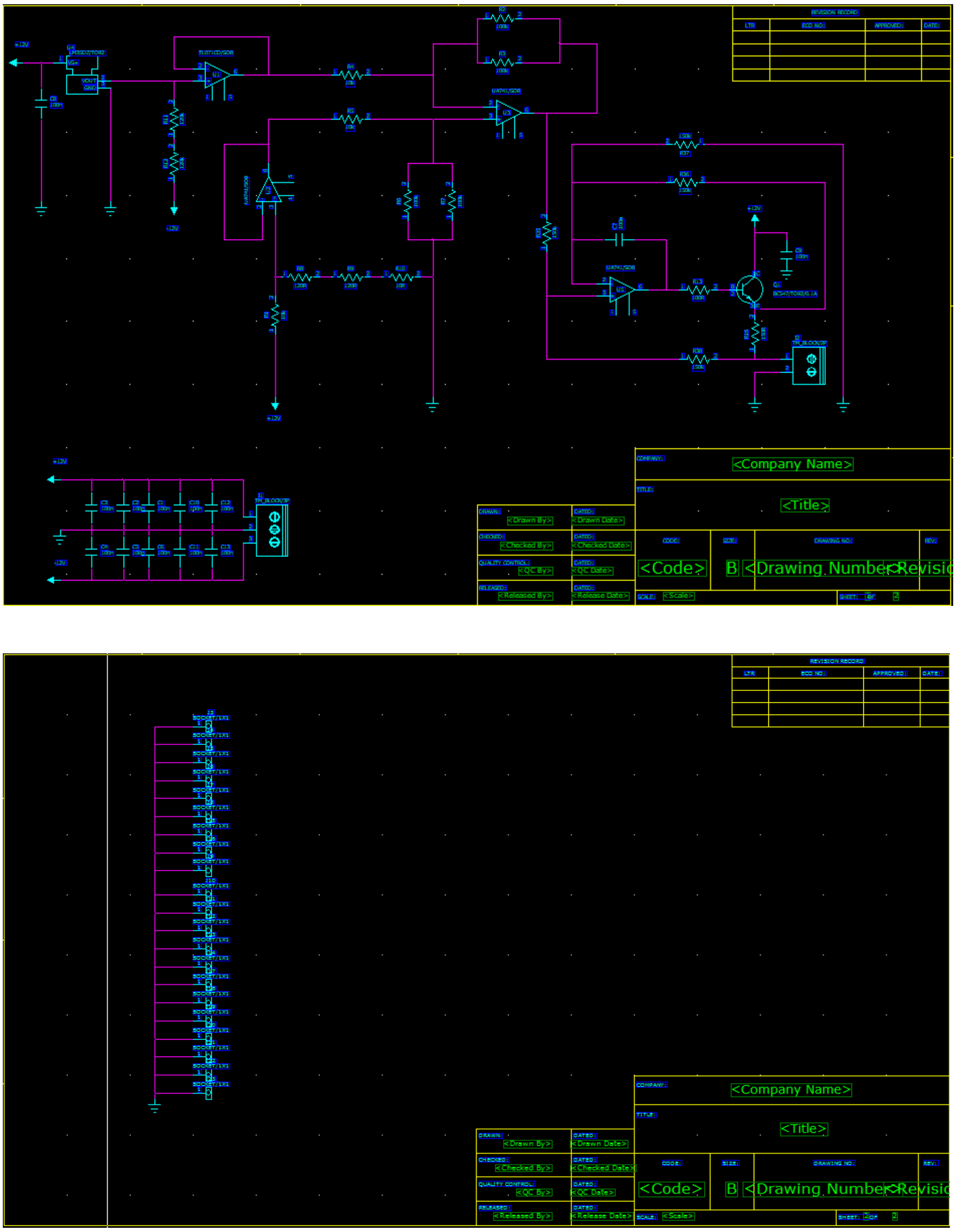
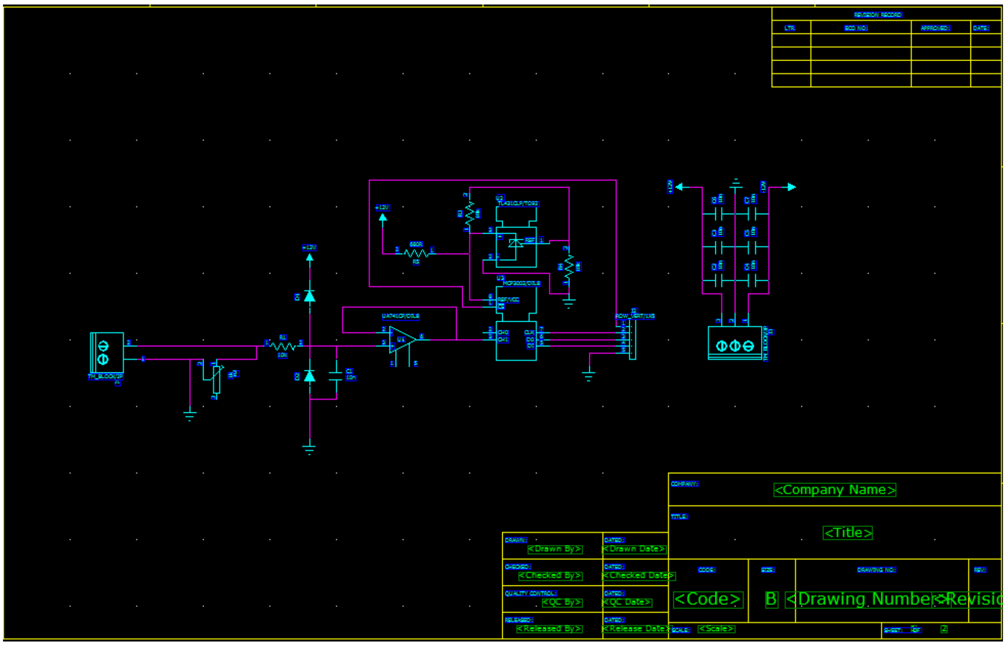


Figure 15. PADS Logic schematic for transmitter circuit



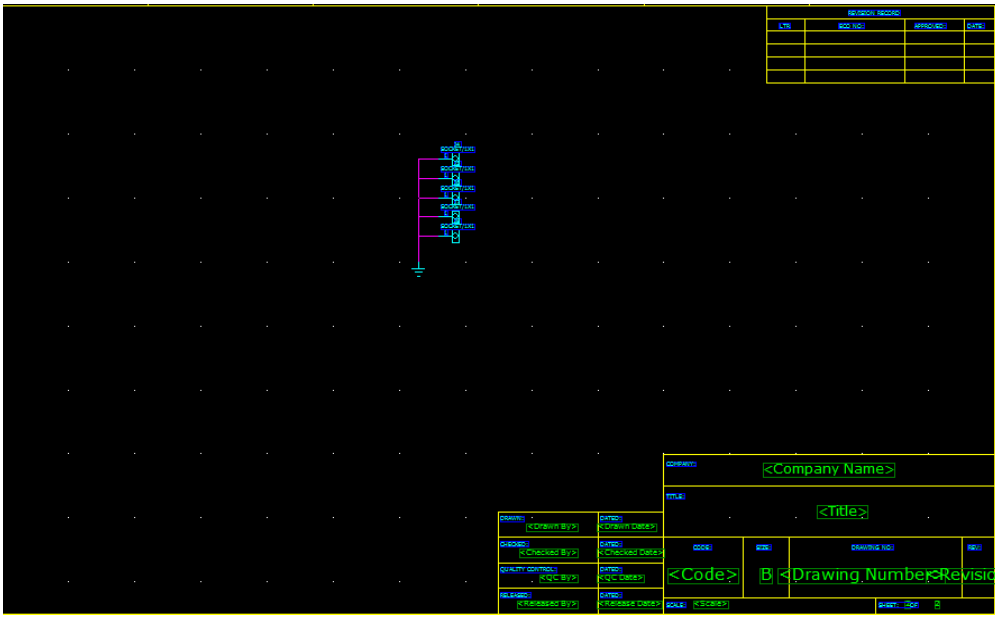


Figure 16. PADS Logic schematic for receiver circuit

7 SCHEMATIC

7.1 Design transmitter and receiver using PADs

Our PADs design for transmitter and for receiver can be seen in figure 17.

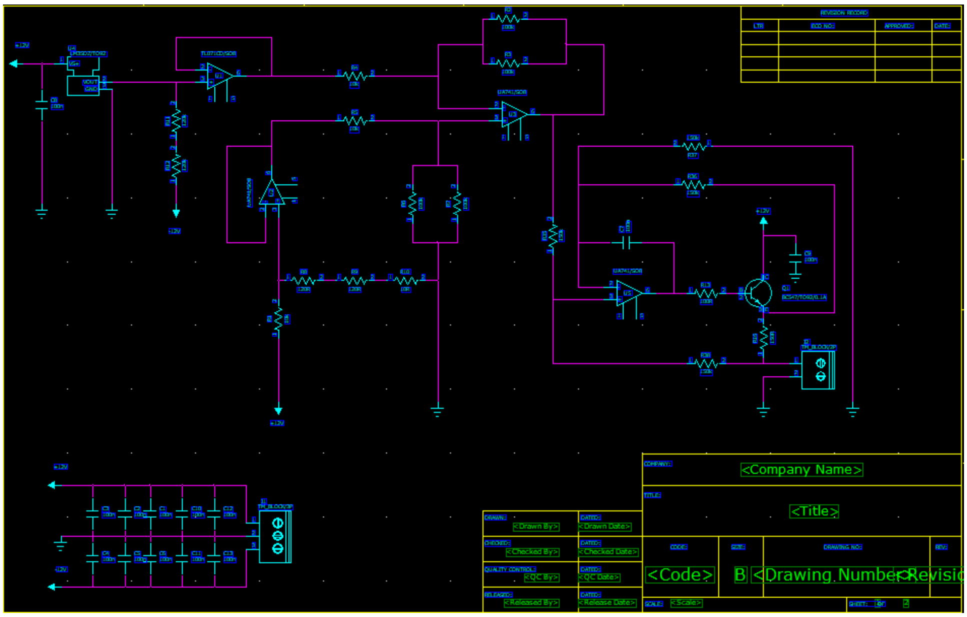


Figure 17. PADS Logic schematic for receiver circuit

7.2 Design printed circuit board (PCB)

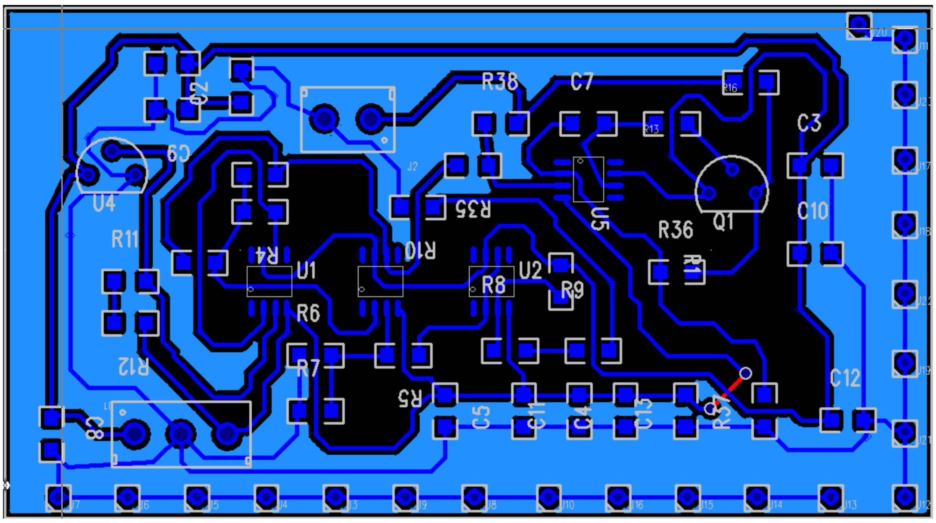


Figure 18. PCB board for the transmitter

Bill Of Materials for LM35.sch on Tue Dec 18 09:03:23 2018

Item	Qty	Reference	Part Name	Manufacturer	Description
1	4	R2-3R6-7	100K/5%/0.125W,100k,+-5%	Multicomp	SMD resistor
2	13	C1-13	100NF/50V/CER,100n,+-10%	Kemet	Multilayer ceramic SMD capacitor
3	1	R13	100R/5%/0.125W,100R,+-5%	Multicomp	SMD resistor
4	3	R1R4-5	10K/5%/0.125W,10k,+-5%	Multicomp	SMD resistor
5	1	R10	10R/5%/0.125W,10R,+-5%	Multicomp	SMD resistor
6	2	R11-12	120K/5%/0.125W,120k,+-5%	Multicomp	SMD resistor
7	2	R8-9	120R/5%/0.125W,120R,+-5%	Multicomp	SMD resistor
8	4	R35-38	150K/5%/0.125W,150k,+-5%	Multicomp	SMD resistor
9	1	R16	150R/5%/0.125W,150R,+-5%	Multicomp	SMD resistor
10	1	Q1	BC547/TO92/0.1A, BC547/TO92/0.1A	NATIONAL SEMICONDUCTOR	AMPLIFIER NPN SILICON TRANSISTOR
11	1	U4	LM35DZ/TO92, LM35DZ/TO92		Analog PRECISION TEMPERATURE SENSOR
12	21	J3-23	SOCKET/1X1, Socket, IC		Socket, IC
13	1	U1	TL071CD/SO8, TL071CD/SO8		LOW NOISE, JFET INPUT, OPERATIONAL AMPLIFIER
14	1	J2	TM_BLOCK/2P, Socket, Power Terminal Block, 3 way		Socket, Power Terminal Block, 3 way
15	1	J1	TM_BLOCK/3P, Socket, Power Terminal Block, 2 way		Socket, Power Terminal Block, 2 way
16	3	U2-3U5	UA741/SO8, UA741/SO8		OPERATIONAL AMPLIFIER

Figure 19. Bill of Material for Transmitter circuit

Bill Of Materials for receiver.sch on Wed Dec 19 00:03:30 2018

Item	Qty	Reference	Part Name	Manufacturer	Description
1	3	R1R3-4	10K/5%/0.125W, 10k,+-5%	Multicomp	SMD resistor
2	7	C1-7	10NF/50V/CER, 10n,+-10%	Kemet	Multilayer ceramic SMD capacitor
3	2	D1-2	1N4148/0.2A, 1N4148	Philips	High-speed diodes
4	1	R5	680R/5%/0.125W ,680R,+-5%	Multicomp	SMD resistor
5	1	U3	MCP3002/DIL8, TLC0832IP/DIL8		A/D-converter 12-bit, internal reference 2-channel, SPI-bus
6	1	J2	ROW_VERT/1X5, Plug, Vertical Row Header		Plug, Vertical Row Header
7	5	J4-8	SOCKET/1X1, Socket, IC		Socket, IC
8	1	U2	TL431CLP/TO92, TL431CLP/TO92		Adjustable Micropower Voltage Reference 1,24-5,30V
9	1	J1	TM_BLOCK/2P, Socket, Power Terminal Block, 3 way		Socket, Power Terminal Block, 3 way
10	1	J3	TM_BLOCK/3P, Socket, Power Terminal Block, 2 way		Socket, Power Terminal Block, 2 way
11	1	R2	TRIMMER/1K,1k		Trimmer, 1k
12	1	U1	UA741CP/DIL8, uA741CP/DIL8		OPERATIONAL AMPLIFIER

Figure 20. PCB board for the transmitter.

8 PRINTED CIRCUIT BOARD DESIGN

8.1 Explain following terms: EMC and EMI?

EMI: can be defined as electromagnetic energy which affects the functioning of an electronic device. EMI source is another electronic device or electrical system. While EMI can be generated from any electronic device, certain equipment and components are more likely to have disturbances than others.

EMC: is a measure of a device's ability to operate as intended in its shared operating environment while, at the same time, not affecting the ability of other equipment within the same environment to operate as intended. Evaluating how a device will react when exposed to electromagnetic energy is one component of this, known as immunity (or susceptibility) testing.

8.2 You need to make your PCB (embedded system) compliant with EMC. List the basic rules which your PCB should fulfill?

- Ground planes, copper areas covering smaller or larger areas of the board
- Connect the PCB copper plane to the signal ground and ground plane to the ground net
- Use short cables and smaller package
- Distance from the ground plane to the edge of the board should be at least 0.5 mm and solder pads and wires are 0.25 mm
- Current mode should be installed
- Electromagnetic loop loop should be as small as possible
- Use component in correct size.
- Having a proper distance between components.

8.3 Why we need decoupling capacitor for each chip

By decoupling capacitor,noise caused by other circuit elements is shunted through the capacitor, reducing the effect it has on the rest of the circuit. It also prevents the resistor absorbing a portion of the AC output power of the amplifier.

8.4 What is the inductance (nH/cm) for PCB-trace which w = 10 cm, wt = 1mm and h = 0.9 mm (hint: check curve in page 9)?

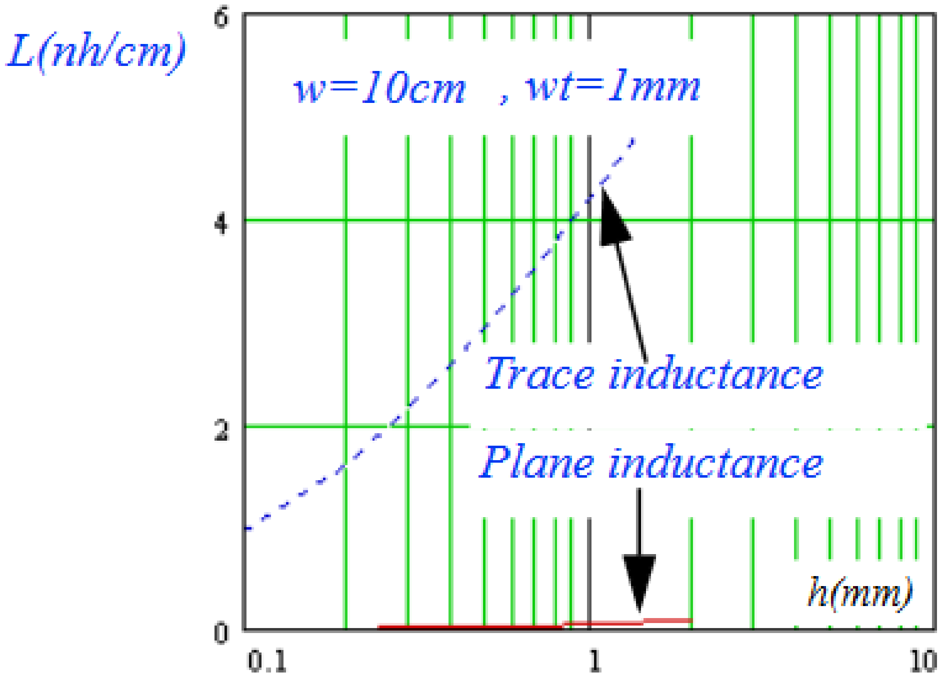


Figure 21. A VSS plane has a lower trace inductance and reduces the PCB track inductance

According to the graph has been shown on figure 21, when comparing value of a PCB-trace which has the specified value: w = 10cm, wt = 1mm and h = 0.9mm, we got the result of the inductance is approximately 4nh/cm

8.5 In circuit theory capacitor is pure (ideal) capacitor. Which components you need to model real world capacitor?

Component which is needed to model a real world can be listed below:

1. 2 metal plates
2. 1 dielectric.

The dielectric can be made out of all sorts of insulating materials: paper, glass, rubber, ceramic, plastic, or anything that will impede the flow of current.

9 CONCLUSION

After this laboratory exercise, we understand more about the mechanism of electronics components (analog and digital) and know how they can be connected to a microcontroller. We also learn about the design process of electronic systems. We have chance to build a small microcontroller-based system.

10 REFERENCES

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