Principles of Measurement & Instrumentation I Laboratory

PHYS417

Experiment 1-Methods of Signal Conversion: Analog to Digital Conversion & Digital to Analog Conversion

Lab-Report

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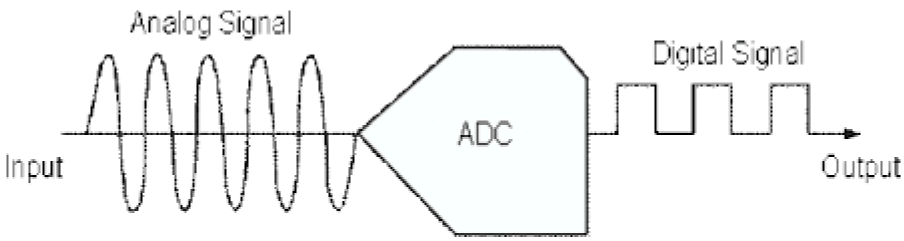
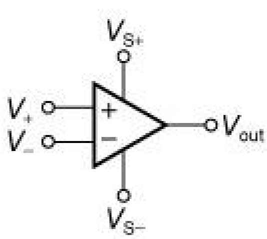
Objectives

The purpose behind the experiment was to understand what is an analog signal, and a digital signal. How to convert these two to each other. What are the discrete peaks in digital signal representation and the possible errors of these types of Analog to Digital and Digital to Analog converters. In the experiment, I thought that we would see 0's and 1's directly. That is what I thought about Digital signals. But, actually thanks to Deniz hocam and Enver hocam they showed us the logic indicators, and from the comparison of the input voltage and the voltage we give as an analog signal we have seen red and green lights, in which red indicated 1 and green indicated 0. Which is actually shows when a certain voltage in a continuous signal passed. We also used offset which was quite interesting too. It was an eye-opening experiment for me.

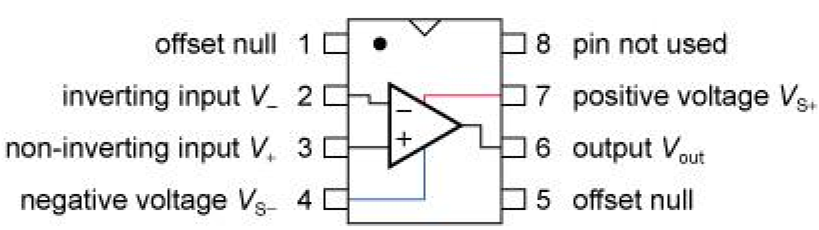


In Proteus and other types of PCB designers, you can see various types of ideal opamps which are not like the ones in the below picture. In the experiment we used LM741 which is on picture b and its ports that we needed to put our jumpers too.



(a)

(b)



(c)

This type of schematic helped me out to design the system in the lab.

Introduction

How do Op-amps work?

Op-amps have very complicated circuits inside, but in essence, they are high-gain(gain is a measure of the ability of a two-port circuit to increase the power or amplitude of the signal from I to O i/o.) electronic voltage amplifiers. For Op-amps there are two important rules, first is there is no potential difference between inverting and non-inverting parts. Secondly, there is no current passing on V+ and V-. From these two rules, we can create op-amp systems. In the pre-report op-amps and inverting amplifier, systems are explained. Here we will explain the comparator system. So, when we deliver voltage to both inputs, the system compares them. If both inputs are the same polarity and number, the output will be 0. Other than that if negative input is higher than the positive input, again it is 0. On the other hand, the positive side is higher than the negative. So in essence it is for determining input voltages.

ADC Working Principle

A signal can be a voltage, current, light, sound, pressure, etc. Basically, a signal changing in continuous time and amplitude is an analog signal, and when it's discrete-time and amplitude it is a digital signal. In the ADC signal system, we are converting this continuous analog signal into a digital signal in the binary coded format, we are doing this so to analyze data on the computers from sensors for being fast and accurate.

DAC Working Principle

DAC is the opposite of ADC, it is a Digital-Analog converter, this system takes digital data and converts this digital data to an analog signal. So, as mentioned above it is the reverse of the ADC. One should think of why doing this? In the past we used to store sound in analog signals, hence no conversion was needed. But, in recent times signals are converted into digital signals to make them more efficient. Hence, if you want to listen to a record again, you need to convert the digital signal into an analog signal.

Types of equipment

Multimeter

It can be used as amperemeter, voltmeter, and ohmmeter. I used it to see potential differences at the points A, B, C, D, and D0, D1, D2, and D3.

Breadboard

It is where we design our circuit on.

Oscilloscope

I opened it but, actually didn't use it other than once looking if I am giving the correct analog signal.

Resistors

In the experiment, 12k, 24k, 10k, 100k ohm resistors are used. The resistor is the passive component of the circuit to provide electrical resistance.

Op-Amp IC LM741

In the IC LM741, it has one op-amp inside. It has 8 pins. 2 offset null, 1 inverting input, 1 non-inverting input, 1 -Vcc, 1 +Vcc, 1 output, and 1 not connected null.

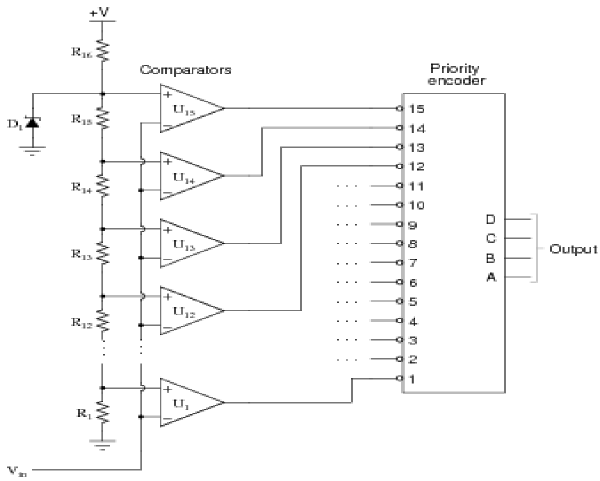
Quad Op-Amp IC LM324

LM324 has 4 op-amps, and 14 pins inside of it. 4 output, 4 inverting input, 4 non-inverting input, 1 +Vcc, 1 - Vcc.

Procedure

PART A

In part A, we designed Analog to Digital converters. We put Op-amps and 5x 10k ohm resistors on the breadboard. In the circuit, we supplied voltage to the opamp, also to the general circuit. Also, we supplied 5 Vpp signal generators from non-inverting inputs, and then we connected the inverting inputs to the resistors respectively. In the system, when we grounded the circuit and opamps, we measured the voltage differences of resistors and opamp's outputs between grounds. In the system, there needed to be a repetition, but we didn't do it. The Assistant said it is not necessary. The first part was smooth and we got the results clearly. In the experiment, we measured a similar voltage as we give an analog signal to the input Vcc and received from the output voltage. The system shows us that from the logic indicator when we give 0 offsets and min 0 V analog signal starting from 1Vpp to 5Vpp. We made a comparator device. When the threshold voltage of the A, one logic indicator started to turn red which means 1 in the system. Later when we passed 2 of the thresholds 2 of the logic indicators now started turning red but similar to the form of the wave we see, sind red appears when we pass the threshold and since the system is an analog signal it is not all the time as giving offset voltage. It continued as we increased the voltage to the 4Vpp then all started to flicker, which meant we passed the 4Vpp.

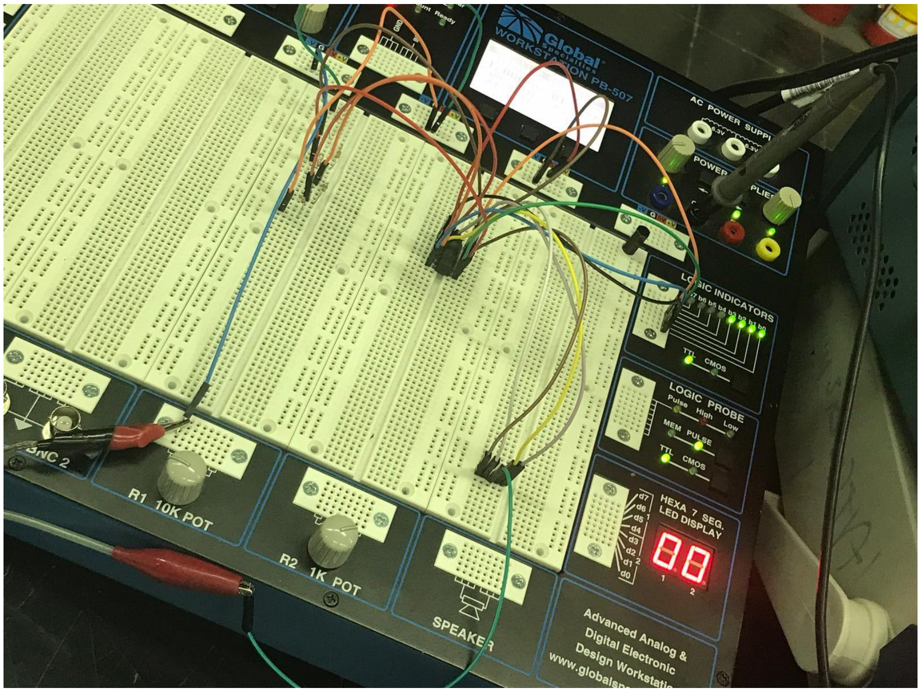


DATA

For 10k Ohm.

A	B	C	D	E
Vpp (5.0854 V	A	B	C	D
1	1.0172Vdc	2.0370Vdc	3.0452Vdc	4.0588Vdc
2	1.017Vdc	2.0373Vdc	3.045Vdc	4.059Vdc

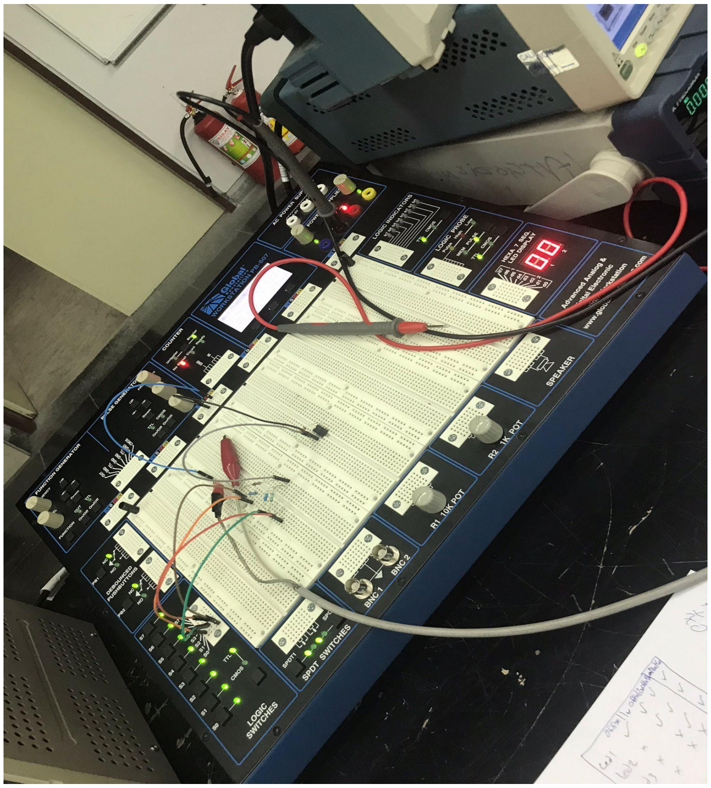
We didn’t do a separate resistor system with different ohms, we talked about the difference in the ohm, but its indifference in the system with the lab assistant. So, we only used 10k ohm.



(Part A)

PART B

In part B, we designed a circuit which was a digital to analog converter, we used 4 different resistors to measure,we didn’t use the exact valued ohms in our system (98.6 kOhm, 47.992kOhm, 23.290 kOhm, and 17.023 kOhm resistances are used.). These resistances correspond to the binary weight of the input bit representation. Then we used opamp as a current to voltage converter. It has two important disadvantages, one is these resistors must be perfectly accurate, in which they are not all of them had different ohms, so not exactly half each. Latter is, N input means there are N binary weighted resistor values needed which is a big system a lot.



DATA

A	B	C	D	E
Output	D0	D1	D2	D3
1.7mV == 0	0	0	0	0
294.2mV	1	0	0	0
877.7mV	1	1	0	0
2.0932V	1	1	1	0
4.4967V	1	1	1	1
585.5mV	0	1	0	0
1.2183V	0	0	1	0
2.3967V	0	0	0	1
1.8012V	0	1	1	0
2.9803V	0	1	0	1
4.2018V	0	1	1	1
3.6149V	0	0	1	1
1.5101V	1	0	1	0
3.9085V	1	0	1	1
2.6888V	1	0	0	1
3.2732V	1	1	0	1

From this, we see the most significant and least significant bits in the system. D0 is least, D3 is most.

PART C

In this part again we designed a DAC circuit. In this part, we wanted to choose 30kOhm to 15kOhm, but there were not any in the lab so we went with 24kOhm and12 kOhm ones. Again none were exact resistance and what we ended up with for R = 11.996 kOhm, 2R= 24.240 kOhm resistance values. There was no reason to pick 24k and 12k other than that, they just need to be R to 2R in general. In this system when I opened some switches Vout increased, but in exactly D2 or S5 the voltage dropped which both I and the assistant didn't understand the reason.

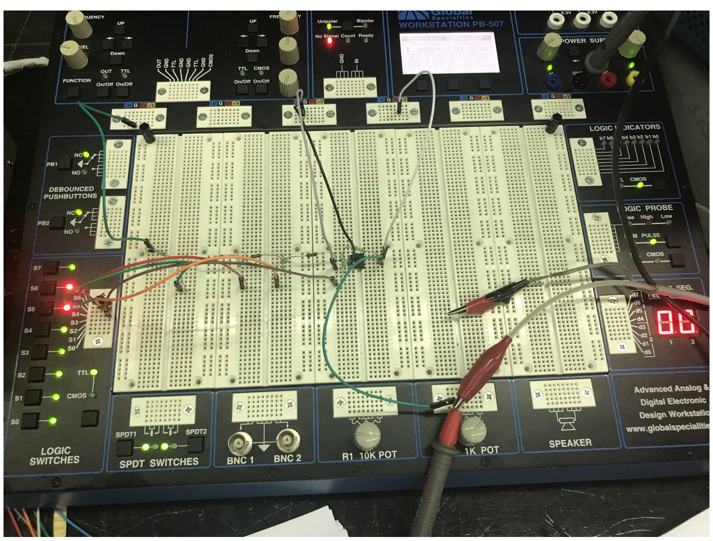
One needs to look at the resolution range of Vout to understand the system more clearly.

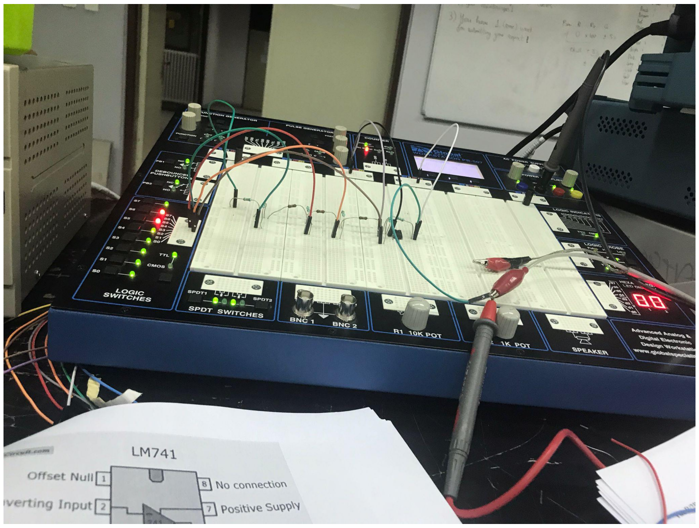
Resolution = Range of Vout/2^N

Range of the Vout = 0 to 5V and N = 4 so;

Resolution = 5 / 2^4 = 0.3125

I got the exact same results even though the S5, D2 are problematic, we from scratch made the setup over and over again like 3 times and all was the same. In the end, We got more or less voltage by switching the binary inputs in DAC from S7 to S4. It is really cheap as I asked the assistant to get this 8 bit DAC system, and it was easy to set up of course with help of an assistant. One can discuss that better results with different resistors and perhaps with different op-amp might be better and the error at S5 might be reduced with that. Other than D2, S5 the converter for one on is monotonic, but if we open more than one the voltage decreases to a certain level and with the drop percent we can find MSB and LSB. By this method, we overcome the problem in Part B that the necessity of N binary weighted resistor values, we only used R and 2R.





DATA

A	B	C	D	E
Output	D0 – S7	D1 – S6	D2 – S5	D3 – S4
4.3774V	0	0	0	0
4.3823V	1	0	0	0
4.3842V	0	1	0	0
3.5178V	0	0	1	0
4.3785V	0	0	0	1
4.0620V	1	1	0	0
2.9544V	1	0	1	0
1.9004V	1	0	0	1
1.9113V	1	1	1	0
1.9014V	1	1	0	1
1.9027V	1	0	1	1
1.9042V	1	1	1	1
1.9035V	0	1	1	1
1.9022V	0	0	1	1
1.9010V	0	1	0	1
2.3925V	0	1	1	0

Calculation

Experimental Result

PART A

This experiment is only conducted for 10kOhm for my case only for 100kOhm.Our assistant said changing resistors or Vpp won’t change anything, because the resistors were connected in series and all of them are equal to each other, hence voltage drop will always be 1V for each resistor theoretically.

PART B

I already measured the 0000 of the system which was 1.7mV for part B. I from that we can see the increases by subtracting this value from the 0001 or else. Then can compare with theoretical values.

PART C

For part C, the measured 0000 value is 4.3774V, and other than D2 all fit the reasoning which none of us could understand why that happened.

Theoretical Result

PART A

I=V/(R1+R2+R3+R4+R5)

Because the resistors are connected seri and R1=R2=R3=R4=R5;

VR1= (V/5R)*R = VR2 = VR3 = VR4= VR5

Therefore each voltage difference on the resistors is 1V and 1V is dropped for each resistor.

PART B&C

For part B and C we can think them together but still has different formulas.

I used two general equations for these circuits.

For part B: Vout=Rf*(V1/R+V2/2R+V3/4R+V4/8R)

I_total = Vout/Rf and I_total= Rf*(V1/R+V2/2R+V3/4R+V4/8R) by that we get the theoretical result. One can add the currents because it is a parallel circuit and hence, the current is divided. In other words, it has the same potential difference in each part.

For Part C: Vout = Vref*[(D0/2^n)+(D1/2^(n-1)) +(D2/2^(n-2)) +…+(Dn-1/2^1))]

The formula gives the voltage difference between the op-amp and the digital inputs. Since, no voltage difference between the negative sign and the positive sign of op-amp, the voltage difference on the Rf will be equal to the right side of the equation. Hence the theoretical result will be as reported in the pre-report.

ERROR

Part A: My error is (Theo-Exp)*100/Theo =1.4487% I only looked at D and assumed the error is the same in all but should take a mean normally.

Part B & Part C: Due to the error at the S5 we have a huge error in the system of S7S6S5.

(S7+S6+S5+S4) / (S7+S6+S5)   = 0.9987 Exp

(S7+S6+S5) / (S7+S6) = = -72.47 Exp due to the error at S5. (-0.8479)

(S7+S6) / S7 = =2.387 Exp (0.0117)

experimental errors are close to each other, other than S7+S6+S5 and they are not that high but since there is an issue with S5, I can neglect that and discuss it in the discussion part.

DISCUSS

(I learned about om-amps, used breadboard which is cool, also about ADC's, DAC's, MSB and LSB and many other things. I had difficulties at setting up the systems but I learned how to approach linearly and much more simply rather than approaching it as a chaotic nonlinear system. Also learned about how bits in essence act and what should we think about, when someone says Digital Signal.) I never thought that signal is what we did in the lab. But now I am much more relieved and understanding about the electrical basics.

PART A: I am satisfied with the experience of part A since both teacher and assistant helped us and I learned a lot. Also data is really close to what we needed at the end.

PART B & PART C: I still couldn't figure out what is wrong with S5, but other than that DAC experiments are also quite great I learned about the MSB and LSB from that, also from the logic indicators that the assistant made us use in the part A. So it was a relief to see what it really is. I plan on neglecting S5 since it is probably a device error at the time.

References:

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