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On the Difference Between Proteus Simulation Program and Practice in Single Power Supply Use of $\mu A741$

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***Abstract*: Since the use of simulation software is widely used in designing electronic circuits, it is very important to increase the accuracy of the simulation program. We found the difference between the simulation results of the simulation software Proteus and the experiment results in the single power supply use of the $\mu A741$ operational amplifier and verified the experimental results through the analysis of the internal structure of the $\mu A741$ op amp. In the Proteus 8.15 simulation program, the inverting input level of the op amp using a single power supply varies according to the value of the negative feedback resistor. The experiment showed that when using a single power supply of 15 V and applying negative feedback to $\mu A741$, the inverting input voltage is almost 2 V rather than 1.5 V.**

***Keywords*: operational amplifier (op amp), Proteus, Single power supply, 741.**

1. Introduction

The simulation program - Proteus is used in simulation in many electronic design applications because of its simulation performance [1]-[4].

In [1], a capacitive power transformer (CPT) system is proposed and its characteristics are simulated using Proteus 8. In [2], various DC-DC converters are designed using Arduino nano controller and simulated with Proteus 8. In addition, the results were analyzed by using Proteus 8 in the method of monitoring greenhouse parameters using wireless sensor network and also in the PWM DC motor speed control circuit [3], [4].

The op amp is a basic analog circuit element, which is used in many electronic circuits, such as amplification, filtering, signal conversion, signal processing, etc. [5], [10].

The details of the op-amp are given in [5], [8], 10].

Usually, an op amp uses a symmetrical power supply, but a single power supply can be used as required. To the best of our knowledge, there is no detailed description of the method of using a single power supply in op amp $\mu A741$.

We found that the experimental and simulation differed during the single power supply and confirmed this.

The paper is organized as follows.

Section 2 presents the differences between experiments and simulations for the single power supply use of $\mu A741$ op amp, and Section 3 demonstrates the experimental results through analysis of the internal structure of the operational amplifiers.

2. Experiments of Op Amp Using a Single Power Source

In [6], the inverted amplifier configuration is shown when a single power supply is used (see Fig. 1). As can be seen in the figure, this amplifier can only amplify the ac signal.

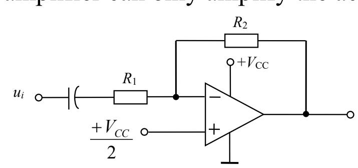

Fig. 1. Inverted amplifier using single power supply

In [8], the detailed descriptions of the circuit using a single power supply are given with TLV247X.

We have found the same phenomenon as in Fig. 2 during the Proteus simulation to construct an amplifier circuit for the dc signal using a single power supply with $\mu A741$.

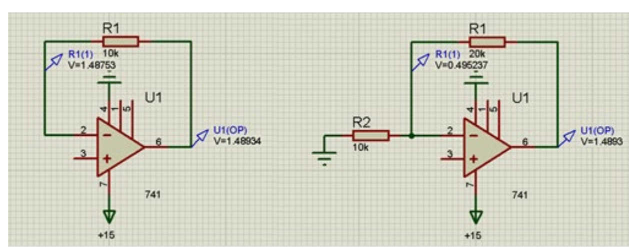

Fig. 2. The simulation circuits in proteus8.15

From the figure, it can be seen that the output value is fixed and the value of the inverted input voltage changes with the feedback resistor.

To confirm this, an experimental circuit like Fig. 2 was constructed and the measurements were carried out using an oscilloscope. Fig. 3 shows the measured oscilloscope waveform and Fig. 4 shows the operational amplifier used in the experiment.

Since the measuring probe performs 10:1 conversion, the measured value using an oscilloscope shows that the inverted input voltage is 200 mV×10=2 V. This value did not change

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even though the value of the feedback resistor was changed.

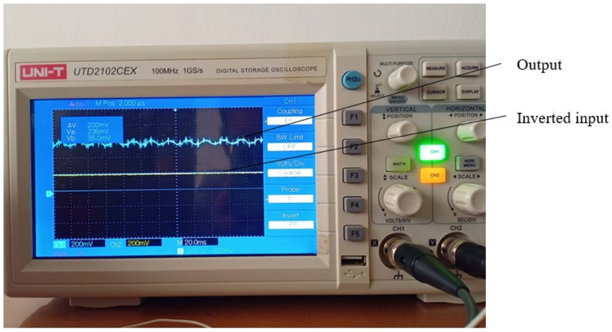

Fig. 3. Inverted input and output waveforms measured by oscilloscope

Fig. 4. Operational amplifiers used in experiments

It is also shown that the output voltage is approximately 6 V when the feedback resistor R_f is doubled by the inverter input resistor.

This can be said to be the result obtained from the gain equation $1+\frac{R_f}{R}=1+\frac{20}{10}=3$ of the non-inverting amplifier circuit.

3. Validation of experimental values from the structure of $\mu A741$.

In [9], a detailed description of the structure of $\mu A741$ is given. Fig. 5 shows the internal circuit of the op amp shown in [9].

Using the figure, we consider the bias when a single power supply is used.

The current passes through transistor Q_{12} and passes through resistor R_5 through transistor Q_{11}. This current can be obtained when V_{CC} = 15 V as follows:

$$I_{C11}=\frac{V_{CC}-2\times V_{BE}}{R_5}=\frac{15-1.4}{39k\Omega}=349\mu\text{A}$$

The transistors Q_{10} and Q_{11} form the current source circuit of Widlar.[9] Therefore, the current flowing through the collector of Q_{10} is expressed by,

$$R_4 I_{C10}=V_T\ln\frac{I_{C11}}{I_{C10}} \tag{1}$$

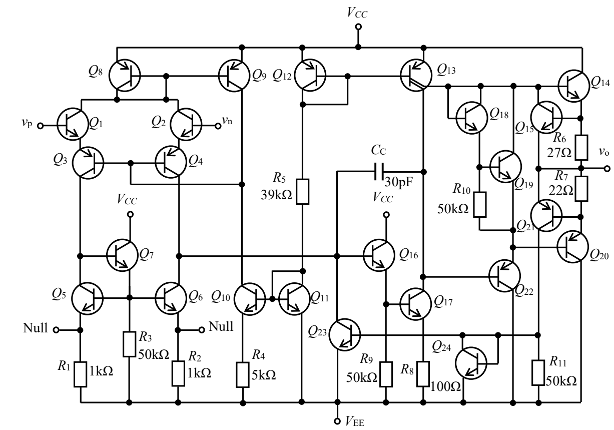

Fig. 5. The internal structure of $\mu A741$

In the equation, V_T is the thermal voltage and is 0.0259 V. Using Eq. 1, we obtained I_{C10} = 16 μA .

On the other hand, the collector current flowing through the transistor can be expressed as [9]:

$$I_C=I_s e^{V_{BE}/V_T}\left(1+\frac{V_{CE}}{V_A}\right) \tag{2}$$

Using Eq. 2, we can calculate V_{CE10}. In Table 1, the corresponding V_{CE10} values are estimated for different power supply voltage V_{CC} values. Here, we used V_A=80V and I_S=1.427nA.

Table 1
Voltage and current at different power supply voltages

V_{CC}(V)	I_{C11}(μA)	I_{C10}(μA)	V_{BE10}(mV)	V_{CE10}(V)	V_{C10}(V)
15	349	16	599	1.036	1.116
12	272	15	597.335	1.0155	1.0905
10	220.5	14.25	596.02	0.9733	1.04455

When the resistor is connected between the inverted input and output, Q_2 and Q_4 are biased forward by the output voltage. The pnp-type transistor Q_4 was used with low current gain according to [9]. Therefore, the sum of the on-state voltages of these two transistors can be considered as,

$$V_{BE2}+V_{BE4}=0.9\text{ V} \tag{3}$$

So, the inverted input potential i.e., the base potential of Q_2 is following.

$$V_{B2}=V_{C10}+(3) \tag{4}$$

These values are shown in Table 2.

Table 2
The inverted input potential at different power supply voltages

V_{CC}(V)	V_{C10}(V)	V_{B2} (V)
15	1.116	2.016
12	1.0905	1.9905
10	1.04455	1.94455

As can be seen from the table, the inverted input voltage at different power supply voltages is approximately equal to 2V. It can be said that this is in agreement with the measured values.

From Fig. 5, it can be seen that the non-inverted input voltage V_p should not be lower than 2V. When constructing an inverting amplifier, the additional voltage to the non-inverted input must be greater than 2V so that transistors Q_1 and Q_3 can be turned on and the op amp can be operated.

It is also found that if a non-inverting amplifier circuit is constructed for DC signal amplification, only the signal with input voltage above 2 V can be amplified.

3. Conclusion

In this paper we demonstrate the difference between simulation and practice in $\mu A741$ operational amplifier using the single power supply. We have demonstrated an experimental value of 2V of inverted input voltage when it is negative feedback from the structure of $\mu A741$ by applying the characteristic analysis method of transistor.

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