VE311 Lab 4

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1. Common-Source with NMOS Diode-Connected Load

(a) In this part, we first build the circuit below (Figure 1) in Pspice.

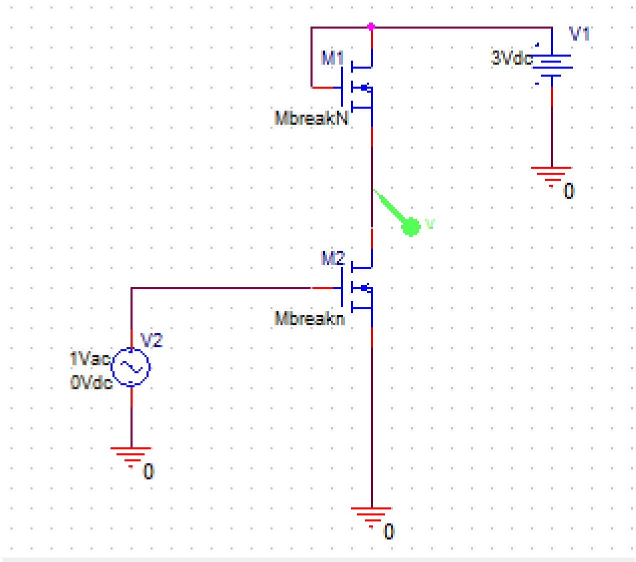

Figure 1. Pspice circuit

Then, we use DC sweep in Pspice to get V_{OUT} vs V_{IN} (Figure 2).

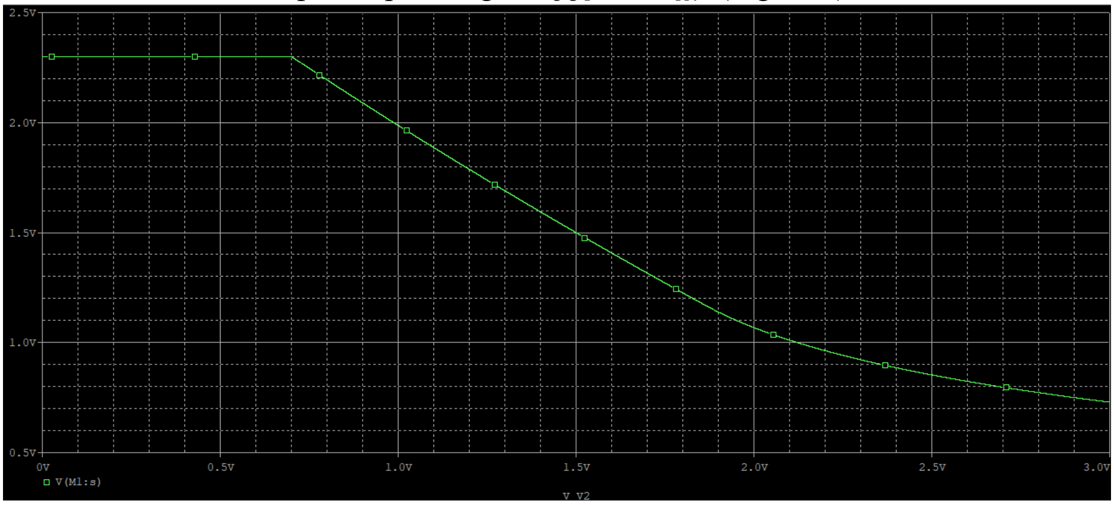

Figure 2. DC sweep

From the figure, we can get (0.99, 1.9972), (1.01, 1.9769), and we can get A_v at $V_{IN} = 1$ V as follows:

$$A_v = \text{slope}_1 = \frac{1.9769 - 1.9972}{1.01 - 0.99} = -1.015.$$

In lab, we get the following data (Table 1).

V_{IN} (V)	V_{OUT} (V)
0.1	2.354
0.2	2.335
0.3	2.316
0.4	2.197
0.5	2.007
0.6	1.809
0.7	1.612
0.8	1.42
0.9	1.234
1.0	1.057
1.1	0.907
1.2	0.799
1.3	0.739
1.4	0.702
1.5	0.675
2.0	0.605
2.5	0.572
3.0	0.55

Table 1. Measurement result

And we can get the following plot (Figure 3).

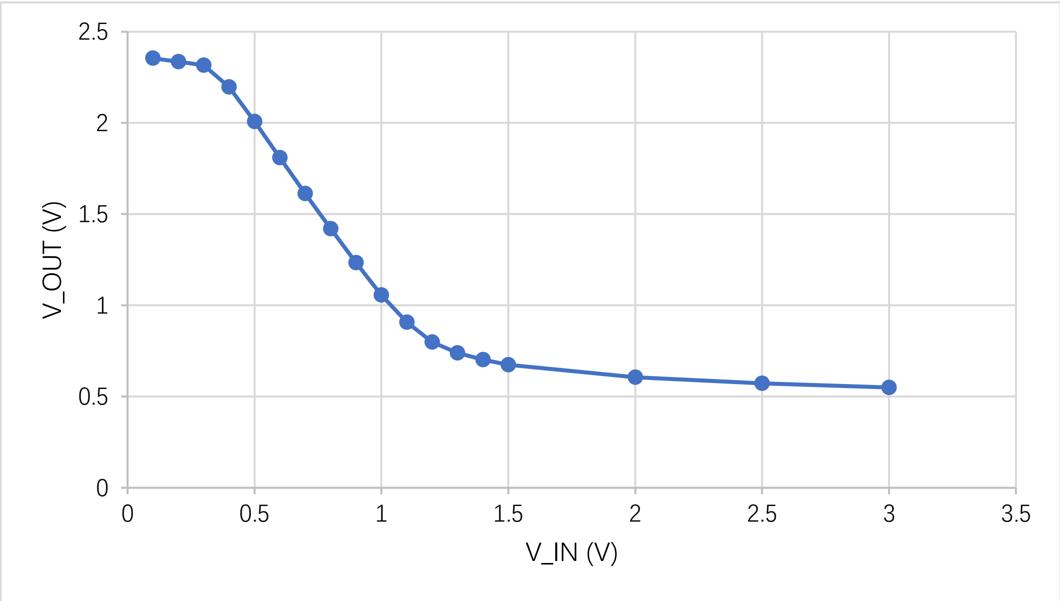

Figure 3. V_{OUT} vs V_{IN} for measurement result

We can calculate the voltage gain at 0.75 is -1.92.

(b) In this case, we modify the circuit. In Pspice, we can get the following figure (Figure 4).

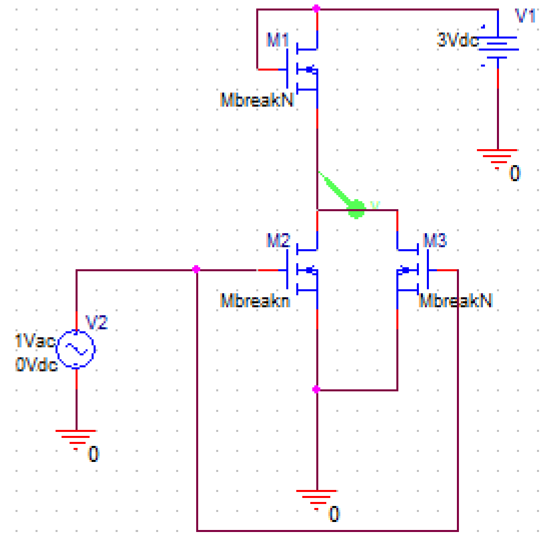

Figure 4. Pspice circuit

Then, we use DC sweep in Pspice to get V_{OUT} vs V_{IN} (Figure 5).

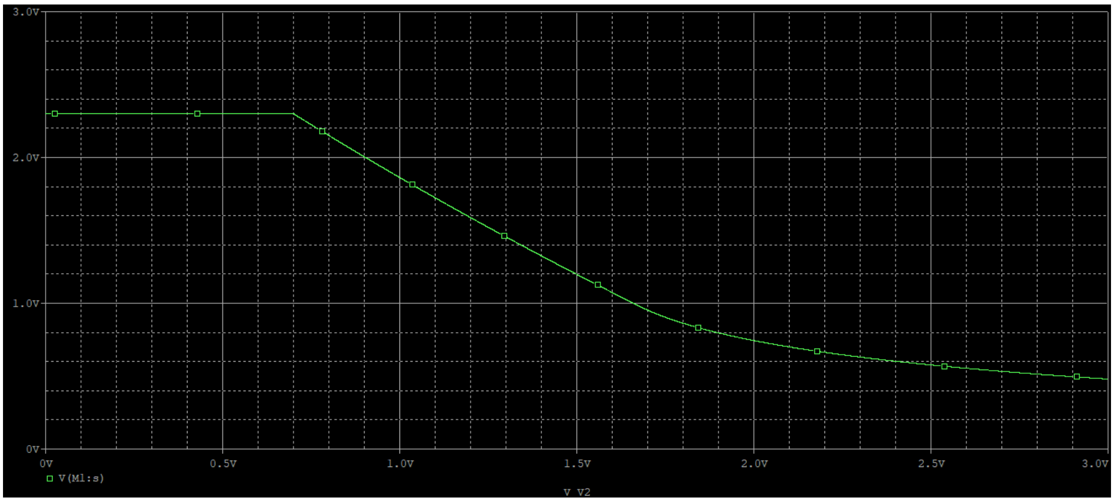

Figure 5. DC sweep

From the figure, we can get (0.99, 1.8762), (1.01, 1.8481), and we can get

$$A_v = \mathrm{slope}_1 = \frac{1.8481 - 1.8762}{1.01 - 0.99} = -1.405.$$

It does not double. Previously, $A_v = G_m \times R_{out} = -\mathrm{gm}_2(\frac{1}{\mathrm{gm}_1}||\frac{1}{\mathrm{gmb}_1}||\mathrm{r}_{01}||\mathrm{r}_{02})$. Now,

$A_v = G_m \times R_{out} = -(\mathrm{gm}_2 + \mathrm{gm}_3)(\frac{1}{\mathrm{gm}_1}||\frac{1}{\mathrm{gmb}_1}||\mathrm{r}_{01}||\mathrm{r}_{02}||\mathrm{r}_{03})$. Therefore, the new A_v is not double of the previous A_v.

In lab, we get the following data (Table 2).

V_{IN} (V)	V_{OUT} (V)
0.1	2.365
0.2	2.344
0.3	2.313
0.4	2.175
0.5	1.976
0.6	1.763
0.7	1.524
0.8	1.267
0.9	1.006
1.0	0.75
1.1	0.563
1.2	0.473
1.3	0.425
1.4	0.395
1.5	0.372
2.0	0.312
2.5	0.284
3.0	0.266

Table 2. Measurement result

And we can get the following plot (Figure 6).

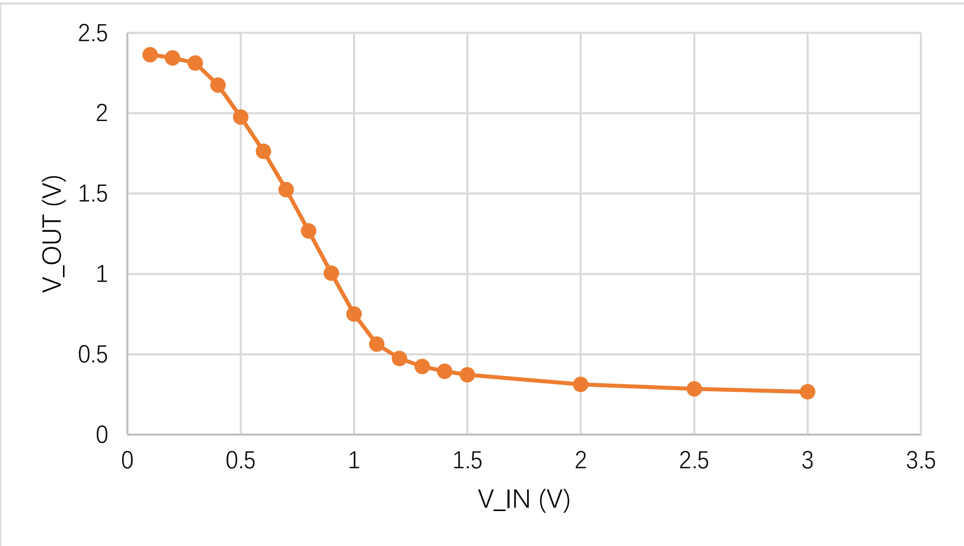

Figure 6. V_{OUT} vs V_{IN} for measurement result

We can calculate the voltage gain at 0.75 is -2.57.

It also does not double. Previously, $A_v = G_m \times R_{out} = -\mathrm{gm}_2(\frac{1}{\mathrm{gm}_1}||\frac{1}{\mathrm{gmb}_1}||\mathrm{r}_{01}||\mathrm{r}_{02})$.

Now, $A_v = G_m \times R_{out} = -(\mathrm{gm}_2 + \mathrm{gm}_3)(\frac{1}{\mathrm{gm}_1}||\frac{1}{\mathrm{gmb}_1}||\mathrm{r}_{01}||\mathrm{r}_{02}||\mathrm{r}_{03})$. Therefore, the new A_v is not double of the previous A_v.

(c) In Pspice, we use $V_{in} = 1.0 + 0.01\sin(2\pi 10^2 \cdot \text{time})$ and get the following figure (Figure 7).

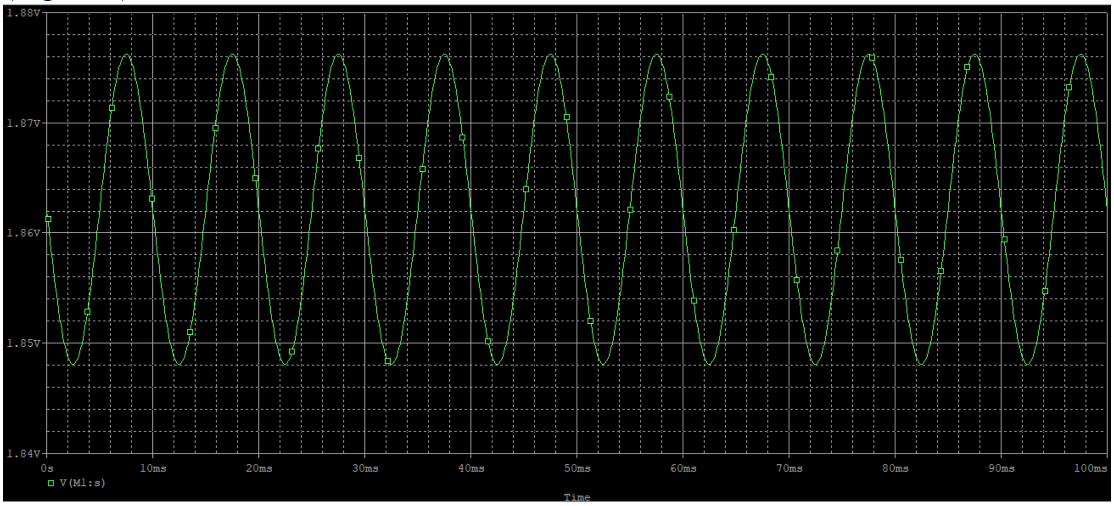

Figure 7. Simulation result

Using cursor, we can get

$$v_{out} = \frac{1.8762 - 1.8481}{2} = 0.01405.$$

Also, from **(b)**, we have

$$0.01 \times |A_v| = 0.01 \times 1.405 = 0.01405.$$

They are close. Therefore, we can confirm that the amplitude of v_{out} is close to $0.01 \times A_v$.

In lab, since 0.01 is too small to generate and measure, we use $V_{in} = 0.75 + 0.1\sin(2\pi 10^2 \cdot \text{time})$ instead and get the following figure (Figure 8).

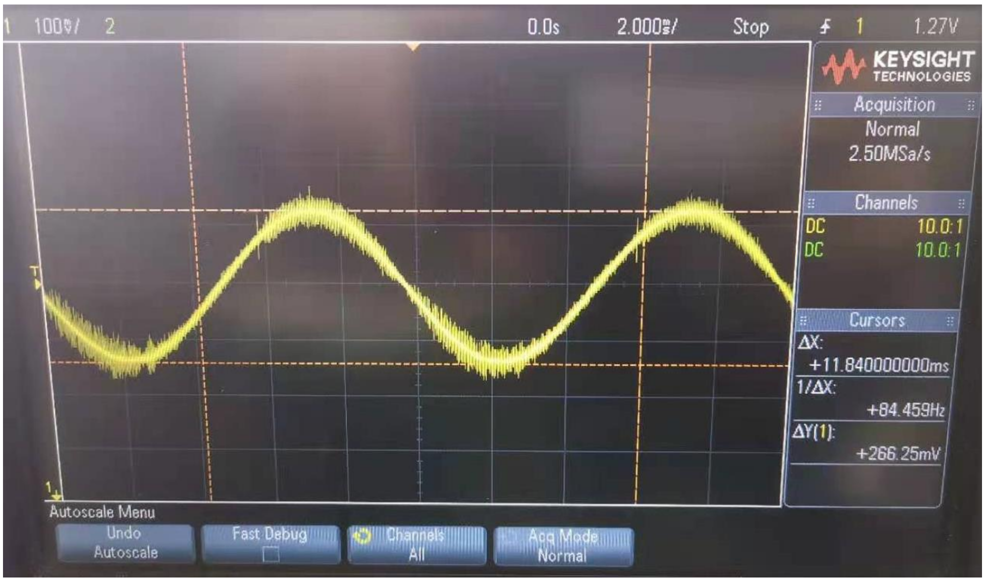

Figure 8. Measurement result for $V_{in} = 0.75 + 0.1\sin(2\pi 10^2 \cdot \text{time})$

We can get that $v_{out} = 0.133125$ V. However, it is smaller than $0.1 \times |A_v| = 0.1 \times 2.57 = 0.257$. It may be because that the circuit is not ideal and has inner resistance.

2. Common-Source with PMOS Diode-Connected Load

(a) In this part, we first build the circuit below (Figure 9) in Pspice.

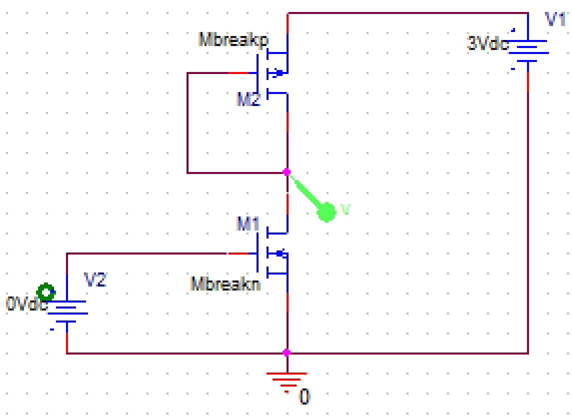

Figure 9. Pspice circuit

Then, we use DC sweep in Pspice to get V_{OUT} vs V_{IN} (Figure 10).

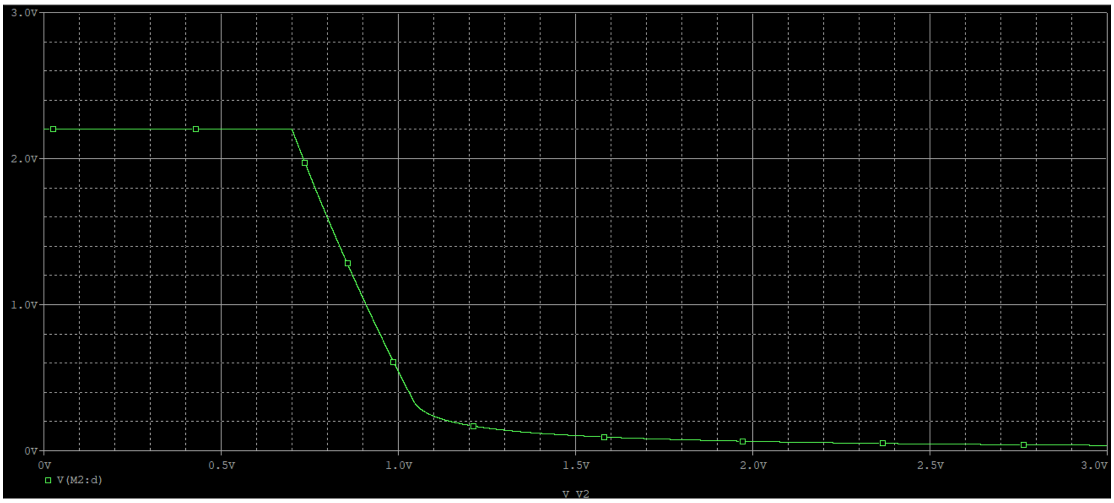

Figure 10. DC sweep

From the figure, we can get (0.89, 1.0990), (0.91, 0.994186), and we can get A_v at $V_{IN} = 0.9\ \text{V}$ as follows:

$$A_v = \text{slope}_{0.9} = \frac{0.994186 - 1.0990}{0.91 - 0.89} = -5.2407.$$

In lab, we get the following data (Table 3).

V_{IN} (V)	V_{OUT} (V)
0.1	1.516
0.2	1.522
0.3	1.474
0.4	1.29
0.5	1.03
0.6	0.769
0.7	0.504
0.8	0.258
0.9	0.155
1.0	0.122
1.1	0.105
1.2	0.095
1.3	0.089
1.4	0.083
1.5	0.079
2.0	0.066
2.5	0.06
3.0	0.056

Table 3. Measurement result

And we can get the following plot (Figure 11).

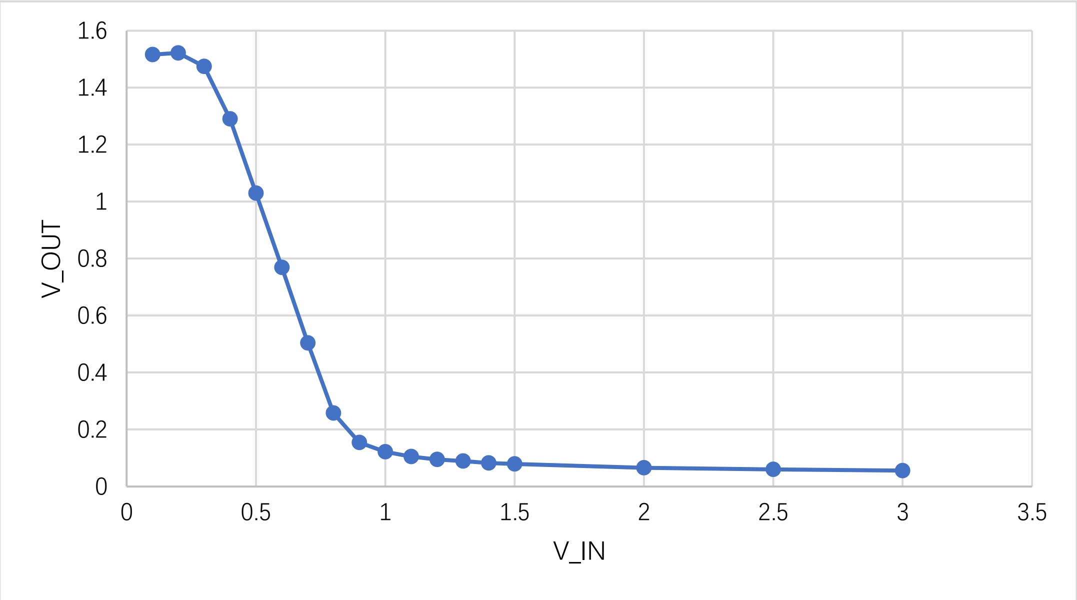

Figure 11. V_{OUT} vs V_{IN} for measurement result

We can calculate the voltage gain at 0. 5 is -2.6.

(b) In this case, we modify the circuit. In Pspice, we can get the following figure (Figure 12).

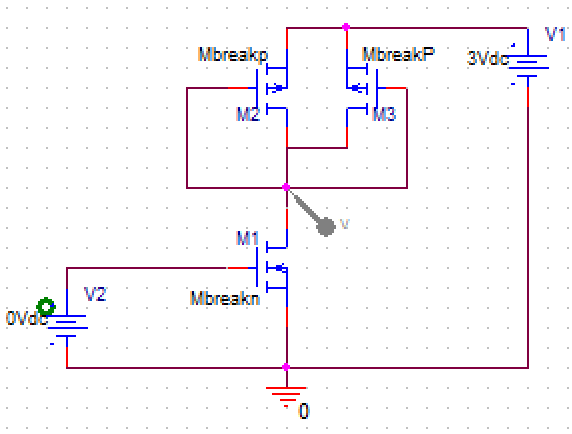

Figure 12. Pspice circuit

Then, we use DC sweep in Pspice to get V_{OUT} vs V_{IN} (Figure 13).

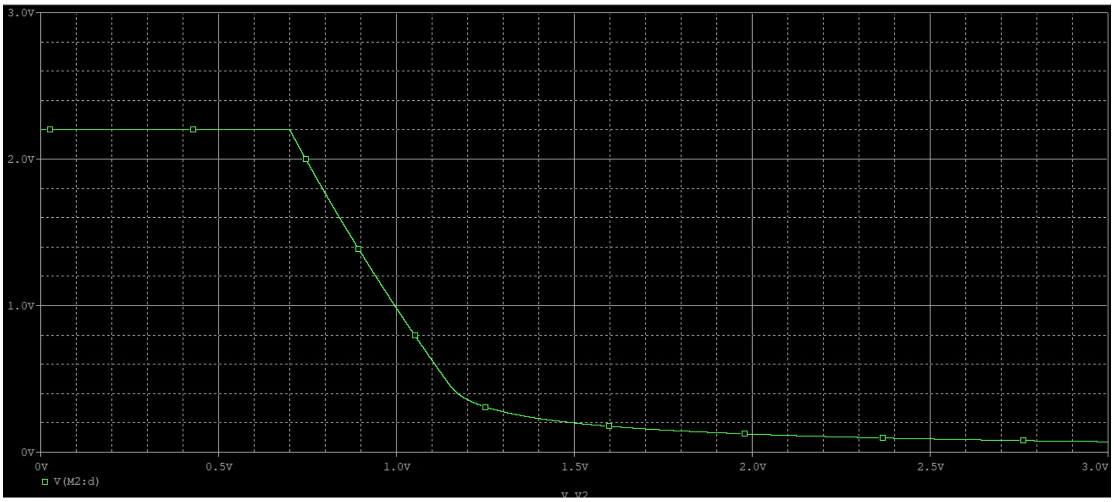

Figure 13. DC sweep

From the figure, we can get (0.89, 1.4008), (0.91, 1.3226), and we can get A_v at $V_{IN} = 0.9$ V as follows:

$$A_v = \text{slope}_{0.9} = \frac{1.3226 - 1.4008}{0.91 - 0.89} = -3.91.$$

We can find that the absolute value of voltage gain becomes smaller. The reason may be that previously, $A_v = G_m \times R_{out} = -\text{gm}_1(\text{r}_{02} \| \text{r}_{01})$. But, now, $A_v = G_m \times R_{out} = -\text{gm}_1(\text{r}_{02} \| \text{r}_{03} \| \text{r}_{01})$. Therefore, the absolute value of new voltage is smaller.

In lab, we get the following data (Table 4).

V_{IN} (V)	V_{OUT} (V)
0.1	1.548
0.2	1.541
0.3	1.503
0.4	1.324
0.5	1.068
0.6	0.824
0.7	0.596
0.8	0.389
0.9	0.255
1.0	0.203
1.1	0.179
1.2	0.166
1.3	0.155
1.4	0.148
1.5	0.14
2.0	0.123
2.5	0.115
3.0	0.109

Table 4. Measurement result

And we can get the following plot (Figure 14).

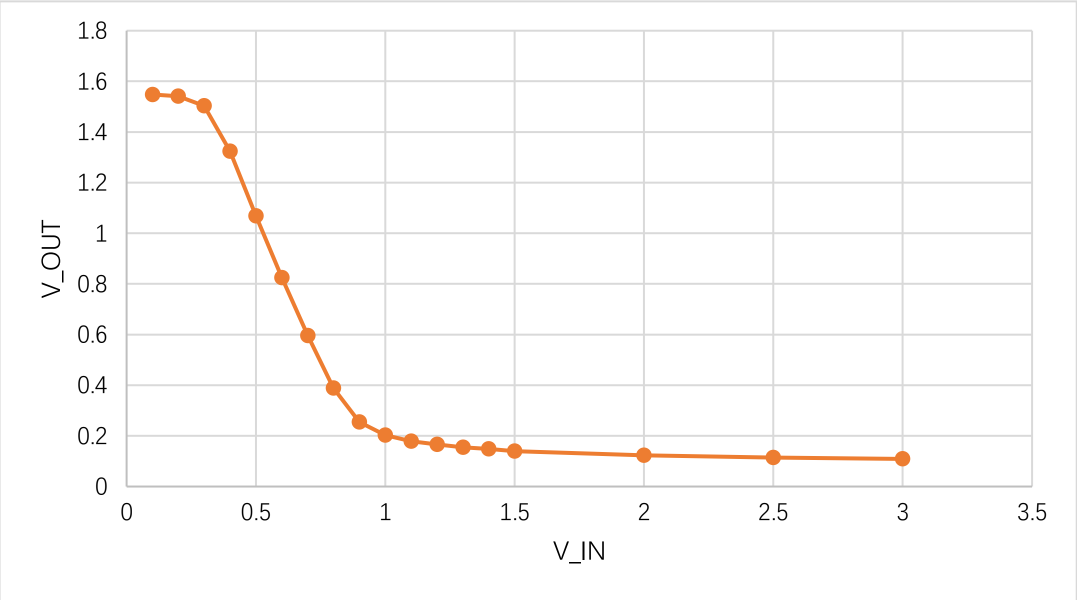

Figure 14. V_{OUT} vs V_{IN} for measurement result

We can calculate the voltage gain at 0. 5 is -2.56, whose absolute value is smaller than the previous one. The reason may be the same. Previously, $A_v = G_m \times R_{out} = -\mathrm{gm}_1(\mathrm{r}_{02} \| \mathrm{r}_{01})$. But, now, $A_v = G_m \times R_{out} = -\mathrm{gm}_1(\mathrm{r}_{02} \| \mathrm{r}_{03} \| \mathrm{r}_{01})$. Therefore, the absolute value of new voltage is smaller.

(c) In Pspice, we use $V_{in} = 0.9 + 0.01\sin(2\pi 10^2 \cdot \text{time})$ and get the following figure (Figure 15).

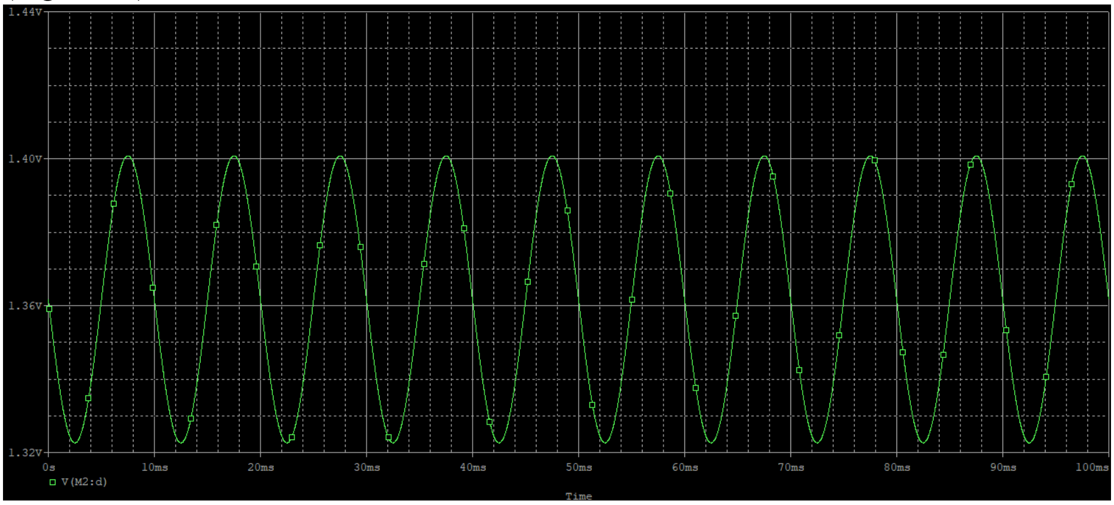

Figure 15. Simulation result

Using cursor, we can get

$$v_{out} = \frac{1.4007 - 1.3226}{2} = 0.03905.$$

Also, from **(b)**, we have

$$0.01 \times |A_v| = 0.01 \times 3.91 = 0.0391.$$

They are close. Therefore, we can confirm that the amplitude of v_{out} is close to $0.01 \times A_v$.

In lab, since 0.01 is too small to generate and measure, we use $V_{in} = 0.5 + 0.1\sin(2\pi 10^2 \cdot \text{time})$ instead and get the following figure (Figure 16).

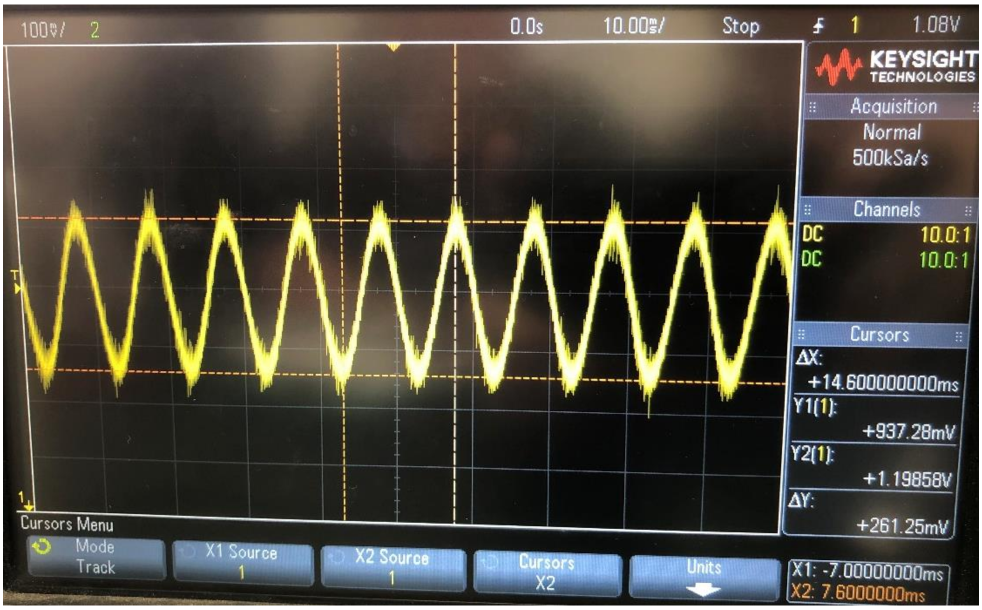

Figure 16. Measurement result for $V_{in} = 0.5 + 0.1\sin(2\pi 10^2 \cdot \text{time})$

We can get that $v_{out} = 0.130625\,\text{V}$. However, it is larger than $0.1 \times |A_v| = 0.1 \times 2.56 = 0.256$. It may be because that the circuit is not ideal and has inner resistance.