

**Analog Electronic Circuits**  
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**Lecture - 30**  
**The Transimpedance amplifier (contd)**

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Good evening everybody and welcome to Analog Electronic Circuits, this is Lecture 15. In the last class we looked at the voltage controlled current. So, I mean current control voltage source where the incremental picture looked like this. This is  $i_n$ , this is  $R_L$  and if you assume that the current source has some internal resistance  $R_s$  then if  $g_m$  tends to infinity, what comment can we make about the input resistance?

Input resistance seen by the source here is 0, what comment can we make about the incremental voltage there? Incremental voltage there is 0, what comment can we make about the incremental current flowing there?

Student:  $i_n$ .

What comment can we make about the incremental voltage there?  $i_n R$ . What comment can we make about the incremental current flowing here? Why because the output voltage is  $i_n R$ . So, the current flowing in the load is  $i_n R / R_L$ . So, what is the current flowing in the transistor?

It is flowing in the opposite direction. If you want to avoid the negative sign that current is nothing, but  $i_n (1 + R/R_L)$ . Sanity checks if  $R_L$  tends to infinity all that current must flow into the transistor. So, does it make sense? Now, what comment can we make about  $R_{out}$ ? When  $g_m$  is infinity it is 0 and so, what is the meaning of large  $g_m$ ,  $g_m$  must be much much larger than?

Student:  $1/R_s$ .

$1/R_s$  and  $1/R_L$  ok. So, that is pressure now we are going to position this is the incremental network we are now in a position to make the real thing and that is again you know you choose you pick your favorite biasing scheme, right.

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The whiteboard contains two circuit diagrams and associated equations. The top diagram shows a transistor with a resistor  $R$  in series with the input. A current source  $i_s$  is connected to the input through a resistor  $R_s$ . The load resistor is  $R_L$ . The input current is  $i_{in}$  and the output current is  $i_{in} R / R_L$ . The total current entering the transistor is  $i_{in} (1 + R/R_L)$ . The equations are:  $R_{in} = 0$ ,  $R_{out} = 0$ , and  $\text{Large } g_m \Rightarrow g_m \gg \frac{1}{R_s}, \frac{1}{R_L}$ . The bottom diagram shows a transistor with a current source  $i_s$  connected to the gate through a resistor  $R_s$ . The drain is connected to  $V_{dd}$  through a resistor  $R_2$ . The source is connected to ground through a resistor  $R_1$  and a load resistor  $R_x$ . The NPTEL logo is visible in the top right corner.

I am going to pick you know something for example, alright let me just pick something with gate voltage is constant, we measure at the source feedback at the source we use a poor man's current source and this is the  $V_{dd}$ , this is  $R_2$ , this is  $R_1$  and this is some  $R_x$ . And the job of  $R_x$  is to reduce the, why do we have  $R_x$  there?

Why do we have  $R_x$  there?

Student: to reduce the source voltage.

To reduce what? How can adding a resistance series to this source reduce its voltage?

Student: It stabilizes the voltage and source.

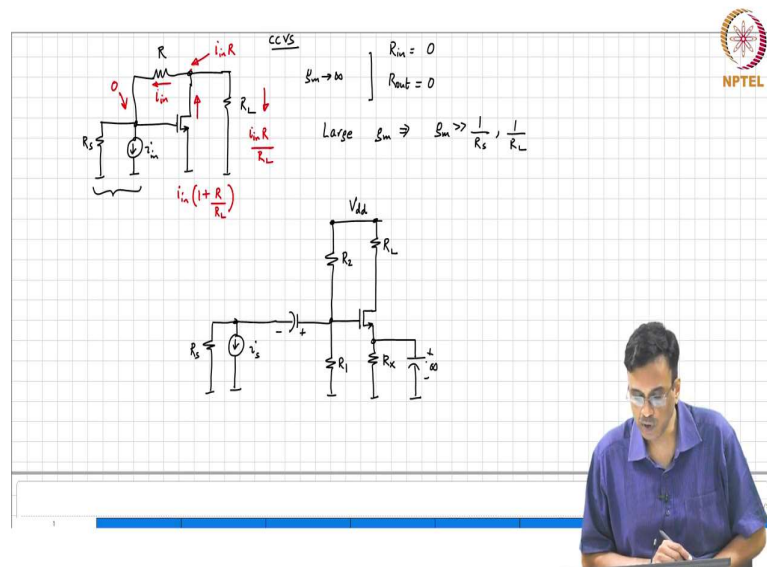
Can somebody give you a more coherent answer? Yes, Ralph?

So,  $R_X$  basically does attempt to do whatever it takes to keep the current in the transistor constant of course, it works only when  $R_X$  is large and what is the meaning of  $R_X$  being large? What is a large  $R_X$ ?

$R_X$  should be much much larger than  $1/g_m$  ok. With all those conditions satisfied I mean this stabilizes the bias current pretty well alright. So, now, we need to make the incremental network look like the one shown on top. So, what do we do?

Ok. So,  $i_s$ ,  $R_s$  straightforward ok, what else?

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So, the load has multiple ways of doing it is to just put in the drain. What else?

The source must be?

Student: Ground rate.

Ground rate, so what do we do?

Student: Infinite capacitor.

Put an infinite capacitor, alright. Have we done it?

In the incremental network we see that the drain and the gate are connected to a resistor R. So, what do we do here?

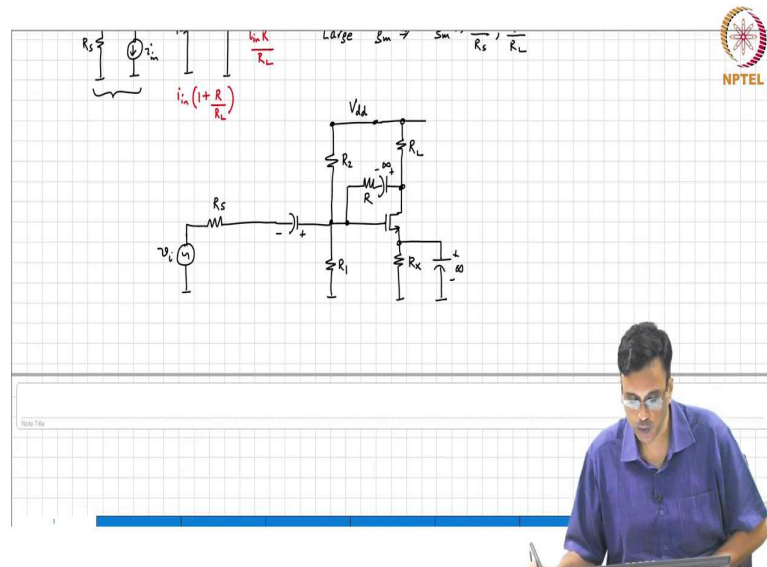
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The image shows two hand-drawn circuit diagrams on a grid background. The top diagram is a simplified model of a transistor represented as a current-controlled current source (CCVS). It features a dependent current source  $\beta i_{in}$  in parallel with a load resistor  $R_L$ . A feedback resistor  $R$  is connected between the output node and the input node. The input current is  $i_{in}$  and the output current is  $i_{in} R$ . The total current entering the input node is  $i_{in} (1 + \frac{R}{R_L})$ . The model is labeled "CCVS" and includes the conditions  $R_{in} = 0$  and  $R_{out} = 0$ . A note states "Large  $g_m \Rightarrow g_m \gg \frac{1}{R_s}, \frac{1}{R_L}$ ". The NPTEL logo is visible in the top right corner.

The bottom diagram shows a more detailed transistor circuit. The gate is connected to a voltage divider consisting of resistors  $R_1$  and  $R_2$  connected to  $V_{dd}$  and ground. A feedback resistor  $R$  is connected between the drain and the gate. The drain is connected to  $V_{dd}$  through a resistor  $R_2$  and to a load resistor  $R_L$ . The source is connected to ground through a resistor  $R_1$  and a bypass capacitor  $C_x$ . The gate is also connected to ground through a capacitor  $C_g$ .

So, that is a transistor. So, what do we do with R? One way of doing it is to use an infinite capacitor to put R. What happens if I do not put a capacitor? Depending on the choice of  $R_1$ ,  $R_2$  and  $R_L$  a current could flow between through the resistor R and thereby disturb the operating point of the transistor, alright. So, this is basically you know perfectly working current controlled voltage source and you know nothing basically as we discussed the last time.

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If this is  $v_i$  and this is  $R_s$  as  $g_m$  tends to win as  $g_m$  becomes very very large. What comment can you make about the incremental voltage at the output. What is the incremental voltage at the output  $-R/R_s v_i$ . I hope that is apparent. We spent a lot of time in the last class alright. So, basically, I mean if you want to impress your friends you can draw the draw big circuit like this right and you can by simply staring at the picture without doing any math right you can be sure that the gain is going to be approximately  $-R/R_s$ , even the circuit looks quite complicated with you know half a dozen resistors and few capacitors and so on, alright, ok. So, that covers the current controlled voltage source.