ALL MOS AMPLIFIER

CMOS Amplifier using All MOS philosophy

How Stuff Works - Abstract

Topologies used: Differential Pair, Current Mirror biasing, Active Load and Cascode Current Source

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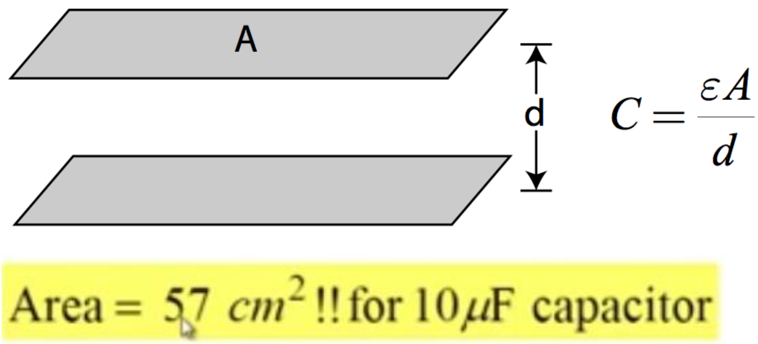
1. MOTIVATION AND AIM

- Biasing is important for proper operation of an amplifier. For discrete circuits, biasing is achieved by using a **voltage divider network** at the input side.

- However, for integrated circuits **power is a constraint.** Moreover, using a resistor will also involve **bypass capacitors** in the **microfarad** range.

- In ICs microfarad capacitors are not feasible as it would occupy a large area relative to that of a transistor.



- So how do we a **build an amplifier without the use of resistors and capacitors?**

2. BJT VS MOSFET

MOSFETs can be made much smaller in size compared to BJTs. Hence all ICs predominantly use CMOS technology. Also only Enhancement type MOSFETs are considered in this abstract.

3. DUAL POWER SUPPLY AND DIFFERENTIAL PAIR

- When a **single supply** is used, **a voltage divider** has to be used in the input side, so that the Gate terminal is at higher potential than the source terminal.

- When **dual supply** is used as in the case of ICs, then voltage divider and hence the **coupling capacitors** can be removed in the input side.

- To eliminate **source bypass capacitors**, we have to use a differential amplifier.

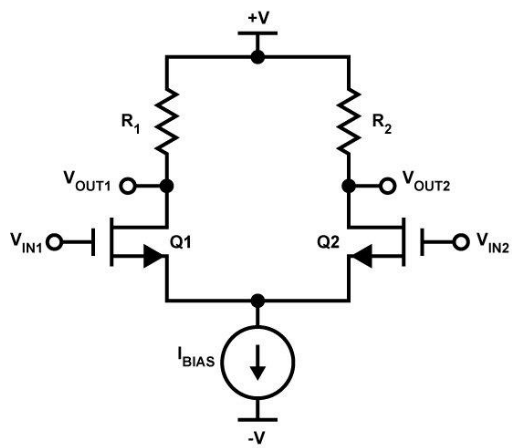
- Now, we have removed all the capacitors!

4. CONSTANT CURRENT SOURCE BIASING

- The bias current $\mathbf{I_Q}$ is implemented as a **current source** instead of a biasing resistor.

- A current source **resists changes** in current due to voltage changes.

- Thus stability of bias current is achieved.



- The resistance seen through a current source determines its stability.

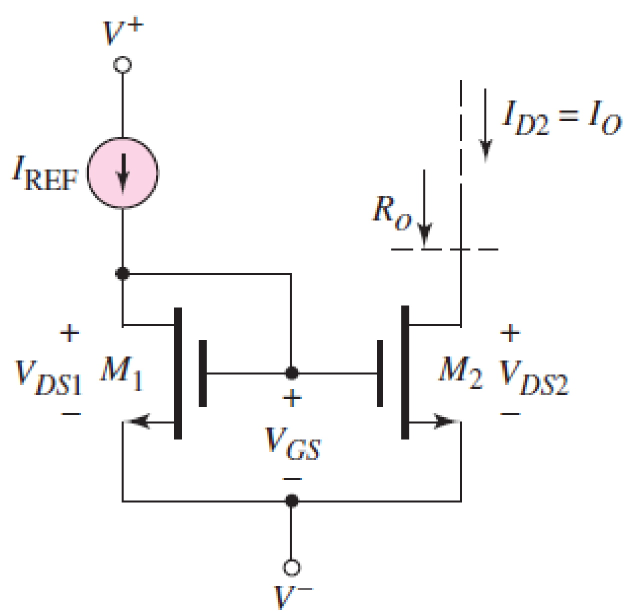
5. CURRENT MIRROR CIRCUIT

Basic Idea:

- A current source is usually created by using a **band-gap reference** circuit.

- But it is **highly complex** and cannot be used at everyplace wherever a current source is required.

- We wish to **make copies** of this is **"Golden current source".**



- By using a current mirror, we can **make copies** of a reference current source in another circuit.

Circuit interpretation:

- M_1 acts as a **diode-connected** transistor.
- V_{GS} of M_1 will have a square-root relationship with that of I_{REF}.
- Since the gate-source voltage of both the MOSFETS are the same V_{GS}, it is inferred that they will have same drain current.

Design:

Neglecting channel length modulation, λ = 0, the reference current can be given as

$$I_{\mathrm{REF}} = K_{n1}(V_{GS} - V_{TN1})^2$$

$$K_n = \frac{W\mu_n C_{\mathrm{ox}}}{2L}$$

where C_{ox} is the oxide capacitance per unit area.

$$C_{\mathrm{ox}} = \epsilon_{\mathrm{ox}}/t_{\mathrm{ox}}$$

Where

V_{TN1} – turn on voltage or threshold voltage

K_{n1} - trans-conductance parameter

Solving for V_{GS} and substituting in output current I_O,

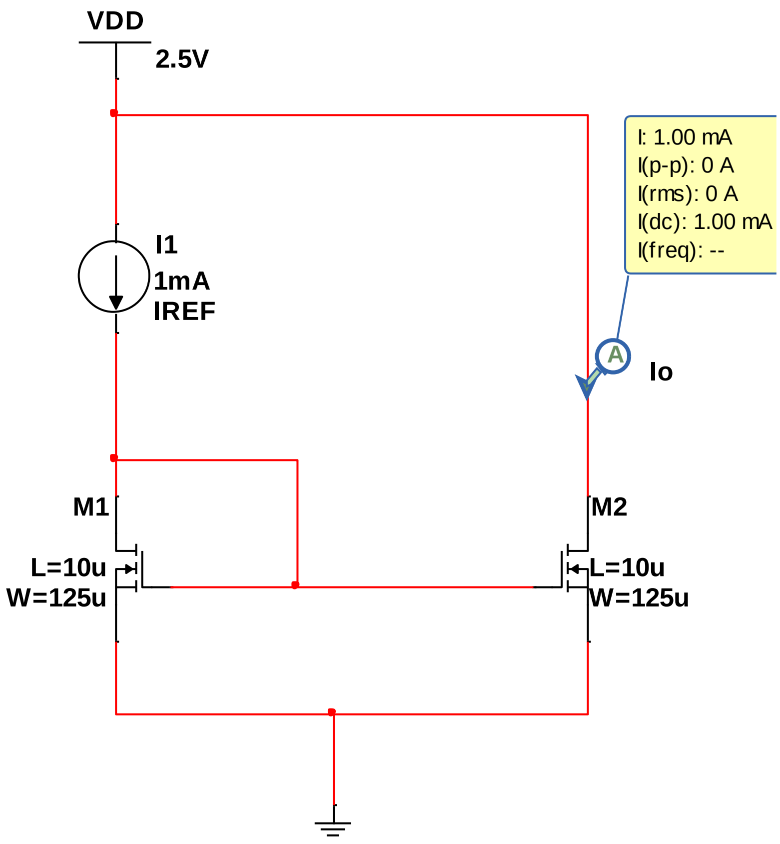
$$V_{GS} = V_{TN1} + \sqrt{\frac{I_{\mathrm{REF}}}{K_{n1}}}$$

$$I_O = K_{n2}(V_{GS} - V_{TN2})^2$$

$$I_O = K_{n2}\left[\sqrt{\frac{I_{\mathrm{REF}}}{K_{n1}}} + V_{TN1} - V_{TN2}\right]^2$$

If M_1 and M_2 have identical parameters, then the output current is simply,

$$I_O = \frac{(W/L)_2}{(W/L)_1} \cdot I_{\mathrm{REF}}$$



6. REFERENCE CURRENT SOURCE

The reference current can be established by using additional transistors.

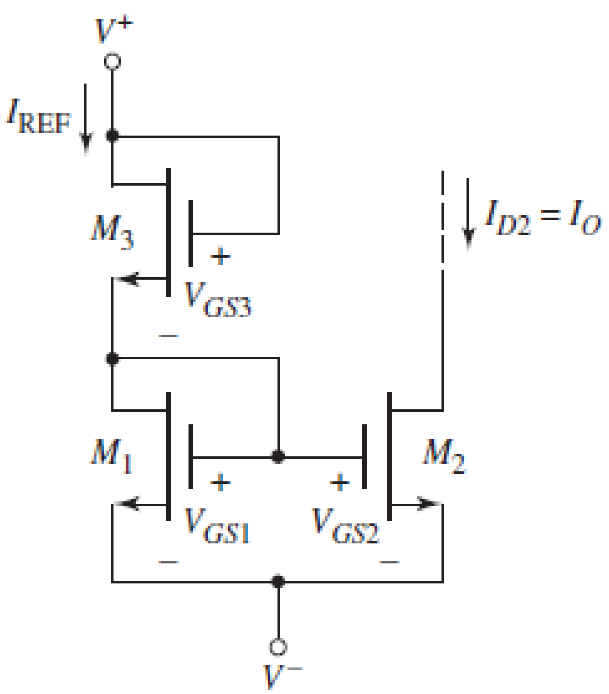
Now MOSFETS M_3 and M_1 are in series.

$$K_{n1}(V_{GS1} - V_{TN1})^2 = K_{n3}(V_{GS3} - V_{TN3})^2$$

$$V_{GS1} + V_{GS3} = V^+ - V^-$$

Solving for I_O, we get

$$I_O = \frac{k_n'}{2} \cdot \left(\frac{W}{L}\right)_2 (V_{GS2} - V_{TN})^2$$

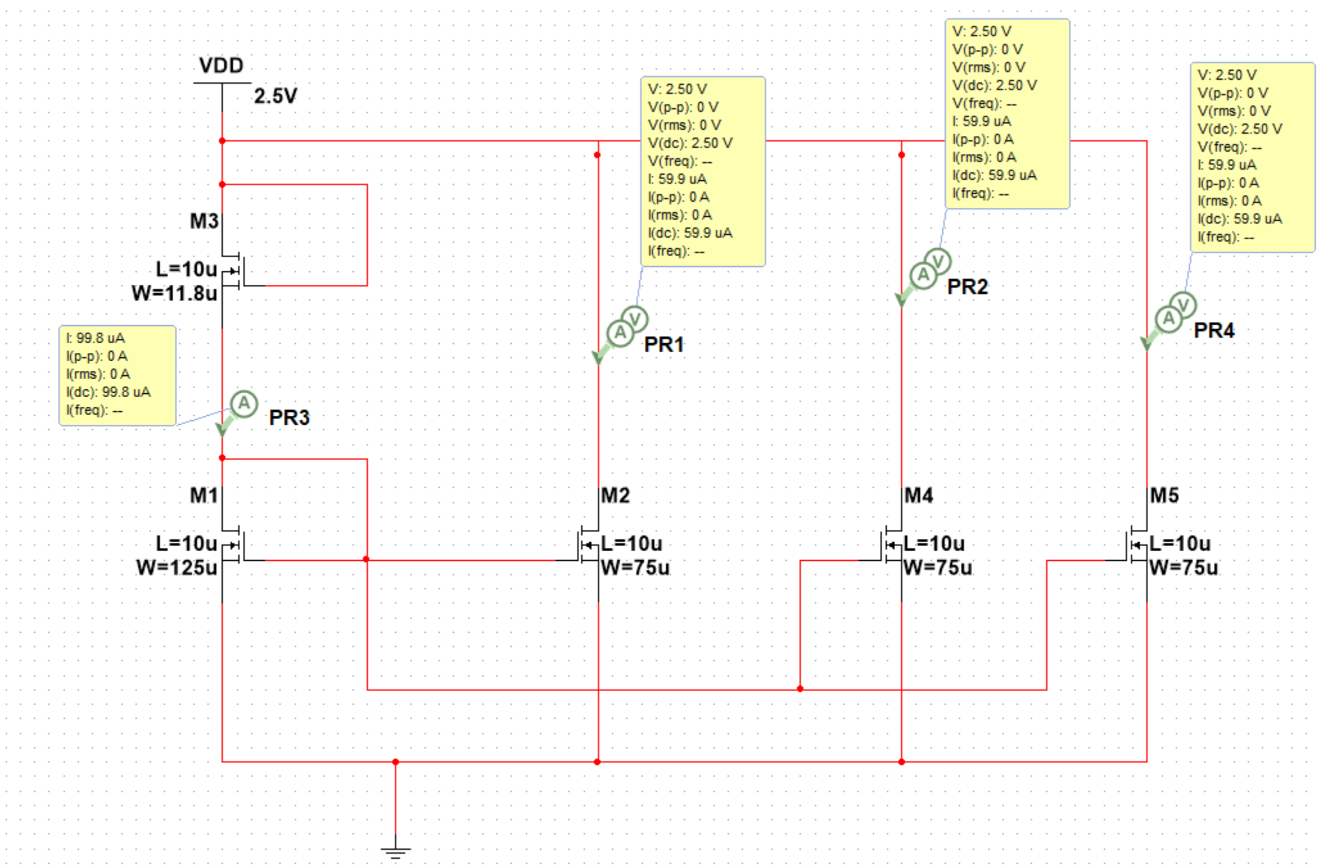


Remarks:

- The drain terminal of M_2 can be connected to the tail end of a differential pair.
- The output resistance of M_2 should be sufficiently high so that the current does not change with fluctuations in supply voltage.
- Stability is a **major concern.**
- Stability can be improved by placing stacking a transistor on top of other. (**Cascoding**).
- The **resistance** seen through the **drain terminal** is **large**

7. MULTIPLE CURRENT MIRRORS

The V_{GS} voltage can be applied to the input of many MOSFETS to create a number of current sources.

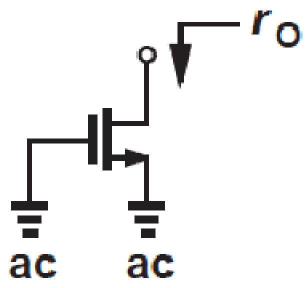


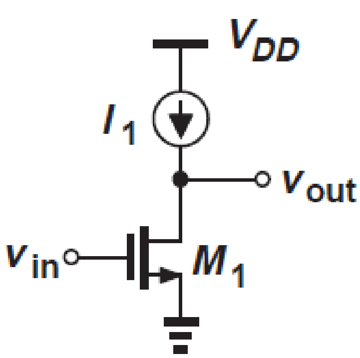
Remarks:

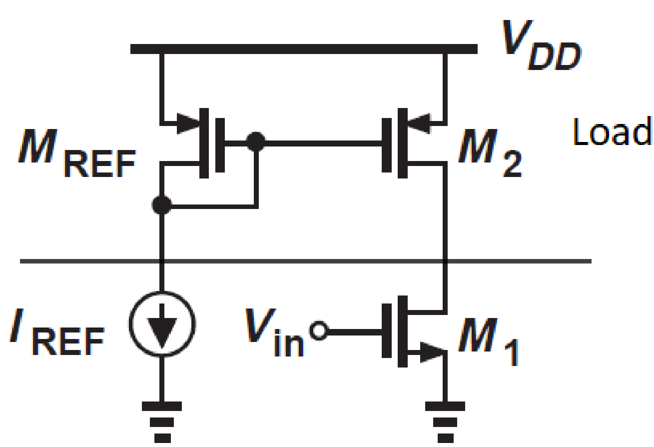
- The current can be adjusted by adjusting **width-length ratio**. (W/L)
- Mostly the length of the channel is kept constant and width is adjusted.
- The output resistance is a measure of the stability with respect to changes in the output voltage
- Output resistance can be increased by **stacking another transistor** on top of the desired transistor.

8. CURRENT SOURCE AS A LOAD ELEMENT (PMOS ACTIVE LOAD)

- Normally a large resistor is used to obtain higher small-signal gain.
- Small signal gain, $A_v = - g_m * R_d$
- But using a resistor also produces a considerable DC voltage drop.
- $V_{DS} = V_{DD} - I_D * R_d$
- We need a device which provides **large small-signal impedance** but should **allow** the **DC bias current** to flow through **without** a voltage drop.

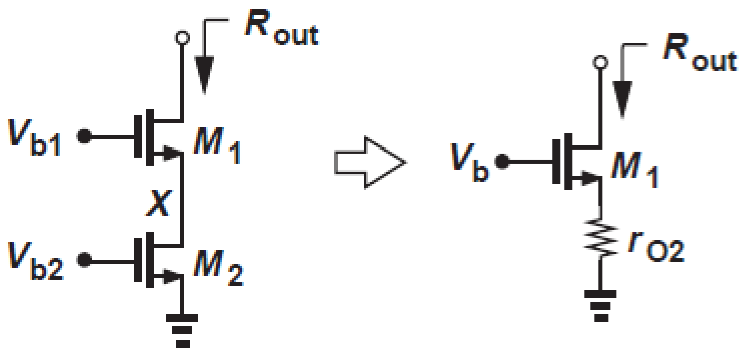






- **r_O** is due to **channel length modulation**.
- Since it is very large we can use a MOSFET as the load element.
- A **PMOS** acting as a current source becomes the load.
- The PMOS load is biased using a current source
- Now the output impedance = $(r_{o1} \,||\, r_{o2})$
- The small-signal voltage gain, $A_v = -\, g_{m1} * (r_{o1} \,||\, r_{o2})$
- The MOSFETs should be **saturation**.

9. CASCODING OF TRANSISTORS



- MOS transistors acting as a current source can be **stacked** one upon another to increase the output impedance.

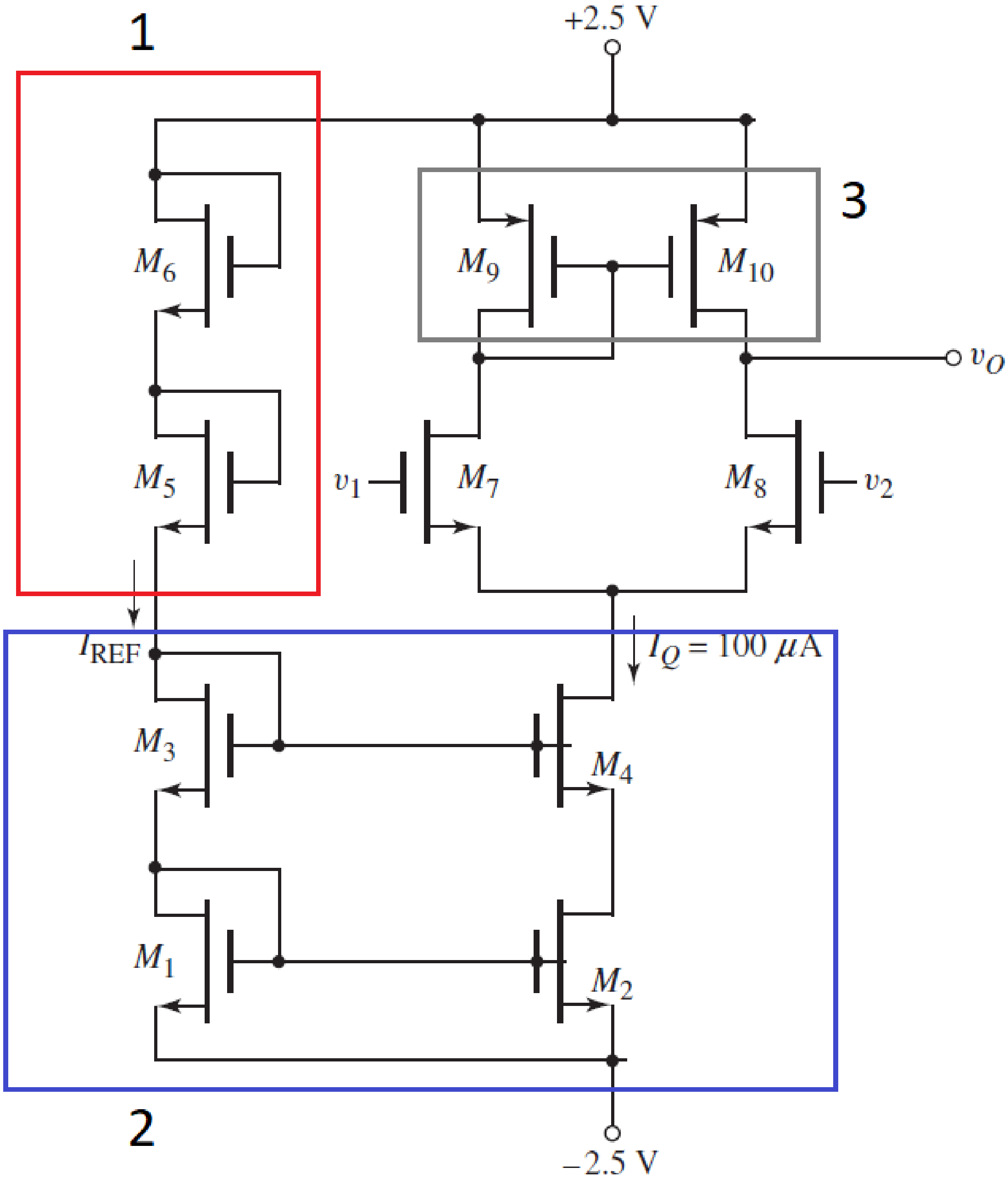
- For the above circuit, $R_{out} \sim g_{m1} * r_{O1} * r_{O2}$

- The output impedance is proportional to the intrinsic gain of the cascode device.

- This cascode arrangement can also be used as the load to increase the overall gain of the transistor.

10. ALL MOS AMPLIFIER

With the knowledge of the topologies gain so far, we can now analyze and design a high-gain differential amplifier.



Circuit Interpretation:

1 – **Reference current**: This is used to establish the reference current. It is a cascode structure so the stability of current source is increased.

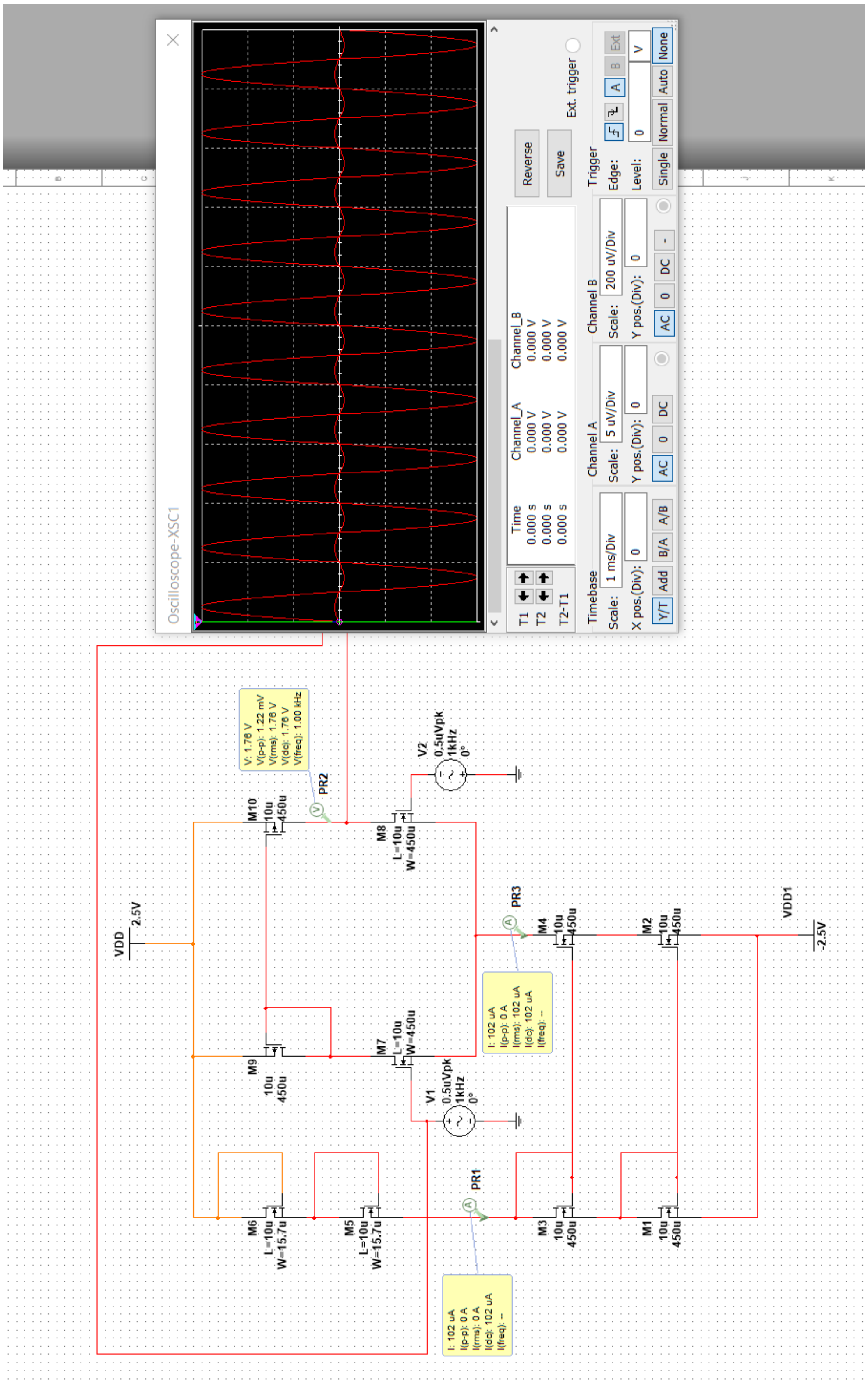
2 – **Cascode Current Mirror Circuit:** This is used to establish the bias current or the drain current of the differential pair. It gives large output resistance. The output impedance

3 – Active load: This topology uses PMOS load biased by a current mirror as the active load.

Working:

Differential pair is working in single ended output mode. The I_{REF} established by part 1 of the circuit. This is mirrored by part 2 of the circuit and becomes the bias current of the differential amplifier. The load of the differential amplifier is a PMOS current mirror. So the gain of the transistor is quite high.

11. SIMULATION



12. RESULT

Thus we have designed an amplifier without using bias resistors and capacitors.

13. BIBLIOGRAPHY

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