# Lab 6 prelab

Wednesday, September 25, 2024 21:39

## MOSFET OP AMP

- differential inputs - wide range of common mode inputs
- very large open-loop gain - negative feedback networks to create amplification + filtering circuits independent of op amp design
- very large input impedence - prevents loading 'high impedence' outputs (accuracy not lost)
- low output impedance - enables driving small impedance loads without loss of linearity/accuracy
- High bandwidth - allows amplification of high frequency signals

Negative feedback network can control system's gain + bandwidth
- circuits can also be easily cascaded

input $\pm$ → Differential gain ⟶ voltage gain ⟶ current gain ⟶ output

- ideal opamp has infinite open loop gain

common source amp

$$A_v = g_{m8}(r_{o8} \| r_{o4})$$

$$r_{out} = r_{o8} \| r_{o4}$$

## Lowering output impedance: Source follower

Source follower = common drain amplifier
- provides amplifier with current gain | reduce output impedance so amplifier can deliver more current with less V drop

assuming Q7 in sat in fig 6.5:

$$V_S = V_{in} + V_{SG} = V_{in} + \sqrt{\frac{i_D}{\frac{W}{2L}k'}} + |V_{th}|$$

tracks input voltage with offset $V_{th}$
- Source voltage "follows" the input voltage

source follower gain

$$A_V = \frac{V_{out}}{V_{in}} = \frac{g_m(r_o \| R_{source})}{1 + g_m(r_o \| R_{source})}$$

as long as $g_m(r_o \| R_{source}) \gg 1$
→ gain will approx be $A_V = 1V$
(if transistor in sat & has high k')

source follower output resistance

$$r_{out} = \frac{1}{g_m}$$

## Final design: Op amp

Satisfies: provides differential input
overall gain exceeds 60 dB
input resistances nearly ∞
output impedance reasonably low

## Prelab Questions

this diagram is scuffed as hell, sorry.

1. Small signal model for entire opamp

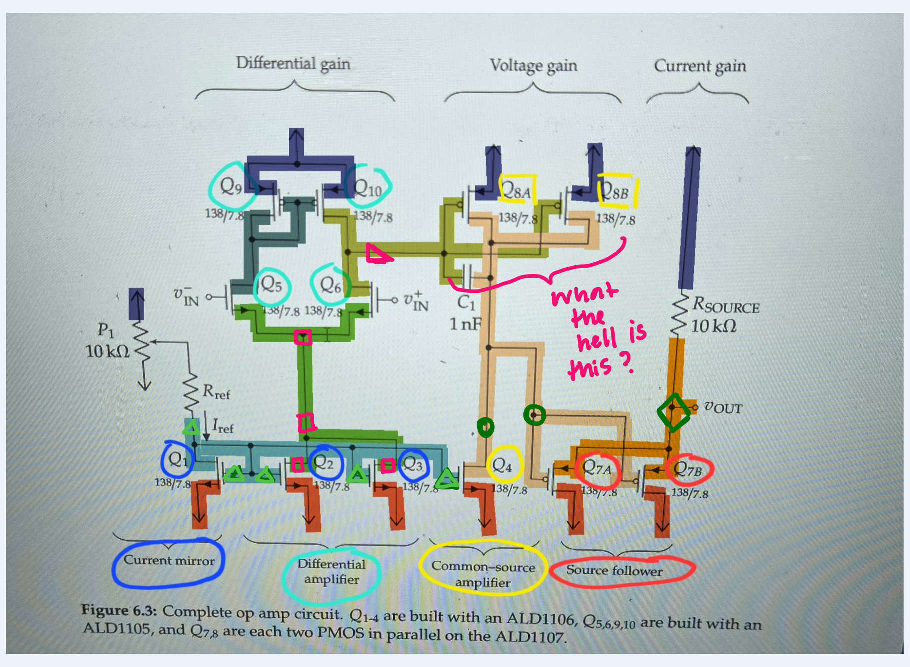
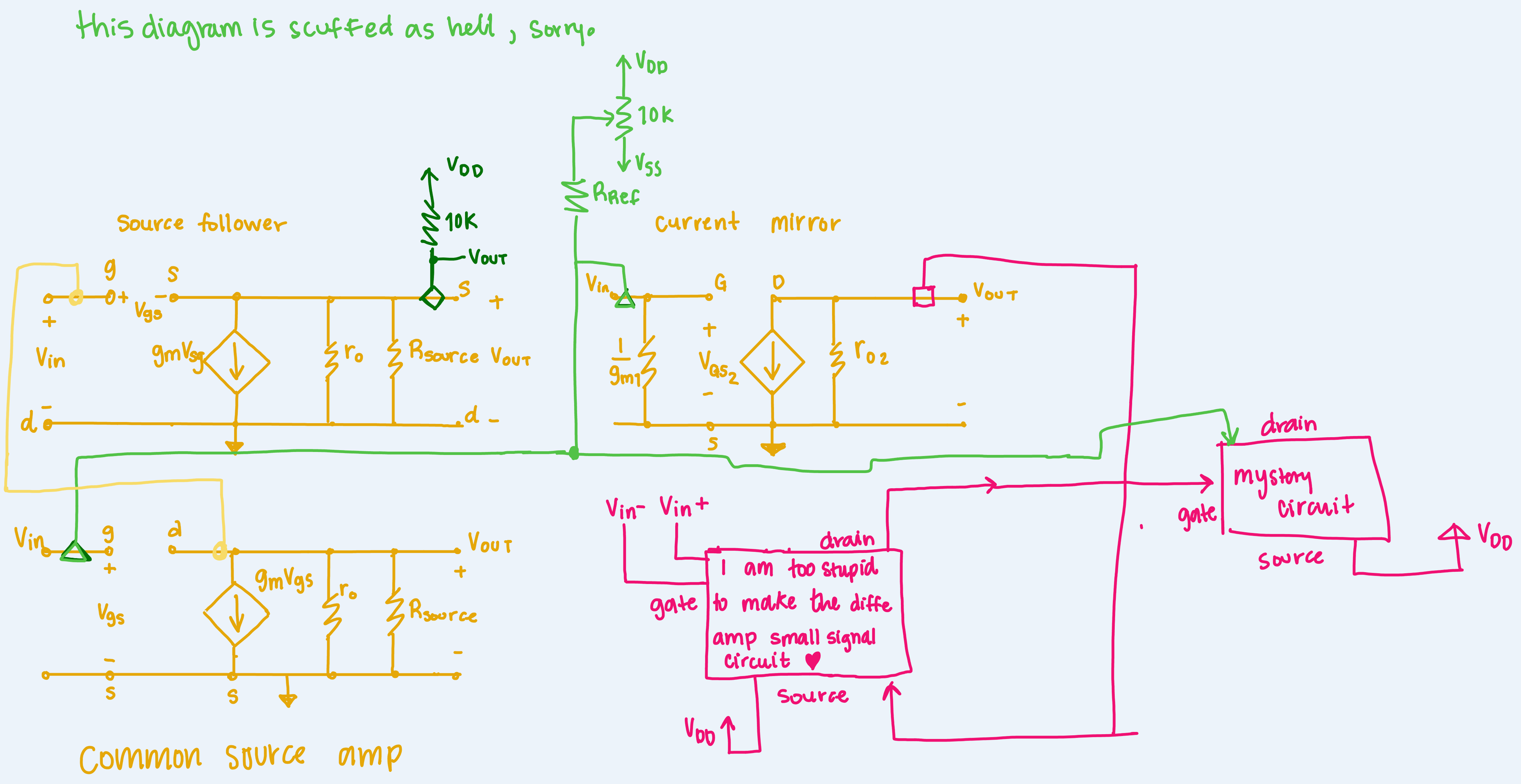


Figure 6.3: Complete op amp circuit. $Q_{1\text{-}4}$ are built with an ALD1106, $Q_{5,6,9,10}$ are built with an ALD1105, and $Q_{7,8}$ are each two PMOS in parallel on the ALD1107.




2. Open loop gain without source follower
→ in terms of transistor params + Iref

Current Mirror: Q 1 - 3

Differential Amp: Q 5, 6, 9, 10

CS Amp: $Q_4$ & Q8A-B

Source follower: Q7A - 7B

◇ Diffe Amp Gain

$Q_5$ & $Q_6$: Input ($V_{in\pm}$ input signals)
- amplifies difference in the 2 inputs

$Q_9$ & $Q_{10}$: active load
- high output impedance (more V gain)

$$A_{V(Diffe\ amp)} = g_{m5}(r_{o6} \| r_{o9})$$

◇ CS Amp Gain
- just $Q_4$ ◡̈ yay!

Similar to page 68 on the manual

$$A_{V(CSA)} = g_{m4}(r_{o2} \| r_{o4})$$

◇ Source follower Gain (current gain)
Q7 A + B

$A_{V(SF)} \approx 1$ (page 70, lab manual)

Open loop Gain: product of all gains

$$A_{V(open)} = A_{V(diff\ amp)} \times A_{V(CSA)} \times \underbrace{A_{(SF)}}_{\approx 1}$$

$$A_{V(open)} = A_{V(diff\ amp)} \times A_{V(CSA)}$$

$$A_{V(OL)} = (g_{m6}(r_{o6} \| r_{o9})) \times (g_m (r_{o2} \| r_{o4}))$$

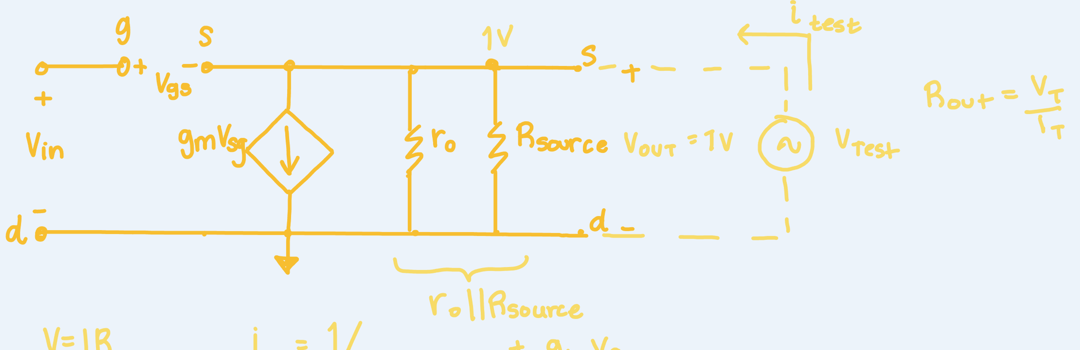
$$g_{m6} = \sqrt{2K\frac{W_6}{6L_6}I_{ref}} \qquad g_{m4} = \sqrt{2K_2\frac{W_2}{L_2}I_{ref}}$$

3. Estimate output resistance of CD output amp in 6.3

$V_{OUT} = 0\,V$

common drain = source follower

Source follower:




$$R_{out} = \frac{V_T}{I_T}$$

V = IR
I = V/R

$$i_T = 1/_{r_o \| R_{source}} + g_m V_{sg}$$

common drain: $R_{OUT} = 1/g_m \| r_o \| R_{SOURCE}$

↓

$R_{OUT} \approx 1/g_m$ (6.1)

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$$g_m = \sqrt{2K\frac{W}{L}I_D}$$

$I_D = 200\,\mu A$ (task 6.5.1)

$\frac{W}{L} = \frac{138}{7.8}$

$K = 11\,\mu A$

$g_m = 8.8\ mS$

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$$r_o = \frac{1}{\lambda_p I_D}$$

$\lambda_p = .008$
$I_D = 200\,\mu A$

$r_o = 625\ \Omega$

$$= \frac{1}{8.8 \times 10^{-3}} \| 625 \| 10K$$

$$= \left(8.8 \times 10^{-3} + \frac{1}{625} + \frac{1}{10K}\right)^{-1}$$

$$\boxed{r_o = 95.2\,\Omega}$$

Fig 6.5: $R_{source} = 10\,k\Omega$