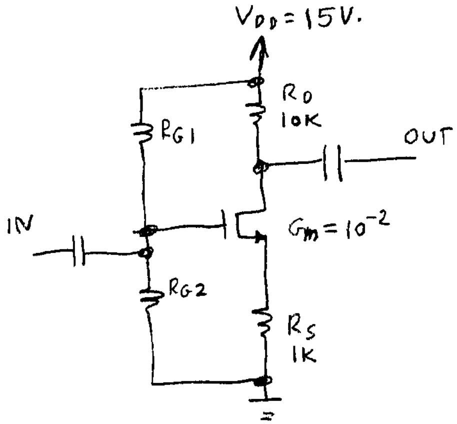
The "Four resistor" bias circuit

7A ①

We want → more control of gain and bias
→ better consistency of performance.



We want to set the bias point for Maximum possible Voltage swing at the drain.

Target:
Half of the voltage in the resistors
Half of the voltage in the transistor.

To solve it .....

If $V_{DD} = 15$, we want 7.5 in resistors
7.5 in transistor.

$$I = \frac{V}{R} = \frac{V_{DD}/2}{R_D + R_S} = \frac{7.5}{10k+1k} = \frac{7.5}{11K} = 682\ \mu A$$

This makes: $V_{RD} = (682\ \mu A)(10K) = 6.82\ V.$
$V_{RS} = (682\ \mu A)(1k) = .682\ V.$

Homework: ① Find the bias point for $G_m = 10^{-3}, 10^{-1}$
② Find the gain for $G_m = 10^{-3}, 10^{-1}$
for both bypassed and unbypassed.

②

We need to determine the gate voltage

Device characteristics: $I_D = G_m V_{GS}$ (Properties of this type device)

rearrange formula: $V_{GS} = \frac{I_D}{G_m}$

substitute: $V_{GS} = \frac{682\ \mu A}{10^{-2}}$

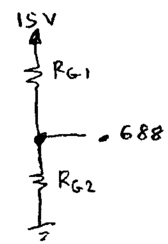
$V_{GS} = 68.2\ mV$

(.0682 V.) ← These small voltages are typical.

We can think of it as "zero"

$$V_G = V_S + V_{GS}$$
$$= .682 + .0682$$
$$= .75\ V.$$

Now choose R_{G1} and R_{G2} for .75 V



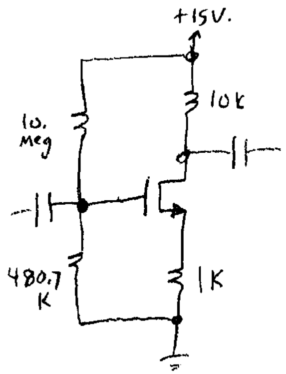
Voltage divider --

$V_{RG2} = .75$

$V_{RG1} = 15 - .75 = 14.25$

$$\frac{R_{G1}}{R_{G2}} = \frac{14.25}{.75} = \frac{19}{1}$$ ← Any resistors in this ratio will work – Choose high

$$\frac{R_{G1}}{R_{G2}} = \frac{10\ Meg}{526.3K}$$ ← a possible pair of values.

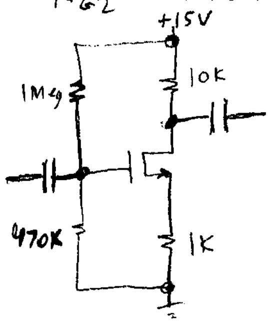


1. What is the gain?
2. What happens when components are a little different?

(2) first ---

Components are a little different

$R_{G2} = 470K$ (standard value)



What is the real bias point?

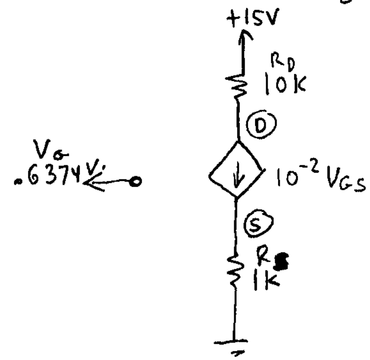
First: Find V_G

$$V_G = V_{DD} \frac{R_{G2}}{R_{G1}+R_{G2}}$$

$$= 15 \frac{470K}{10470K}$$

$$= .6734 \text{ V.}$$

Next: Find V_S by



KCL at node (S)

$$\frac{V_S}{R_S} - G_m V_{GS} = 0$$

$$\frac{V_S}{1K} - 10^{-2}(.6374 - V_S) = 0$$

$$10^{-3} V_S - 6.374 \times 10^{-3} + 10 \times 10^{-3} V_S = 0$$

$$V_S - 6.374 + 10 V_S = 0$$

$$11 V_S = 6.374$$

$$V_S = \frac{6.374}{11}$$

$$V_S = .580$$

$$I_S = 580 \mu A$$

we wanted 680 μA

Does it matter?

$$V_{RD} = I R$$

$$= (580 \mu A)(10K)$$

$$= 5.8 V.$$

(wanted 6.82)

$$V_{Transistor} = 15 - 5.8 - .58$$

$$= 8.62$$

(wanted 7.5)

→ The bias point has moved by ≈ 1 volt.

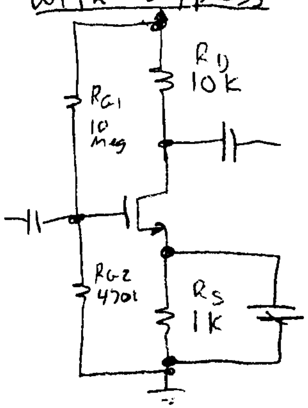
Probably it is still close enough!

7A (5)

Finding the gain:

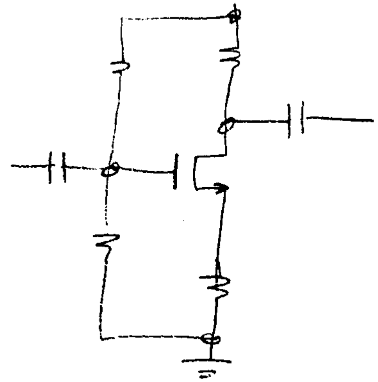
Two variations:

With Bypass



High gain

No bypass



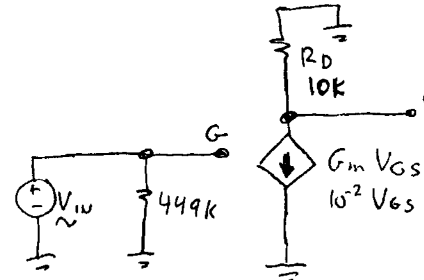
Low gain.

First --- with bypass - high gain

→ Bypassing the source resistor makes gain the same as if R_S wasn't there, but we keep the benefit in getting better bias.

substitute model: , use AC equivalent circuit

7A (6)

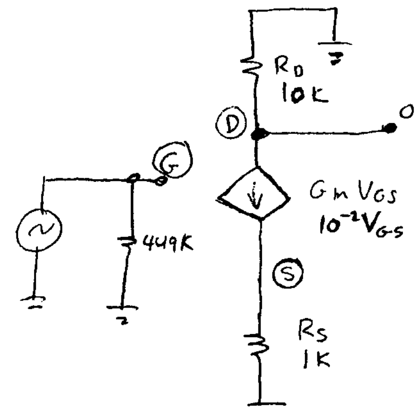


(by formula - You could do KCL at (D))

$$Gain = -G_m R_L$$
$$= -(10^{-2})(10^5)$$
$$= -100$$

7A got this far.

No bypass - Lower gain



The hard way:

KCL --

at (D) $\frac{V_D}{R_D} + G_m V_{GS} = 0$

(S) $\frac{V_S}{R_S} - G_m V_{GS} = 0$

$V_{GS} = V_G - V_S$

(D) $\frac{V_D}{R_D} + G_m(V_G - V_S) = 0$

(S) $\frac{V_S}{R_S} - G_m(V_G - V_S) = 0$

2 equations, 2 unknowns V_S, V_D

R_D, R_S, G_m, V_G are known.

7A

(7)

solve (S) first – it has no V_D

$$\frac{V_S}{R_S} - G_m V_G + G_m V_S = 0$$

$$V_S\left(\frac{1}{R_S} + G_m\right) - V_G(G_m) = 0$$

$$V_S\left(\frac{1}{R_S} + G_m\right) = V_G G_m$$

$$\frac{V_S}{V_G} = \frac{G_m}{\frac{1}{R_S} + G_m} = \frac{10^{-2}}{10^{-3}+10^{-2}} = \frac{.01}{.011} = .91$$

a little less than 1

voltage divider

$$V_S = \left(\frac{G_m}{\frac{1}{R_S} + G_m}\right) V_G$$

solve (D)

[note that: $\frac{V_S}{R_S} = G_m V_{GS}$

substitute ...

$$\frac{V_D}{R_D} + G_m V_{GS} = 0$$

$$\frac{V_D}{R_D} + \frac{V_S}{R_S} = 0$$

$$\frac{V_D}{R_D} = -\frac{V_S}{R_S}$$

$$\frac{V_D}{V_S} = -\frac{R_D}{R_S} = -\frac{10K}{1K} = -10$$

$$\frac{V_D}{V_G} = \frac{V_D}{V_S}\frac{V_S}{V_G} = (-10)(.91) = -9.1$$

$$\frac{R_1}{R_1+R_2} = \frac{\frac{1}{R_2}}{\frac{1}{R_2}+\frac{1}{R_1}} = \frac{G_2}{G_2+G_1}$$

$$\frac{G_m}{\frac{1}{R_S} + G_m} = \frac{R_S}{\frac{1}{G_m} + R_S}$$

$$\frac{\frac{R_S}{G_m}}{\frac{R_S}{G_m}}$$

$$\frac{V_D}{V_S} = \left(-\frac{R_D}{\cancel{R_S}}\right)\left(\frac{\cancel{R_S}}{\frac{1}{G_m} + R_S}\right)$$

$$= \frac{-R_D}{\frac{1}{G_m} + R_S} = \frac{10K}{\frac{1}{10^{-2}} + 1K} = \frac{10K}{1100}$$

$$= -9.1$$