Cascode
Gain Circuit

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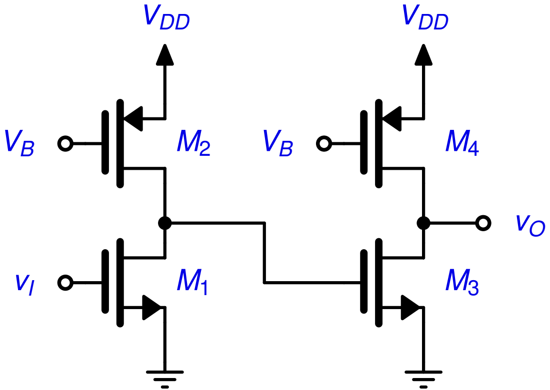
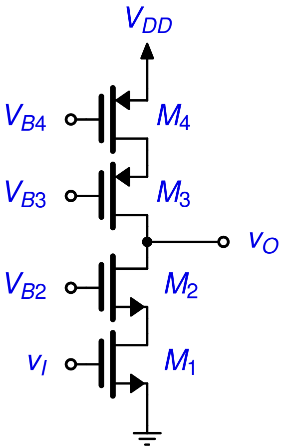
Cascade Amp



- If all r_o are the same and $g_m = g_{m1} = g_{m3}$
- $v_o = (-g_m r_o/2)(-g_m r_o/2)v_i = \frac{1}{4}(g_m r_o)^2 v_i$
- But we use twice as much current

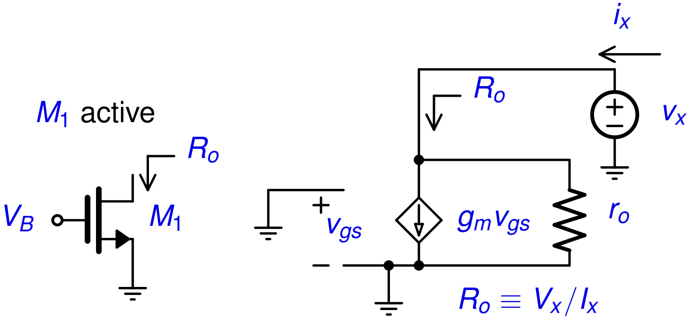
Cascode Amp



- We will see its gain is approx $-\frac{1}{2}(g_m r_o)^2$
- So twice as much gain and no extra current
- Will need a higher power supply value

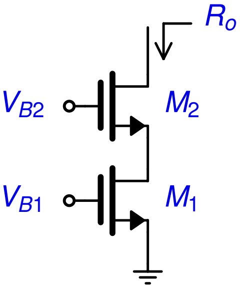
Output Impedance of Active Transistor

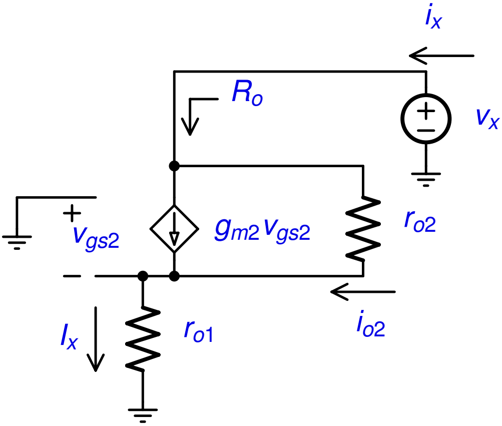
- To find impedance R_o, zero all independent sources, apply voltage v_x and find i_x



- Since $v_{gs} = 0$, $g_m v_{gs} = 0$ so $i_x = v_x / r_o$
- $R_o \equiv v_x / i_x = r_o$

Output Impedance of Cascoded Transistor





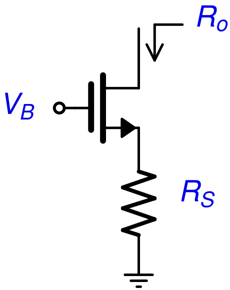
Output Impedance of Cascoded Transistor

- i_x flows through $g_{m2} v_{gs2}$ and r_{o2} and recombines so that i_x flows through r_{o1}
- $v_{gs2} = 0 - i_x r_{o1}$
- $i_x = i_{o2} + g_{m2} v_{gs2} = i_{o2} + g_{m2}(-i_x r_{o1})$
- $i_{o2} = (v_x - i_x r_{o1})/r_{o2}$
- $i_x = (v_x - r_{o1} i_x)/r_{o2} - g_{m2} r_{o1} i_x$
- $i_x(1 + g_{m2} r_{o1} + (r_{o1}/r_{o2}) = v_x/r_{o2}$
- $R_o \equiv v_x/i_x$

- $R_o = r_{o2} + (1 + g_{m2} r_{o2}) r_{o1}$
- If $g_{m2} r_{o2} \gg 1$ and $r_{o1} \approx r_{o2}$ (a common occurrence)
  - $R_o \approx g_{m2} r_{o2} r_{o1}$
- Note: $g_m r_o \gg 1$ is the same as $r_o \gg 1/g_m$

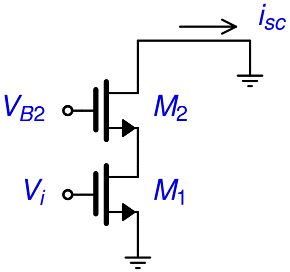
Output Impedance of Cascoded Transistor

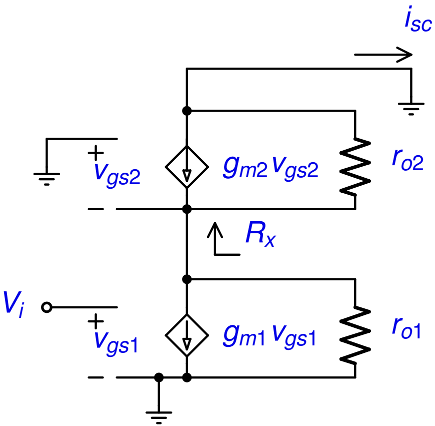
- In general,



$$R_o = r_o + (1 + g_m r_o) R_S \tag{1}$$

Short Circuit Current of Cascoded Transistor

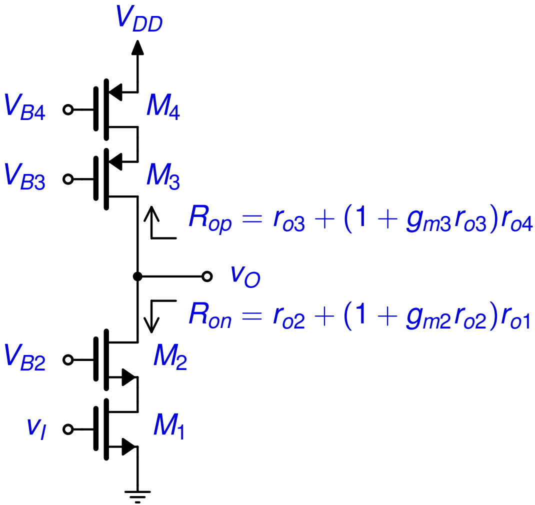




Short Circuit Current of Cascoded Transistor

- We can find $R_x = (1/g_{m2}) || r_{o2}$
- Now using the current divider rule, we find
- $i_{sc} = \frac{r_{o1}}{r_{o1}+R_x}(-g_{m1}v_i) = \frac{r_{o1}}{r_{o1}+(\frac{1}{g_{m2}}||r_{o2})}(-g_{m1}v_i)$
- For $g_m r_o \gg 1$, $i_{sc} \approx -g_{m1}v_i$

Cascode Amp Gain



Cascode Amp Gain

- $v_o = i_{sc}(R_{op}||R_{on})$
- $v_o/v_i = -g_{m1}(R_{op}||R_{on})\left(\frac{r_{o1}}{r_{o1}+(\frac{1}{g_{m2}}||r_{o2})}\right)$
- For all g_m and r_o the same and $g_m r_o \gg 1$
  $v_o/v_i = -\frac{1}{2}(g_m r_o)^2$
- Cascode amps and current mirrors are commonly used in integrated circuits.
- A cascode transistor can be put on top of a cascoded transistor and get even more output impedance but a even higher power supply is needed

Topics Covered

- Cascade Amp
  - To increase gain with multiple amps
- Cascode Amp
  - To increase gain with single amp
  - Output impedance of cascoded transistor
  - Increased gain for cascode amp