E151 Lecture 20 – Differential Pairs

Matthew Spencer
Harvey Mudd College
ENGR151

1

Disclaimer

These are notes for Prof. Spencer to give the lecture, they were not intended as a reference for students. Students asked for them anyway, so I'm putting them up as a courtesy. Remember that they are not intended as a substitute for attending lecture.

2

What is Differential

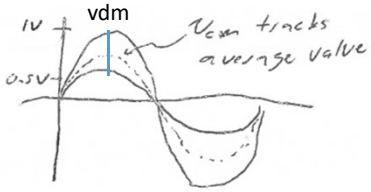
- Op-amps: A(v+ - v-) … how do we do that?
- Can represent any two signals as a common & differential mode
- Often useful b/c lots of noise (and distortion) is common mode

$v_{dm} = v_1 - v_2$ or $v_{cm} = \frac{v_1 + v_2}{2}$ (instantaneous / average value)

(usually small signal) ⇒ can express $v_1 = v_{cm} + \frac{v_{dm}}{2}$ $\left(v_2 = v_{cm} - \frac{v_{dm}}{2}\right)$

- EG: $v_1 = 1V \cdot \sin(\omega t)$

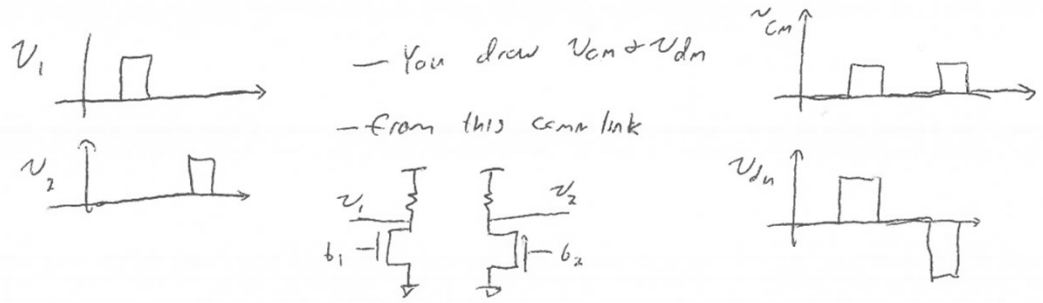
  $v_2 = 0.5V \sin(\omega t)$



4

Example of Differential Signals

You try pseudo-diff signaling ~ a common digital technique

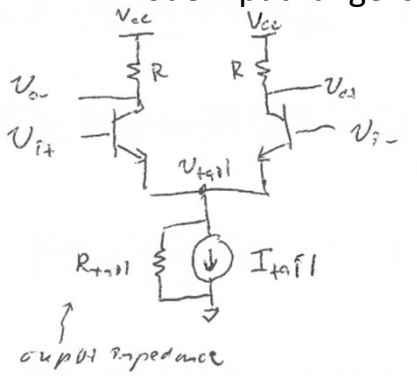


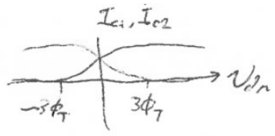
- This isn't called purely differential signaling b/c there is some CM
- How would you measure rin_cm of an amp? rin_dm?

5

Emitter Coupled Pair + Large Signal Behavior

- The most common circuit that amplifies DM but not CM is ECP
- Big picture: works by current steering … DM does and CM doesn't
- Diff mode input range is ~3*phi_th. Better w/ degeneration.





$$v_{i+} - v_{be1} + v_{be2} - v_{i-} = 0$$

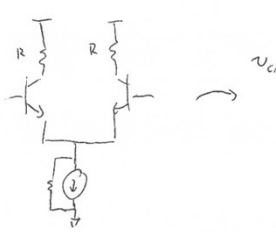
$$v_{i+} - v_{i-} + \phi_T\left(\ln\frac{I_{c2}}{I_{s2}} - \ln\frac{I_{c1}}{I_{s1}}\right) = 0$$

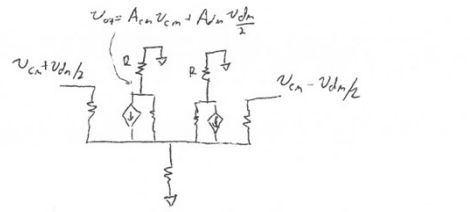
$$\frac{I_{c1}}{I_2} = e^{v_{dm}/\phi_T}$$

6

½ Circuit Analysis

- Analyze the small signal model w/ symmetry and superposition.
- dm vs cm parameters – av, rin, rout, etc.
- CMRR=adm/acm

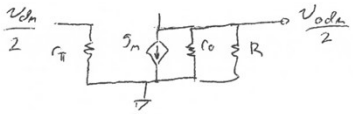




- superposition breaks into cm & dm circuits
- symmetry lets us draw ½ circuits

dm ½ circuit

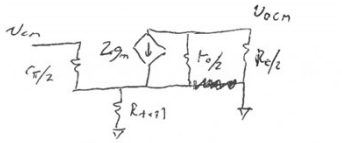
- v_{tail} is dm ground, no seesaw ∴ small sig gnd.
- dm doesn't result in any current into R



$$A_{dm} = g_m(r_o \| R)$$

cm ½ circuit

- everything is in parallel



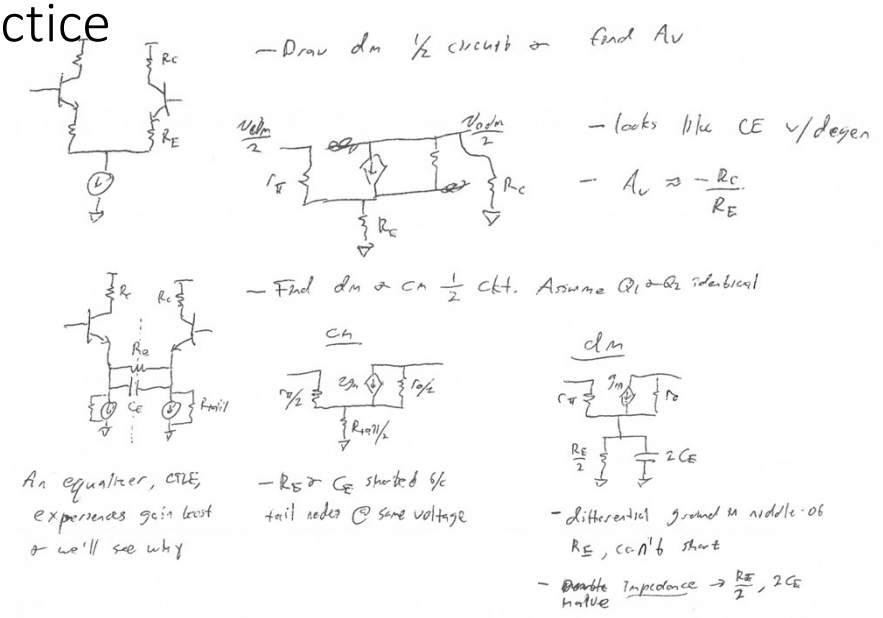
$$A_{cm} \approx \frac{R_c}{2R_{tail}}$$

½ looks like CE w/ degen

7

½ Circuit Practice

- Extends linear input range to Itail*Re (same as linear design)
- An equalizer, CTLE, gain boost at high freq.
- Note ½ ckt OCTC and SCTC



8