E151 Lecture 20 – Differential Pairs

Matthew Spencer
Harvey Mudd College
ENGR151

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.

What is Differential

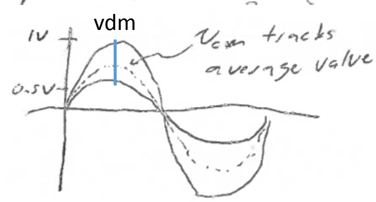
- Op-amps: A(v+ - v-) … how do we do that?
- Can represent any two signals as a common & differential mode
- Often useful b/c lots of noise (and distortion) is common mode

$v_{dm} = v_1 - v_2$ (usually small signal) & $v_{CM} = \frac{v_1 + v_2}{2}$ instantaneous (average value)

can express $v_1 = v_{CM} + \frac{v_{dm}}{2}$ $\left(v_2 = v_{CM} - \frac{v_{dm}}{2}\right)$

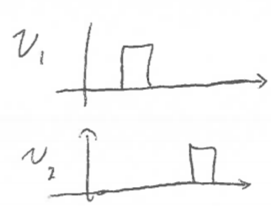
- EG: $v_1 = 1V \cdot \sin(\omega t)$

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



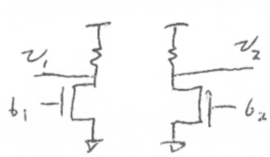
Example of Differential Signals

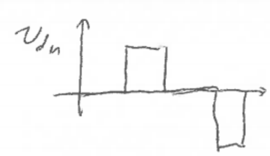
You try pseudo-diff signaling ~ a common digital technique



— You draw v_{cm} & v_{dm}

— from this comm link

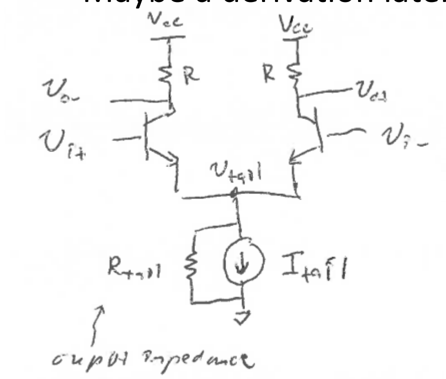


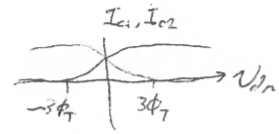


- This isn't called purely differential signaling b/c there is some CM
- How would you measure rin_cm of an amp? rin_dm?

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
- Maybe a derivation later … gets at linearity and other cool stuff





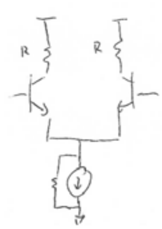
$$v_{i+} - v_{be1} + v_{be2} - v_{i-} = 0$$

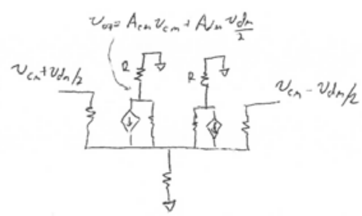
$$v_{i+} - v_{i-} + \phi_T\left(\ln\frac{I_{c2}}{I_{s2}} - \ln\frac{I_{c1}}{I_{s1}}\right) = 0$$

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

½ Circuit Analysis

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

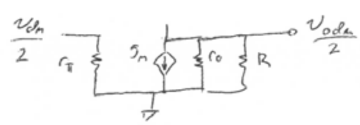




– superposition breaks into cm & dm circuits
– symmetry lets us draw ½ circuits

dm ½ circuit

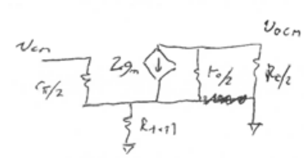
– v_{tail} is dm ground, no seesawing ∴ small sig gnd.
– dm doesn't result in any i flow into R



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

cm ½ circuit

– everything is in parallel



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

½ looks like CE w/ degen

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