Week 4: FETs & more on Bipolar (NPN) Transistors – 3 terminal devices. Tue Feb 18

H&H L6&7, MUST SKIM P124-165, but ASSIMILATE 134-138,156-162.
DO NOT DO 6-2, 6-3; 7-3b) & c), 7-4
... If extra time, go back & do any missed labs

SHOW & TELL:
Heat sinks
Resistors: 1st 2-bands = std ±10% values: 10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68, 82
How FETs work

Please turn off everything upon leaving for the day (unlike AdLab, where stability critical).

Transistors: for low noise front ends, use Differential Amps *vs.* single-ended...
typical transistor current gain β ~ 100 ac or dc
= an impedance multiplier/matcher:
emitter follower: impedance is β x R_E emitter resistor p96
R_E provides negative feedback to stablize gain; warm up xister w/two fingers.
common emitter input Z: = β x R_C (collector resistor)
bias your xister "quiescently" to avoid saturation, clipping, distortion, etc.
input dynamic range, relative to 0.6 V_{BE}, otherwise xister is not active
output voltage compliance see p140, "Jargon"
= output voltage dynamic range of current source
...limited by the 2 rails, typically ground, and ±5, ±6, ±12, ±24vdc (why±?)
i_S saturation current, R_C limits output current

FET (Field Effect Transistor) "β" > 1000...the front-end that's hidden inside all op amp ICs.

Pretty simple: current amplifier: $I_C = \text{Beta} \cdot I_B$

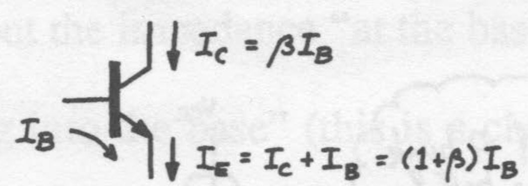

Figure N4.2: Transistor as *current*-controlled valve or amplifier

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Very simple: say nothing of Beta (though assume it's at work)

- Call V_{BE} constant (at about 0.6 v);
- call $I_C = I_E$.

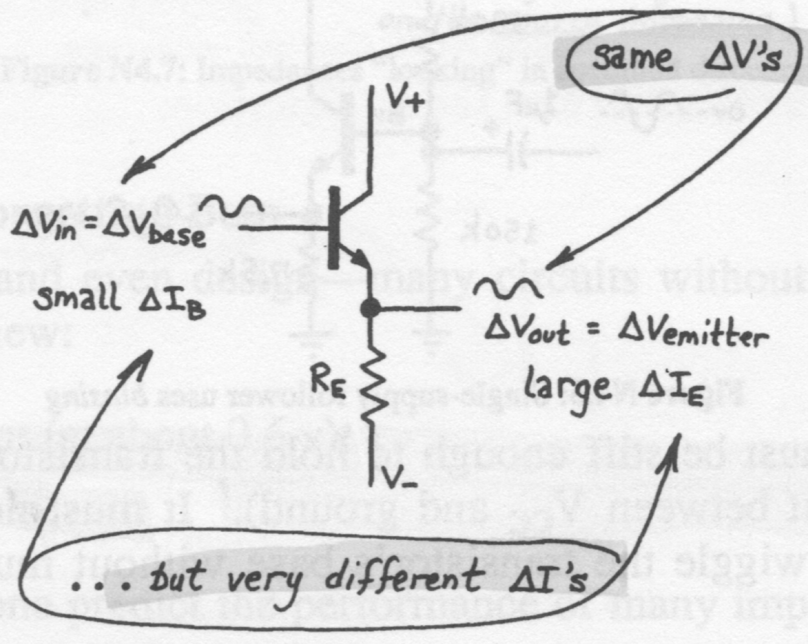


Figure N4.3: How a follower changes impedances

$$\Delta R = \frac{\Delta E}{\Delta I}$$

See P 85 & 90-93

RECIPE FOR COMMON-EMITTER PIE

What output current do you want to drive?

With quiescent V_{out} ~ 1v, need output blocking capacitor?
...if not one on the input to next stage

Input dc base bias must be dc stiff, not affected by dc changes.

Set the ratio R2/(R1+R2) to give 1.6v.

$R_{IN}C$ must pass relevant frequencies:
$\beta \times R_E$ is big, so $Z_{in} \sim R_1 \,||\, R_2$

P115

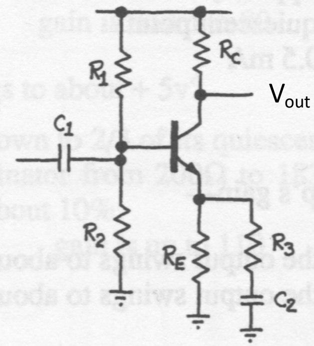


Figure X5.1: Skeleton Circuit

Setting *DC* conditions

1. Choose R_C to center V_{out}, given $I_{C\,(quiescent)}$
2. Choose R_E to put V_E somewhere around 1 volt, for temperature stability
3. Let R_{Th} for the bias divider be about 1/10 (R_{in} transistor, which is $\beta \cdot R_E$). As for the follower recently designed, the *AC* path to ground is to be ignored: the path through R_3 is closed to DC, so invisible to the bias divider.
4. Choose R_1, R_2 to put V_{base} at (V_E + 0.6V). R_{Th} is roughly R_1, since the divider is so far unbalanced.

Determining AC performance: Gain (what happens to signal)

1. Choose R_3 (if any) for gain at quiescent point
2. Choose C_2 for f_{3dB}: the relevant "R" is $R_3 + r_e$
3. Choose C_1 as usual; relevant "R" is circuit's Z_{in} , as usual: the circuit's *AC* input impedance, as for the follower: we look through capacitor C_2, and see R_3 as a path to ground.
   In choosing C_1 we need to be generous, since two high-pass filters are at work: those using C_1 and C_2. So, if we made the mistake of putting the f_{3dB} for each filter precisely at our target f_{3dB} for the *circuit*, we would be disappointed: we would find the *circuit's* response down *6dB*.

Impedances of an amp (or any component)...how to measure?

Treat amp as a Thevenin black box: *i.e.* a V_{th} in series with R_{th}.

R_{in}: looking "forward," into the input terminal.

R_{out}: looking "backward," into output terminal from next stage.

Measure the open circuit V, = V_{th}.

Add a variable R in series (a substitution box is most convenient)

Change R until V across it is = ½ V_{th}.

Then, R_{th} = R.

DVM *vs* VOM, for this application

DVM...10 MΩ input impedance...a FET input stage

hi-Z input, followed by op amp for feedback stability *vs.*

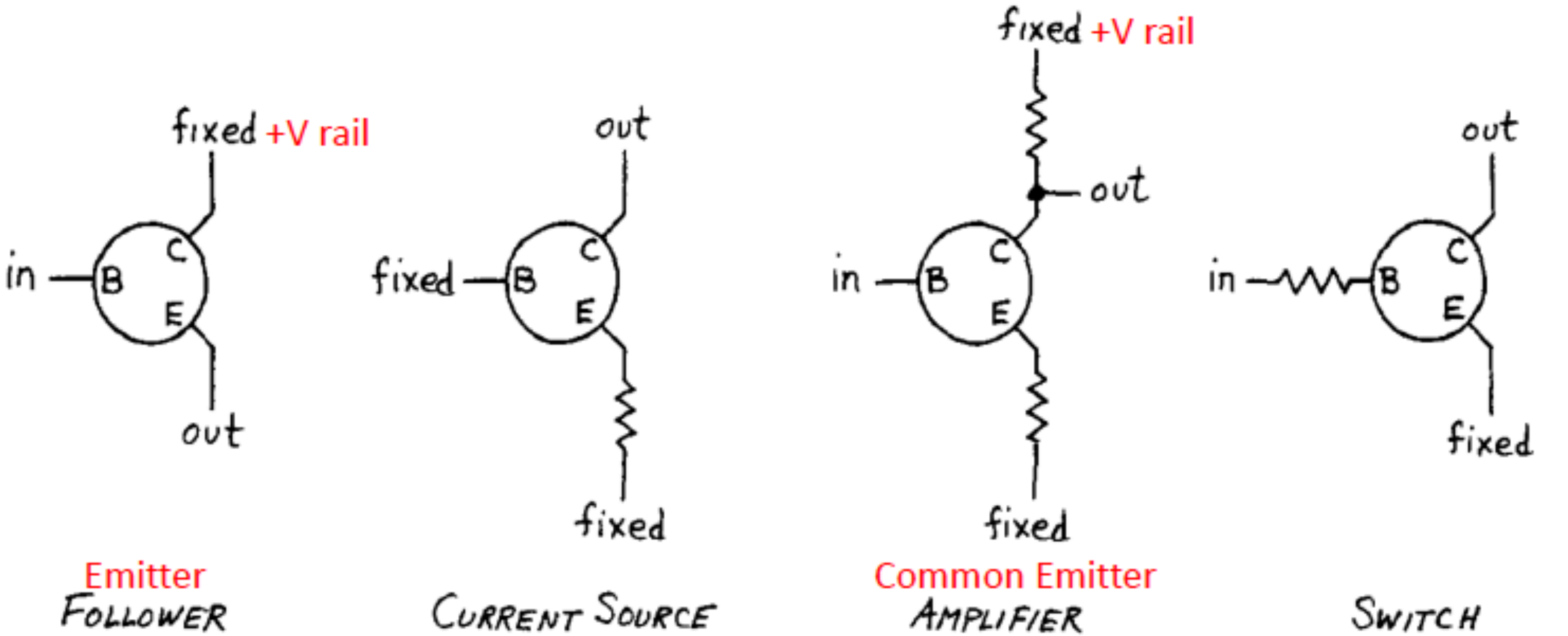
VOM...much lower input impedance, 20 kΩ/v...& variable at that!

Beware of body resistance, ~1MΩ,

e.g. don't short out a 10 MΩ instrument by your body fluids!

Common transistor circuits...

recognized by where you take your output, where V fixed p89



Current Amp

Voltage Amp