Tim Savas
Homework 05

1 Follower to Lower Amp's R_{out}

1.1 Output impedance of CE amp

Rout = 7.5K

A blurb from page 167 in the book:

> An output at the collector, in contrast, provides high impedance. because at that terminal it is current, not voltage that is determined. So the quotient of ΔVCE/ΔIC is very large (since ΔIC is very small—ideally, zero)… Rdynamic at the collector is very large: ideally, infinite; practically, at least hundreds of kilohm. This fact is important not only for current sources, but also for the common-emitter amplifier, whose Rout is determined by RC alone, since the effective Rout is RC in parallel with the collector's huge Rdynamic.

So in my own language, another way to say this is that there's a nice high impedance at the collector, and so the only path for current to go down is the RC. Rout for a common-emitter amplifier is therefore RC.

1.2 Reduce that Rout

You can just add a follower to the CE. It will reduce Rout by a factor of 10x.

I will try to solve this out.

I will create a Thevenin model of the two parallel resistors before the base of the CE amp.

Vin	R1	R2	RThev	VThev, VB	VE
15	56000	5600	5091	1.4	0.76

Ok now that we know the VE and the RE, we can figure out the IE, and therefore IC. From there we also know the RC, and can deduce VC, which is our voltage out.

V_E	R_E	I_E, I_C	R_C	V_C, Vout
0.76	750	0.001	7500	7.6

So if I understand this correctly, we know the Rout and the Vout.

If I understand this correctly, now that we have the Vin to the base of the next transistor, along with the desired IC of that transistor, we can determine the RE, or the value of the R that is attached onto this follower transistor.

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$$V_E = V_B - 0.6V$$

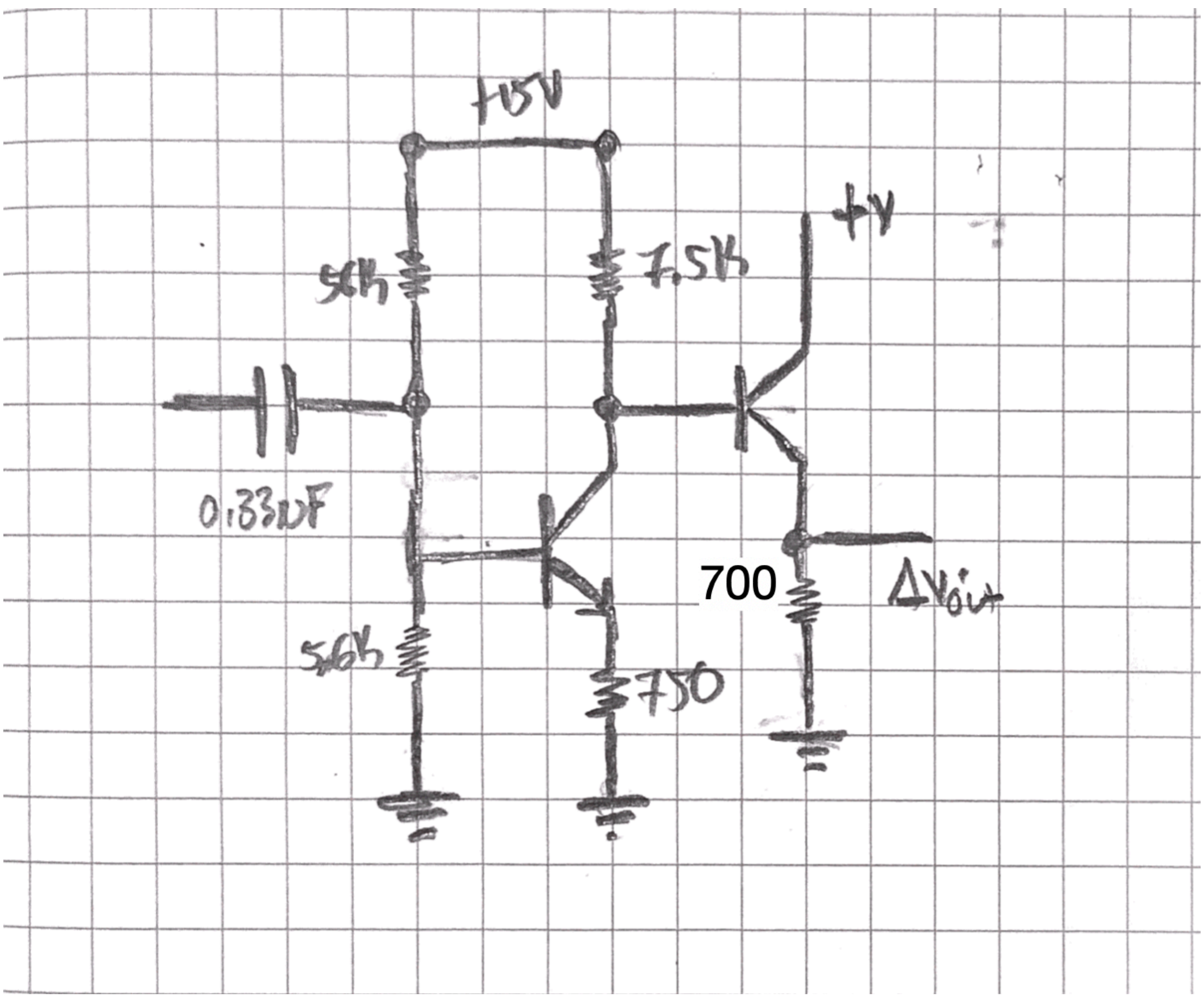
$$V_E = 7V$$

$$R_E = V/I$$

$$R_E = 7V/10mA$$

$$R_E = 700\ Ohm$$

I believe the follower's collector would be connected to 15V, or at the least some +V supply. Running out of time to solve so I've got to leave it here!



2 Current Source: active version

Last time, we asked to design a passive current source. The question sounded like this:

***. Current source (passive)** The passive current sink was to behave like a "current source" whose I_{out} varied no more than $\pm1\%$ from 10 mA as V_{out} ranged ±10V from a quiescent voltage of +10V.

Here, we would like you to design a circuit that behaves the same way, but this time use a transistor and two power supplies: +20V and -5V.

Wow, tricky.

Just thinking abstractly about this, the question is asking us to build a constant current source using a transistor. We did that in class and it's in the book. The skeleton circuit will look like a transistor with a R on the emitter and a variable R on the collector. The question then is what are the values, and also where do you connect the power supplies?

We need a V drop from both the collector and the base. We have only one +V supply. That's okay, voltage "drop" is always relative.

If we put the -5V after the R on the collector, and tie the base to ground, that's a "drop" from 0 to -5V. Now a current is flowing to the emitter. Then we can put the +20V at the collector.

So what are values of the resistors?

Here is a relevant aside that Oliver gave during the "transistor impedance" part of lecture 05:

> $R_{in} = \Delta V_B/\Delta I_B$
>
> This is just saying that if you have a voltage change, you should get a resulting current. If we were looking at a resistor, and we moved the V from 0V to 1V, and then look at change in I from that increase, and use Ohm's Law, it will give a R value. We're doing that here except we're using a transistor instead.
>
> We know we have a 3.3K R. We also know there is a 0.6V drop. So if we input 3.6V from the base, it will result in 3.3V/3.3K which is 1mA for I_E.

In that case we were trying to solve for IE. In this case we know I_E and ΔV_{BE} and we want to solve for R. The question is, what R does our V need to drop through in order to produce 10mA of current?

First we calculate V.

0-0.6V = -0.6V <—this is the drop going form base to emitter, like a diode

ΔV_{BE} = -5 + 0.6 = 4.4V <—-this is the delta, so it's the absolute difference.

From here we use Ohm's law to figure out the R value.

R = V/I

R = 4.4/(10/1000)

R = 440 Ohms

Now we can think about the variable R between +20V and the Vout and the collector. In one extreme scenario, the variable R is set super low and behaves like a wire. The Vout would be 20V, passing on all of that spare +20V voltage in order to maintain the IC = IE = 10mA relationship.

So the question next is, at what R does the IE stay at 1mA and drop all 20V? Well not all 20V. We need at least a spare 0.2V because VCE needs to be >= 0.2V in order for the transistor to be "on." Should we consider this?

0.2V is only 1% of 20V. Let's ignore it. Now it's an Ohm's Law question.

R = V/I

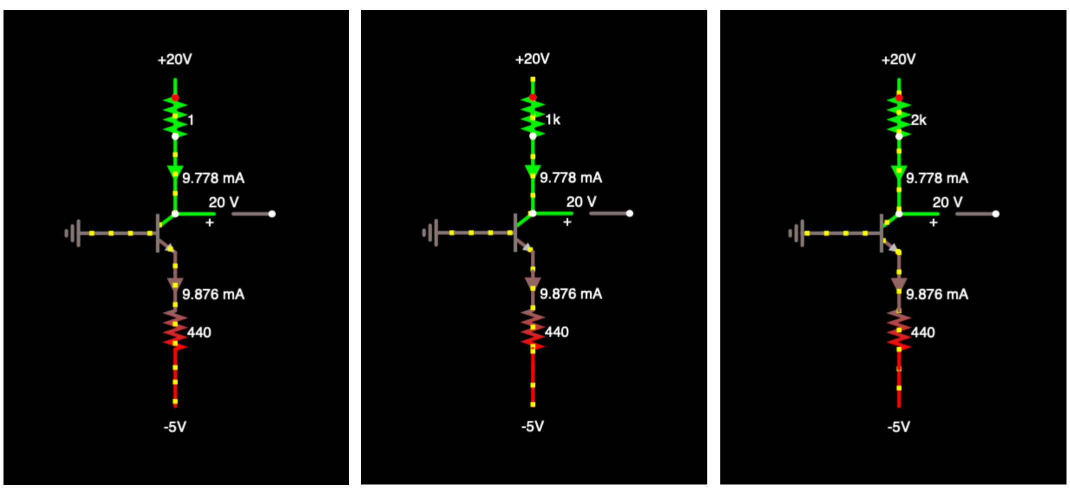
R = 20/(10/1000)

R = 2K

Here is the solution working in Falstad.

Here are some screenshots and tables showing the three scenarios from quiescent to +/-10V at the Vout.

Link to Falstad: http://tinyurl.com/y455vpgz



I_C	I_E	V_{out}	R
0.01	0.01	10	1000
0.01	0.01	0	0
0.01	0.01	20	2000

*I heard late in office hours that we may have needed to use a bias network. I have limited time to go back and make the change but wanted to make the acknowledgement.

2.2 Power dissipated

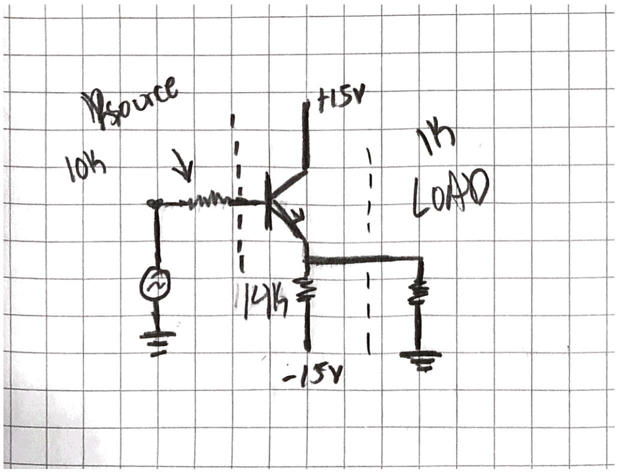
Worst-case power dissipation for the active and passive versions of the current source.

$P = V^2/R$

Type	R	V	$P = V^2/R$
Passive	100000	1010	10.2
Active	1000	10	0.1
Active	0	0	0.0
Active	2000	20	0.2

It looks like worst case scenario for the active version is when the R is 2K and V is 20V, giving 0.2W. That is substantially lower than 10.2W from the passive version. Note that I have used 1010V for the passive version because that was my worst case scenario from when I solved the problem.

3.2 Inferring



I understand how to do this problem but ran out of time. The instructions are describe in part in our lecture and also on the bottom of page 164. We can determine Rout of the transistor because we know the Rload and the drop. Since we know source impedance and the impedance looking into the transistor, we can figure out beta. I scribbled down some attempted steps but simply ran out of time. This is an easy problem.

Vout = Vin(R2/R2+R1) probably don't need to use this

Rout

If a 1K load causes a 5% drop, then maybe that means Rout is 50 Ohms.

Rout = RE || Rin / β

β = Rout/RE || Rin

My answer is 200 is beta

R_{in}	R_{out}	R_E	$R_E \parallel R_{in}$	β
10000	50	15000	49.8338870431894	200.7

$I_C = I_E = 10\text{mA}$

$V_E = 14.4\text{V}$

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$R_E = V/I$

$R_E = 14.4K$

$R_E = 15K$ value

$R_{in} = \Delta V_B/\Delta I_B$

$15K = \Delta V_B/\Delta I_B$

15K

$R_{in} = \Delta V_E/(1/\beta)* I_E)$

Rout = RE || Rsource / β <—this is key. Once you figure out Rout, you can solve for this.

Rin = β(RE || Rload)

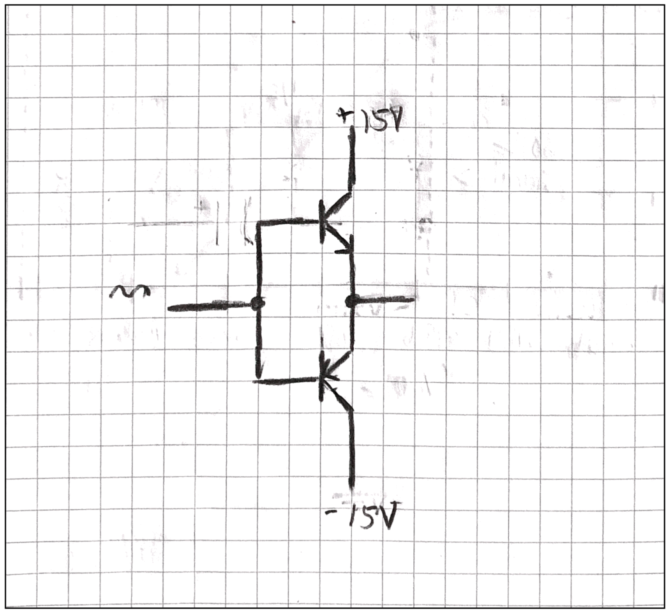
β = Rin/(RE || Rload)

Below is wrong.

R_{in}	R_{load}	R_E	$R_E \parallel R_{load}$	β
10000	1000	15000	937.5	10.7

7 Push-pull

Draw the circuit:



a) What's annoying about the circuit are the artifacts left by the fact that Qup and Qdown do not "turn on" until their respective VBE reaches 0.6V. So you get a strange plateau at zero —a "dead section"—in their output waveform.

b) What's good about the push-pull is that it is very efficient in comparison to a standard follower. It dissipates little power with Vout at 0V. Note that the fix that repairs the noise described in (a) does consume a bit more power due to the solution.