BEE 332 Devices & circuits II

Spring 2017

Lab orientation

Nicole Hamilton

https://faculty.washington.edu/kd1uj

Lab sections

AA Wednesdays, 3:30 pm to 5:30 pm

AB Wednesdays, 1:15 pm to 3:15 pm

Discovery 264 – *but might move to BB 220*

I do not require attendance. You are free to do the labs on your own during open lab hours *but you do so on your own.*

Nicole Hamilton

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Education

BS & MS EE, Stanford, 1973.

MBA, Boston University, 1987.

Background

Most of it as an entrepreneur selling a C shell I wrote for Windows.

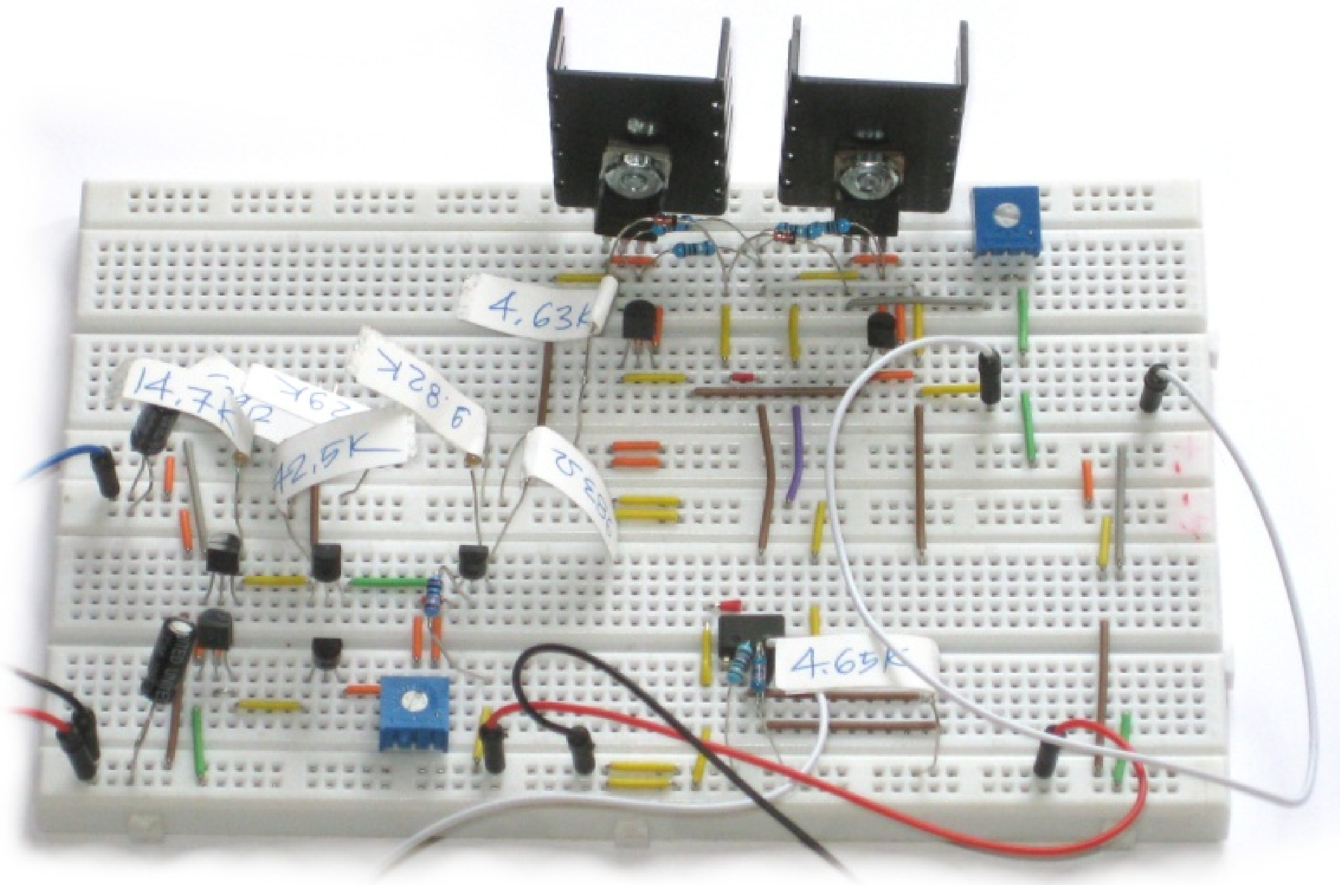
Also worked at IBM, Microsoft and RealNetworks.

At Microsoft, I wrote the ranker and query language for the first release of what's now Bing.

Here at UWB since 2013, initially as a Capstone advisor.

Download a free copy from my faculty page.

You finally get to build something!



You will design, build and debug a 0.5 W amplifier, then demo it playing music.

The big ideas in BEE 332

Theory in the lectures

1. The small signal model.
2. The Hybrid π model.

Practice in the labs

3. The three basic transistor amplifiers.
4. Useful multi-transistor circuits.

The theory

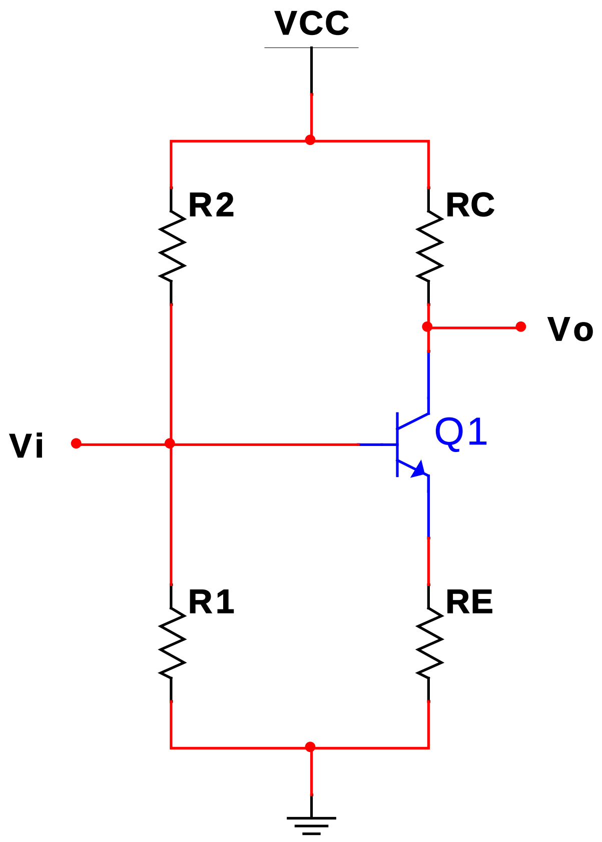
1. The small signal model

A four-resistor network is used to DC bias a transistor into what's called the ***forward active*** region.

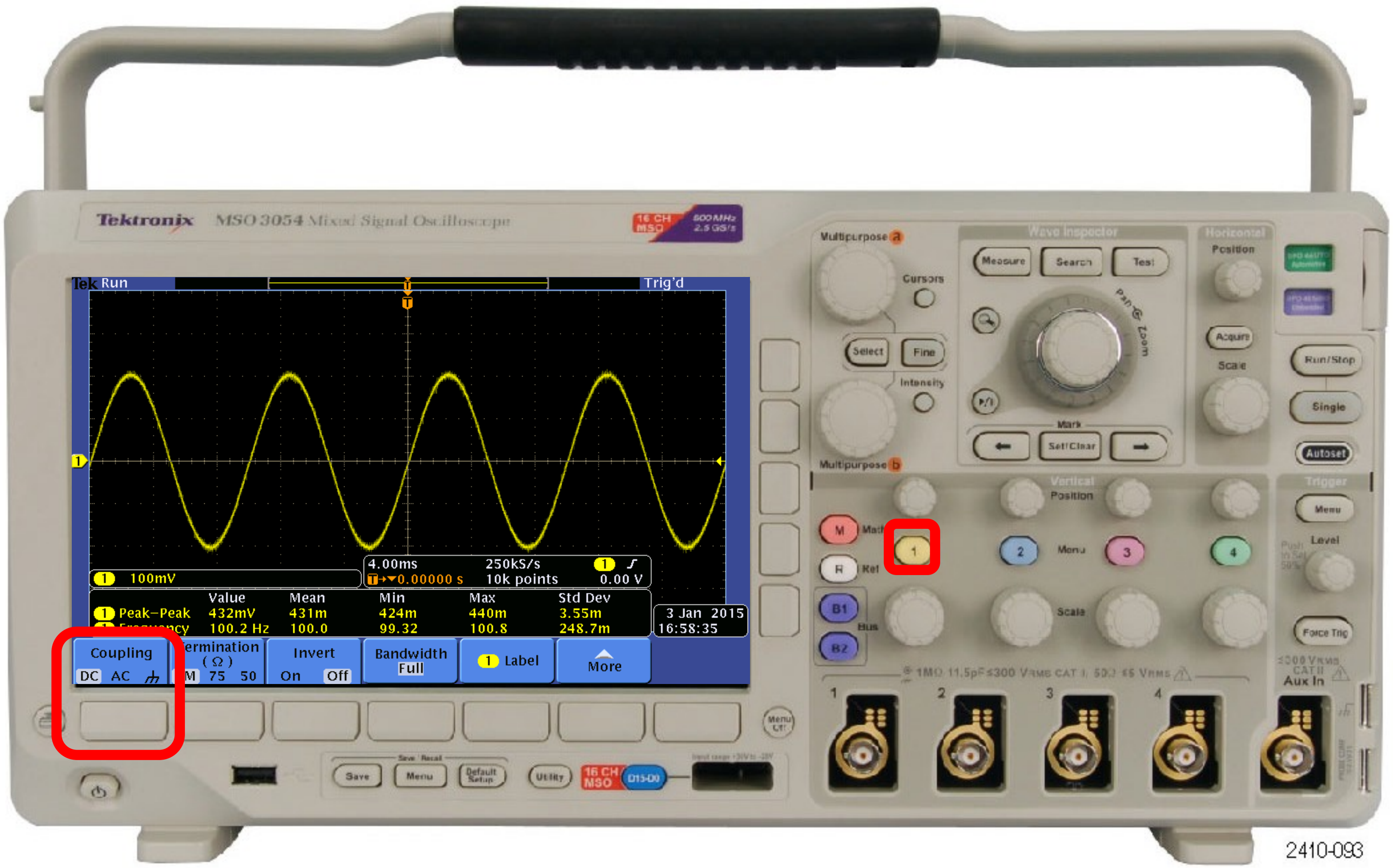
We then wiggle the input slightly around that DC bias point.

Small changes in Vi make small changes in base current, causing big changes in collector current.

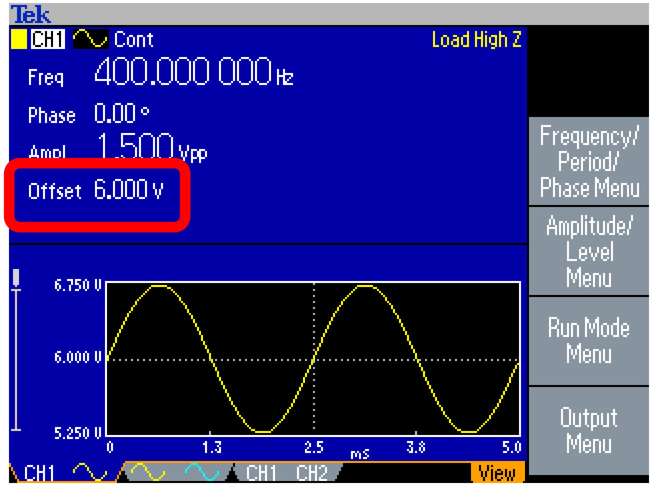
This allows it to be used as an amplifier.



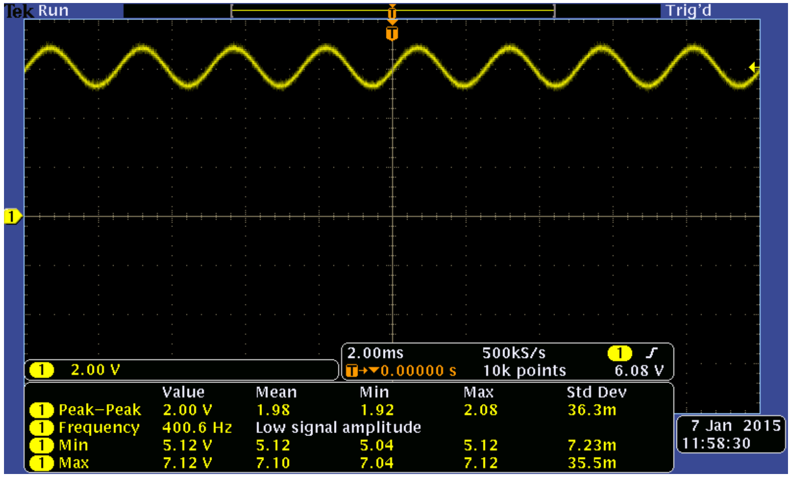
It’s like using the AC coupling setting on the oscilloscope.



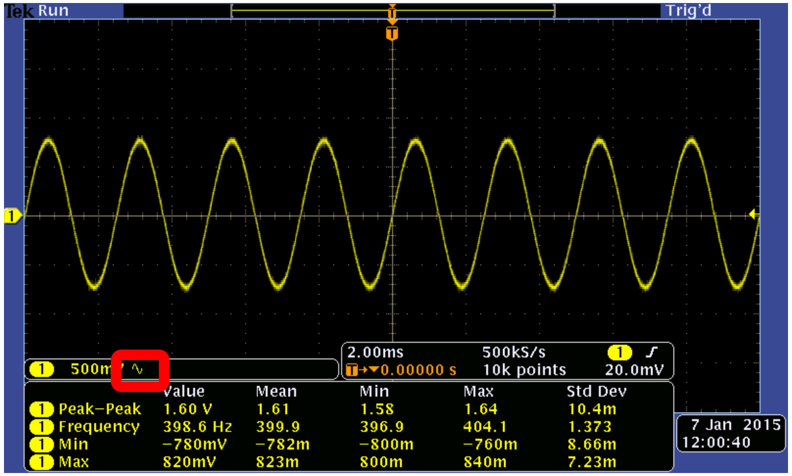
AC coupling filters out the DC component.



1.5 Vpp 400 Hz +6.0 V offset

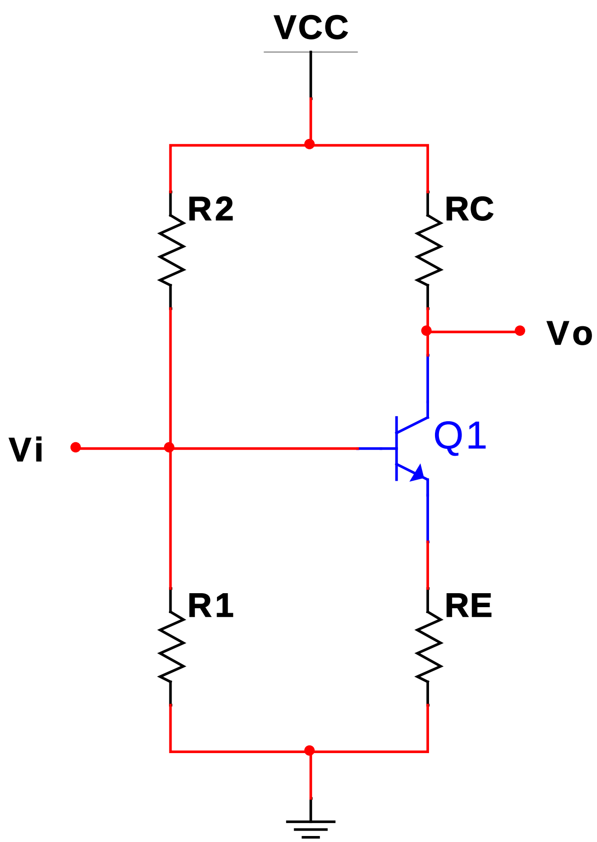


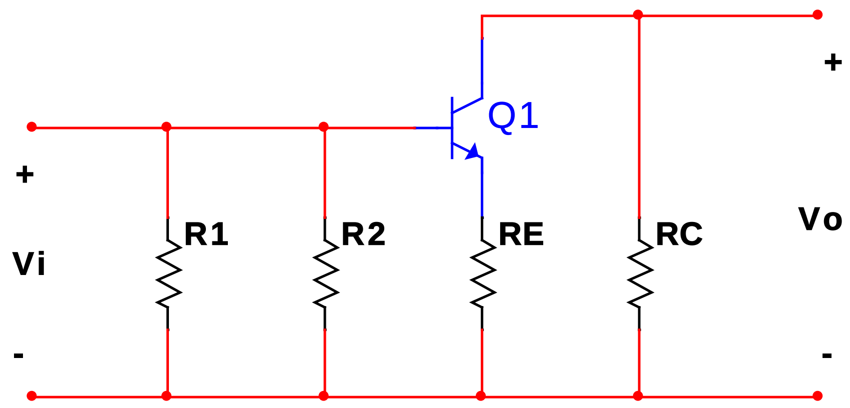
DC coupling



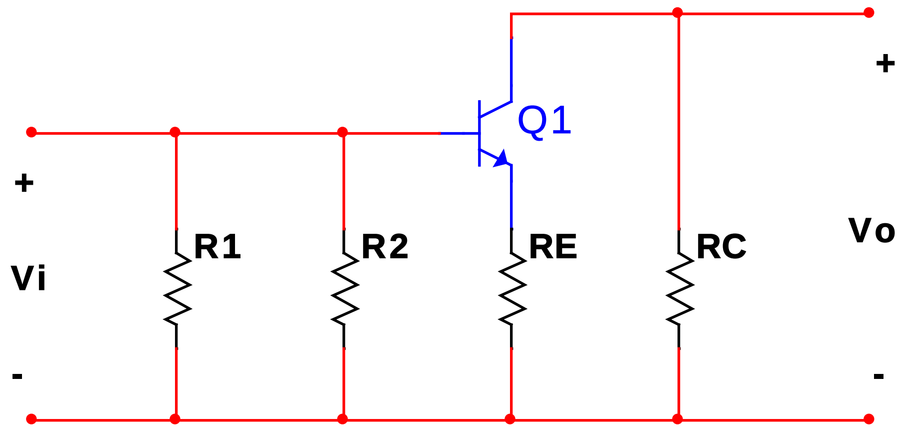
AC coupling

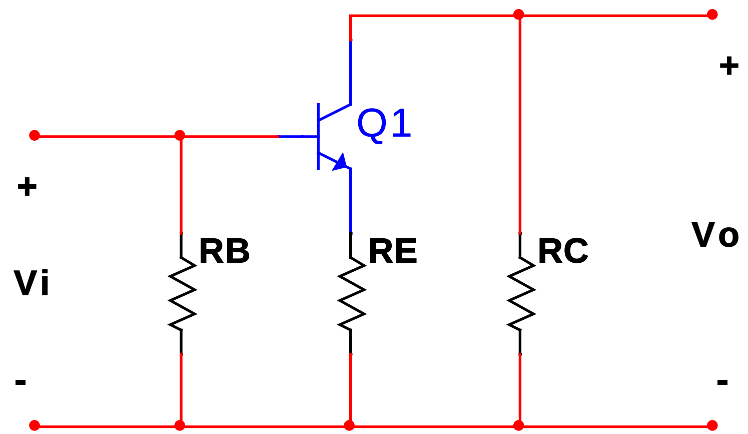
In the small signal model, we ignore the DC component and focus on the AC small signal changes.





We treat VCC and ground as if shorted together for small signal analysis.

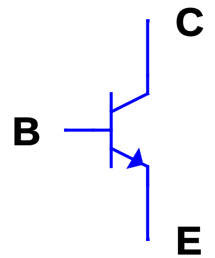


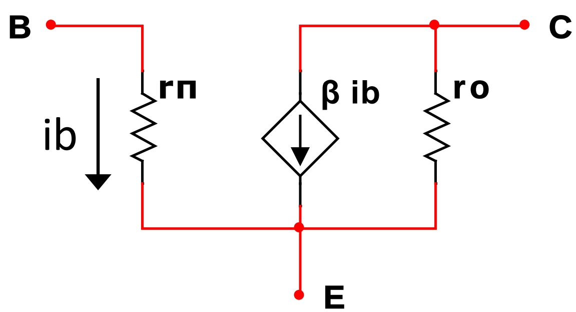


We can replace R1 and R2 with RB = R1 || R2.

2. The Hybrid π model

We can model the transistor in the forward active region as an input resistance and a controlled current source.





Where:

$$r_\pi = \frac{\beta}{g_m} \qquad g_m = \frac{I_C}{V_T} \qquad r_o = \frac{V_A}{I_C}$$

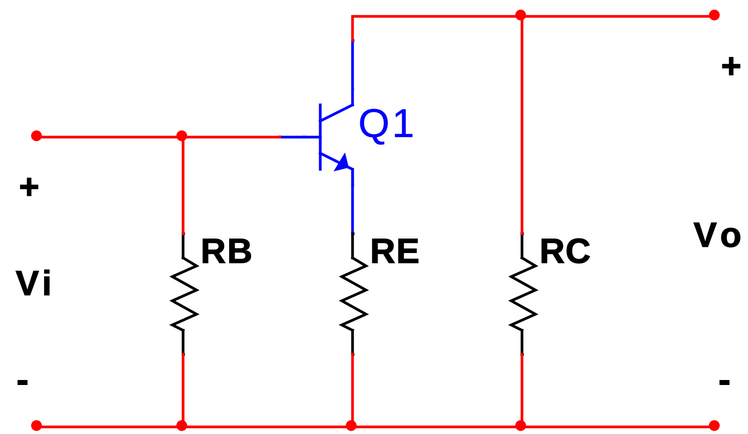
$\beta = h_{fe} = Current\ gain\ from\ datasheet$

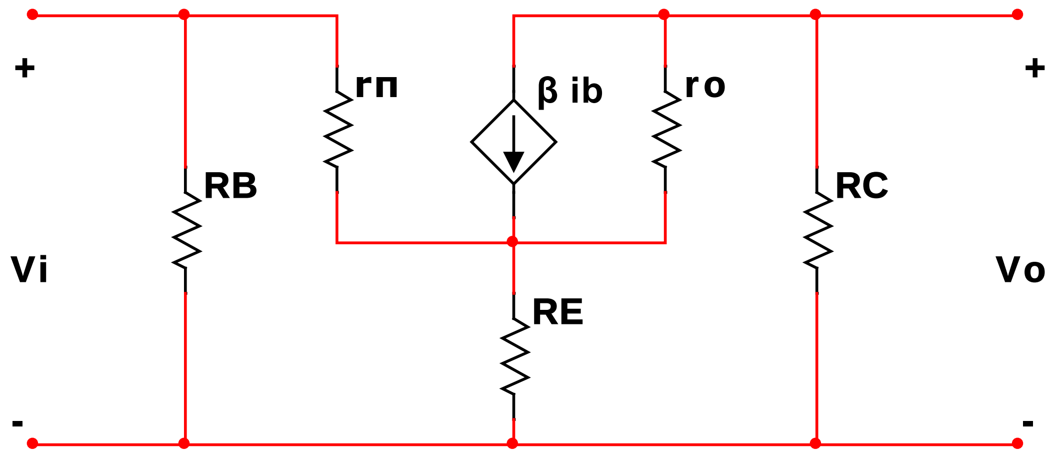
$i_b = AC\ small\ signal\ base\ current$

$I_C = DC\ collector\ current$

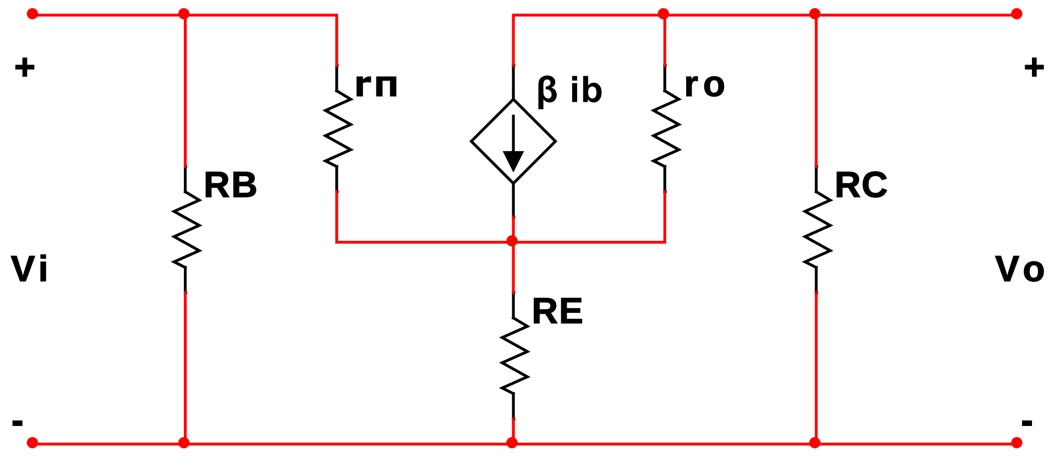
$V_T = Thermal\ voltage = 25\ mV$

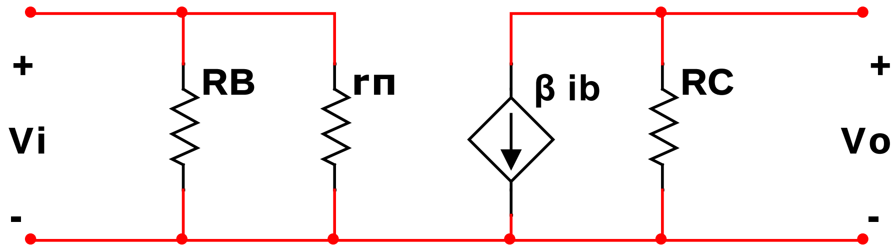
$V_A = The\ Early\ voltage, typically\ 15\ to\ 150\ V$





We can replace the transistor with the Hybrid π model.





RE is often bypassed with a capacitor (a short at high frequency) and ro is generally >> RC, allowing further simplification.

The practice

Objectives in the lab

1. Learn how to design, build and debug basic transistor circuits.
2. Develop your intuition about how transistors and transistor circuits work.
3. Develop your lab skills, using the instruments and taking measurements.

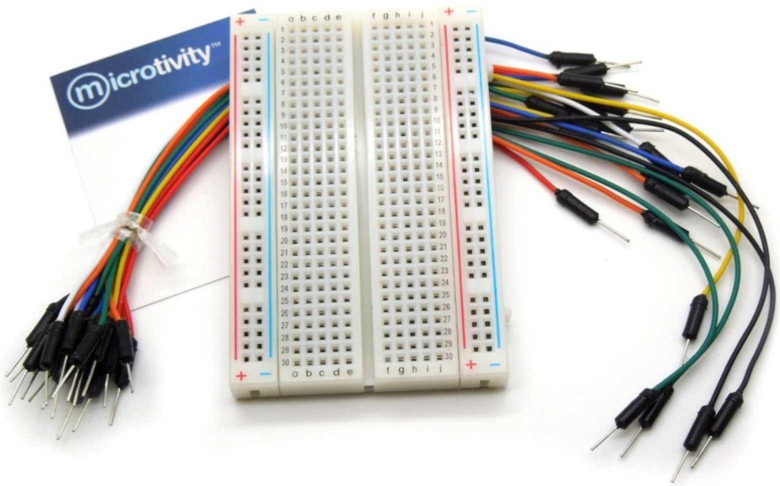
Your parts kit

Includes all the parts you need, including (yes!) breadboards and wires.

But you may want several breadboards so you don’t have to tear down one circuit to build the next.

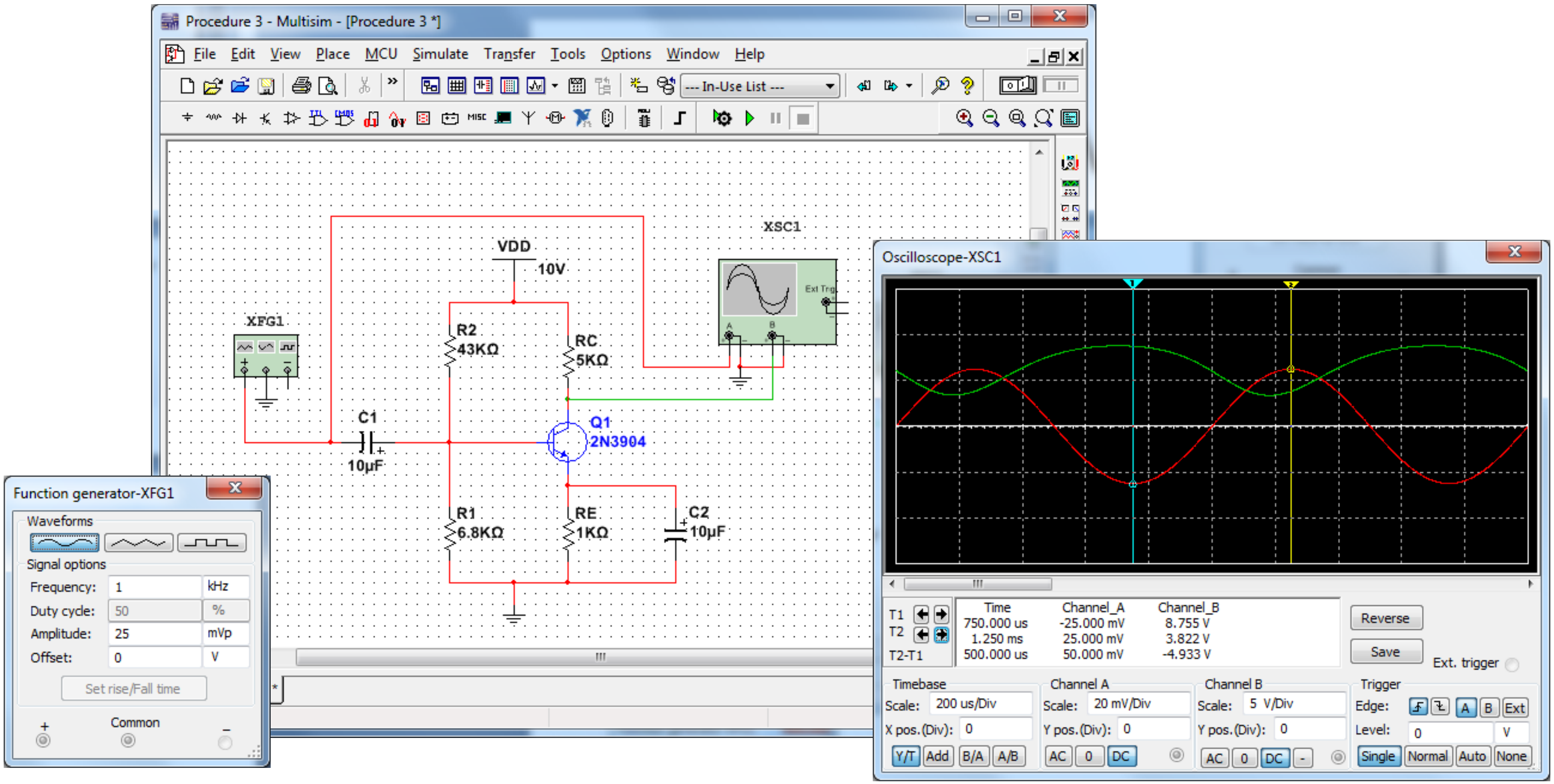
You will also a need a thumb drive or a laptop to capture screenshots.

Breadboards and wires



1. All the holes in a row are connected together.
2. Red is VCC (5 V), blue is ground. If a red or blue line is broken, it's disconnected at that point.
3. TTL chips are inserted straddling the trough in the middle and must have power.
4. Flexible wires are for going off the board.
5. Pre-formed wires are for making connections between places separated by specific numbers of holes on the board.
6. Don't rebend the pre-formed wires or use them to go off-board unless you want everyone to know you're a newbie.

Multisim is on all the lab machines



You'll find it helpful to simulate the circuits you're testing.
A student license is $40 and probably worth the money.

Teams of 2

- No exceptions unless we have an odd number.
- It is up to you to select your partner.
- Both partners are expected to contribute equally to each lab.
- My grading will assume you've done that, meaning you'll both get the same grade.
- Each team should submit *only one* copy of each report but with both names on it.
- To turn off the complaint from canvas, submit an otherwise blank sheet that gives your teammate's name.

Reports

1. Reports may be typed or handwritten neatly *in ink* and submitted in PDF format or on paper.

2. I will not accept cellphone photographs of your work. If you submit a scan, it must have been made on an actual scanner.

3. I already have a copy of the assignment, so I do not need you to copy-and-paste it into your report.

4. I also do not need title pages with colorful backgrounds, boxes identifying who did what, a list of the standard lab instruments at each bench or anything else not called for in the assignment.

Schematics

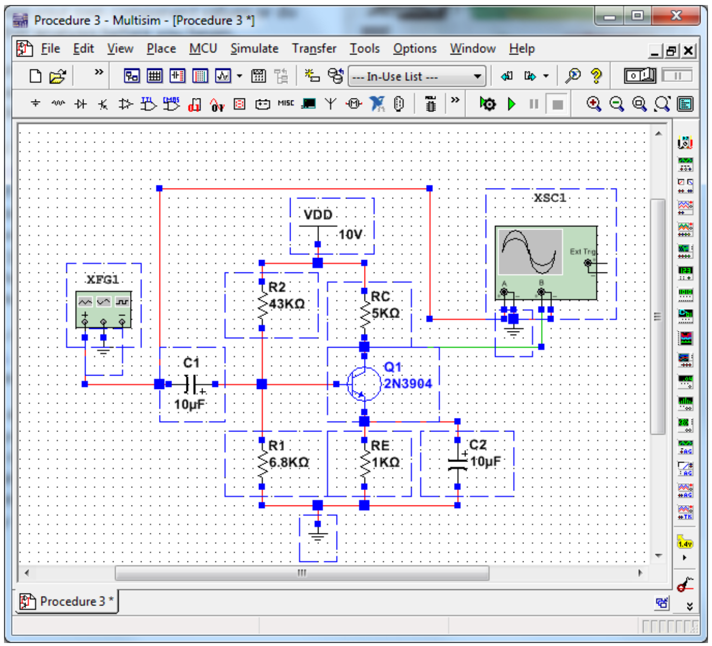
Your reports must include a schematic for each circuit being discussed.

If you add a wire, I need a new schematic.

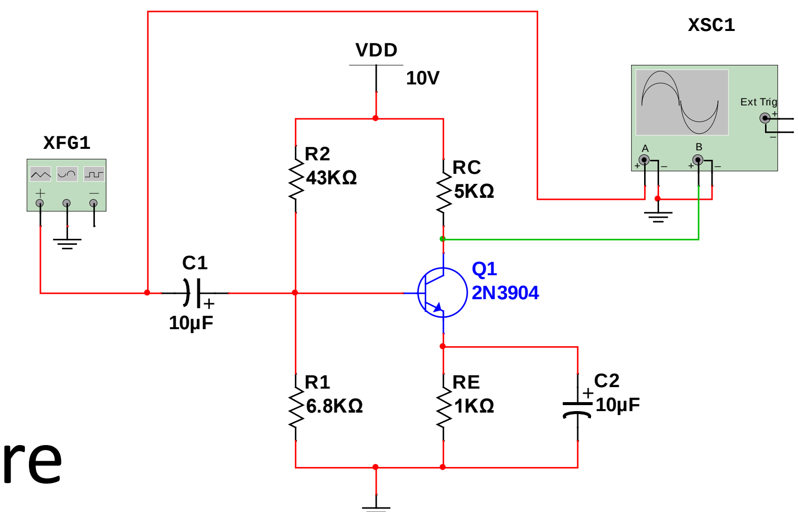
I'll accept handwritten but the easy way to do a schematic is with Multisim.

If you're only asked build to build a circuit and take measurements, not simulate it or design it yourself, you may also copy schematics from the assignment.

To copy a schematic from Multisim



Select and copy all (Ctrl-A, Ctrl-C) in Multisim.



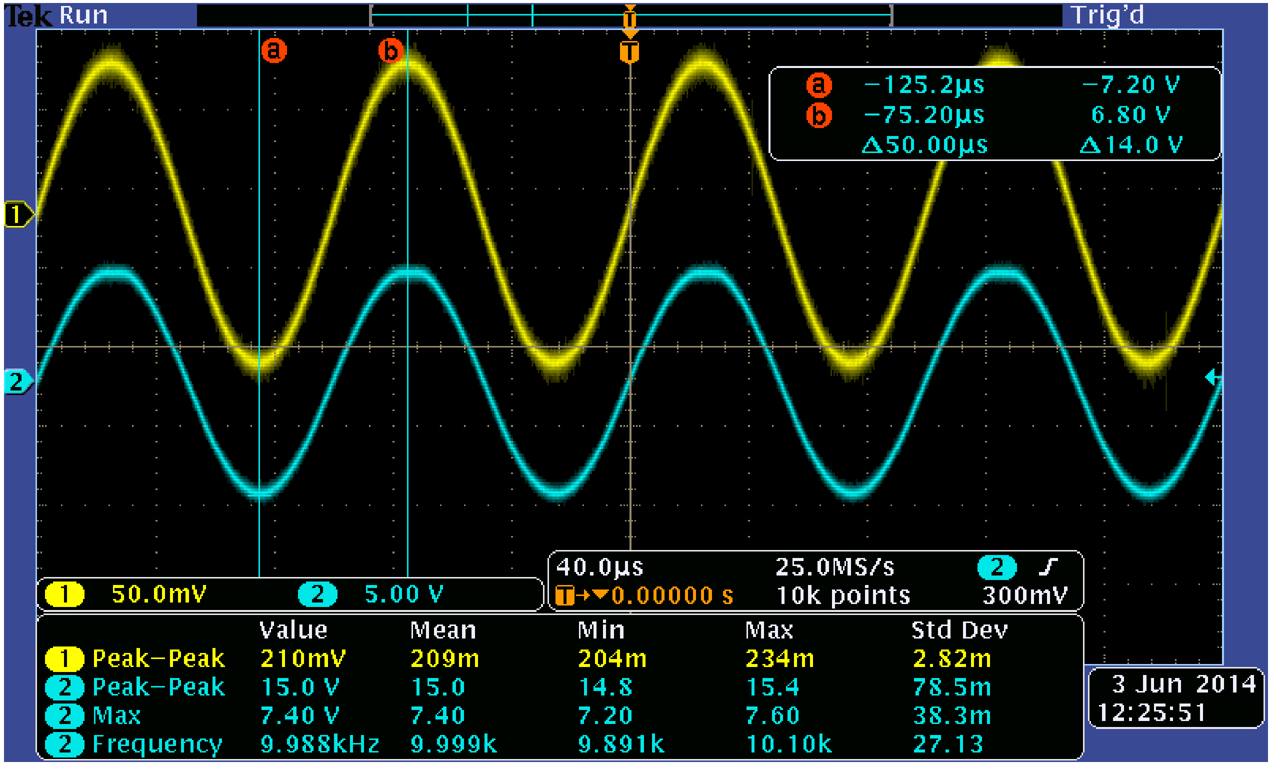
"Paste Special" as "Picture (Enhanced Metafile)" in Word.

Measurements

You'll be expected to show that you know how to use the instruments.

1. Set the output impedance of the function generator.
2. Use the oscilloscope to fine tune the function generator output.
3. Capture a useful screenshot on the oscilloscope.

Screenshots



Make them big, input on channel 1, output on channel 2.
Add useful on-screen measurements.

For more: *"Using the lab instruments".*

Grading

1. I tend to count up the number of “things” a given lab is asking for and assign each a roughly equal value.

2. I never deduct points simply because your measured results didn’t perfectly match the expected.

3. I am *extremely* picky. I give a lot of 40s and 50s to people who’ve never seen them before.

4. Each lab is only worth a small percentage of your grade, I do this to everyone and it all gets curved.

All the work must be your own

1. Copying answers from another student or off the internet will get a zero, even if you’re clear about where you got them.
2. If you omit the attribution, submit work that’s not your own or try to deceive me with fabricated results, you will, in addition, find yourself reported for academic misconduct.
3. I’m good at spotting misconduct and very good at reporting it.
4. ***I do not give warnings. I report everything.***

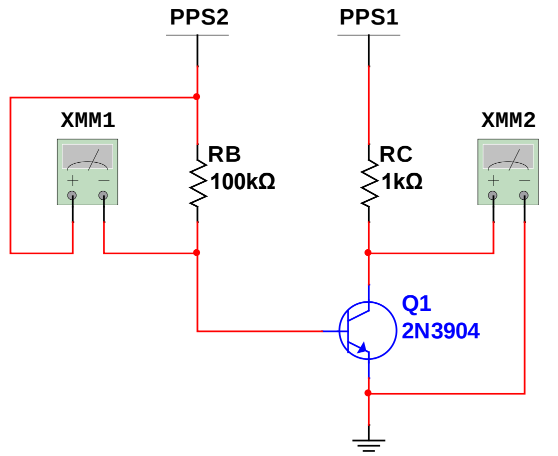
The experiments

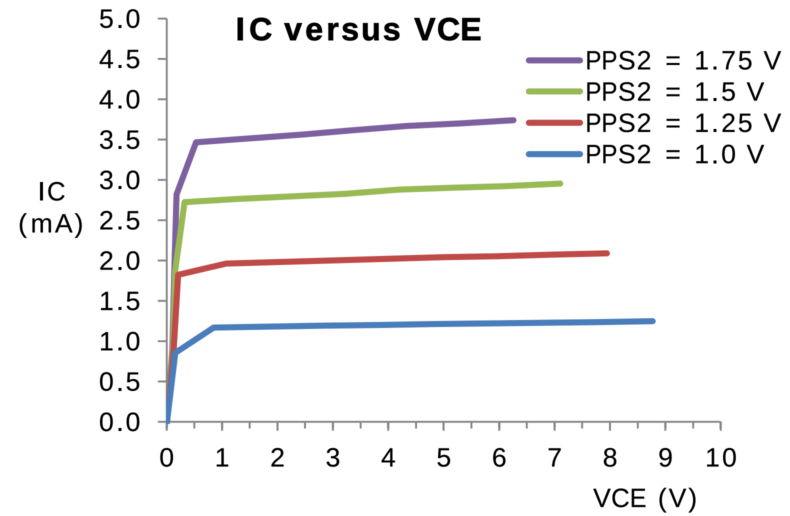
Lab 1: Characterizing bipolar junction transistors
Lab 2: Single-stage BJT amplifiers
Lab 3: Multi-transistor configurations
Lab 4: Multi-stage amplifiers
Design project: 0.5 W audio amplifier

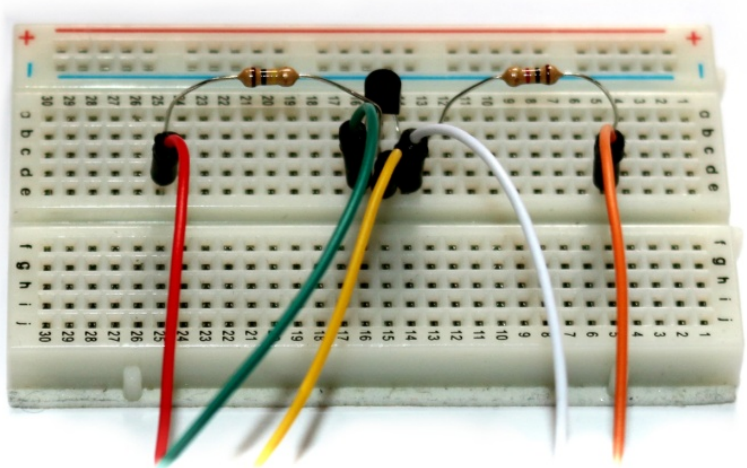
Due at two-week intervals.

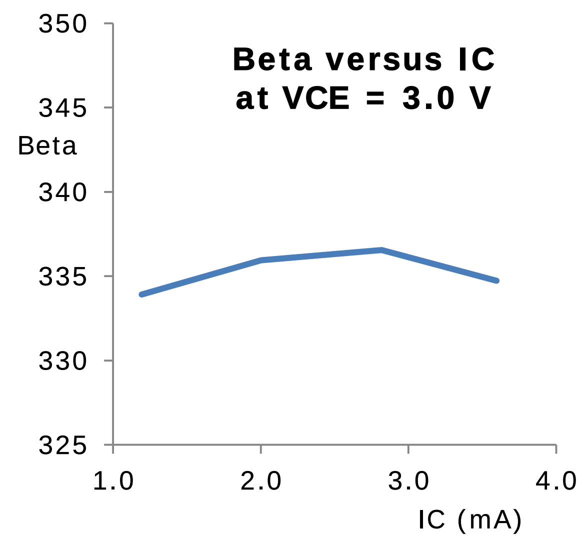
All have been posted, but I may update them slightly between now and when we actually do them.

Lab 1: BJT Characterization

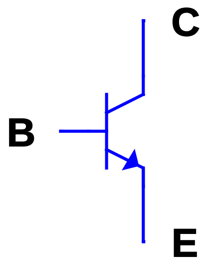


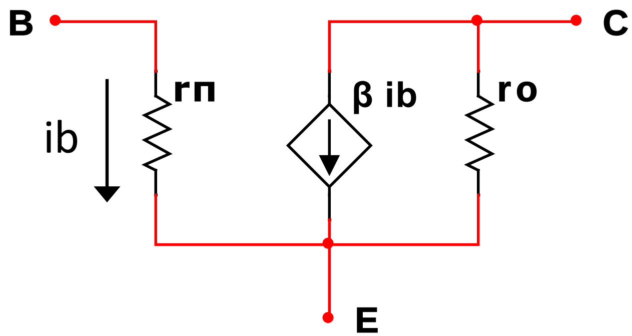


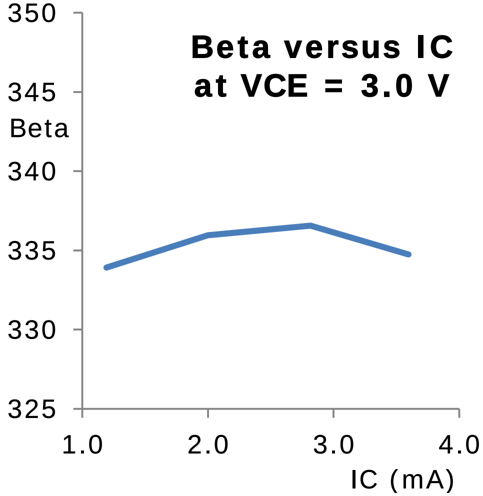




Find values for the Hybrid π model





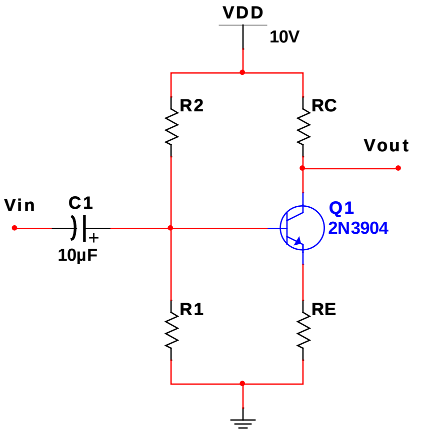


$$r_\pi = \frac{\beta}{g_m} \qquad g_m = \frac{I_C}{V_T} \qquad r_o = \frac{V_A}{I_C}$$

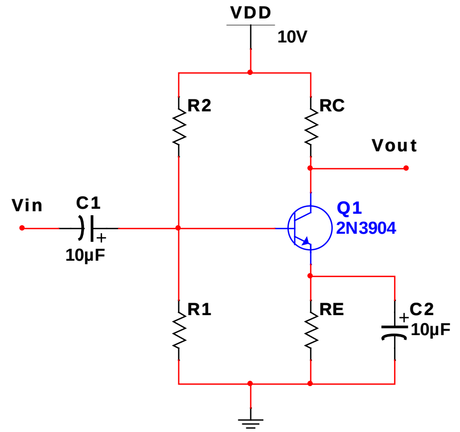
$$V_T = Thermal\ voltage = 25\ mV$$

PPS2 (V)	ICsat (mA)	Slope (mA/V = mS)	VA (V)	λ = Slope/ICsat (1/V)
1.00	1.1633	0.0097	119.928	0.00834
1.25	1.9461	0.0183	106.344	0.00940
1.50	2.7188	0.0344	79.035	0.01265
1.75	3.4460	0.0485	71.052	0.01407

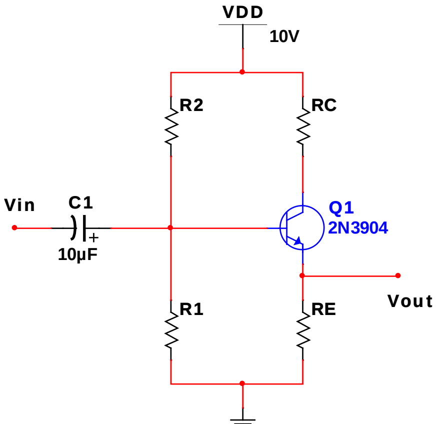
Lab 2: Single stage amplifiers



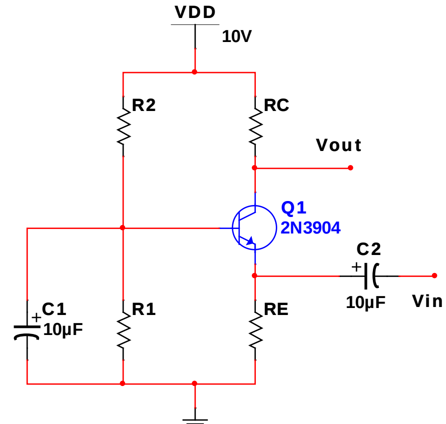
Common emitter



Common emitter with bypass

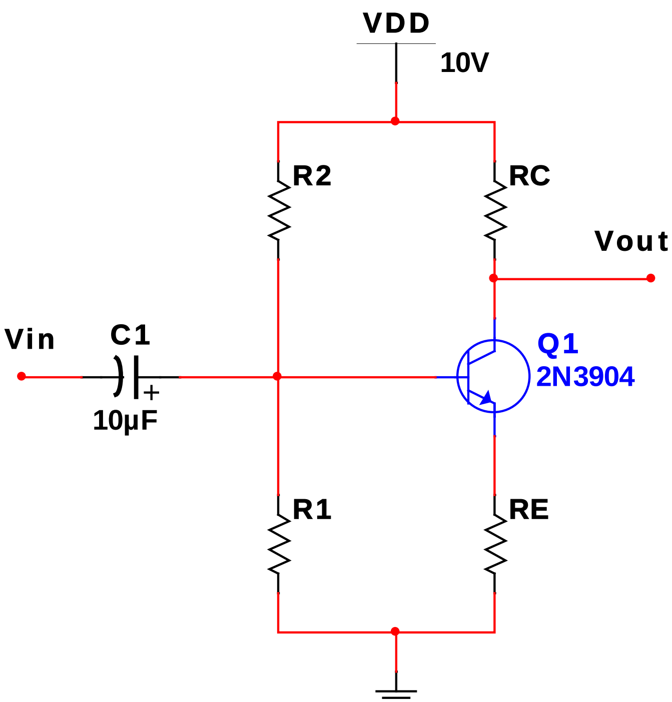


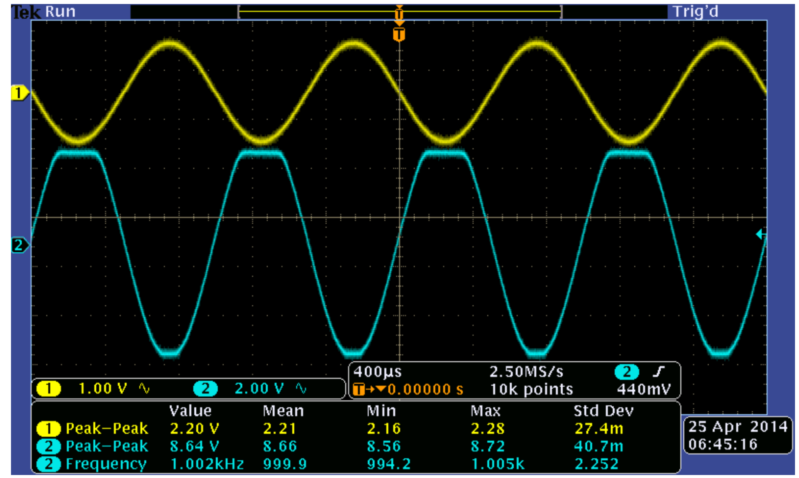
Common collector

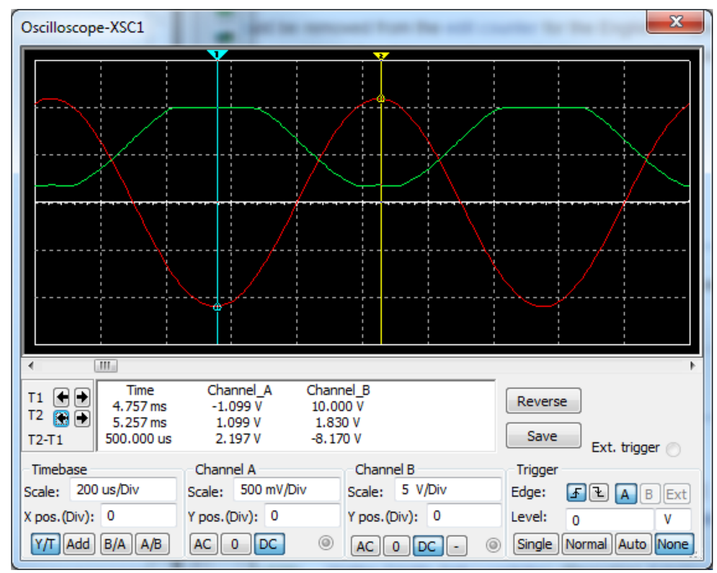


Common base

Example measurement: Clipping levels

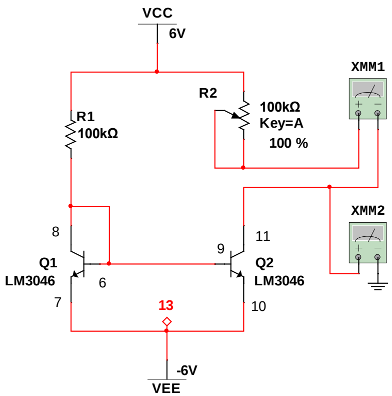




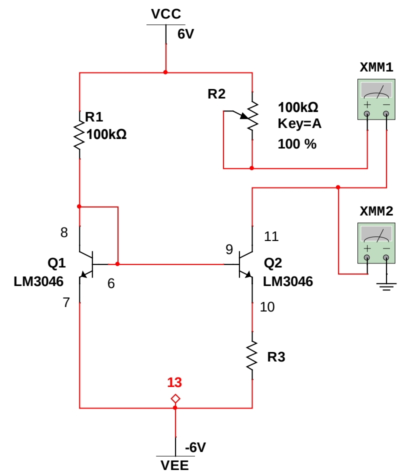


Common emitter amplifier clipping on both peaks.

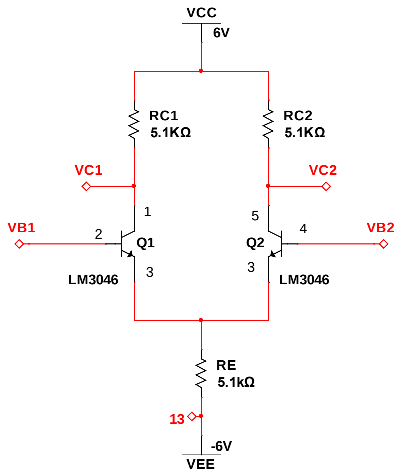
Lab 3: Multi-transistor circuits



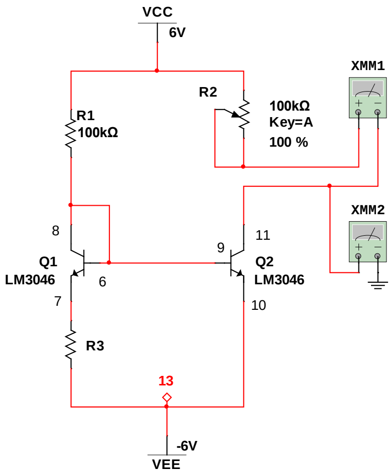
Current mirror



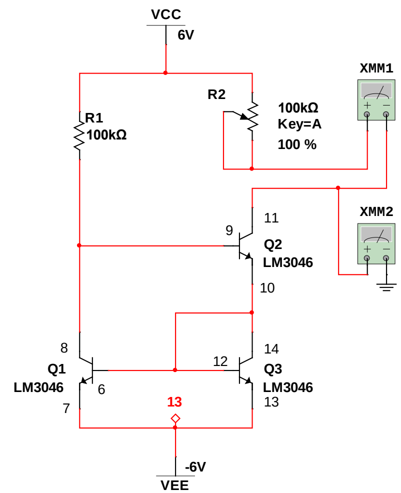
Widlar reducing current source



Differential amplifier

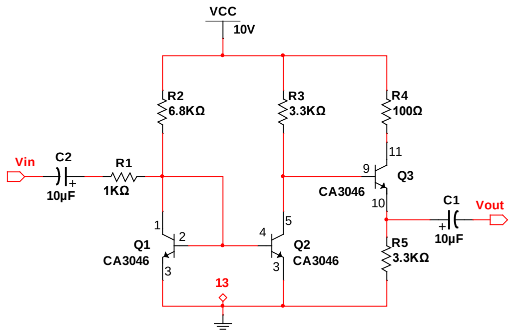


Widlar boosting current source

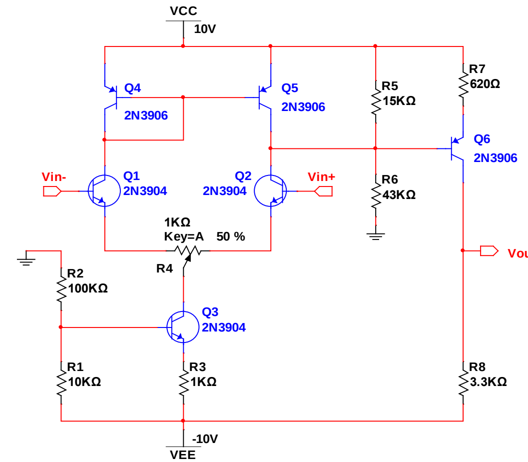


Wilson current source

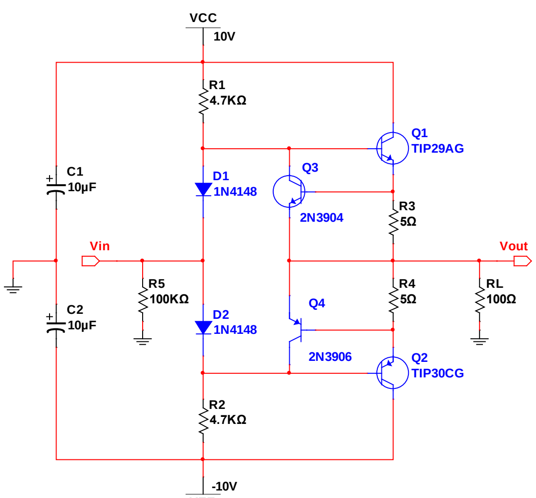
Lab 4: Multi-stage amplifiers



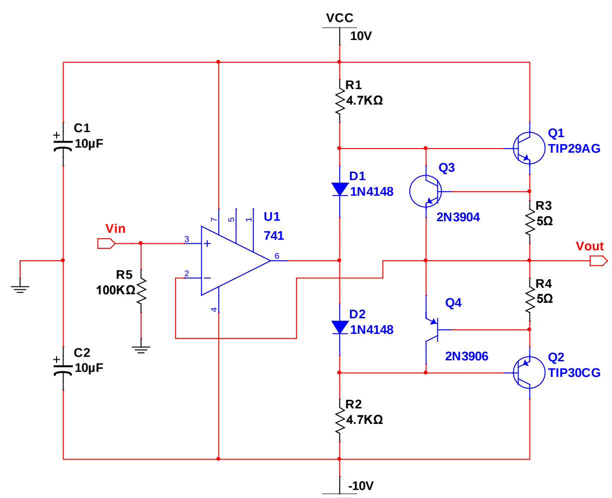
Wideband CE-EF amplifier.



A simple opamp.

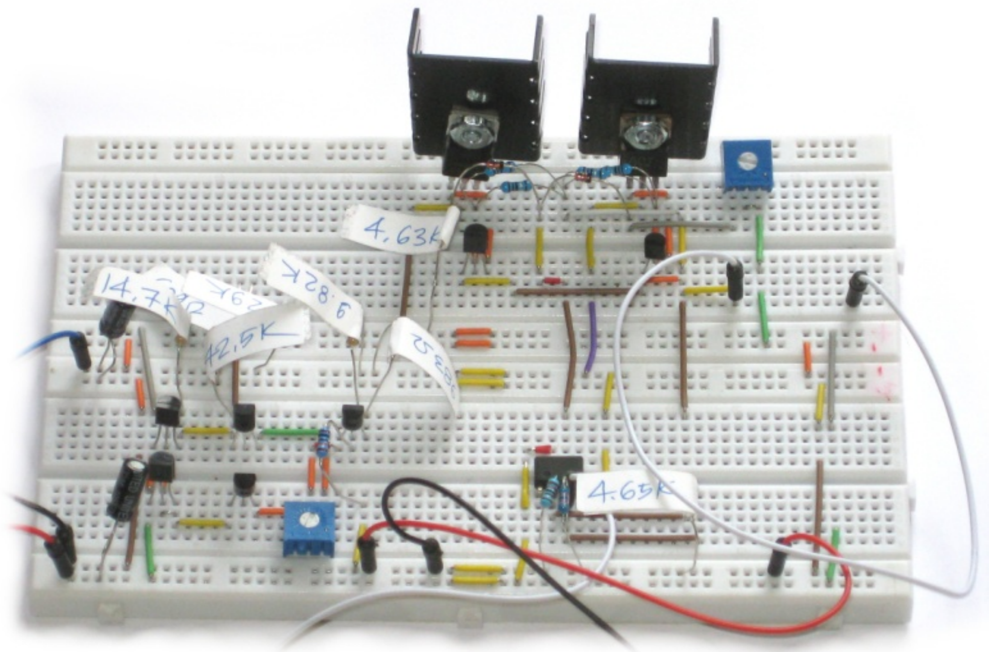


Complementary class AB output stage.



Multi-stage amplifier with feedback.

Design project: 0.5 W amplifier



Design, build, and debug an amplifier capable of driving 0.5 W into 8 Ω.

You must demonstrate it playing music.