BJTs, Biasing, and Amplifiers

Please refer to H&H, Ch. 2.0 thru 2.3.5. Hands-On Electronics, Ch. 4. IMPORTANT!: see these Canvas documents: "Transistors and Mosfets", "BJT Basics", and General Thoughts on Amplifier Design".

Read this lab through completely before starting - All four pages.

Part 1: Design a one-transistor amplifier with the following specs:

AC Gain: 25; Zin (in passband): >10K; Zout (in passband): <10K; Vout: >12Vp-p Vsupply = 15V.

Frequency Response: Flat from 2kHz to 3kHz, rolling off on each side so gain is < 15 at 200Hz and 30kHz .

•Design your amplifier and prepare a schematic. • Optimize for maximum output signal swing. • Use a 2N4401 or similar NPN. • Build and test your circuit, providing a series of relevant oscilloscope traces. **(P).** Plot frequency response the with the oscilloscope Bode plotter. **(P)** Show how values were derived.

Part 2: •Load (to ground) the output of the amplifier in Part 1 with a 1K resistor. Note the change in the output voltage waveforms. •Add an NPN emitter follower to the output, with Re equal 4.7K. Repeat the load test and note the results. •What happens to output voltage waveform if you add a 1K load connected to the positive rail?

Part 3: Design and build a circuit which will light a #194 lamp when the frequency of an input sinewave (from a function generator) is OUTSIDE of 1600 Hz to 2400 Hz, +/- 10%. The lamp must be OFF when the frequency is within these limits. Operate your circuit on a single **13 VDC** bench supply; the lamp must **operate at (very close to) its full 13V rated voltage**. You must include at least one PNP transistor in your circuit!!!

The amplitude of the input (from a generator) will vary from 0.01Vp-p to 0.03Vp-p. (Use the *Attenuator* control.) However, the switching point frequencies must not change as the input amplitude varies!!. The lamp should switch **abruptly** and cleanly. •Prepare a schematic. You must, of course, incorporate hysteresis so that the lamp "snaps" on and off, and is never partially ON. **(P)**

Record test results here:

Set the generator at 0.01V_{pp} and 1KHz (lamp will be OFF); slowly increase f until lamp lights and record f_{incr}. Next, decrease f until lamp turns OFF; record f_{decr}. The difference between these values is the hysteresis.

Slowly increase the generator frequency towards the 2400 Hz switching point. Record the f when the lamp turns ON, and when it turns OFF as the frequency is slightly reduced.

Repeat this procedure with the generator set at 0.03 V_{pp}.

V_{IN}	f_{LO}	f_{HI}
0.01 Vpp	F_{incr} = f_{decr} =	f_{incr} = f_{decr} =
0.03 Vpp	f_{incr} = f_{decr} =	f_{incr} = f_{decr} =

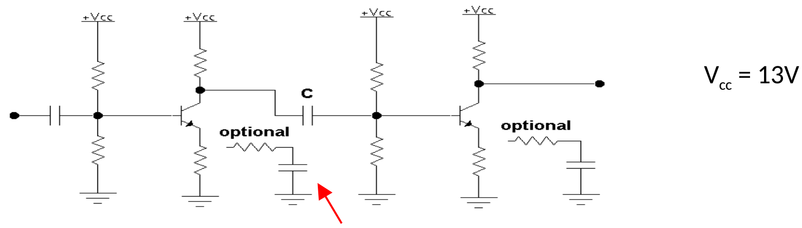
Please email me preliminary schematics of Parts 1 and 3, with rough values, by Saturday, 6 PM.

Sorry, no op-amps, comparators, or vacuum tubes allowed; **only discrete BJTs are to be used in this lab**. Please have Part 1 and 2 schematics and test results available for the recitation. Please have your Part 3 circuit completely set up and prepared to demonstrate for the recitation.

Comments on Project Lab 5, Part 3

CAPACITOR COUPLING

You will need gain to increase the input to several volts peak-peak for further processing. The traditional way to couple amplifier stages is capacitor coupling:

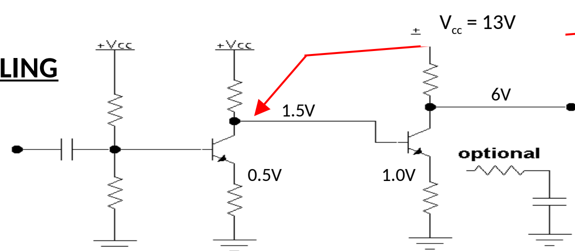


The cap C is necessary so that the voltage on the collector of Q1 does not interfere with the bias network of Q2 (it blocks the DC). Even with the cap, however, the INPUT IMPEDANCE OF STAGE 2 WILL LOAD THE OUTPUT IMPEDANCE OF STAGE 1. You may lose as much as ½ the gain due to this loading, so the composite gain will not be the simple product of the two voltage gains. Note that the low-freq response of the amp will be limited by C. You can estimate the roll-off by simply adding the output resistance of stage one and the input resistance of stage two; the sum of the resistance works with cap C to produce a high-pass filter.

However, since the output swing of the first stage will be much lower than the output swing of the second stage (due to the gain of the second stage), you can sometimes employ DIRECT COUPLING. To do this, you carefully bias the first stage so its collector bias point (Q point) is not at ~ ½ the supply. Instead, you choose a Q point for the 1st stage that will directly bias the 2nd stage. Also note that sometimes you do not need the output of an amp to swing rail-to-rail; therefore you may not need to bias at exactly ½ the supply:

DIRECT COUPLING

Note that direct coupling is nice because you eliminate the additional loading (and signal attenuation) of the 2nd stage's bias network.

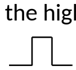


The quiescent voltage here will be very close to ground. Therefore, it will swing positive to about 11.5V (almost to the positive rail). But it can swing only about 0.7V below the quiescent point. That is ok because the signal swing here is very small; the following stages have a lot of gain.

Nominal bias voltages are shown.

Part 3: AMPLITUDE DEPENDENCE AND OTHER COMMENTS

Regarding the requirement to hold the frequency switch points steady as the input amplitude changes; I did not provide a definition for "steady". Therefore, you have some wiggle room here. Your design must acknowledge the requirement, but the circuit need not be perfect. The less change in frequency switch points, the higher the grade.

If you had an ideal (infinitely high Q) filter like this:  , the frequency would be independent of input amplitude, since the frequency response would not change as the input amplitude changed. But since you probably don't have an ideal filter, think about "limiting" to eliminate the effect of signal amplitude. Remember, loading your filter will reduce Q.

Think carefully about how to convert the signal to a proportional DC voltage so you can use a comparator to sense a threshold and turn on the lamp. If you simply low-pass filter the conditioned signal, it won't work because the average value of an AC (signal) voltage is zero. You could peak-detect the output of an amplifier stage, but this might not work too well with a BJT amplifier because at zero signal you will still have a large DC voltage (the collector bias voltage). So, remember some of the passive circuits previously studied in lecture and lab.

When switching a heavy load, such as a lamp, you should almost always place the load at the collector rather than the emitter. If the load is in the emitter (as in an emitter follower), the load cannot be driven with the full supply voltage because a BJT can never be saturated in the emitter follower configuration. Also, with the load in the collector circuit you will get helpful voltage gain, which is not the case if the load is in the emitter. ALWAYS DRIVE HEAVY LOADS WITH A SATURATED TRANSISTOR!!!

- Remember that beta generally drops significantly as I_c increases; always confirm that beta is as high as you think when driving a heavy load with a BJT. Therefore, you must always provide extra base current when driving a saturated transistor.

- You could construct the BP filter with an RC high pass and an RC low pass filter. However, this may not produce a BP filter that is sharp enough. Keep this in mind.

IMPORTANT!

1. Always assemble circuits one stage at a time, and thoroughly test and characterize each stage independently. Remember, however, you must allow for the loading of successive stages.

2. Your circuit might get a little complicated. Always keep an up-to-date schematic. You cannot visualize or follow anything by staring at your breadboard.

3. What did one photon say to another?

4. Always build a circuit so that it "looks like" the schematic as closely as possible:
5. inputs on the left, outputs on the right, negative/ground rail on the bottom, positive rail on top. This way you can quickly identify components and trace signal flow.

5. Regarding Part 3:

   If you choose to use a resonant circuit, **please carefully reread the lecture on RLC circuits, focusing on resonant circuits.** When you drive a parallel resonant circuit (with the bottom of the parallel LC combination connected to ground) you must always drive it with a series resistor- several KΩ or more. If this resistor is too low in value, the parallel LC circuit will be closely coupled to the source (which has very low resistance) and the voltage across the LC circuit will simply be the same as the voltage across the source; as a result, the circuit will behave as if the LC parallel circuit is not there. You need a relatively large series resistor so that the parallel LC circuit can do its thing and provide a sharp Q. Of course, at resonance (with the parallel LC circuit acting like an open circuit), you can only drive a load resistance that is much higher than the series resistor; otherwise, your circuit will be heavily loaded and the Q will be very poor. See the Module 5 paper, *Comments on Lab #5*.

6. Please remember to review the specifications carefully. The lamp must "snap" ON and OFF and must be either fully ON or fully OFF (hysteresis will ensure this) and be driven at full rated voltage.

7. I'm sick and tired of your interference.

Please Note: Projects in this course may include some specifications that are difficult to meet. This is not an uncommon situation in the engineering world and is part of the fun. I expect you to get as close as you can and be prepared to explain any compromises you made.