# Physics 117 Lab 5:OP-Amp and JFET properties and applications

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## 1. Transistor Switch (4-9)

### *1.1. Part A*

In this lab, the first experiment was to observe the saturation region of the 2N4400 transistor, which can be seen in figure 1. In normal observation of transistors $I_C = \beta * I_B$, though when a object is saturated it is in a fully conductive state, specifically the voltage and current defy a linear relationship, specifically because the Base-emitter junction is at a full forward bias, making the transistors $\beta$ variable as it does not control the collector current rather the collector load controls the output of current, for us this is shown when we drive a small voltage through the 1k resistor compared to the larget 47 lamp, we ant the base voltage to be small because the saturation region itself is shown when the emitter voltage is small, and the collector current is large. The next step of the lab was to measure $I_B$ by turning the base current on and off as well as pulling a resistor out of the breadboard yielding us a value of $I_B = 4.26mA$, which is fairly large considering we are inputting 5 Volts into the system.

The next step was to measure $\beta$ values at differing input voltages, and see its variability

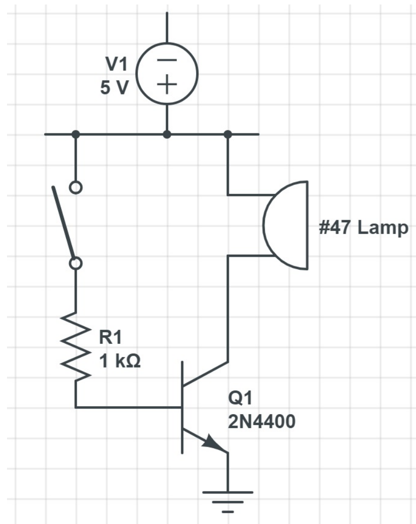


Figure 1: This simple schematic represents the Transistor Switch circuit

| $V_{in}$ | $I_C$ | $I_B$ | $\beta$ | $V_{CE}$ |
|---|---|---|---|---|
| 1 | .56 mA | 4 mA | 1.4 | .312 V |
| 3 | .153 A | 2.4 mA | 63.75 | .132 V |
| 5 | .205 A | 4.4 mA | 46.59 | .134 V |
| 7 | .248 A | 6.4 mA | 38.75 | .240 V |
| 10 | .304 A | 9.4 mA | 32.34 | .150 V |
| 12 | .334 A | 11.4 mA | 29.29 | .157 V |
| 15 | .379 A | 14.4 mA | 26.3 | .167 V |

The equations used were

$$I_B = \frac{V_{in} - .6}{R} \qquad [1]$$

$$I_C = \beta * I_B \qquad [2]$$

We are now asked three questions first, what is minimum $\beta$ to light the bulb which prompted the chart and was about 1. Next we are asked how our $V_{CE}$ value compared to the ones in previous circuits, the answer is that it was small compared the earlier circuits, physically because the base voltage is small and the reason is we are trying to observe the saturation region, meaning we are trying to get a small voltage through the $V_{BE}$ and $V_{CE}$ junctions and large current, and lastly we are asked what power the transistor dissipates when the switch is on, so looking at our values at an input of 10 Volts, with our currents and $V_{CE}$ we get 51.24 mW of power being dissipated. The formula for power is below.

$$P = (I_B * .6) + (I_C * V_{CE}) \qquad [3]$$

## 2. Push Pull (5-6)

### *2.1. Part B*

The next circuit we observed was a Push-Pull, specifically to see a crossover distortion, using 2 transistors a PNP and NPN. The push-pull circuit can be seen in figure 2. All we are asked to do in this circuit is observe its output, and change its amplitude, we do this in figure 3.

Then we are asked a few questions, first, the output of the single transistor circuit was better why is this one worse, firstly this circuit requires more power in general, then the middle section of the wave is not as clear. Then we are asked the advantages of this circuit, a class A transistor is always on, this circuit is a class B meaning that transistors run on 180 degree cycles or only one transistor is on at time, this allows it to survive for longer, it has a high input impedance and low output, and DC offsets and quiescent points are unnecessary.

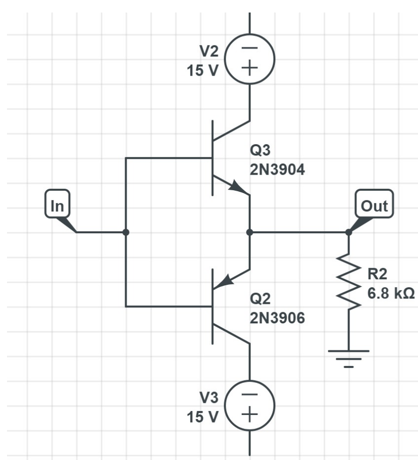


Figure 2: This Shows the circuit diagram for the Push Pull circuit

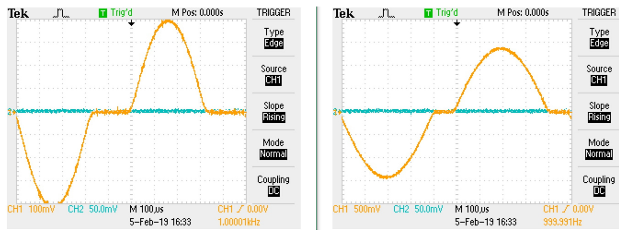


Figure 3: This Shows the Output for the Push Pull circuit at varying amplitudes

## 3. Field-Effect Transistor

### *3.1. Part C*

We then seek to understand a new component called a JFET, the circuit we utilized is given in figure 4. The first objective was to see how the -5V worked versus the 0V, when at 0V the JFET was on and at -5 the JEFET was off, showing that JFET essentially acts as a switch rather than a set of diodes like how a normal transistor would preform. Then we are asked why we need the 270Ω, resistor, the reason simply being we would burn the diode we placed in the circuit. We are then asked to use our hand instead of a resistor to connect the -5V, when our hand was placed the circuit would not work meaning that the input impedance through that circuit is larger than that of a human, meaning it is very large. We then are asked to remove the resistor and observe how the circuit reacts, what is shown that the circuit would turn on or off based on dancing and feet placement but not in a comprehensible way to see how movement actually effects the circuit.

## 4. Open-Loop Test Circuit (8-1)

### *4.1. Part D*

The next section had us create a Open-Loop Test Circuit which can be seen in figure 5. This is our first interaction with Op-Amps, as such all we are asked to do is observe the output and the gain, which can be seen in figure 6.Op-Amps specifically are voltage amplifiers specifically it consists of an inverting input and nonvoting input based on negative and positive voltages applied at specific pins on the Op-amp itself and then you can apply voltages which you want to amplify through different pins, and applying resistors allows for a more accurate read on the voltages and their gain, Op-amps are also differential operators, as it can amplify the voltage between the negative

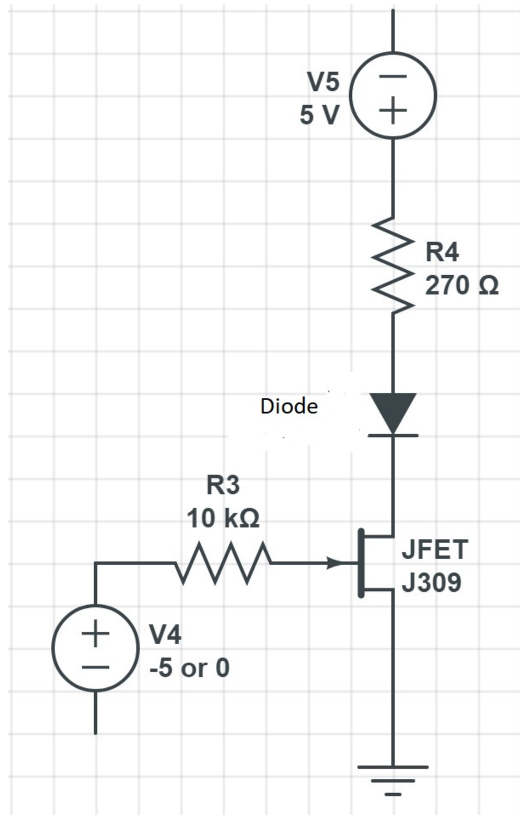


Figure 4: This figure shows the circuit diagram for the Field Effect Transistor

and positive input puns. Which can be seen in the equation below, where $A_{OL}$ is the open-loop gain.

$$V_{out} = A_{OL}(V_+ - V_-) \qquad [4]$$

The behavior is consistent with the 411 specification of 200V per mv of input, but the rails of this op-Amp are 15V and -15V so it will never give a value greater than those.

## 5. Inverting Amplifier (8-2)

### *5.1. Part E*

We are then asked to create an inverting but amplifying circuit. You can see the circuit in figure 7. To see the output of the circuit look at figure 8.

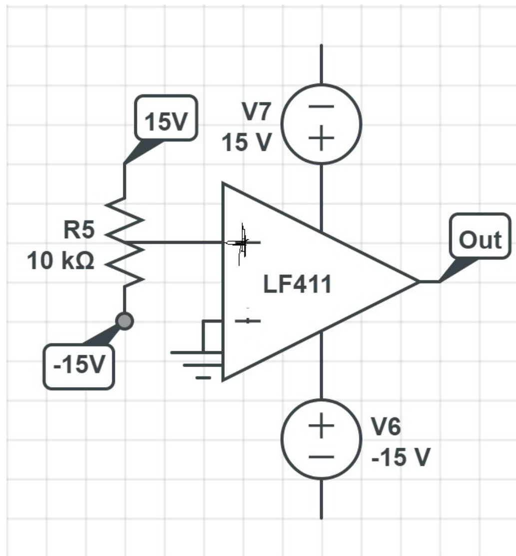


Figure 5: This shows the circuit diagram for the open loop test circuit

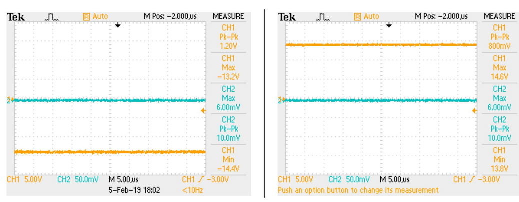

Figure 6: This shows the output of the Open-loop test circuit, with 200V per mV amp but railed to 15V or -15V depending on resistor

We are asked a few questions, first what is the gain, this can be simplified as a ratio of resistors, in our case since we are using a 1k and 10k Ω resistors the gain is simply 10. Then we are asked what the maximum output swing was, in our case it was -15 to 15 volts, then we are asked about linearity, it was as linear as the inputted wave which was very linear. We are asked to vary the frequency till we find the breakdown, for us that occurred around 100 kHz. We are asked to measure the input impedance of the amplifier by adding a 1kΩ resistor, what we received was a 1V in changed to about .6 V and applying the voltage divider equation, we found the input impedance to be about $1k\Omega$ as well. Then we are asked to measure the output impedance which was about 9.68 Ω, though in reality you can not measure the impedance since the Op-Amp has a current shortage trying to accomplish this. We did not need a blocking capacitor because there is no DC in the circuit we needed to filter out.

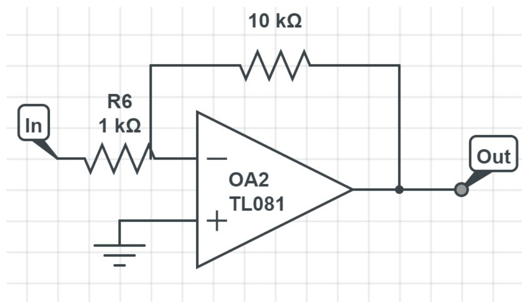


Figure 7: This shows the circuit diagram for the inverting Amplifier.

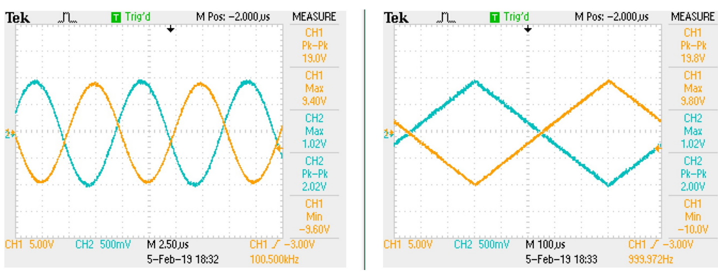


Figure 8: This shows the Output for the Inverting Amplifier.

### *5.2. Part F*

We are then asked to find a $f_{3db}$ for the op-amp at 1V of amplitude input signal. The value we received was about 410 kHz, which is not in the prescribed range indicated in the datasheet, for which it should be around 250-300 kHZ, this could be due to the op-amp being aged or an error in the voltmeter.

### *5.3. Part G*

We are then asked to measure the Bandwidth of a 741 Op-Amp and compare it with the 411 Op-Amp, the 741 op-amp has a bandwidth from our calculations of about 90 kHz, the difference in value is due to the reaction time which is the slew rate of the op-amps, this is not consistent with the data sheets of these components again which it should be around 50 kHz, though it is not far off, the real reason we are asked to compare these two is to see how their slew rates are dramatically different for which they are, as the 411 was 410 kHz and the 741 was 90 kHz .

## 6. Common Emitter Amplifier (8-3)

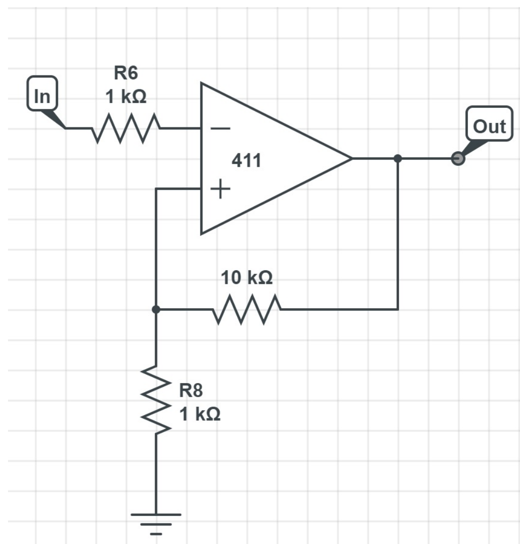


Figure 9: This shows the circuit diagram for non inverting amplifier.

### *6.1. Part H*

The last part of this lab was to show the output of a non-inverting amplification using the Op-amp, which circuit is shown in figure 9 and output in figure 10 and 11. This is just an amplifier that is in phase with the input, the input voltage is amplified and railed at -15 and 15 Volts.

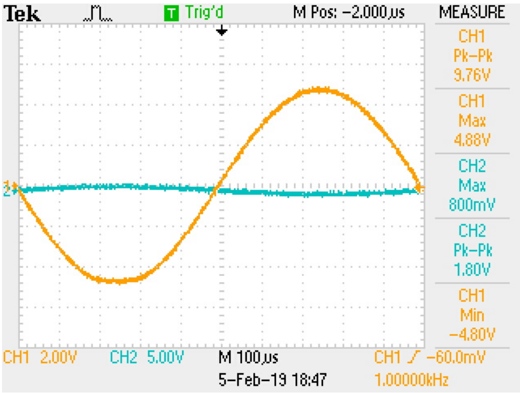


Figure 10: This shows the Output for Non-Inverting Amplifier.

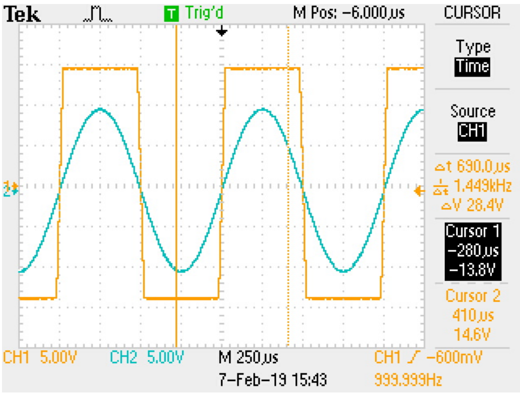


Figure 11: This shows the Output for Non-Inverting Amplifier, at to much voltage amplification, causing the top amplitudes to have a 15 volt max.