ECE 422/522

Project report

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https://www.pdx.edu/ece/tektronix-circuit-design-and-testing-laboratory

1 Abstract

Our objective is to design an RF amplifier that can be used for tranception at 144MHz. Things such as Miller capacitance, impedance matching and maintaining a high gain despite the components possibly resonating. The design simulates very well and maintains a 20dB gain. We also designed an EAGLECAD lay out to be used for the router. Our next goal is to install these components onto a layout and test its amplification ability in the real world. We were able to create an amplifier of gain at around 20dB for voltage and a gain of 10dB for power.

2 Theory

The most obvious choice for the first amplifier was to have a common base input. This allowed us to tailor the input impedance directly to 50 Ωwhile also maintaining a very high gain. The common base amplifier works by first sending a signal into the emitter and afterwards biasing it such that the voltage drop across the resistance between the base and emitter can be easily controlled by the input. Next the transistor acts as a current source between the emitter and collector. The direct parameter of this current source is the voltage drop mentioned previously multiplied by the transconductance. This is made evident by the model shown below.

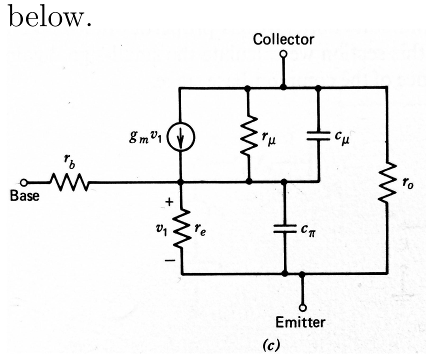

Figure 310 (a) from Grey and Meyer, P 140

Due to the fact that the transconductance changes with respect to the input signal, the internal resistance of the current source is also changing.

2.1 The common base

The common base has multiple unique qualities, the first and foremost being the ability to easily control the input impedance. Another quality is the fact that the miller capacitance is effectively in series with one another, which would double the input impedance caused by them. The common base amplifier is designed like a 4 resistor bias circuit, with input impedance and gain in mind. Things such as current gain and output resistance are usually not designed for in the common base. We first determine the collector current for the desired input impedance. We follow the equation $R_{in} = \frac{1}{G_m}$ and bias the resistors accordingly. We know certain voltage drops across RC and RE, namely 6V (VCC/2) and 200mV, respectively, and because of this we can determine their values. With the RC and RE determined, we then divide the collector current by 10 (to get the current I_b) and bias R1 and R2.

2.2 The common emitter

The common emitter is designed in a similar way. Our design has a pseudo common emitter circuit, known as the class e amplifier.

This amplifier is known for its high performance in RF amplifier design. We first bias the circuit as if it was a standard 4 resistor bias circuit, afterwards replacing the resistor with an inductor that resonates that same impedance at the desired frequency. We then scale the load through the use of a transformer, followed by a filter. This allows us to make a filter that has the desired input impedance AND realistic capacitance/inductance quantities. The gain on a class e amplifier is totally dependant on the what the load demands, this is why we see filters almost always placed at the output of the amplifier.

3 Development

3.1 Common Base

Our first attempt was a common base simulation following the steps detailed in Chapter 3.0 in *Analysis and Design of Analog Integrated Circuits*. This didn't work and is most likely due to the simplistic design detailed. We attempted the calculations provided in the book, however these did not simulate properly and were quickly abandoned. Our calculations are provided below.

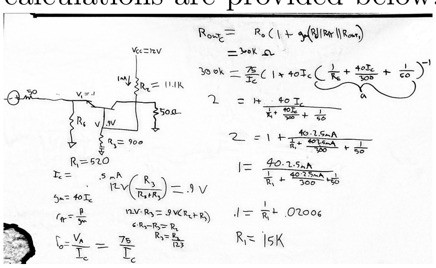

Figure 3.1: Initial common base calculations

After further study and watching *lecture 31: Common base Amplifiers* by The Offset Volt on Youtube, we were lead towards the Hybrid pi model on page 140.

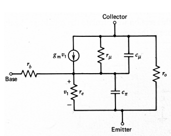

Figure 310 (a) from Grey and Meyer, P 140

We then applied what we learned from the hybrid pi model and applied it to the 4 resistor bias circuit. We realized that having a voltage bias at the base would decrease the amount of thermal noise introduced by the transistor, compared to the original design. The common base amplifier is featured below.

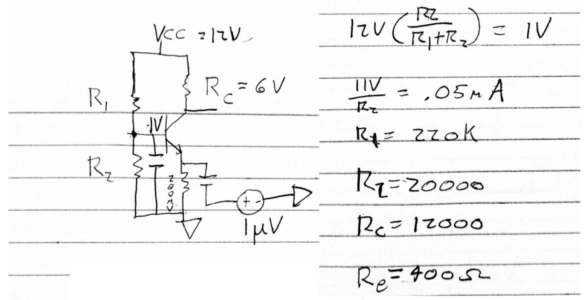

Figure 3.2: Finalized common base configuration.

When this was simulated, there was a total harmonic distortion of less than .5% and had a gain of roughly 10.

3.2 Common Emitter

This design was more intuitive than the previous one, since we have practiced common emitters repeatedly in our previous year of schooling. We designed a 4 resistor bias circuit and replaced the collector resistor with an inductor that provides 1kΩ of resistance at our desired frequency. The biggest hurdle faced when designing the common emitter amplifier was to eliminate the Miller capacitance.

We first tried resonant circuits to change the output impedance of the common base to below the 500Ω input impedance at this frequency, however this did not work as planned and the L circuit caused amplitude oscillations. Our next try was to add inductors at the collector and emitter ends, not simply to help amplify a specific frequency, but to eliminate the capacitance with a series opposite reactance. Again, this added unnecessary harmonics and oscillations. At once point we were totally fooled by an amplifier design that provided a gain of 20dB in a totally different frequency due to its oscillations. In a fit of desperation, we put a series inductor between the common base and common emitter. This not only increased the input resistance but removed a significant amount of the miller capacitance. After proper scaling, an impedance of roughly 1000jΩ worked very well. At the final output our circuit, the total harmonic distortion was measured at .6%

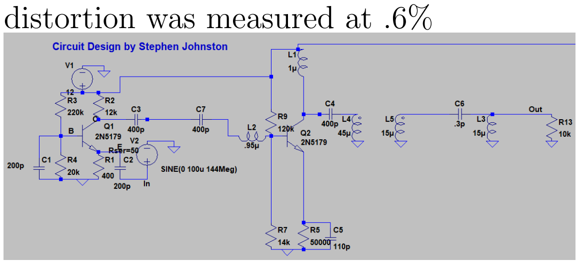

Figure 3.3: Finalized amplifier design

3.3 PCB design

With our finalized circuit, we then designed a prototype schematic in EAGLECAD using readily available parts and the recommended transistor 2N5179. Each line impedance is scaled for 40Ω, which worked very well with the transistor layout.

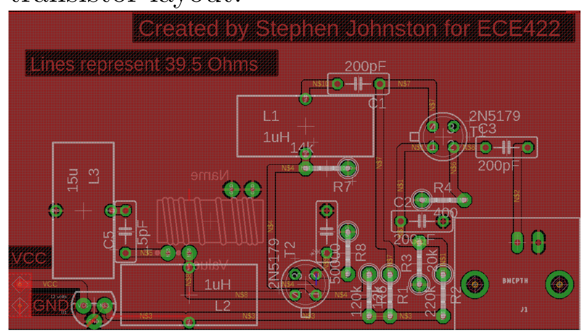

Figure 3.4: Finalized PCB layout

4 Conclusion and Goals

Now that we've designed and finished something capable of amplifying an input signal of 144MHz with little distortion, our next goal is to implement it and test it in real life. We will utilize things such as the VNA to determine the actual input impedance so that we can perform proper impedance matching. As well, we will be performing LCR measurements each component so that we can properly determine the exact parasitic resistance, inductance and capacitance during installation. As well, a spectrum analyzer will be used so that transmission in other frequency bands can be predicted and prevented. As well, for further power implementation, our last goal is to put forward a common collector amplifier and to create a high enough gain that we can transmit the signal from Timberline Lodge^{TM}.

5 References

Robert G. Meyer, and Paul R Gray. ANALYSIS AND DESIGN OF ANALOG INTEGRATED CIRCUITS, Wiley; 5th edition (January 20, 2009)

"31. Common Base Amplifiers", *The Offset Volt* url:https://www.youtube.com/watch?v=oci80Csr1zk

Bowick, Chris, John Blyler, and Cheryl J. Ajluni. RF Circuit Design. Amsterdam: Newnes/Elsevier, 2008. Print.