Week 2 Report
ECE 432 Microwave Circuit Design II

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I. Introduction

This lab involves measuring a SAV 541+ transistor from MiniCircuits and obtaining the transfer characteristic curves. The results obtained in the lab agree very well with the manufacturer's data.

II. Questions & Answers

1. Make nice plots of items 1-2 above. For item 1 comment on how well it compares with specs. For item two, plot the I-V curve but also calculate gm (transconductance) and overlay it. Comment on the dependence of gm on IDS. What are the pros and cons of trying to maximize gm?

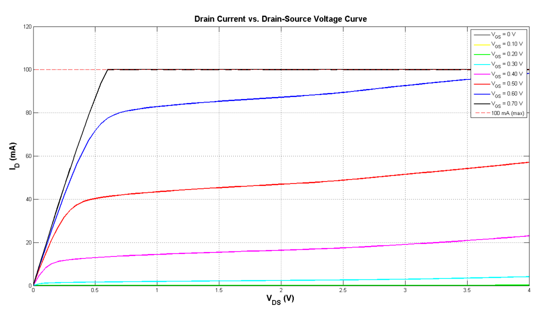


Fig. 1. I_D vs. V_{DS} Curve

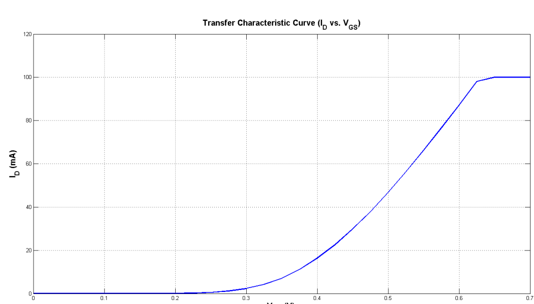


Fig. 2. Transfer Characteristic

Comparing Figure 1 against the manufacturer specs shows a fairly significant difference between the drain current for a given drain-source voltage.

The relationship between g_m and I_{DS} are given by the following equation:

$$g_m = \frac{2I_{DS}}{V_{GS} - V_T} \tag{1}$$

The pros of maximizing gm is higher current gain (acts more like an amplifier). The main tradeoff to this is higher power consumption and more heat dissipation.

2. For items 3 and 4 compare measured data with S-parameters provided by the company (it's in Touchstone format). Do it separately for all four S parameters and use dB plots for magnitude. For S11 and S22 also plot Smith chart and compare the two results.

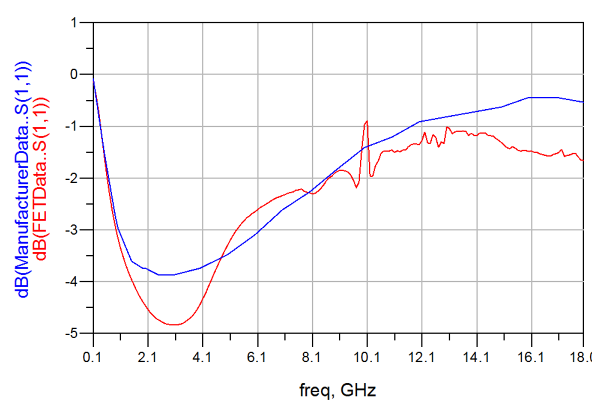


Fig. 3. S11 Magnitude

The measurements from the lab matched the manufacturer figures well[1]. Looking at the S11 and S22 Smith Charts (see Figure 7 and Figure 8) gave poor results. This is most likely due to interference caused by the test fixture; deembedding the data may help clean this up.

3. Measure S-parameters for the fixture and try to use our deembedding procedure from 431/531. Comment on

[1] There was an abnormal glitch noticed at 10 GHz

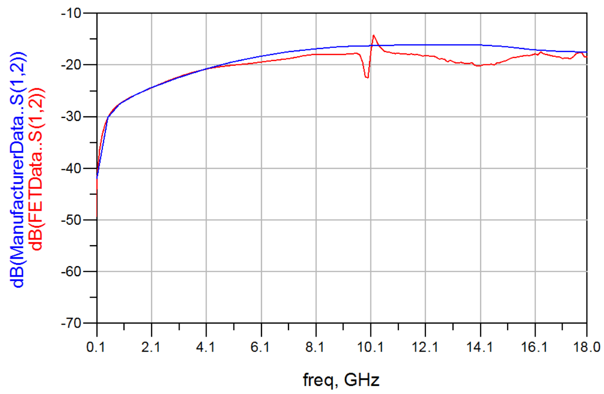


Fig. 4. S12 Magnitude

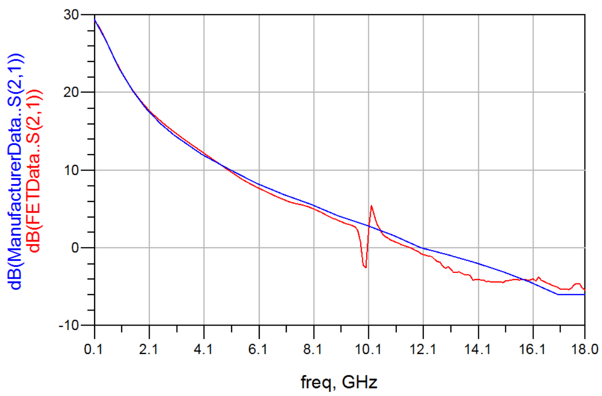


Fig. 5. S21 Magnitude

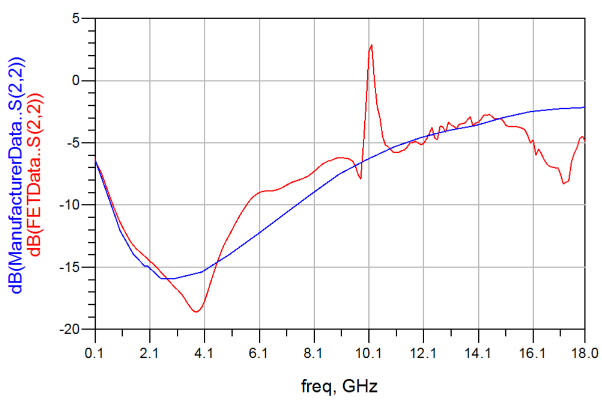
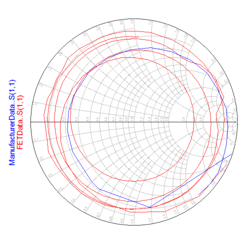
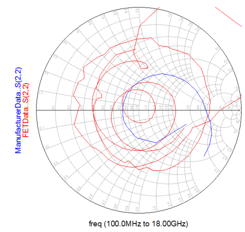


Fig. 6. S22 Magnitude



freq	FETData..S(1,1)	freq	...turerData..S(1,1)
300.0 kHz	1.002 / -0.412	100.0 MHz	0.990 / -18.300
100.3 MHz	0.985 / -24.713	500.0 MHz	0.840 / -79.600
200.3 MHz	0.955 / -48.570	900.0 MHz	0.730 / -117.700
300.3 MHz	0.919 / -71.221	1.000 GHz	0.710 / -125.300
400.3 MHz	0.875 / -92.655	1.500 GHz	0.660 / -153.700
500.3 MHz	0.834 / -112.546	1.900 GHz	0.650 / -170.200
600.3 MHz	0.796 / -131.061	2.000 GHz	0.650 / -173.800
700.3 MHz	0.764 / -148.434	2.500 GHz	0.640 / 170.200
800.3 MHz	0.736 / -164.617	3.000 GHz	0.640 / 156.400
900.3 MHz	0.713 / 179.969	4.000 GHz	0.650 / 132.900
1.000 GHz	0.694 / 165.450	5.000 GHz	0.670 / 112.400
1.100 GHz	0.678 / 151.613	6.000 GHz	0.700 / 94.000
1.200 GHz	0.665 / 138.178	7.000 GHz	0.740 / 77.400
1.300 GHz	0.653 / 125.298	8.000 GHz	0.770 / 62.100
1.400 GHz	0.643 / 112.818	9.000 GHz	0.810 / 47.700
1.500 GHz	0.634 / 100.802	10.00 GHz	0.850 / 33.600
1.600 GHz	0.625 / 89.119	11.00 GHz	0.870 / 20.500
1.700 GHz	0.617 / 77.687	12.00 GHz	0.900 / 8.300
1.800 GHz	0.610 / 66.620	13.00 GHz	0.910 / -3.500
1.900 GHz	0.604 / 55.692	14.00 GHz	0.920 / -14.400
2.000 GHz	0.598 / 44.948	15.00 GHz	0.930 / -23.000
2.100 GHz	0.593 / 34.367	16.00 GHz	0.950 / -30.500
2.200 GHz	0.588 / 23.903	17.00 GHz	0.950 / -39.100
2.300 GHz	0.584 / 13.429	18.00 GHz	0.940 / -48.500
2.400 GHz	0.581 / 3.114		
2.500 GHz	0.579 / -7.235		
2.600 GHz	0.577 / -17.731		
2.700 GHz	0.575 / -28.093		
2.800 GHz	0.574 / -38.512		
2.900 GHz	0.573 / -48.882		

Fig. 7. S11 Smith Plot Before Deembedding



freq	FETData..S(2,2)	freq	...turerData..S(2,2)
300.0 kHz	0.533 / 3.883	100.0 MHz	0.480 / -16.400
100.3 MHz	0.474 / -21.994	500.0 MHz	0.360 / -62.300
200.3 MHz	0.452 / -42.727	900.0 MHz	0.270 / -93.100
300.3 MHz	0.431 / -62.507	1.000 GHz	0.250 / -99.800
400.3 MHz	0.403 / -81.309	1.500 GHz	0.200 / -126.400
500.3 MHz	0.375 / -98.844	1.900 GHz	0.180 / -144.200
600.3 MHz	0.349 / -115.288	2.000 GHz	0.180 / -148.300
700.3 MHz	0.326 / -130.674	2.500 GHz	0.160 / -167.000
800.3 MHz	0.305 / -145.367	3.000 GHz	0.160 / 176.500
900.3 MHz	0.287 / -159.388	4.000 GHz	0.170 / 147.500
1.000 GHz	0.271 / -172.707	5.000 GHz	0.200 / 124.000
1.100 GHz	0.257 / 174.554	6.000 GHz	0.240 / 104.400
1.200 GHz	0.245 / 162.002	7.000 GHz	0.290 / 87.200
1.300 GHz	0.234 / 149.859	8.000 GHz	0.350 / 71.900
1.400 GHz	0.224 / 138.110	9.000 GHz	0.420 / 57.500
1.500 GHz	0.217 / 126.705	10.00 GHz	0.480 / 43.800
1.600 GHz	0.211 / 115.641	11.00 GHz	0.540 / 31.200
1.700 GHz	0.206 / 104.867	12.00 GHz	0.590 / 19.400
1.800 GHz	0.201 / 94.586	13.00 GHz	0.630 / 8.600
1.900 GHz	0.197 / 84.639	14.00 GHz	0.660 / -1.600
2.000 GHz	0.192 / 75.039	15.00 GHz	0.710 / -10.200
2.100 GHz	0.188 / 65.689	16.00 GHz	0.750 / -17.900
2.200 GHz	0.184 / 56.368	17.00 GHz	0.770 / -26.400
2.300 GHz	0.180 / 47.044	18.00 GHz	0.780 / -35.000
2.400 GHz	0.175 / 37.822		
2.500 GHz	0.170 / 28.719		
2.600 GHz	0.165 / 19.451		
2.700 GHz	0.161 / 9.715		
2.800 GHz	0.156 / -0.150		
2.900 GHz	0.152 / -10.243		

Fig. 8. S22 Smith Plot Before Deembedding

whether this improves the data overall and comparison with manufacturer's data? (for this we may have to de-solder some parts first)

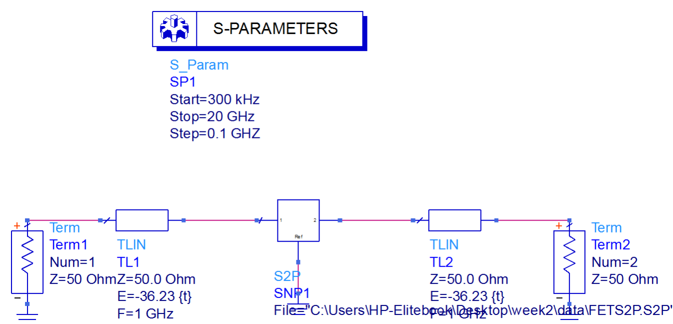


Fig. 9. ADS Deembedding Circuit

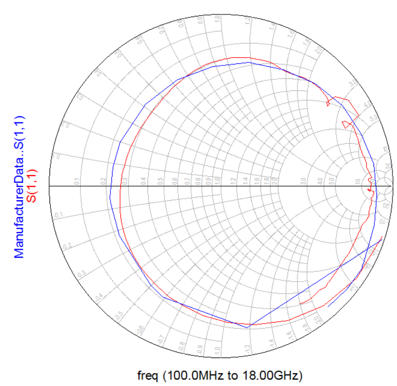


Fig. 10. S11 Smith Plot After Deembedding

Figure 9 shows the circuit used to deembed the lab measurement data. The optimal electrical length was around -36.23 degrees for both sides (the test fixture exhibited symmetrical properties). Looking at the deembedded S11 Smith plot (see Figure 10) showed that deembedding worked well; the S22 Smith plot (Figure 11) has some weird issues that are most likely a glitch in ADS[2]?

[2] I have no idea how to interpret what is going on in the S22 Smith plot simulated from the ADS data

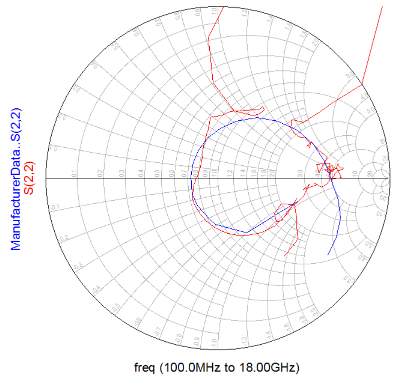


Fig. 11. S22 Smith Plot After Deembedding

4. Try to replicate |S21| and MSG/MAG plots from manufacturers specs; comment on agreement.

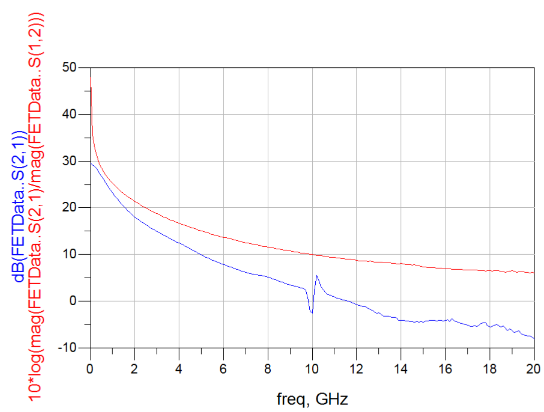


Fig. 12. $|S_{21}|$ and MSG/MAG Plot Generated From Lab Measurement

Figure 12 shows the replicated $|S_{21}|$ and MSG/MAG plot from the in-lab measurement data. It matches the manufacturer's specs extremely closely. This indicates the test setup and measurements were done correctly[3].

III. Weekly Lessons

A. In-Class

Stability and MSG/MAG: In lecture and from the lab, I learned about the maximum available/stable gain (MAG/MSG) and the stability factor K. Notably, when K is greater than one, the amplifier is unconditionally stable; when K is less than one it is potentially unstable.

B. Outside of Class

INA vs. Op Amps[1]: This article examined key differences between instrumentation amplifiers (INA) and op amps. Some notable things were that INA generally contains internal feedback (as opposed to external, RLC-based feedback) and has minimal external-setting resistors. In addition, INAs are specifically used in applications demanding high differential-gain and common-mode rejection characteristics. INAs are designed this way to better amplifiy the signal and reject any common-mode component. The article discussed a few topologies and analyzed the advantages/disadvantages (e.g. input/output resistance, CMR, and differential gain). Overall, building an INA using discrete op amps, while fully possible, will not have the desired performance characteristics as that of a monolothic INA.

References

[1] http://electronicdesign.com/power/what-s-difference-between-operational-amplifiers-and-instrumentation-amplifiers

[3] Props to Dr. B and Lunan for nicely setting up and measuring the transistor circuit