Lab 3 Report

Cory Lanker

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Introduction

This lab explores the small-signal equivalent circuit for a diode and results in discovery of the emission coefficient. The emission coefficient, n_F, is a factor included in the denominator of the diode current vs. voltage equation:

$$I_D = I_S \exp\left(\frac{V_D}{n_F\, V_T}\right)$$

Some research guided me to typical n_F values, between 1 and 2. For IC diodes, n_F is closer to 1, while with the discrete diodes used in the lab n_F is closer to 2. I'll show that the emission coefficient is important to make the small-signal theory align with the measurements.

Setup

I have a square wave generator producing a DC offset V_S and an AC signal v_s. This generator feeds a series combination of a resistor of measured resistance 98.5Ω and 8 1N4148 fast-switching diodes. The 1N4148 diode is similar to the requested 1N914 diode. I use eight diodes so I can have a larger AC signal and still have the small-signal model be valid. The small-signal model is

$$\begin{aligned} I_d = I_S \exp\left(\frac{V_D + v_d}{n_F\, V_T}\right) &= I_S \exp\left(\frac{V_D}{n_F\, V_T}\right) \exp\left(\frac{v_d}{n_F\, V_T}\right) \\ &\approx I_S \exp\left(\frac{V_D}{n_F\, V_T}\right)\left(1 + \frac{v_d}{n_F\, V_T}\right) \end{aligned}$$

where the last approximation is due to the Taylor series expansion of $exp(x) \approx 1 + x$ when $0 < x << 1$ meaning v_d (the AC signal) magnitude should be much less than 50 mV (since $n_F = 2$).

Measurements

The AC signal measured was the amplitude of the 1kHz square wave about its DC signal (given in mV in the table). All measurements performed with a Fluke 175 multimeter. The following table shows the measurements:

- `V_in_mV`: the DC signal magnitude at node `in`, in mV
- `V_out_mV`: the DC signal magnitude at node `out`, in mV
- `V_in_ac`: the AC signal amplitude (about the DC signal) at node `in`, in mV
- `V_out_ac`: the AC signal amplitude (about the DC signal) at node `out`, in mV
- `I_d_mA`: the current through the eight series diodes, in mA

- `r_pi`: $\frac{n_F V_T}{I_D}$, the theoretical r_π per diode using $n_F = 2$
- `p_obs`: observed voltage drop proportion for the eight diodes
- `r_est`: observed $r_\pi = \frac{R}{8} \frac{p}{1-p}$ as calculated from the voltage drop proportion p
- `obs_err`: percent error in observed r_π vs. theoretical values

V_in_mV	V_out_mV	V_in_ac	V_out_ac	I_d_mA	r_pi	p_obs	r_est	obs_err
5492	5259	15.5	10.2	2.37	22.0	0.658	23.7	7.2%
5492	5259	49.9	32.7	2.37	22.0	0.655	23.4	6.1%
6316	5695	36.7	16.6	6.30	8.25	0.452	10.2	18.9%
6313	5691	143	64.5	6.31	8.23	0.452	10.2	19.0%
6055	5571	154	77.5	4.91	10.6	0.505	12.5	15.6%
5164	5024	136	103	1.42	36.6	0.757	38.3	4.4%
5169	5030	95.2	72.0	1.41	36.8	0.756	38.2	3.6%
6358	5713	23.3	10.4	6.55	7.94	0.446	9.93	20.0%
6357	5711	13.8	6.30	6.56	7.93	0.457	10.3	23.3%
6355	5709	77.1	34.2	6.56	7.93	0.444	9.82	19.2%

Figure 1 shows that the error is related to the diode current. It is interesting that a fit line passes close to zero error when the current goes to zero.

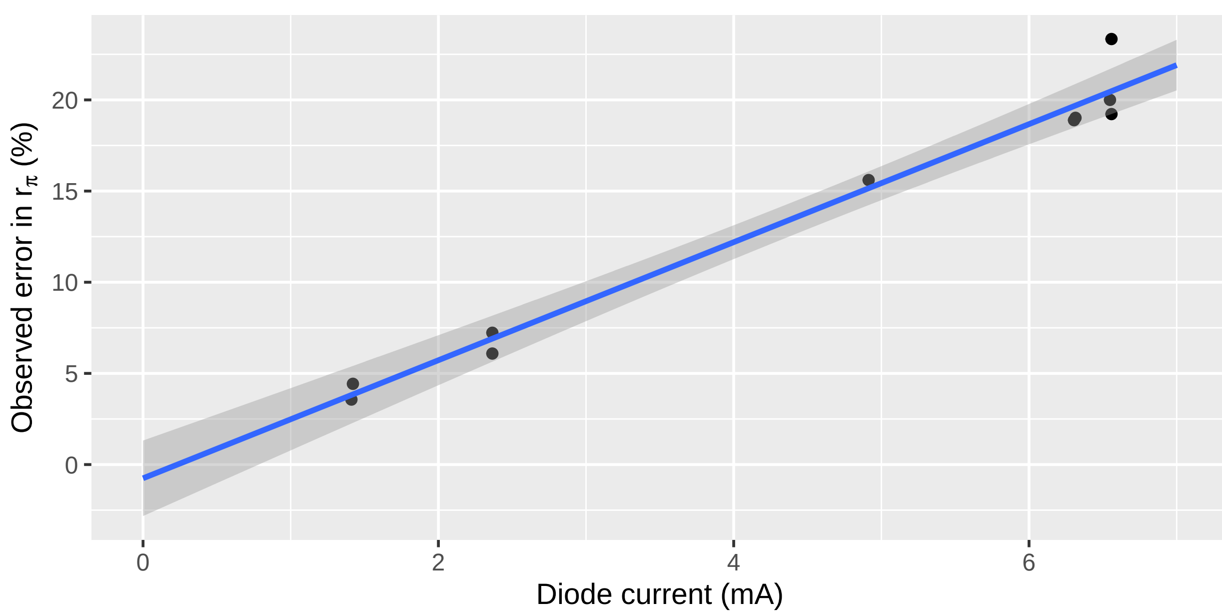

Figure 1: Estimated small-signal resistance errors.

Discussion

An emission coefficient of 2 is appropriate for these diodes. And it seems that the theoretical r_π calculation is valid for small diode currents. With higher diode currents there appears to be an increase in the diode's small-signal resistance.