Electrical Engineering Department
Integrated Circuits Laboratory

Universidade Federal de Santa Catarina

TEACHING LOW VOLTAGE ELECTRONICS: THE CASE OF THE RECTIFIER CIRCUIT

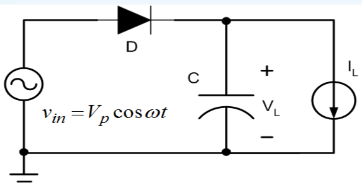
Authors: Adilson Jair Cardoso – adilson@eel.ufsc.br
Carlos Galup Montoro – carlosgalup@gmail.com
Marcio Cherem Schneider - marcio@eel.ufsc.br

Introduction

. The classical constant-voltage-drop model of the diode is inappropriate for very-low-voltage circuits.

Eq. (1): Formula from some classical text books for the peak value of the diode current of the rectifier circuit.

Eq. (2): Formula for the peak diode current of the rectifier circuit using the Shockley (exponential) diode model.



$$I_P = 2\pi\sqrt{\frac{2V_P}{\Delta V}}\, I_L \quad (1) \qquad I_P = \sqrt{\frac{2\pi V_P}{n\phi_t}}\, I_L \quad (2)$$

Fig 1 Half wave rectifier

Eq. (1): ΔV→0, then $I_P \rightarrow \infty$, which is a non physical result.

Half-wave rectifier physical model

Assumptions: the value of the load capacitance is such that the output voltage variation is a small fraction of $n\phi t$

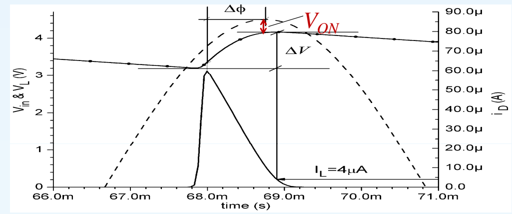
$$I_D = I_S\left[\exp\left(\frac{V_D}{n\phi_t}\right) - 1\right] \quad (3)$$

$$V_L = V_P - \underbrace{n\phi_t \ln\left[(I_P + I_S)/I_S\right]}_{V_{ON}} \quad (4)$$

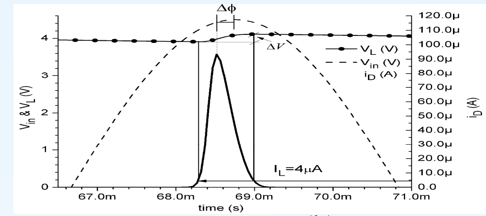
Table I - Peak diode current and diode voltage drop for V_P = 4.5 V, other parameters as in Fig. 2.

	ΔV	I_P →(1)	I_P →(2)	I_P →sim.	V_{ON}→constant voltage drop	V_{ON}→ (4)
(a)	1.1 V	72 μA	97 μA	60 μA	0.6 V	480 mV
(b)	0.22 V	160 μA	97 μA	95 μA	0.6 V	483 mV
(c)	55 mV	320 μA	97 μA	97 μA	0.6 V	484 mV
(d)	0 mV	∞ !	97 μA	97 μA	0.6 V	484 mV

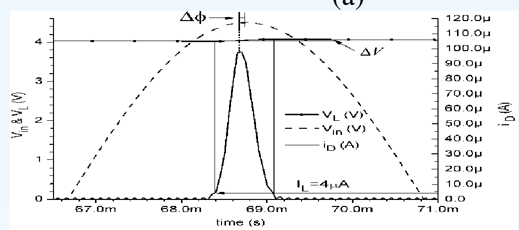
Simulations



(a)



(b)



(c)

Fig 2 Input and output voltage and diode current of the rectifier of Fig.1 for V_P = 4.5 V, f=120Hz and I_L=4μA. The diode parameters are I_S = 4.5 nA and $n\phi_t$=48.5 mV. (a) C=30 nF, (b) C=150 nF, (c) C=600 nF

Experiment

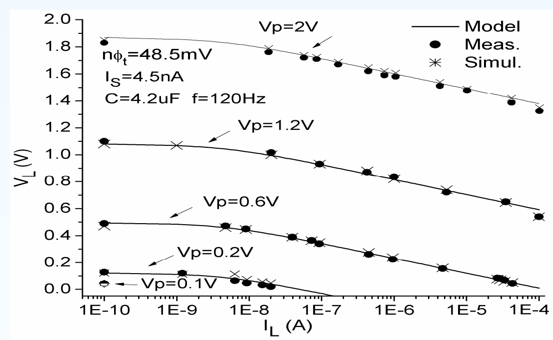


Fig. 3 Simulated and measured output voltage on the half-wave rectifier versus load current for different peak values of the input voltage. Diode:1N4148 and C=470nF.

Conclusions

We presented an analytical model and experiments of the rectifier circuit valid down to very low voltage operation to be included in the next semester lab of Electronics Fundamentals

Integrated Circuits Laboratory
LCI/EEL/CTC/UFSC – 88040-900
Florianopolis – SC – Brazil
Phone +55 48 3721-7720

CNPq

http://www.eel.ufsc.br/~lci