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.

\[ I_p = \frac{2\pi V_p}{\Delta V} I_L \]  

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

\[ I_p = \sqrt{\frac{2\pi V_p}{n \phi_t}} I_L \]

Fig 1 Half wave rectifier

Eq. (1): \( \Delta V \to 0 \), then \( I_p \to \infty \), 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 \( n \phi_t \)

\[ I_D = I_s \left[ \exp \left( \frac{V_D}{n \phi_t} \right) - 1 \right] \]

\( V_L = V_p - n \phi_t \ln \left( \frac{(I_p + I_s)}{I_s} \right) \)

\[ V_{ON} = \frac{V_L}{n \phi_t} \]

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

<table>
<thead>
<tr>
<th>( \Delta V )</th>
<th>( I_p \to (1) )</th>
<th>( I_p \to (2) )</th>
<th>( I_p \to \text{sim.} )</th>
<th>( V_{ON \to} ) constant voltage drop</th>
<th>( V_{ON \to} ) (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) 1.1 V</td>
<td>72 ( \mu )A</td>
<td>97 ( \mu )A</td>
<td>60 ( \mu )A</td>
<td>0.6 V</td>
<td>480 mV</td>
</tr>
<tr>
<td>(b) 0.22 V</td>
<td>160 ( \mu )A</td>
<td>97 ( \mu )A</td>
<td>95 ( \mu )A</td>
<td>0.6 V</td>
<td>483 mV</td>
</tr>
<tr>
<td>(c) 55 mV</td>
<td>320 ( \mu )A</td>
<td>97 ( \mu )A</td>
<td>97 ( \mu )A</td>
<td>0.6 V</td>
<td>484 mV</td>
</tr>
<tr>
<td>(d) 0 mV</td>
<td>( \infty )</td>
<td>97 ( \mu )A</td>
<td>97 ( \mu )A</td>
<td>0.6 V</td>
<td>484 mV</td>
</tr>
</tbody>
</table>

Fig 2 Input and output voltage and diode current of the rectifier of Fig.1 for \( V_p = 4.5 \) V, \( f=120 \)Hz and \( I_L=4 \mu A \). The diode parameters are \( I_s = 4.5 \) nA and \( n \phi = 48.5 \) 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 \( C=470 \)nF.

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

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