Improving an Electronic Circuit Simulator based on Homotopy Methods

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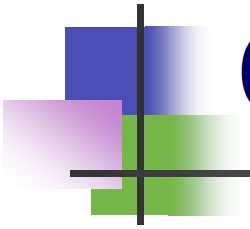
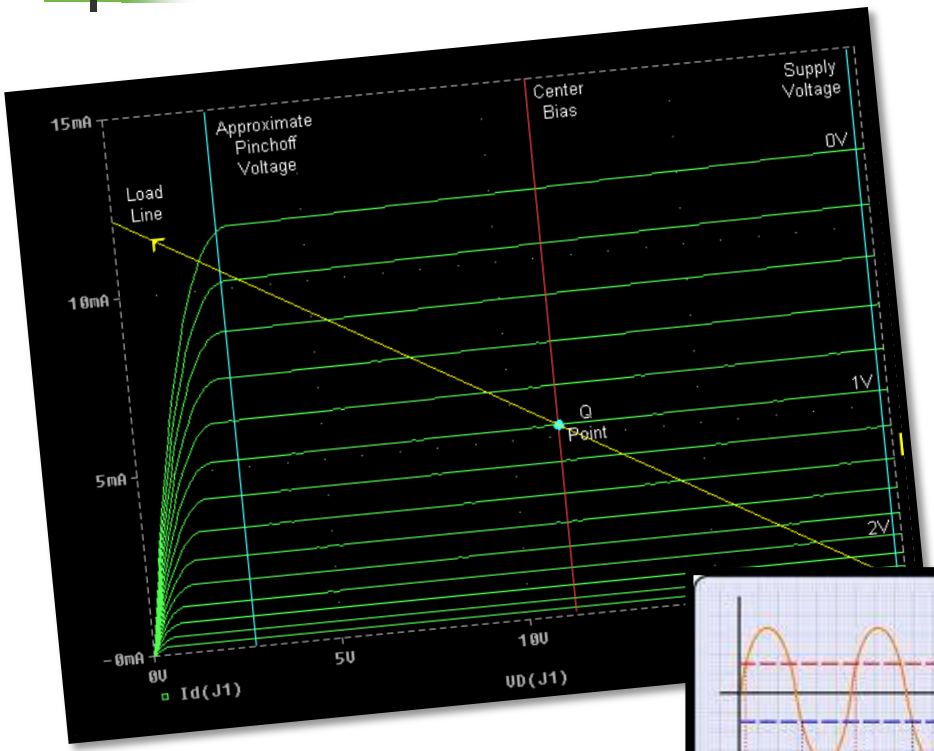
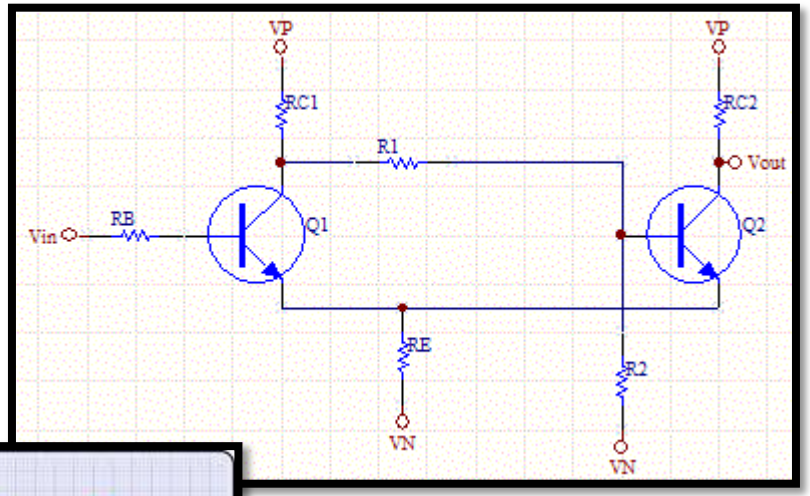


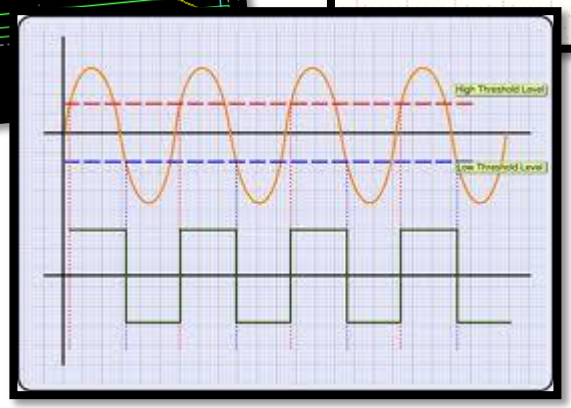
Outline

- Why simulate electronic circuits
- What are DC operating points
- Homotopy Methods
- Parser
- Improvements
- Conclusion

Why simulate

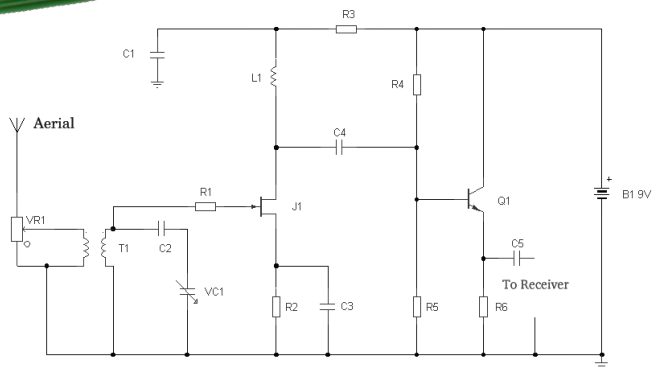




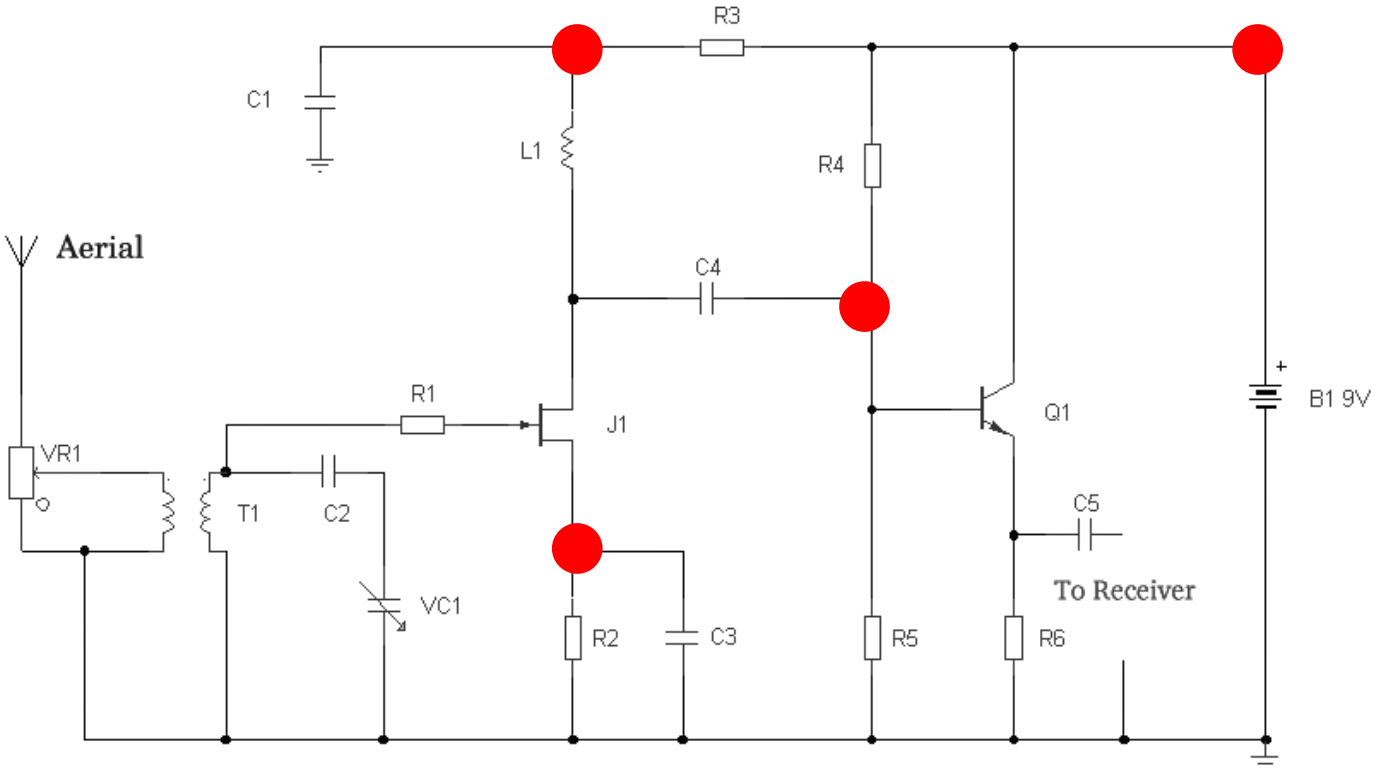


Why simulate

CNL Electronics Circuits*



Why simulate

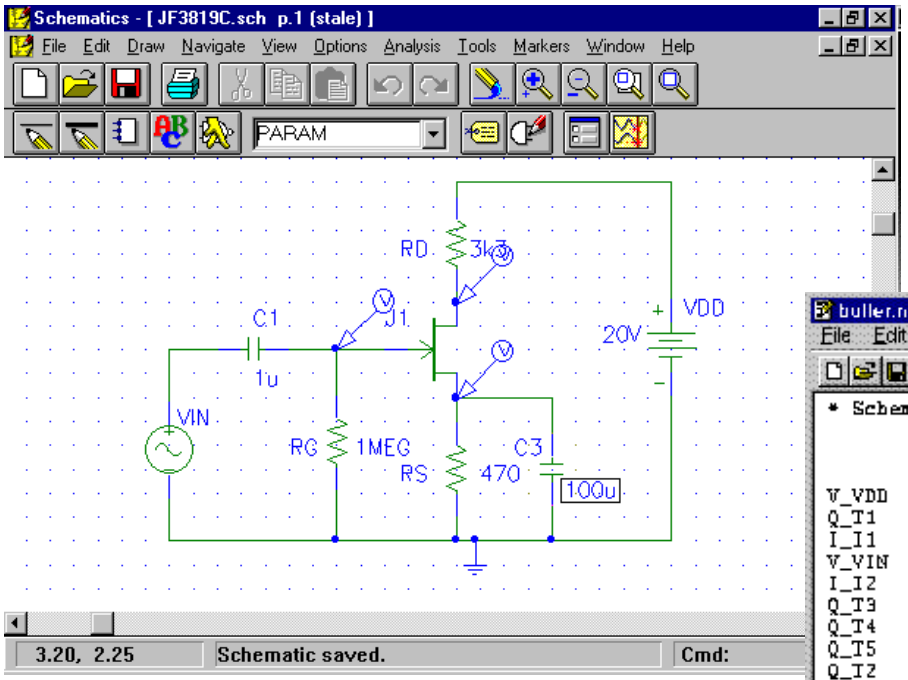


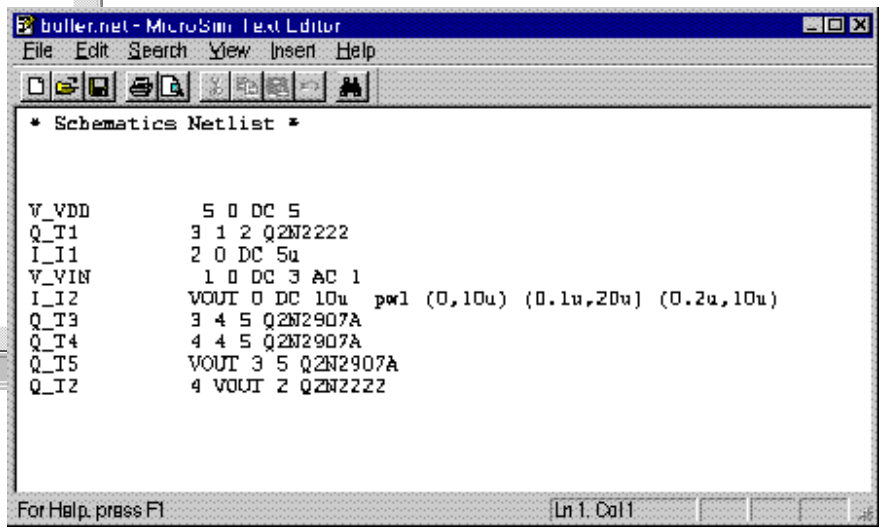
Finding DC operating points

Electronic Circuits Simulators

Finding DC operating points

Electronic Circuits Simulators: circuit description





Finding DC operating points

- Alternative simulator
- Composed for two parts

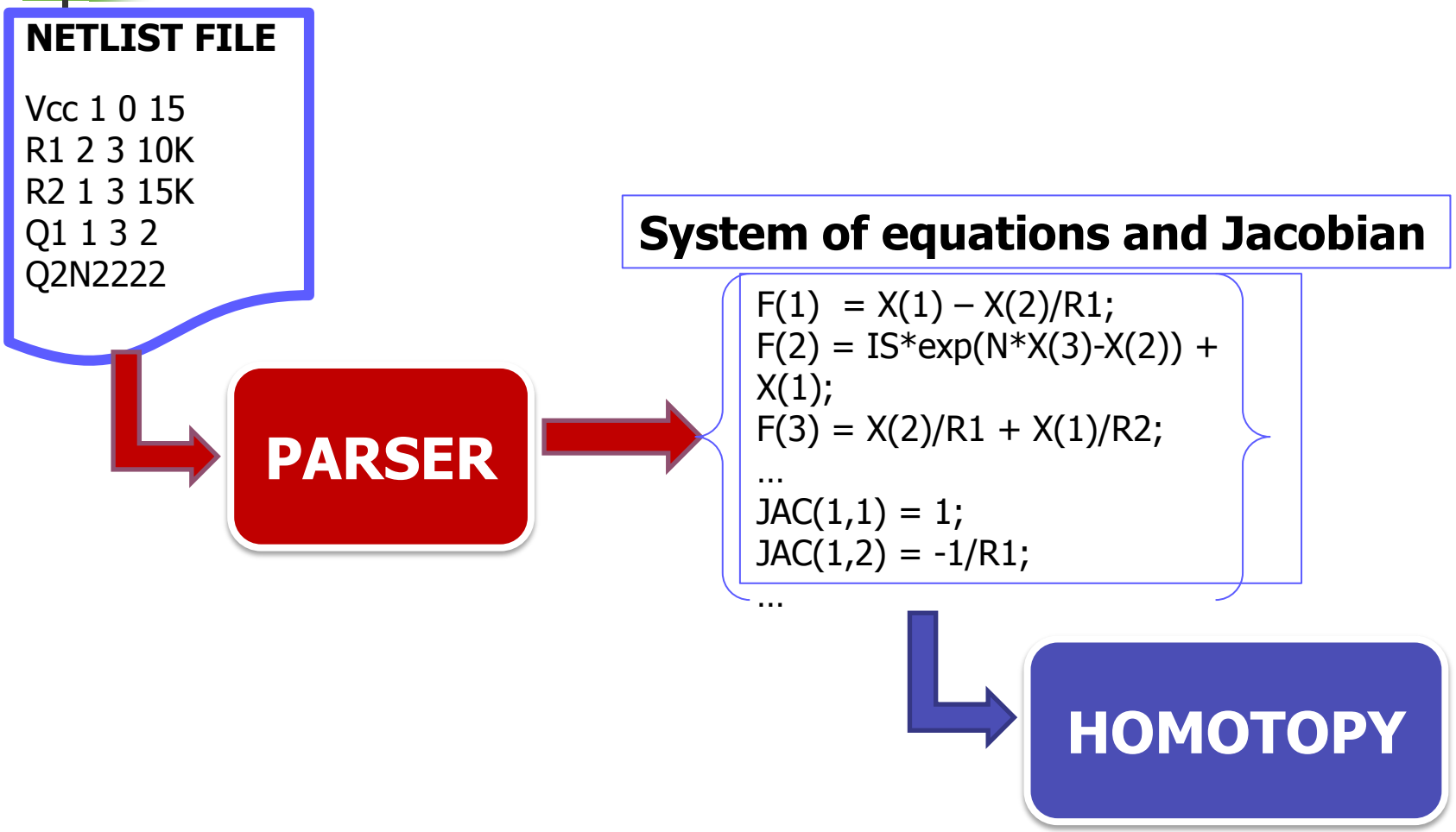
Parser

By Edward Chan

Homotopy algorithm

By Heath Hofmann

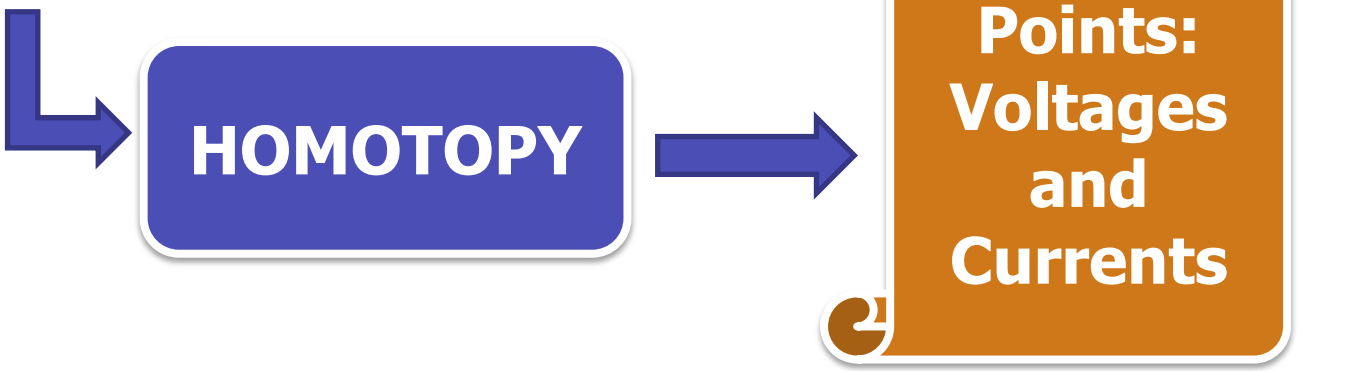
Finding DC operating points



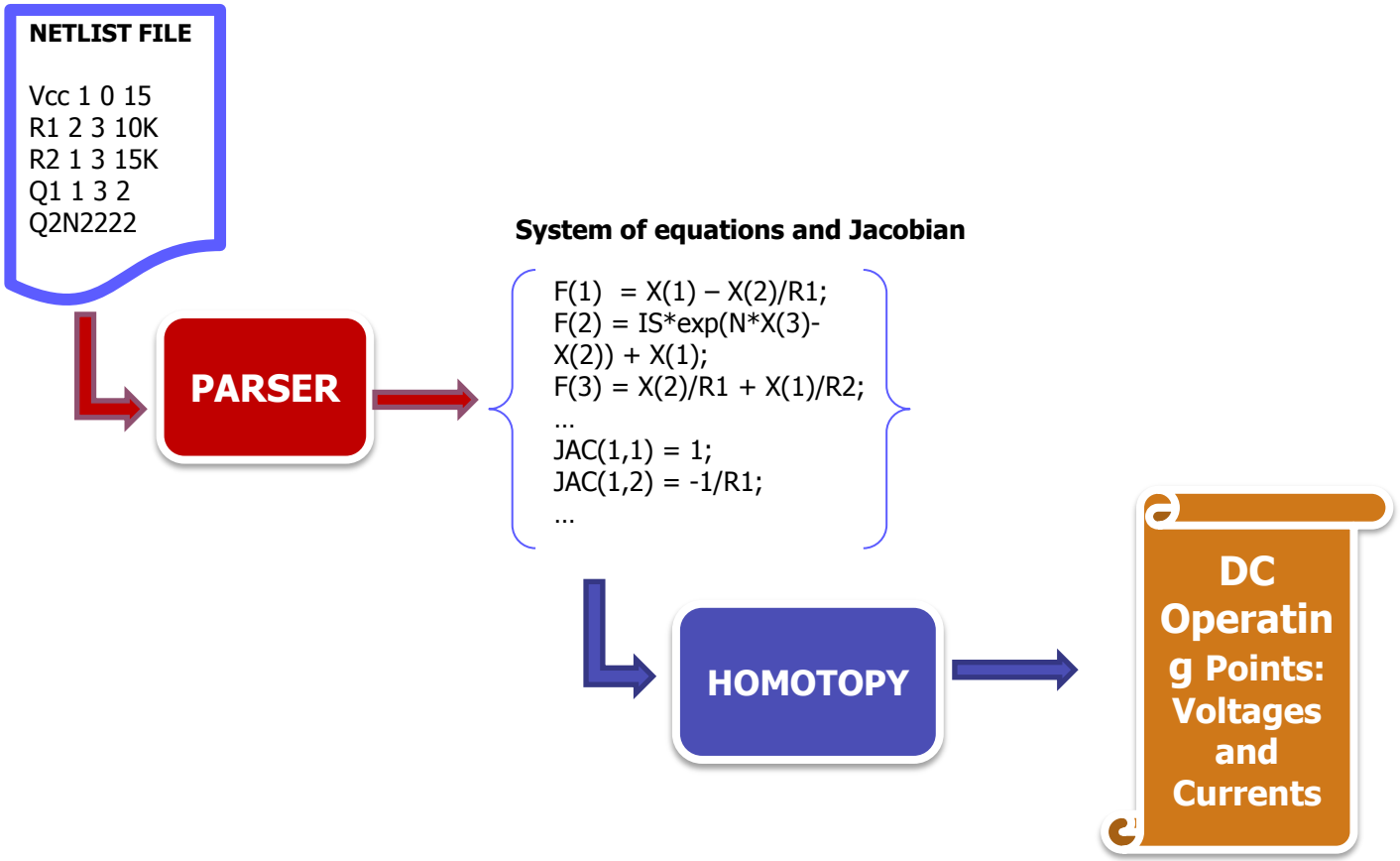
Finding DC operating points

System of equations and Jacobian

```
F(1)  = X(1) – X(2)/R1;
F(2) = IS*exp(N*X(3)-X(2)) +
X(1);
F(3) = X(2)/R1 + X(1)/R2;
…
JAC(1,1) = 1;
JAC(1,2) = -1/R1;
…
```



Finding DC operating points



Homotopy Methods

- A numerical method used to find zeros of a system of equations.
- Create a simpler problem and then deform this problem into the original one.
- A series of zeros is computed from the simple problem until end in the problem of interest.

Homotopy Methods

- Given a system of equations to be solved:

$$F(x) = 0$$

- Create a new function called Homotopy Function:

$$H(x, \lambda)$$

- This function is chosen in such form that deforms a simpler function G(x) into F(x).

Homotopy Methods

- The deformation is made by variation of λ from 0 to 1 continuously.

$$H(x, \lambda)$$

- In such way that:

$H(x, 0) = G(x)$ and $H(x, 1) = F(x)$

Homotopy Methods

- Simple Example of homotopy function:

$$H(x,\lambda) = (1-\lambda)G(x) + \lambda F(x)$$

- Choosing G(x) = (x – a):

$$H(x,\lambda) = (1-\lambda)(x-a) + \lambda F(x)$$

- Then for λ = 0, H(x, 0) = (x – a)
- And for λ = 1, H(x, 1) = F(x)

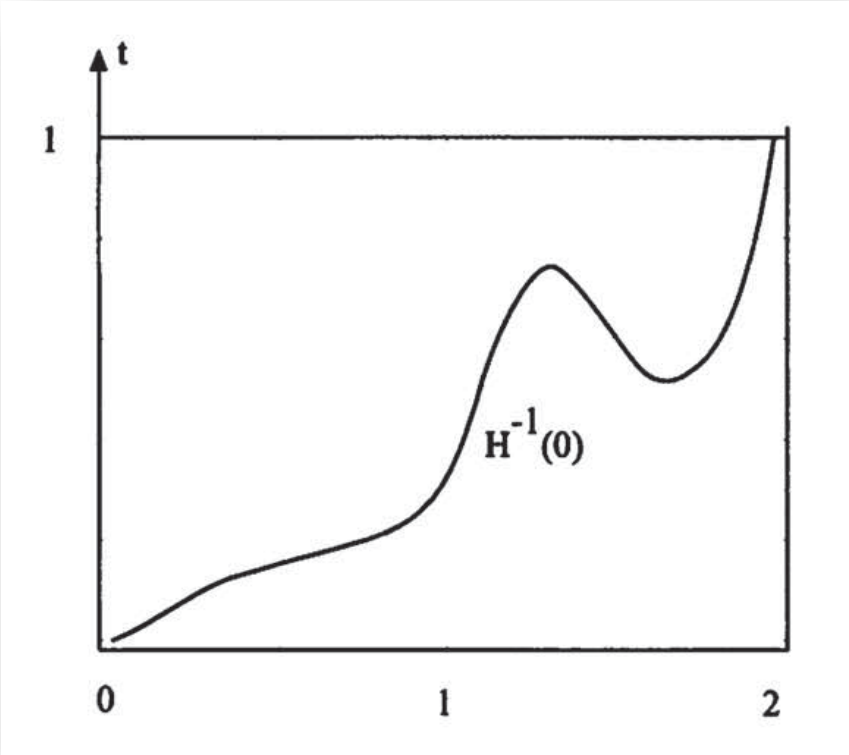
Homotopy Methods

- The objective is found the set:

$$H^{-1}(0) = \{(x,\lambda) \mid H(x,\lambda) = 0\}$$

- Inside this set we hope find a continuous path which connect zeros of $H(x,0) = G(x)$ to zeros of $H(x,1) = F(x)$

Homotopy Methods



$$H^{-1}(0) = \{(x,\lambda) \mid H(x,\lambda) = 0\}$$

Font: Kenneth L. Judd, 1998

Homotopy Methods

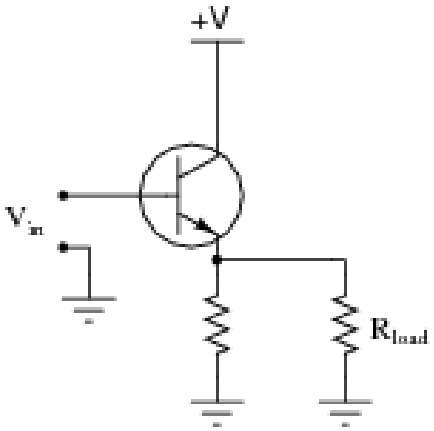
- To trace this curve we use a method that include differentiate the Homotopy Function with respect to x and λ.

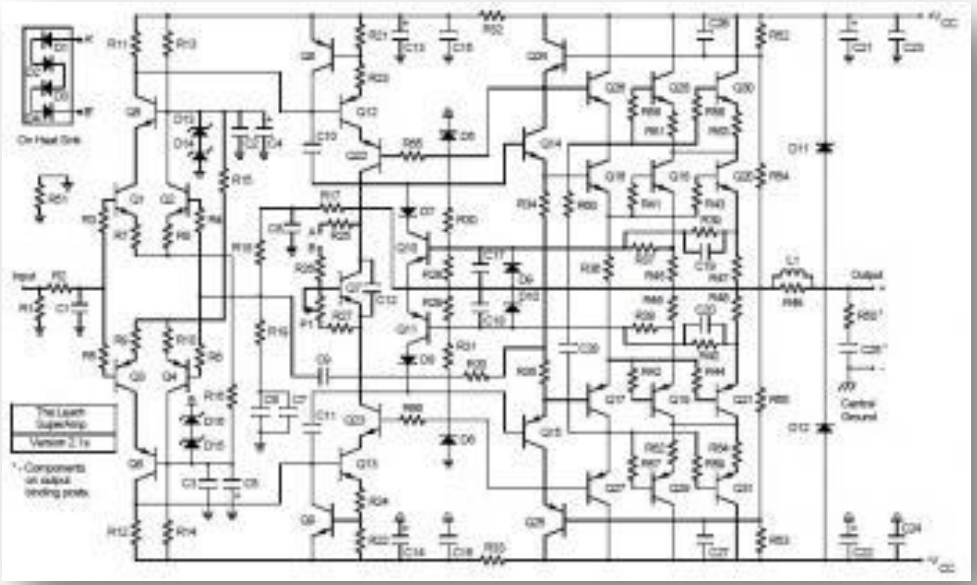
$$H(x,\lambda) = (1-\lambda)G(x) + \lambda F(x)$$

- Then use some numerical method to solve the differential equation(s) created.

The Parser

- The homotopy method require the set of equations.
- For some circuits is possible write by hand.
- Not for others.



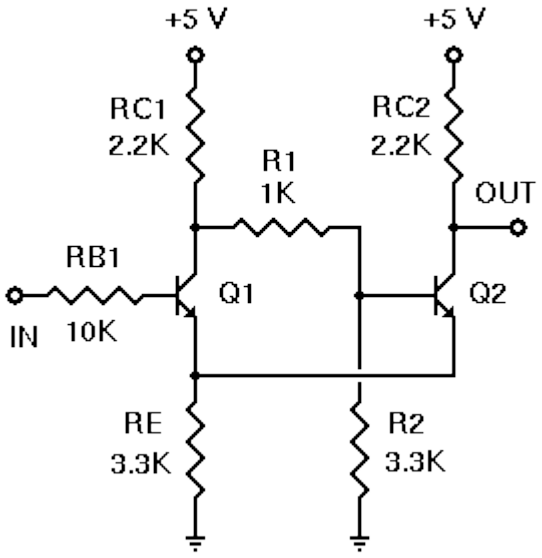


The Parser

- The Parser is a C++ computer program developed by Edward Chan.
- Receive as input a SPICE input file (Netlist).

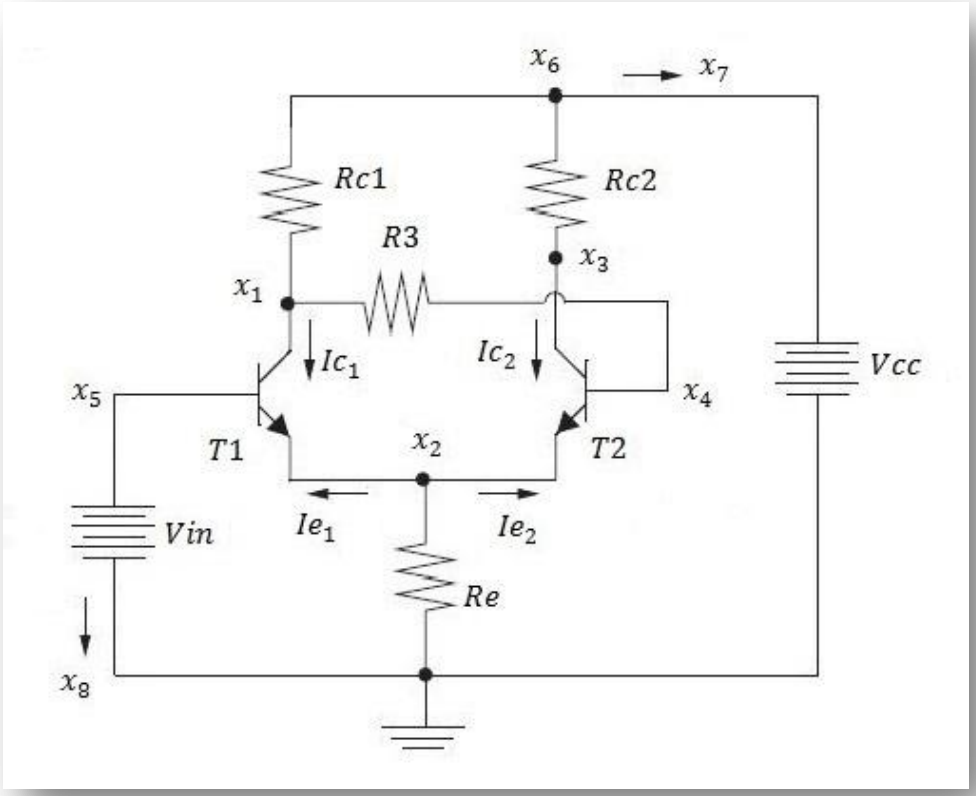
```
Rc1   1 2 2.2K
R1    2 3 1K
Rc2   1 4 2.2K
Q1    2 5 6 Q2N2222A
Q2    4 3 6 Q2N2222A
Vin   5 0 5.0
RE    6 0 3.3K
R2    3 0 3.3K

.model Q2N2222A NPN BF=150 IS=1E-16 BR=7.5
```



The Parser

- Generates nodal or modified nodal equations.



$$\frac{x_1 - x_4}{R3} + \frac{x_1 - x_6}{Rc1} + Ic_1 = 0$$

$$\frac{x_2}{Re} + Ie_1 + Ie_2 = 0$$

$$\frac{x_3 - x_6}{Rc2} + Ic_2 = 0$$

$$\frac{x_4 - x_1}{R3} - Ic_2 - Ie_2 = 0$$

$$x_5 - Vin = 0$$

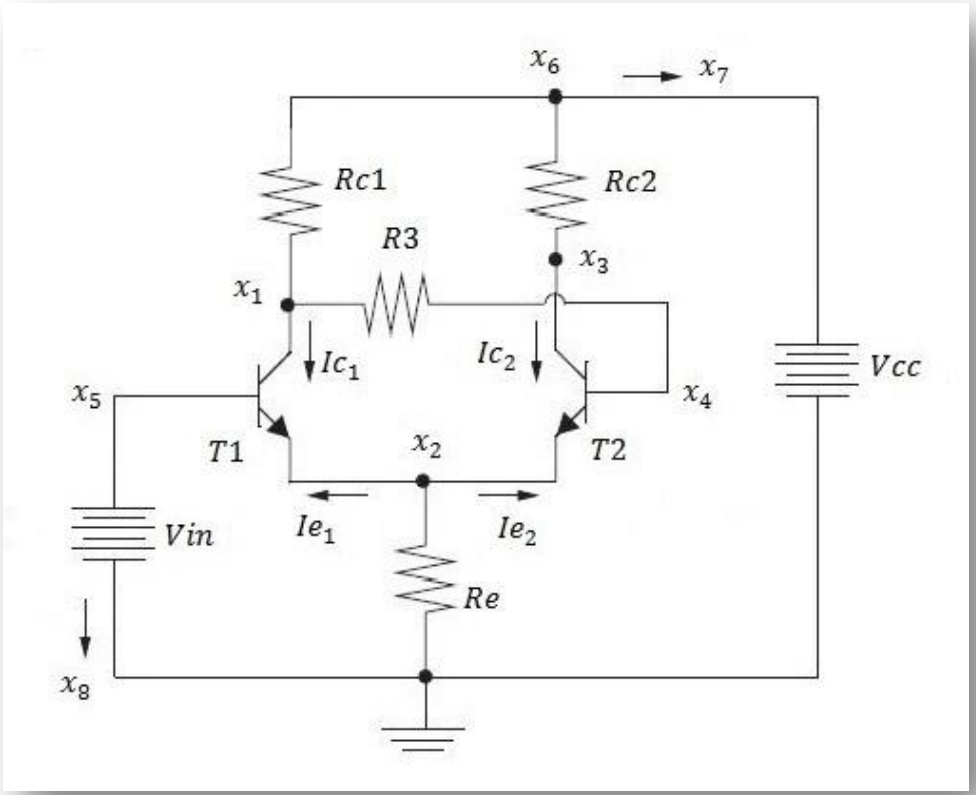
$$x_6 - Vcc = 0$$

$$\frac{x_6 - x_1}{Rc1} + \frac{x_6 - x_3}{Rc2} + x_7 = 0$$

$$x_8 - Ic_1 - Ie_1 = 0$$

The Parser

- Problem: Equations were not in the correct form required by MATLAB algorithm.



$$\frac{x_1 - x_4}{R3} + \frac{x_1 - x_6}{Rc1} + Ic_1 = 0$$

$$\frac{x_2}{Re} + Ie_1 + Ie_2 = 0$$

$$\frac{x_3 - x_6}{Rc2} + Ic_2 = 0$$

$$\frac{x_4 - x_1}{R3} - Ic_2 - Ie_2 = 0$$

$$x_5 - Vin = 0$$

$$x_6 - Vcc = 0$$

$$\frac{x_6 - x_1}{Rc1} + \frac{x_6 - x_3}{Rc2} + x_7 = 0$$

$$x_8 - Ic_1 - Ie_1 = 0$$

The Parser

- Problems: Equations and Jacobian were not in the correct form required by MATLAB algorithm.
- Main problem: Floating Voltage Source.

The Parser

For Nodal Analysis

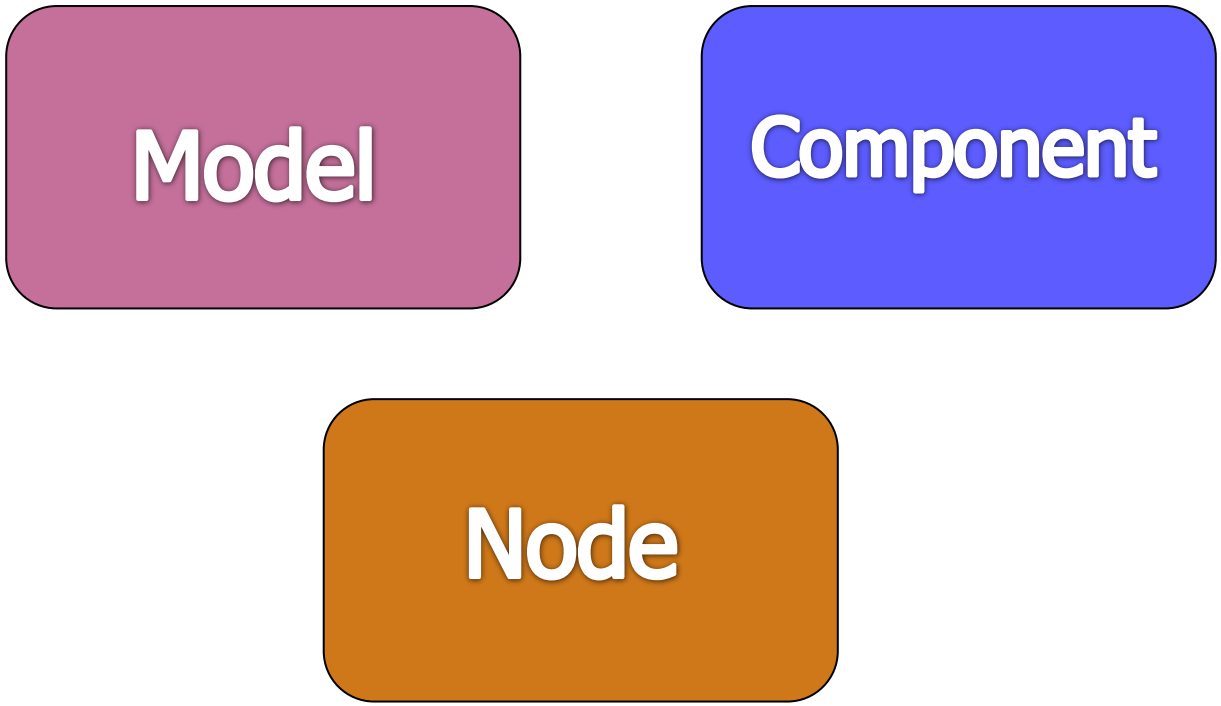
- Missing *supernode* equation each floating source.
- Missing one jacobian for each floating source.

For Modified Nodal Analysis

- Error in the numerating of the equations.
- Missing specific jacobinas for each source.
- Other errors in many jacobians.

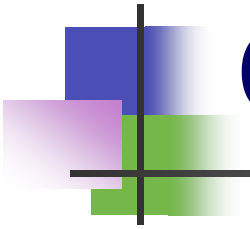
The Parser

- Classes of Parser



The Parser

- Actions performed:
  - Added one more member functions in the Component class: *printSuperNode(…)*
  - Added one more member function in the Node class: *printSuperNodal(…)*
  - Modified existent functions in the Component class: *specialPrintJac(…)*
  - Created function that print the list of components and nodes with respective connections to make the maintenance easier.

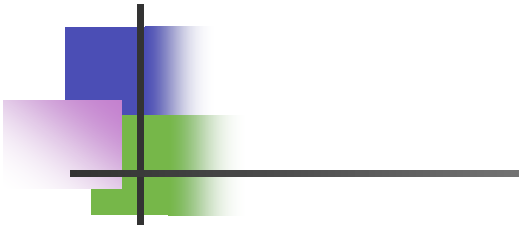


Conclusion

- Contribution in a important project on Electronics field.
- Improve the Parser created by Edward Chan.
- Figuring out the great part of the problems in its operation and results.

Conclusion

- Acquire knowledge in Homotopy Methods.
- Learn how to use Pspice simulator.
- Improve my skills in Matlab script and C++ program language.
- Improve English skill.



Thank you

Erik’s Brasil

Roadmap

- Brasil
  - Presentation
  - Industry and politics
  - Nature and Turism
  - Cosine
  - Football (Soccer)
  - Culture
- Recife (my City)

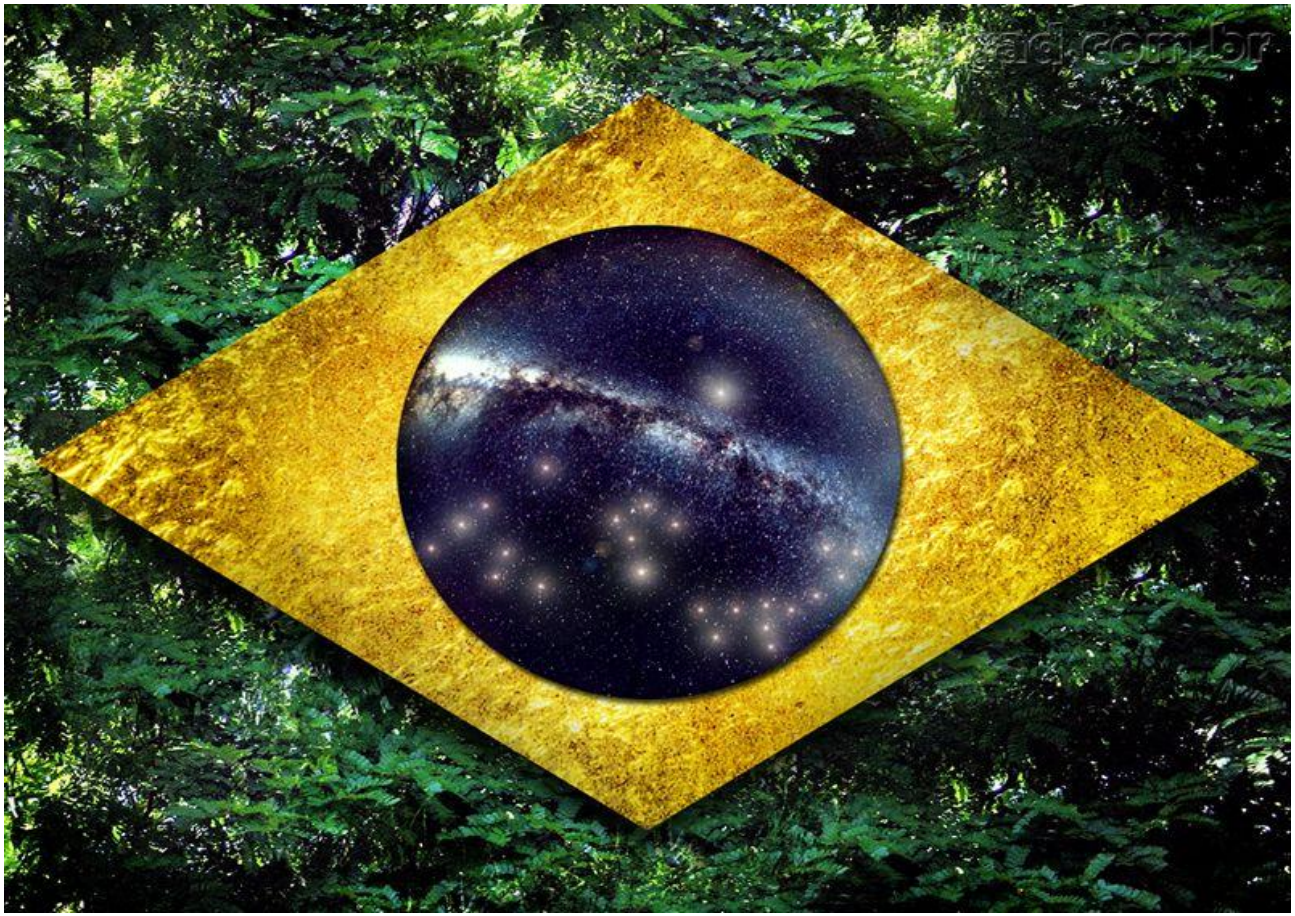
Brasil

- Official Language: Portuguese
- Population:

  202 032 714 hab (5º)
- Area: +8 500 000 Km² (5º)
- Borders: 11 countries

Brazilian Flag

Brazilian Flag



Industry & Politics

- Presidents

- Dilma Rousseff

- Lula da Silva

- Presidential elections 2014

Industry & Politics

- 13th biggest Petrol Company in the world.

PETROBRAS

Nuture & Turism

- Amazonas

Nuture & Turism

- Rio de Janeiro

Nuture & Turism

- Gramado

Nuture & Turism

- Northeast

Nuture & Turism

- Northeast

Cosine

- Rice and beans

Cosine

- Cuscuz and cheese

- Corn foods

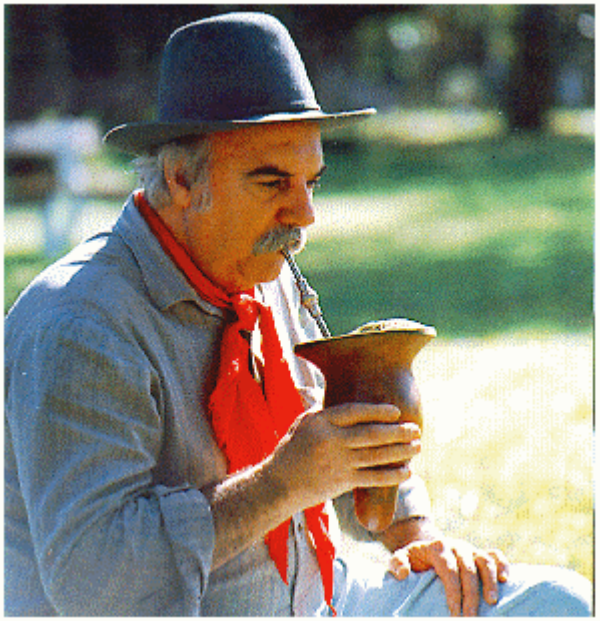
Culture

- Capoeira

- Frevo

Culture

- Chimarrão



- Samba

Climate

- 40ºC Natal
- - 10ºC Caixas

- Average: 25ºC

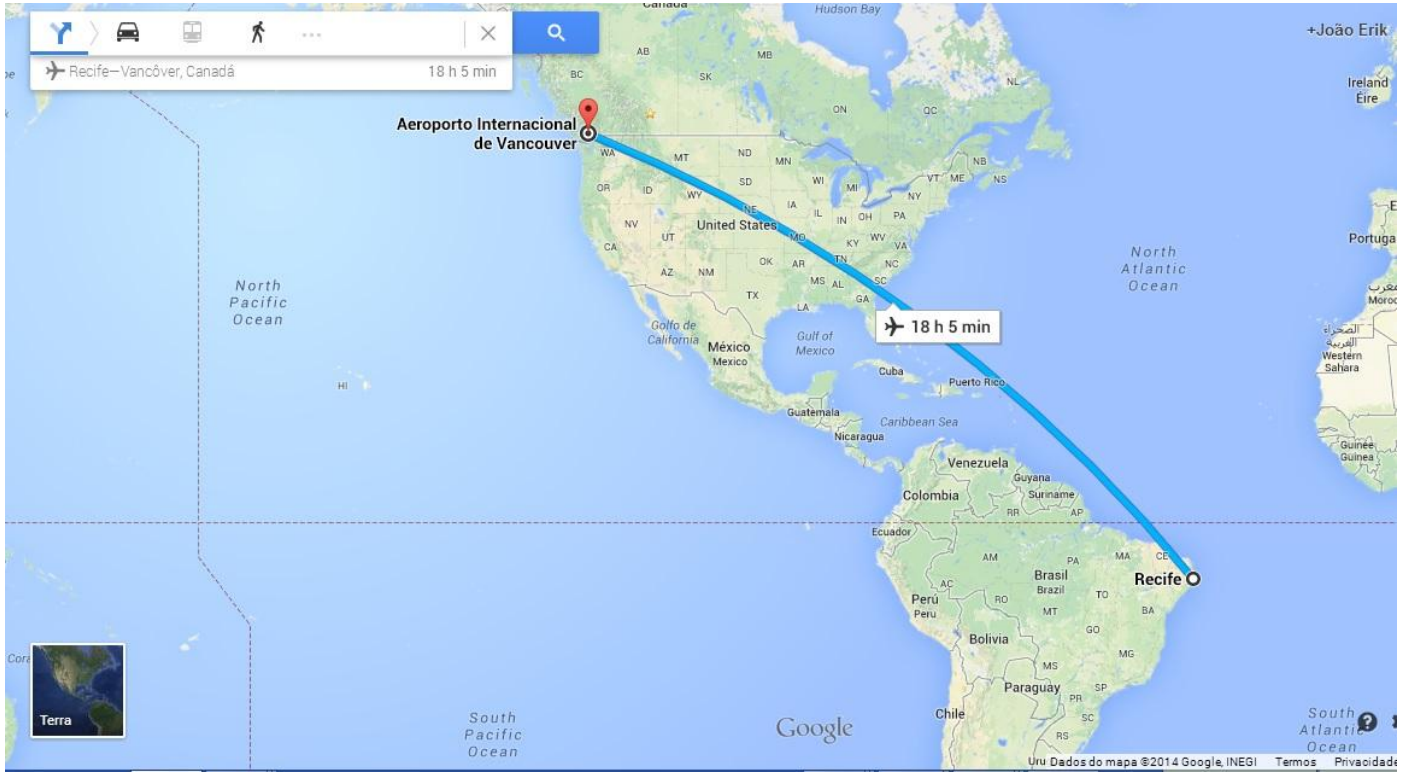
Recife, my city

Recife

- Population:
  1 599 513 hab
- Area: + 218 Km²

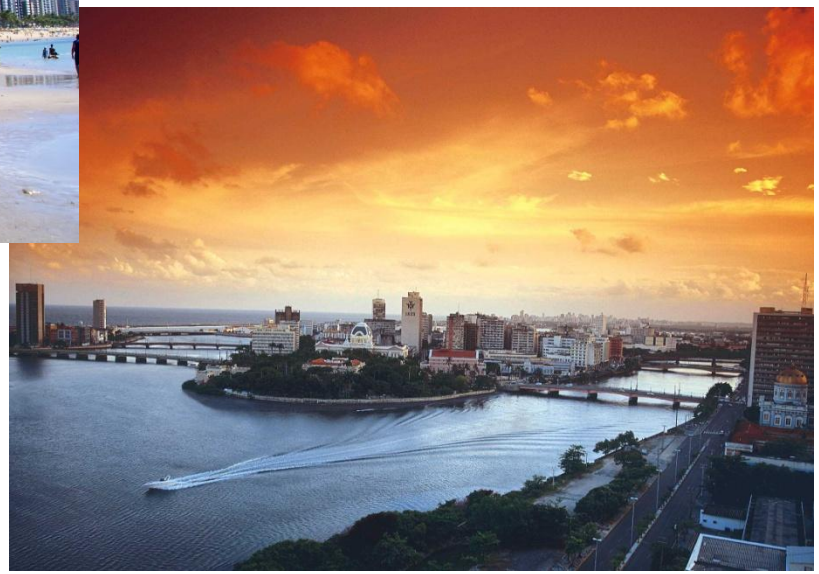
Recife

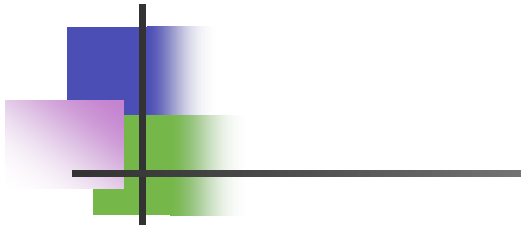
- Distance of Recife to Vancouver



Universidade Federal de Pernambuco

Recife





See you in Brazil