ECALC: A Simple and Powerful Electronics Calculator

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ABSTRACT: This paper describes *ECALC*, an interactive Windows-based software package. The program allows the user to solve DC-bias and SMALL-SIGNAL amplifier circuits without the need to draw the circuit diagram. Customarily, the simulation of electronic circuits rely on programs which are either expensive or time consuming to use for simple calculations. *ECALC* addresses these problems by providing a simple electronics calculator with a powerful graphical user interface.

1. INTRODUCTION

ECALC v2.0 is a menu-driven windows-based[1] interactive program for the solution of *known* electronic circuits. With *ECALC* you can solve the basic types of transistor circuits found in a typical analog electronics course. The main type of calculations that *ECALC* can perform are:

- DC Bias calculations, and
- Small-signal amplifiers calculations

for electronic circuits with one transistor (one stage).

In its present version *ECALC* is capable of analyzing circuits composed of *bipolar junction transistors* (BJT) and some members of the FET family of transistors, namely *junction field-effect transistors* (JFET), *depletion-enhancement metal oxide semiconductor field-effect transistors* (DE-MOSFET), and *enhancement metal oxide semiconductor field-effect transistors* (E-MOSFET). Future versions of the program will include other important types of semiconductor devices and other types of analysis (i.e., frequency response, multistage amplifiers, etc.)

The circuits that *ECALC* addresses are the typical circuits found in standard electronic books like *Electronic Devices and Circuit Theory* by Robert L. Boylestad and Louis Nashelsky [1], and *Electronics Devices* by Thomas L. Floyd [2].

To use the program you have to be familiar with the notation and names used in those books (or an other similar book), because *ECALC* does not have the capability to allow

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[1] There are two versions available at this moment: A MS Windows version that is described in this paper, and a *DOS* version with a window interface.

the user to draw circuits[2]. The program has an extensive database of familiar circuits that the user can select via menus and icons[3]. Thus, for instance, if you want to calculate all the parameters of a *common-emitter amplifier* you should know the structure and topology of the circuit. When a circuit is *called* by the user, *ECALC* will bring to the desktop a data-entry form and the schematics of the circuit. At this point the user enters the parameters of the circuit in the data-entry form after which *ECALC* opens a *solution* window showing the results.

2. AUDIENCE

Why would you use a simple program like *ECALC* when there are many excellent packages like the *Spice* family and *Electronics Workbench* ?

ECALC is intended to be a **calculator** in the general sense of the term. It is specially geared toward students taking an electronics course when, for instance, they want to check the solution of a homework problem, or when they want to make a fast calculation in a lab environment; or even during lectures, the instructor can make use of *ECALC* to show waste of time.

In these instances - and in many others - it is cumbersome to use a more complicated package like, for example, *Electronics Workbench*, to draw the circuit and then find the solution. With *Electronics Workbench*, for instance, the student would spend an enormous amount of time just to make a simple calculation by first drawing the circuit and then finding the solution. Because *ECALC* uses standard circuits, there is no need to draw the circuit in order to find the solution. The solution to an amplifier problem, for example, takes considerable less time with *ECALC* than with any other more sophisticated and expensive program.

3. USING THE PROGRAM

After starting *ECALC* the main window appears as is shown in Figure 1.   All the calculations are made here by selecting menu items from the top menu bar. The menu items are divided into two broad groups: **(a)** DC analysis (for BJT and FET transistors), and **(b)** AC analysis for the calculation of small-signal amplifier parameters for both type of transistor circuits.

In the next two subsections the sub-menu items corresponding to these two groups are discussed.

3.1 DC Analysis. There are two menu entries related to DC analysis of transistor bias circuits, namely BJTDC and FETDC.   The following list shows all the sub-entries

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[2] The program shows the circuits, but does not allow the user to draw them.
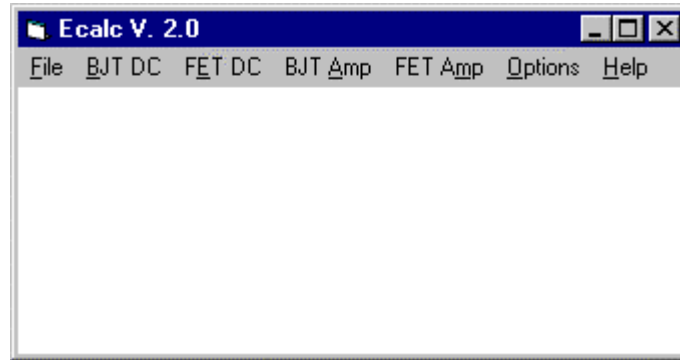[3] The database is easily expandable to satisfy the needs of an instructor.

Figure 1. Main Ecalc Window

of these items.

1. **BJTDC: DC biasing for BJT transistors:**
   a) **Common-Emitter: Biasing for the common-emitter configurations:**
      - Two sources
      - Fixed Bias
      - Fixed Bias w/RE
      - Emitter Bias
      - Voltage Divider
      - Collector Feedback
   b) **Common Base: Biasing for the common—base configuration**
2. **FETDC: DC biasing for the family of FET transistors**
   a) **JFET: Biasing for the junction field-effect transistors**
      - Fixed Bias
      - Self Bias
      - Voltage Divider
   b) **DE-MOSFET: Biasing for the enhancement-depletion FET.**
      - Fixed Bias
      - Self Bias
      - Voltage Divider
   c) **E-MOSFET: Biasing for the enhancement FET.**
      - Feedback Bias
      - Voltage Divider

3.2 AC Analysis. To perform small-signal amplifier simulations there are two main menu items available: **BJT Amp** and **FET Amp.** Each one has several sub-menus that allows the user to select from a database of circuits. The following list shows all the possible selections available at the moment.

1. **BJT Amp: small-signal analysis of BJT transistor circuits.**
   a) **Common-Emitter**
   b) **Common-Collector**
   c) **Common-Base**
   d) **Collector Feedback**
   e) **Collector DC Feedback**

2. **FET Amp: small-signal analysis of FET transistor circuits.**
   a) **JFET: small-signal analysis of JFET amplifiers**
      - Common Source
      - Common Drain
      - Common Gate
   b) **DE-MOSFET: small-signal analysis of DE-MOSFET amplifiers.**
      - Common Source
      - Common Drain
      - Common Gate
   c) **E-MOSFET: small-signal analysis of E-MOSFET amplifiers**
      - Feedback Amplifier
      - Voltage Divider Amplifier

To perform a simulation of a listed dc bias or of a small-signal amplifier circuit the user should navigate these menu items to find the desired simulation entry. As you will see later, when selecting an entry the program will display the schematics of the selected circuit and an *input data-entry form* will be made available to be filled by the user. Once the input data is entered ECALC displays and fills the *output data* form . From the **Options** the user can choose to display the results using one, two, three or four decimals[4].

4. MATHEMATICAL FORMULATION

Embedded in ECALC are the typical calculations found in electronic devices books. ECALC, however, uses *exact* solutions instead of the usual approximations preferred in most books. Thus, some minor differences may be found when comparing results from books that use approximations. This should not present any problem to the students or to the instructors. Before the *electronics age*, approximations were important to accelerate calculations. Now-a-day there is no need to use approximations when making calculations with the help of a computer.

As an example, the approximate and the *mor*e exact solutions for the parameters of a small-signal common-emitter amplifier are given by the following set of equations[5]:

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[4] With the **Options** menu item it is possible to set other preferences like colors or the type of transistors.
[5] These equations can be found in the Boylestad and Nashelsky book[1].

Approximate Solutions

Input Impedance:

(1) $\qquad Z_i = R_B \parallel Z_b$

where

(2) $\qquad Z_b = B(r_e + R_E)$

where B is the transistor current gain (beta).

Output Impedance:

(3) $\qquad R_c = Rc \parallel ro = Rc$

where r_o is the transistor output resistance.

Voltage Gain:

(4) $\qquad A_v = BR_c / Z_b$

Exact solutions

Instead of the previous equations, ECALC calculates these parameters using the following equations:

Input Impedance:

(5) $\qquad Z_i = R_B \parallel Z_b$

but in this case

(6) $\qquad Z_b = Br_e + [((B+1) + R_c/r_o) / (1 + (R_c + R_E)/r_o] R_E$

Output Impedance:

(7) $\qquad Z_o = R_c \parallel [r_o + (B(r_o + r_e) / (1 + Br_e/R_E)]$

Voltage Gain:

(8) $A_v = [((-BR_c) / Z_b)[1 + r_e/r_o] + R_c/r_o] / [1 + R_c/r_o]$

Open loops and short circuits

The resistance of an open loop is infinity. In ECALC if a resistance is infinite the should input a very large value. A value of 1e30 Kohms or bigger is sufficiently *close* to infinity. For example, in amplifiers ECALC expects the user to input the value of the load resistance (RL). If in a particular problem there is no load, then the user should input a large value, otherwise ECALC will not continue with the calculation.
To indicate a short circuit enter a value of zero for the resistance of the branch.

Capacitors

This version of ECALC (v2.0) does not deal with frequency response of amplifiers. However, there are amplifiers (Common-Emitter, for instance) that require bypass capacitors for the emitter and the source. For these cases, ECALC will expect the user to fill the capacitor data field. The only information that the program needs at this moment is an indication of the presence or absence of the capacitor. For this, the user should input any value bigger than zero to indicate the existence of the capacitor, or any value less than zero to indicate that there is no bypass capacitor.

5. EXAMPLES

In this section we present two examples on the use of ECALC.

Figure 2: Voltage Divider Bias Circuit

5.1 BJT Calculation. The first example is the calculation of the DC parameters of a voltage-divider common-emitter amplifier. The element values are indicated in Figure 2. To run this simulation we must open the proper menu item. Starting from the main window, the sequence of selections are: **BJT DC, Common-Emitter, Voltage Divider**. After this selection the window corresponding to the voltage-divider circuit will appear. This is shown in Figure 2. As you can see the circuit windows are divided into three section: The **Input Values section,** the **Results** section and the **Schematics** section. The schematics of the circuit being calculated will be shown automatically, so the user can see what type of parameters are needed for the simulation.

The only section accessible to the user is the *Input Values* section where parameter values are to be entered as is shown in the figure for the particular problem we are simulating here. Once the input values are entered, the results can be seen by pressing the *Accept* button. It is possible to change the colors and the number of decimal places in the results. This is done by using the **Options** menu in the window.

5.2 FET Calculation. The second example is the simulation of the DC parameters of a self-bias circuit using a JFET transistor. The parameter values are shown in Figure 3 together with the results.

For FET transistor calculations it is possible to simulate n-channel and p-channel devices. We select the type of transistor by choosing the proper entry in the **Type** menu shown at the window top.

6.   CONCLUSION

In this paper we presented a software package for the simulation of DC and AC transistor circuits. The program simplicity of use allows the students to make fast calculations without the need of CAD companion.   At this writing ECALC is capable of doing dc and ac *calculations* with BJT and FET transistors. Future versions of the program will include other, more sophisticated, features. For example, at this moment the author is working to include frequency response of one stage amplifiers. ECALC will be able not only to make numerical calculations but also it will produce the plots of gain vs. frequency and phase shift vs. frequency. Other devices[6] and circuits[7] will be added as well.

7.   AVAILABILITY

The program is freely available for educators. Any one interested in incorporating ECALC in electronics courses should send an e-mail message to the author.

REFERENCES

1. Robert Boylestad and Louis Nashelsky. *Electronics Devices and Circuit Theory*. Prentice Hall, Englewood Cliffs, NJ 07632, sixth edition, 1997.

2. Thomas L. Floyd. *Electronic Devices*. Prentice Hall, Englewood Cliffs, NJ 07632, Fourth edition, 1996.

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[6] Such as CMOS and Op-Amps.
[7] Multi-stage amplifiers, power supplies, oscillators, PLL, etc.