Fundamentals of Electric Theory and Circuits

by

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Software simulation of superposition of an ac signal on a dc voltage

A demonstration of the superposition of ac signals on a dc voltage is performed using simulation software. To download the software (freely distributed by Texas Instruments, USA) enter "TINA" in the search box of the homepage www.ti.com. Click the first result that is displayed from the list and follow the instructions to download and install.

Coupling signals to a transistor amplifier

When studying amplifier circuits, we use circuits that require the superposition of a small sinusoidal voltage on a steady dc voltage that biases transistors in the active region as in the common emitter amplifier shown below. 2V DC from ground offsets the signal at the base of the transistor as shown in the Fig. 1.

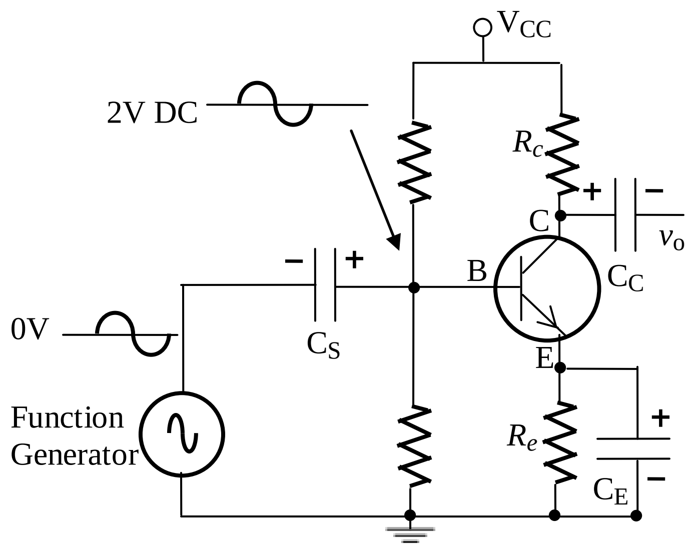


Fig. 1 Common Emitter amplifier

In Chapter 3 of "Fundamentals of Electric Theory and Circuits", a description of the circuit processes that cause a sinusoidal signal applied to a CR circuit with the capacitor initially charged to a DC voltage to superimpose on the DC voltage during the transient period when the capacitor discharges slowly was provided. The signal will eventually swing both positive and negative with respect to ground at the end of the transient period. The first simulation described in the procedure below shows this.

The second simulation shows how the current pulsates (without change in direction) when the sinusoidal signal is applied to the initially charged capacitor. The average current will gradually decay away during the transient and in the steady-state, the current can be observed to swing both positive and negative.

The third simulation shows a sinusoidal signal applied to a capacitor circuit with a potential divider powered by an external DC voltage source. This causes the signal to superimpose on a DC voltage determined by the potential divider and the capacitor which is kept charged by the divider. The signal therefore swings above and below a steady DC value that can say, be used to bias a transistor of a common-emitter amplifier into its active region.

Simulation 1

1. Open the Tina Schematics Editor page. Click the "Basic" tab and pick and place a resistor, capacitor and a voltage generator in convenient locations following the schematic of Fig. 2. (To rid the cursor of the component after placing it on the editor page, click anywhere on the page else, right click and select "Cancel Mode"). Then, place the ground symbol from the Basic tab and a Voltage pin at the output from the Meters tab.

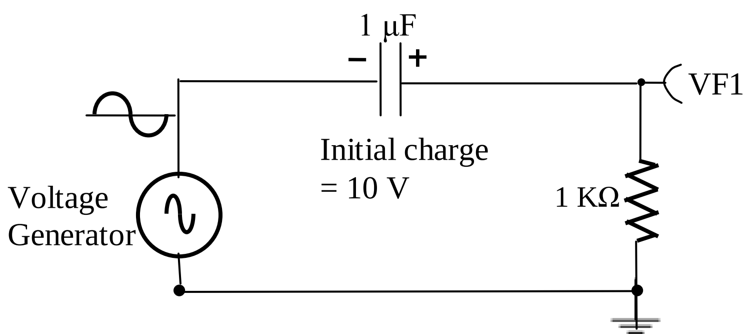


Fig. 2 CR circuit with a charged capacitor

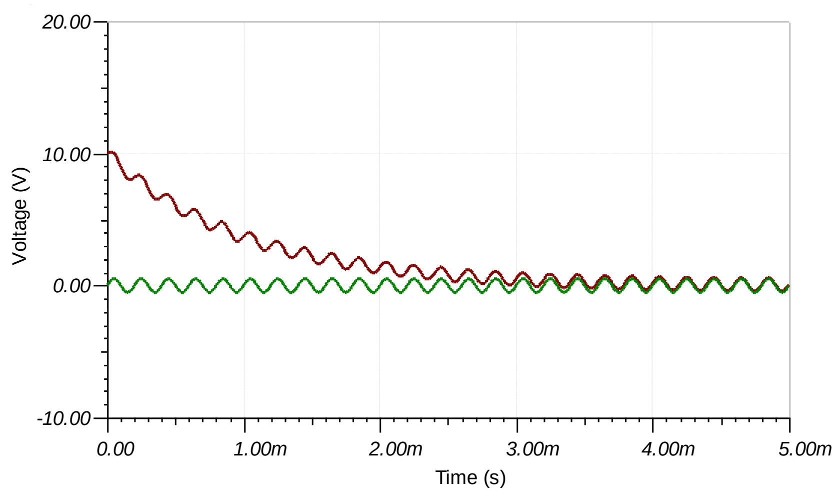
2. Double-click the resistor, capacitor and voltage generator in succession and set the value of each component in the component dialog box according to the values in the schematic of Fig. 2. **Note:** For megohms, use "M", for milliohms use "m", for microfarad use "u" and for nanofarad use "n". Connect the components using the Wire symbol in the menu bar, according to the schematic in Fig. 2.

3. Double-click the capacitor C1 and for the value "Initial DC voltage" enter "-10" to indicate to the software the capacitor is charged initially with 10V and of polarity as in the schematic in Fig.1. Next, double click the voltage generator and in the component dialog box, set the signal in the "Signal Editor" to "Sine wave", amplitude to 500 millivolts and frequency to 5 KHz.

Check the schematic

The Electric Rules Check (ERC) is performed by clicking "Analysis" in the menubar and then clicking "ERC". This will show up errors and warning messages if the schematic is not proper. The schematic should be corrected based on the summary displayed by the ERC.

4. Click “Analysis” in the menu bar and select “Transient”. In the dialog box set the “start” time to 0 sec and the “end” time to 5m (i.e 5 milliseconds). Set the “Use initial conditions” radio button and check the “Draw excitation” box. Then click OK. Note how the ac signal of amplitude 500mv is superimposed on the slowly discharging capacitor from its initial value of 10 volts and then the signal swings alternately positive and negative after around 3.5 milliseconds.



Simulation 2

5. Open the Tina Schematics Editor page. Click the “Basic” tab and pick and place a resistor, capacitor and a voltage generator in convenient locations following the schematic of Fig. 3. (To rid the cursor of the component after placing it on the editor page, click anywhere on the page else, right click and select “Cancel Mode”). Then, place the ground symbol from the Basic tab and an Ammeter in series with the capacitor and the resistor as shown in Fig. 3.

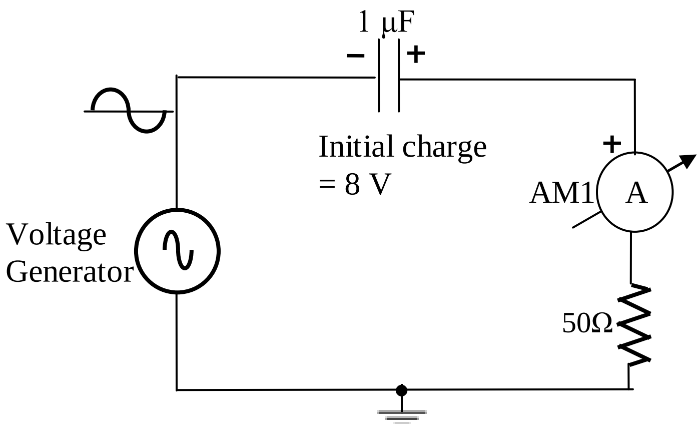


Fig. 3 CR circuit with initial charge on the capacitor and an ammeter

6. Double-click the resistor, capacitor and voltage generator in succession and set the value of each component in the component dialog box according to the values in the schematic of Fig. 3. **Note:** For megohms, use “M”, for milliohms use “m”, for microfarad use “u” and for nanofarad use “n”. Connect the components using the Wire symbol in the menu bar, according to the schematic in Fig. 3.

7. Double-click the capacitor C1 and for the value “Initial DC voltage” enter “-8” to indicate to the software the capacitor is charged initially with 8V and of polarity as in the schematic in Fig.3. Tick the checkbox to the right of the “Initial DC voltage” parameter. Next, double click the voltage generator and in the component dialog box, set the signal in the “Signal Editor” to “Sine wave”, amplitude to 500 millivolts and frequency to 70 KHz.

Check the schematic

The Electric Rules Check (ERC) is performed by clicking “Analysis” in the menubar and then clicking “ERC”. This will show up errors and warning messages if the schematic is not proper. The schematic should be corrected based on the summary displayed by the ERC.

8. Click “Analysis” in the menu bar and select “Transient”. In the dialog box set the “start” time to 0 sec and the “end” time to 400u (i.e 400 microseconds). Set the “Use initial conditions” radio button and **uncheck** the “Draw excitation” box. Then click OK. Note how the ac signal current pulsates in strength in the positive direction (without changing direction) during the transient. Its average value gradually decays and in the steady-state swings (after about 250 microseconds) both positive and negative.

Simulation 3

9. Open the Tina Schematics Editor page. Click the Basic tab and pick and place resistors, capacitor, a voltage generator and a battery in convenient locations following the schematic of Fig. 4.

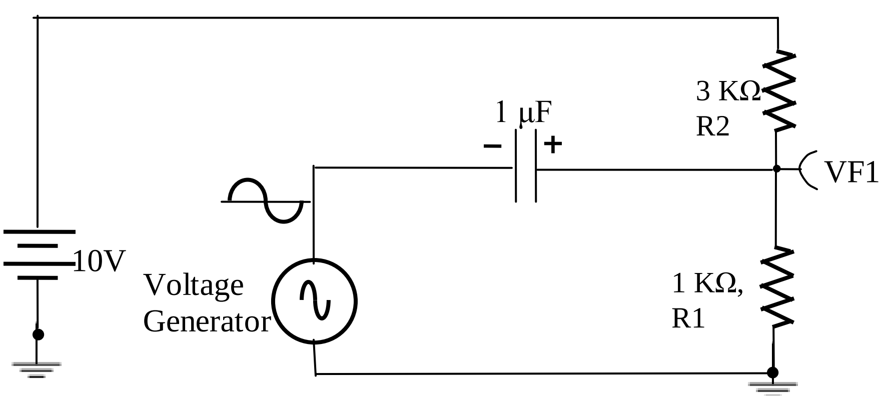


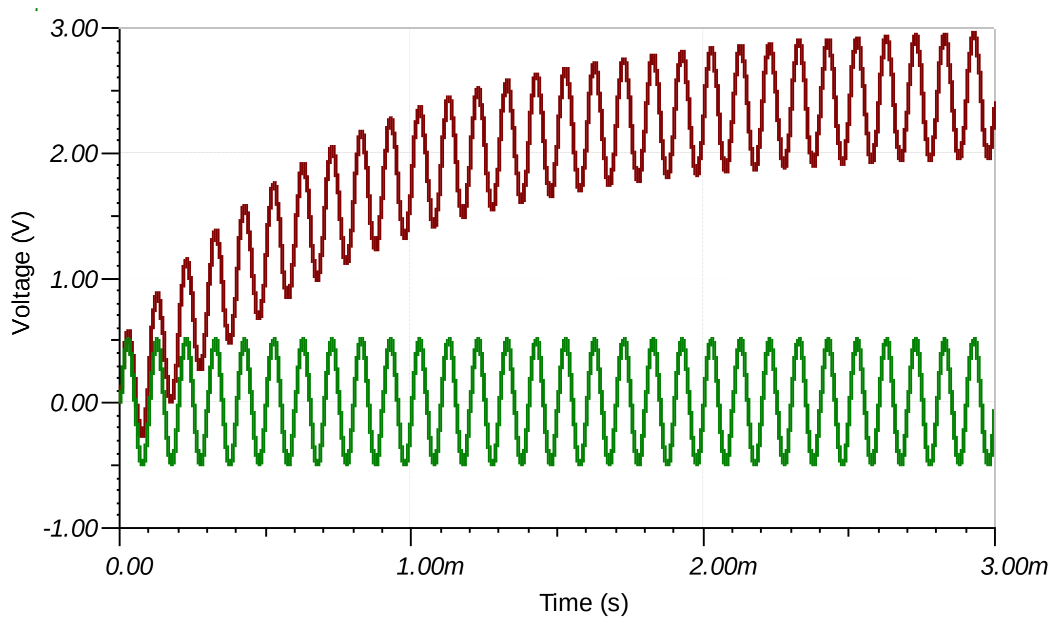
Fig. 4 Capacitor and resistive potential divider circuit

10. Following the steps described in steps 2 and 3 above and after checking the schematic, double-click the capacitor C1, resistors R1, R2 and set their values indicated in the schematic of Fig. 4. Next, double click the voltage generator and in the component dialog box, set the signal in the “Signal Editor” to “Sine wave”, amplitude to 500 millivolts and frequency to 10 KHz.

Next, double click the battery and in the component dialog box, set its voltage to 10V.

11. Click “Analysis” in the menu bar and select “Transient”. In the dialog box set the “start” time to 0 sec and the “end” time to 3m (i.e 3 milliseconds). Set the “Use initial conditions” radio button and check the “Draw excitation” box. Then click OK.

Note how the ac signal of amplitude 500mv is superimposed on the dc voltage of 2.5 volts, which is the voltage between the terminal connecting R1 to R2 and ground. Change the value of the capacitor to 0.1 μF and observe the time taken by the ac signal to superimpose on 2.5voltsDC.



Again, change the value of the capacitor to 10 μF and record the time taken by the ac signal to superimpose on 2.5 volts DC. **Note:** For this observation you will need to increase the “stop time” in the transient analysis dialog box.

When an amplifier in an audio system is turned ON, the duration within which one begins to listen to music will listen to a musical recording will surely exceed a fraction of second. By this time, surely, the capacitor in the bias circuit of a common emitter amplifier in the playback circuit will surely have charged completely thus biasing the transistor into its active region, as may be seen from the results above.