Power amplifiers - BJT

Power amplifiers (1)

Fundamental function of this amplifier is to provide the **power levels** required **to drive the load**. Consequently the active devices in the power amplifiers must be able to **dissipate** the **thermal energy** produced, to contain the rise in temperature.

The temperature must not exceed the maximum value $\mathbf{T_{JMax}}$ (**maximum junction temperature**) characteristic value of each semiconductor device (provided in datashet of each Trans.).

If the junction temperature exceeds this maximum value, usually between 150 ÷ 200 ° C, the device is destroyed. Therefore in general the fundamental requirements of such devices are:

High geometric **dimensions**.
Realization in **distinct element.**
Metal Case to help heat dissipation.
Collector (where it is dissipated more heat) mounted on the case.

Typical case called TO3 for power devices. The cylinder diameter is 2.2 cm. The lower plate is approximately 4 cm wide and has two holes to allow the connection to a heat sink.

Power amplifiers (2)

This amplifier is typically the last stage, or the **output stage** of an amplifier system. The previous stage can be designed to realize: the necessary **voltage amplification**, **buffer** or to change the characteristics of the signal.

To supply the **maximum power** at a generic load, **maximum current and voltage variation** must be ensured

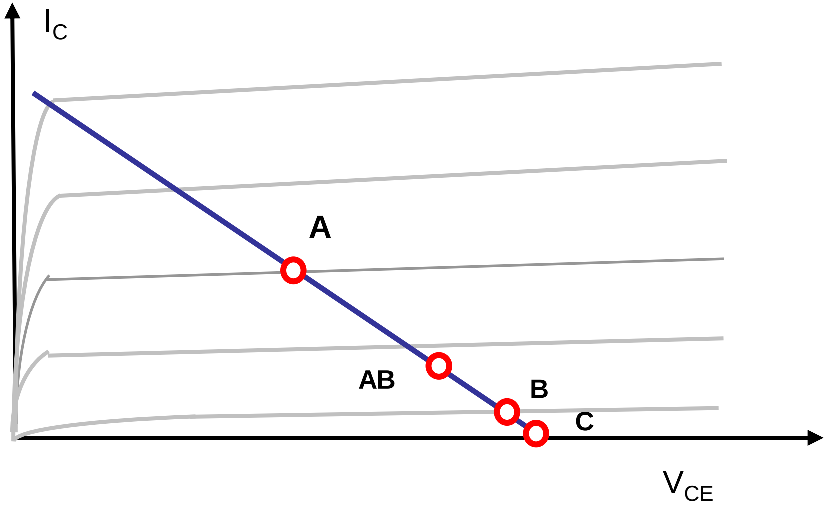
These conditions imply essentially that:

- the device must work over the **whole range** of its output characteristics,
- that the **working point** must be chosen appropriately.

The device works with great signals and fundamental consequences are:

Small-signal models and the linear analysis are not valid,
the distortion of the signal is not negligible.

The power amplifiers can be **classified** taking into account the **biasing** and consequently the **period part** in which the transistor is in conduction (in the presence of an input signal).



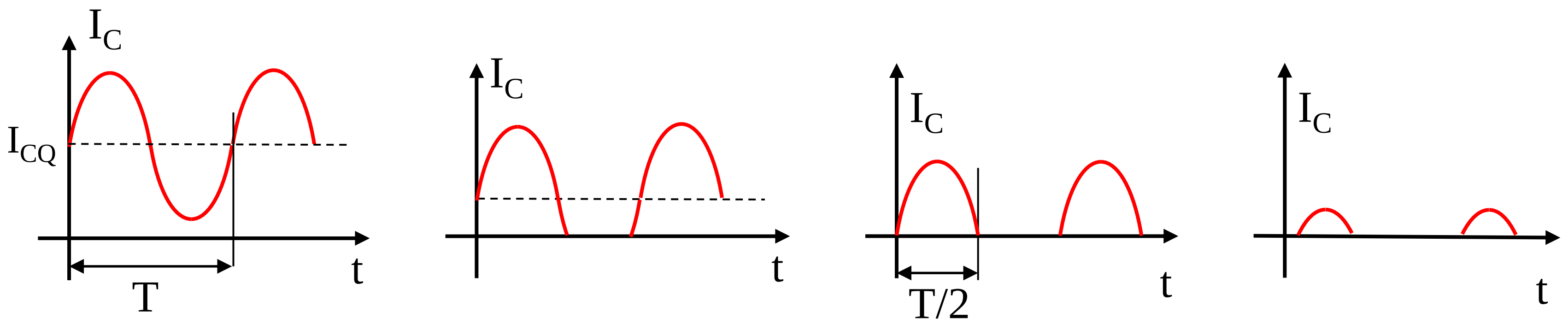
Power amplifiers (3)

Class A Amplifier: the working point is located at the **center** of characteristics, consequently applying a sinusoidal input signal, the device is in conduction over the entire period.

Class B Amplifier: the working point is placed in **interdiction**, so that the current and the power absorbed by the device in the absence of signal are zero. Given a sinusoidal input signal, the device is in conduction on half period.

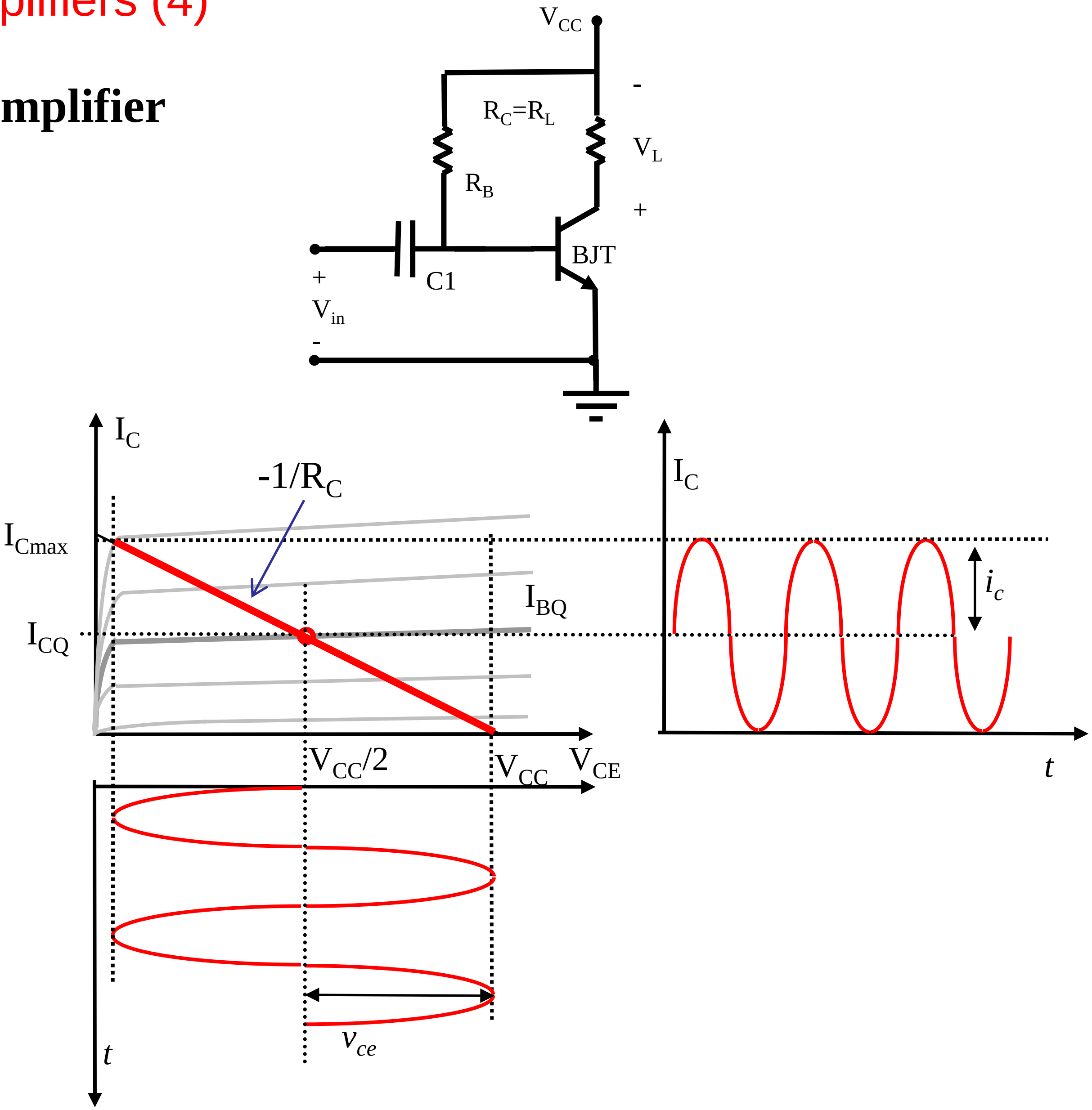
Class AB amplifier: it is midway between the Class A and the Class B.

Amplifier Class C: the working point is placed so that the device is in conduction only for less than half the period of the sinusoidal signal injected at the input.



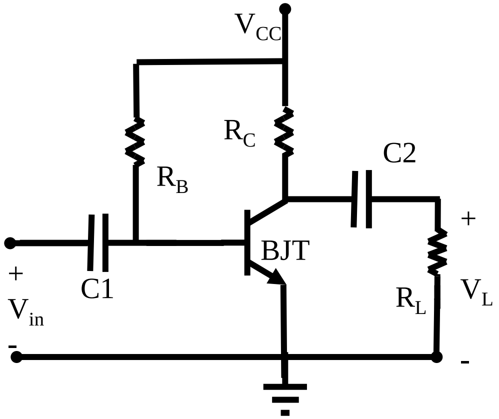
Power amplifiers (4)

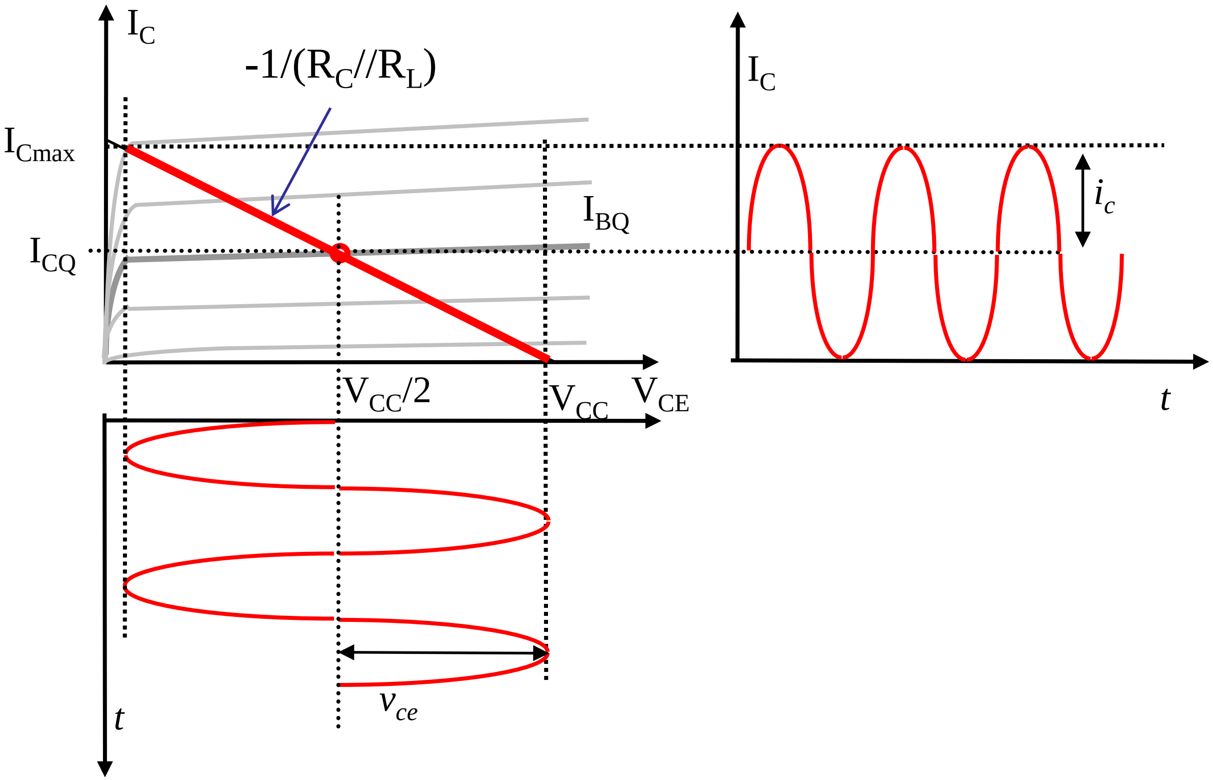
Class A Amplifier



Power amplifiers (5)

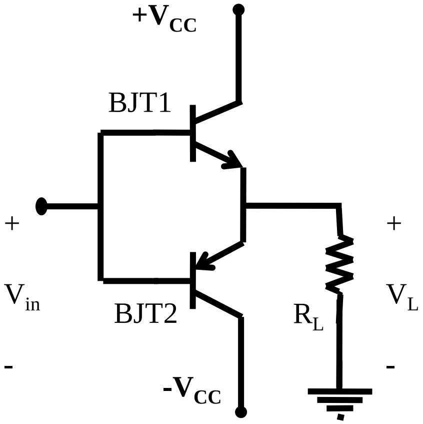
Class A Amplifier

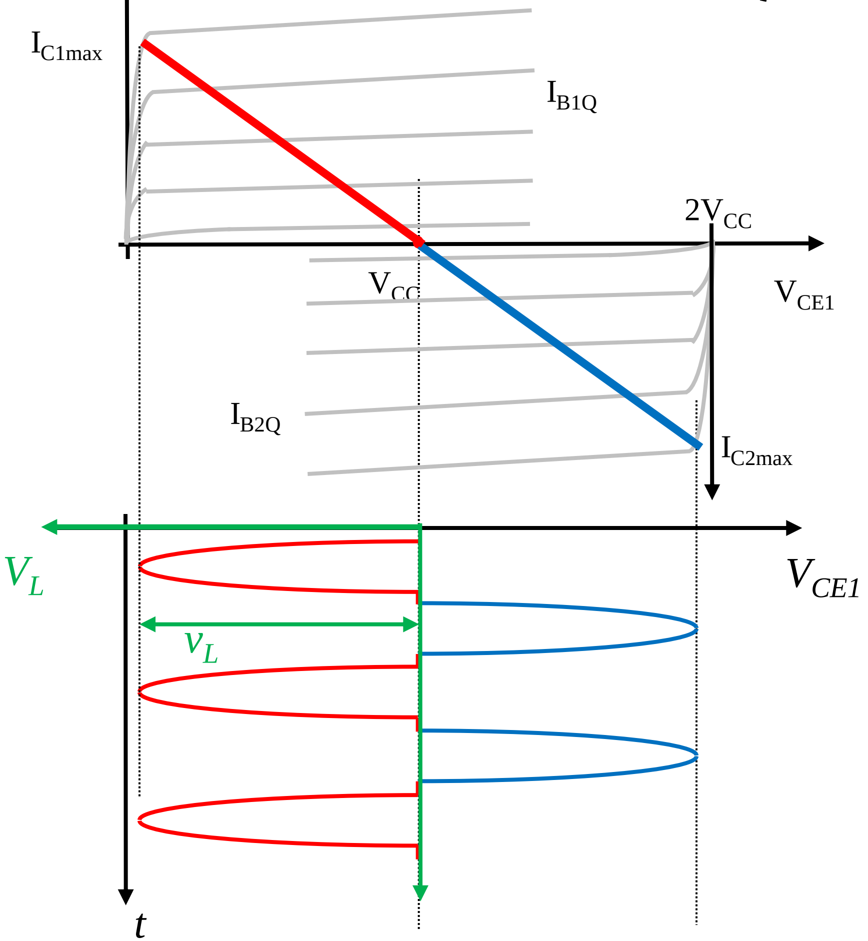


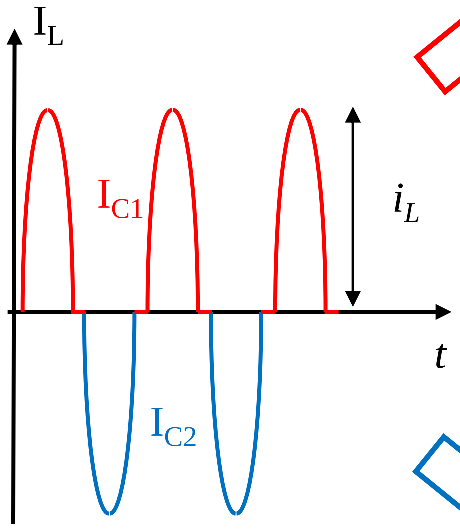


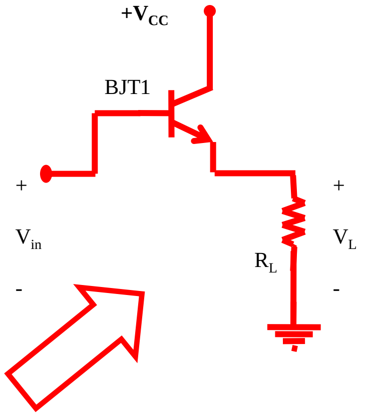
Power amplifiers (6)

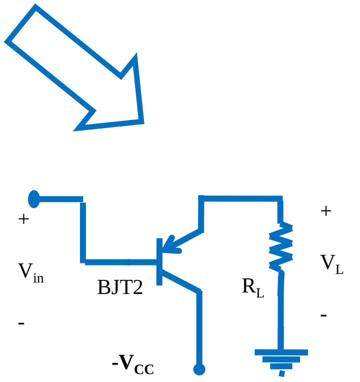
Class B Amplifier











Power amplifiers (6)

Some basic parameters of the power amplifier are:

$$G = \frac{P_L}{P_{in}}$$ = Power gain

$$\eta = \frac{P_L}{P_{dc}}$$ = Efficiency

Where:

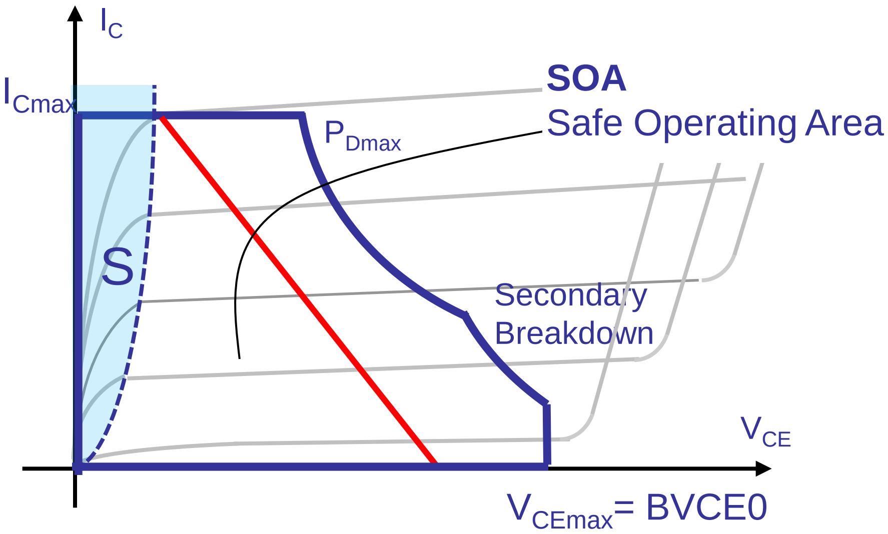
P_L is the load power,
P_{in} is the input power
P_{dc} is the supply power.

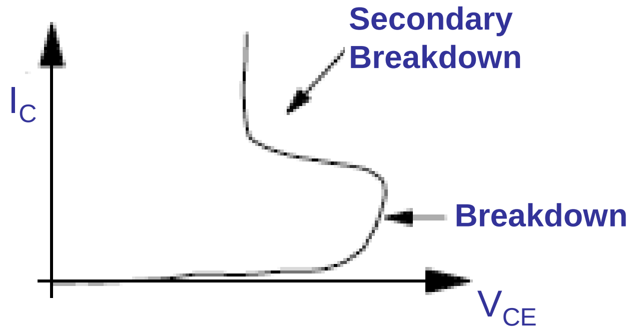
Class A where the load is crossed by the bias current → maximum η = 25%
Class A where the load is not crossed by the bias current → maximum η = 50%
Classe B → maximum η = 78%

Power amplifiers (7)

Safe Operating Area

Power devices there are **limits** in which the device can work. These are represented on the characteristics of the device by means of an area in which the load curve must be contained





Voltage limit→ V_{CEmax}, it is due to the **voltage breakdown** (BVCE0) of the junction BC.
Current limit→ I_{Cmax}, current which **melts the connections** between leads and semiconductor.
Dissipated power limit → P_{Dmax}
Secondary breakdown → Due to the **non-uniform flow** of the base-emitter junction current, which causes localized power dissipation and temperature increase at certain points “hot spots”.

Region S→ represents the **saturation region** which is normally avoided in linear applications since it is highly non-linear. However, digital circuits often make use of this part of the characteristic.

Power amplifiers (7)

Thermal resistance

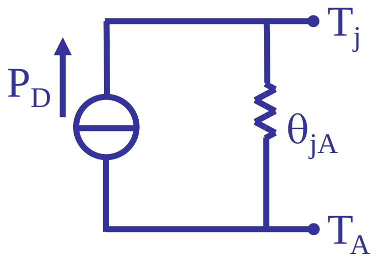
Assuming a situation in which the transistor works in the air. The heat dissipated by the junction is transmitted to the device case then to the surrounding environment. In conditions of **thermal equilibrium** in which the transistor dissipates power (P_D), the **junction temperature** responds to the following relation:

$$T_j - T_A = \theta_{jA} P_D$$

θ_{jA} is called **thermal resistance** between junction and ambient and has unit of measurement °C/W. Using the equation above shows that:

- **junction temperature** increases with the dissipated power. Taking into account that in order not to destroy the transistor the T_j must not exceed T_{JMax} it is essential to work with low values of thermal resistance.
- The **maximum dissipated power** decreases with the increasing of T_A .

The above relation can be expressed by an equivalent electric circuit:



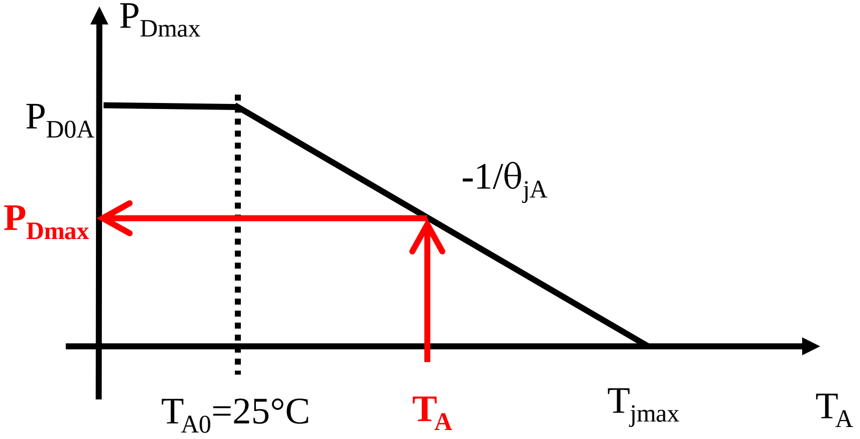
Power amplifiers (8)

Maximum dissipated power

In general manufacturers, to describe the device ability to dissipate power, provide three types of data:

- The **maximum dissipated power** P_{D0} which is guaranteed for temperatures below T_0.
- The **maximum junction temperature** T_{JMax}.
- The **thermal resistance**, whose inverse is the **decrement factor** of the power dissipated for temperatures higher than T_0

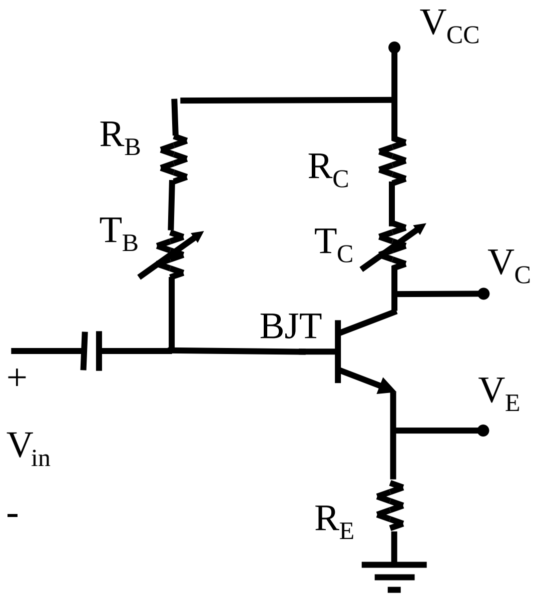
Examining the situation of an isolated transistor account must be taken of thermal resistance between junction and ambient (θ_{JA}) and the temperature to which it is guaranteed the power dissipated PD0A (usually 25 ° C). Therefore, the reduction of the maximum power dissipated is described by the curve shown in the figure and its value, for TA> 25 ° C, can be obtained from the equations below:

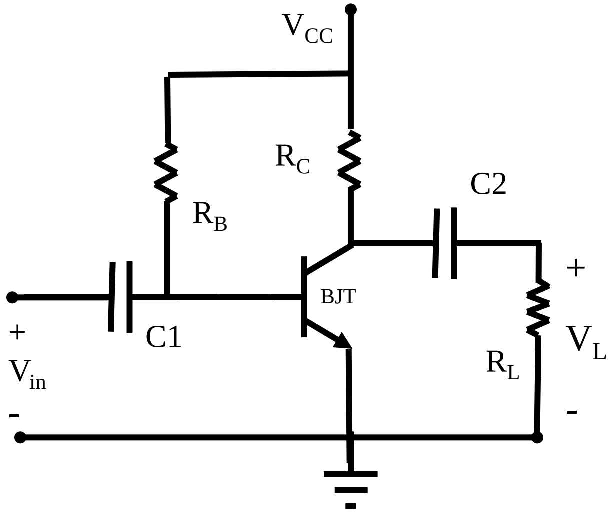


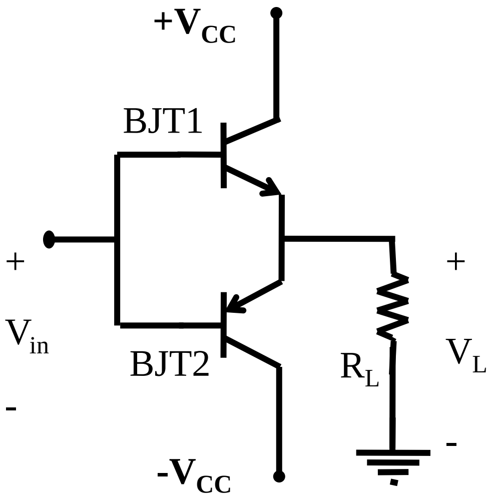
$$P_{Dmax} = \frac{T_{jmax} - T_A}{\theta_{jA}}$$

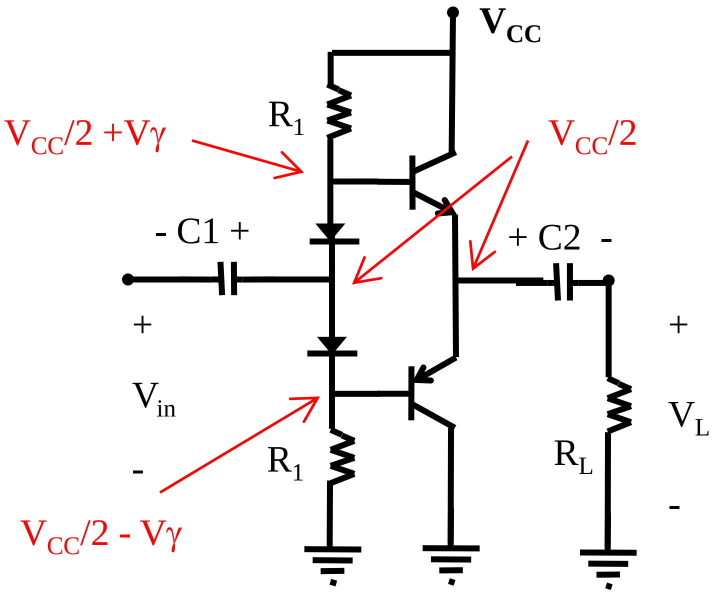
$$\theta_{jA} = \frac{T_{jmax} - T_{A0}}{P_{D0}}$$

Power amplifiers (11)

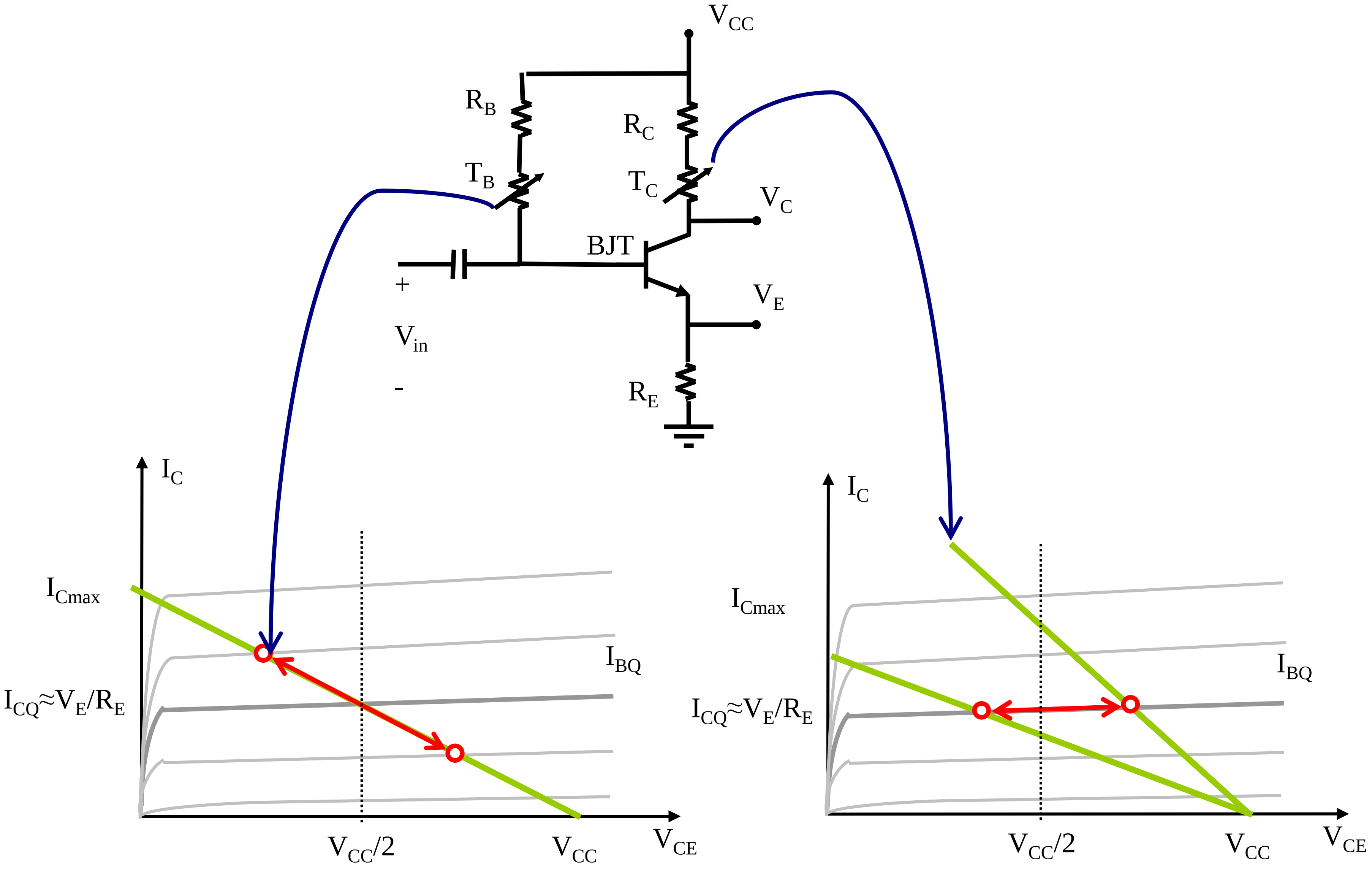






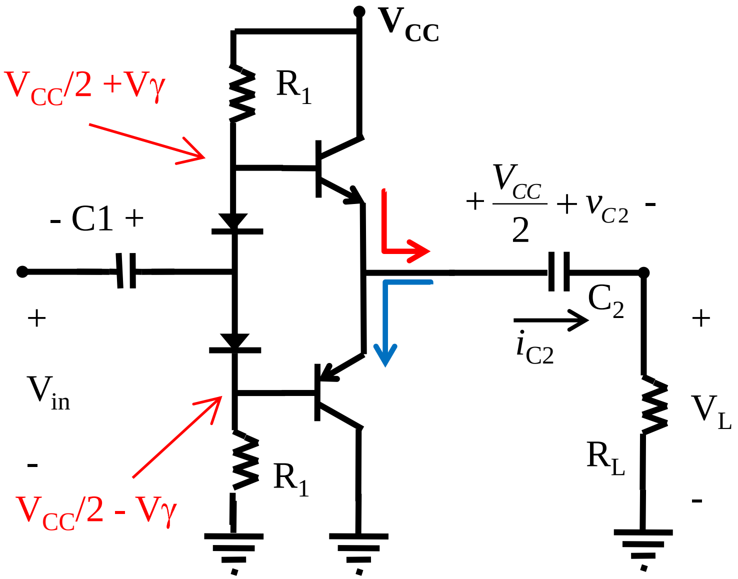


Power amplifiers (12)



Power amplifiers (13)

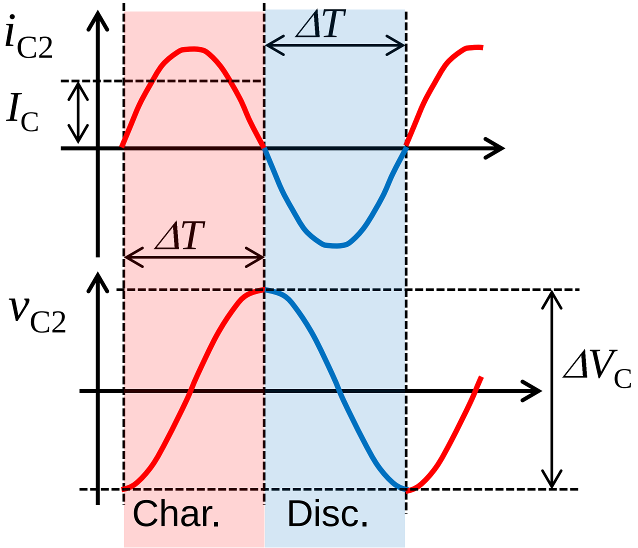
R_1 fixed to obtain a current I_{R1} equal to 1/10 of the average current on the BJTs.
R_L fixed to maximize the output power.
C_2 chosen to obtain a voltage variation on C_2 equal to $V_{CC}/100$



$$2R_1 = \frac{V_{CC} - 2V_\gamma}{\frac{I_{C,Max}}{10\pi}}$$

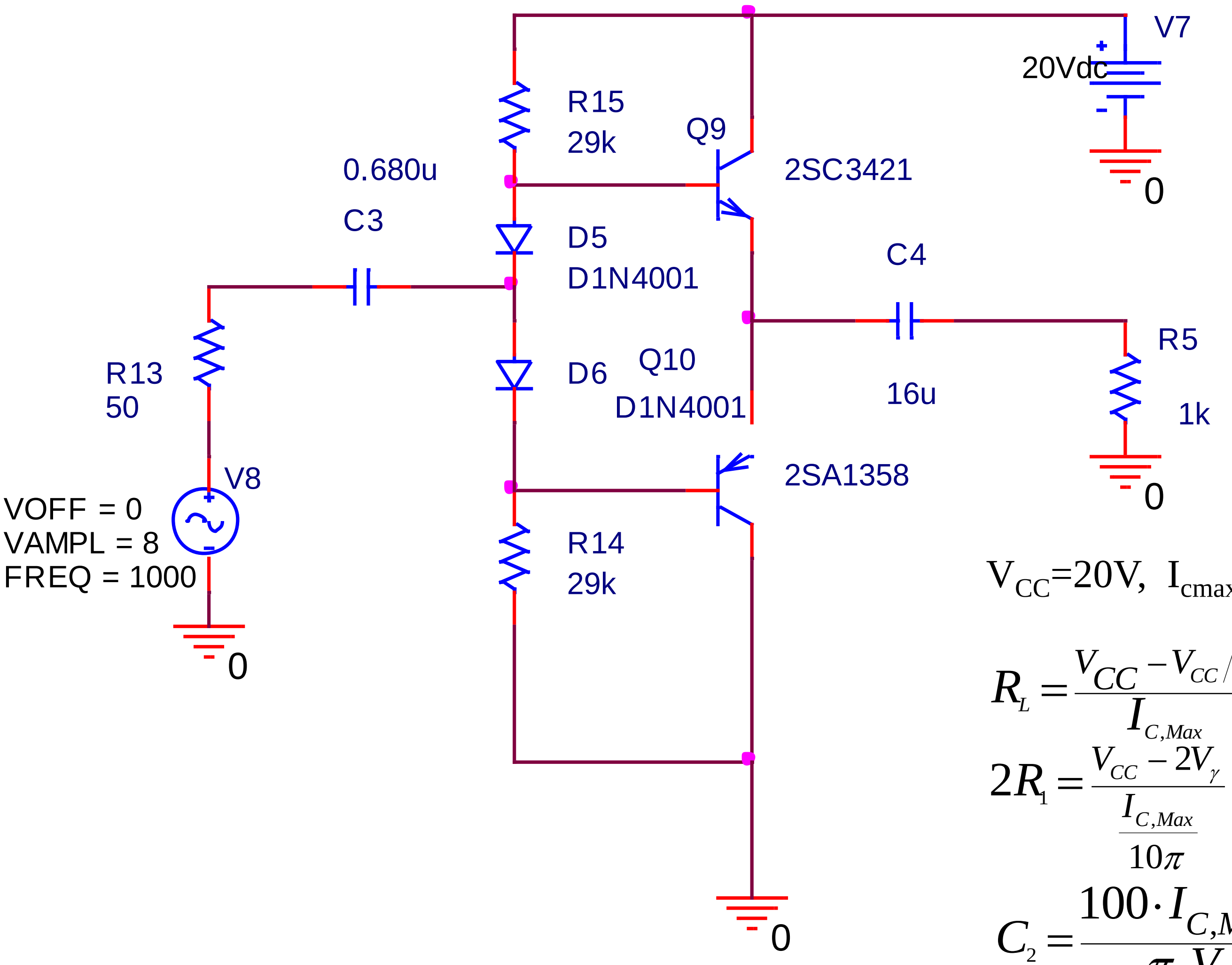
$$R_L = \frac{V_{CC} - V_{CC}/2}{I_{C,Max}}$$

$$C_2 = \frac{100 \cdot I_{C,Max} \cdot T}{\pi \cdot V_{CC}}$$



$$I_C = \frac{\Delta Q}{\Delta T} = C_2 \frac{\Delta V_C}{\Delta T}$$

$$I_C = 2\frac{I_{C,Max}}{\pi}; \qquad \Delta V_C = \frac{V_{CC}}{100}; \qquad \Delta T = \frac{T}{2} = \frac{1}{2\,f_{\min}}$$



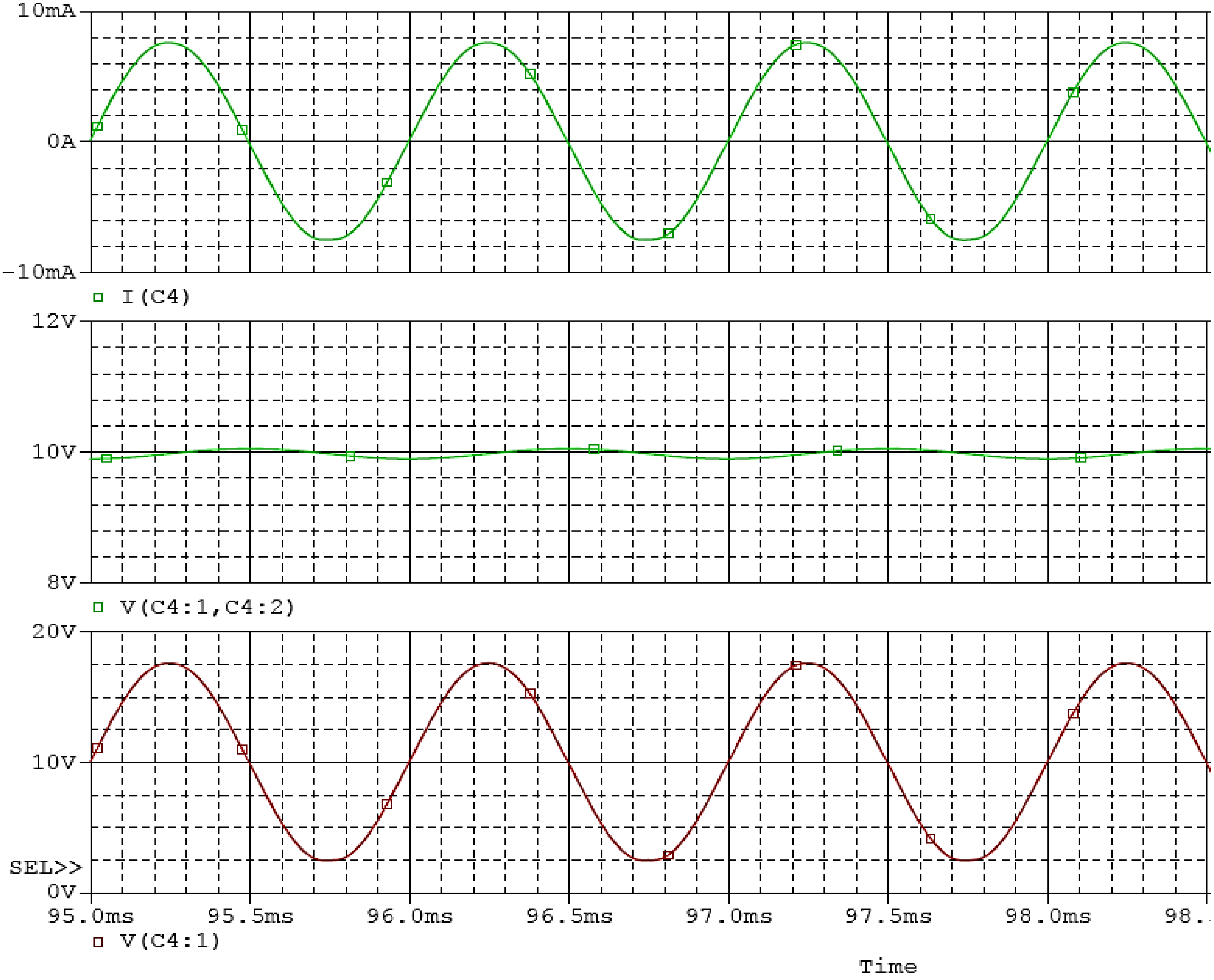
V_{CC}=20V, I_{cmax}=10mA

$$R_L = \frac{V_{CC} - V_{CC}/2}{I_{C,Max}} = 1K\Omega$$

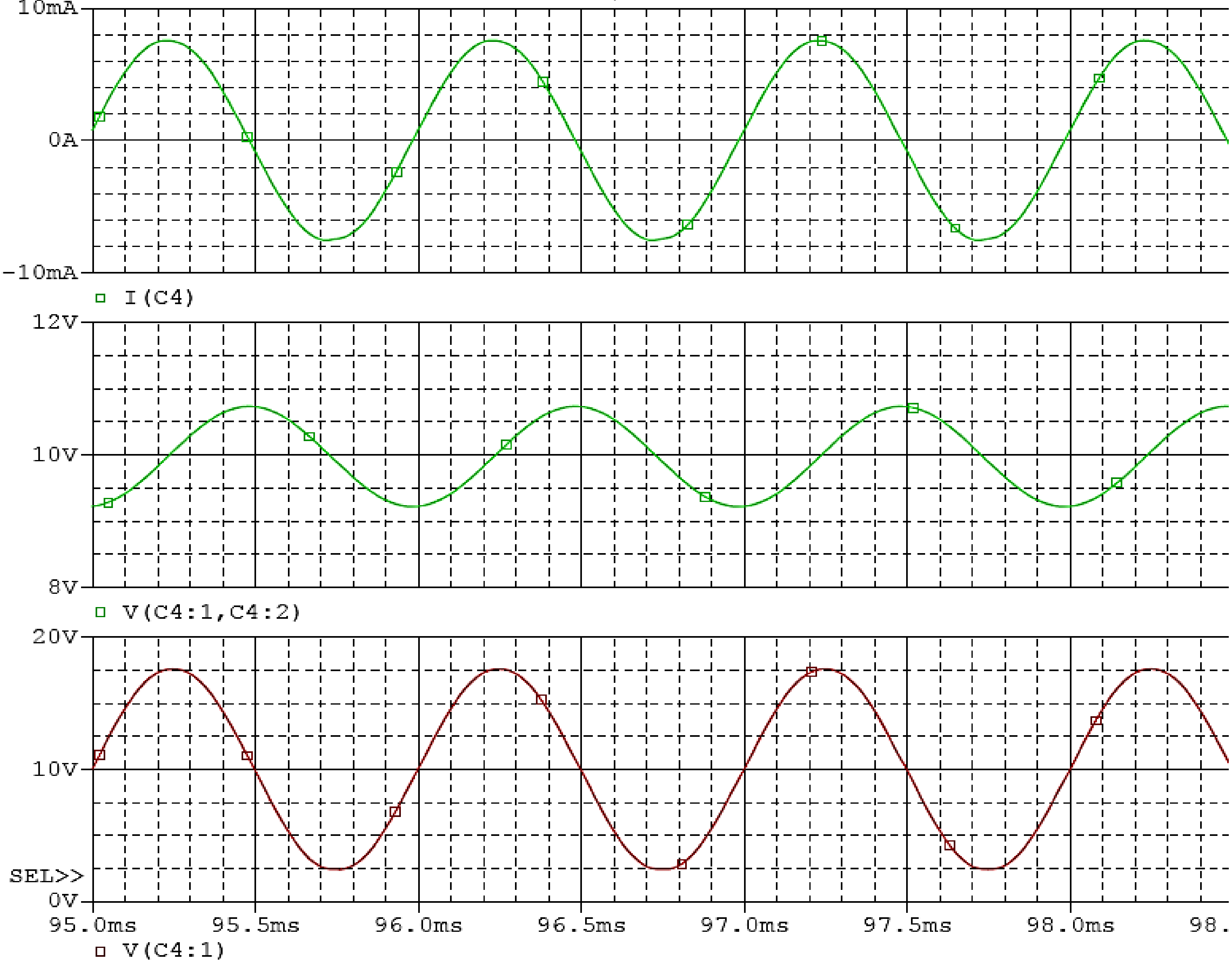
$$2R_1 = \frac{V_{CC} - 2V_\gamma}{\frac{I_{C,Max}}{10\pi}} \approx 58.7K\Omega$$

$$C_2 = \frac{100 \cdot I_{C,Max} \cdot T}{\pi \cdot V_{CC}} \approx 16\mu F$$

C_4=16mF


10mA
0A
-10mA
I(C4)
12V
10V
8V
V(C4:1,C4:2)
20V
10V
SEL>>
0V
95.0ms
95.5ms
96.0ms
96.5ms
97.0ms
97.5ms
98.0ms
98.
V(C4:1)
Time

C_4=1.6mF


10mA
0A
-10mA
□ I(C4)
12V
10V
8V
□ V(C4:1,C4:2)
20V
10V
SEL>>
0V
95.0ms
95.5ms
96.0ms
96.5ms
97.0ms
97.5ms
98.0ms
98.
□ V(C4:1)