1A

FETs AND BJTs ARE CCDs

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The RESISTOR is a reduced version of an active device.

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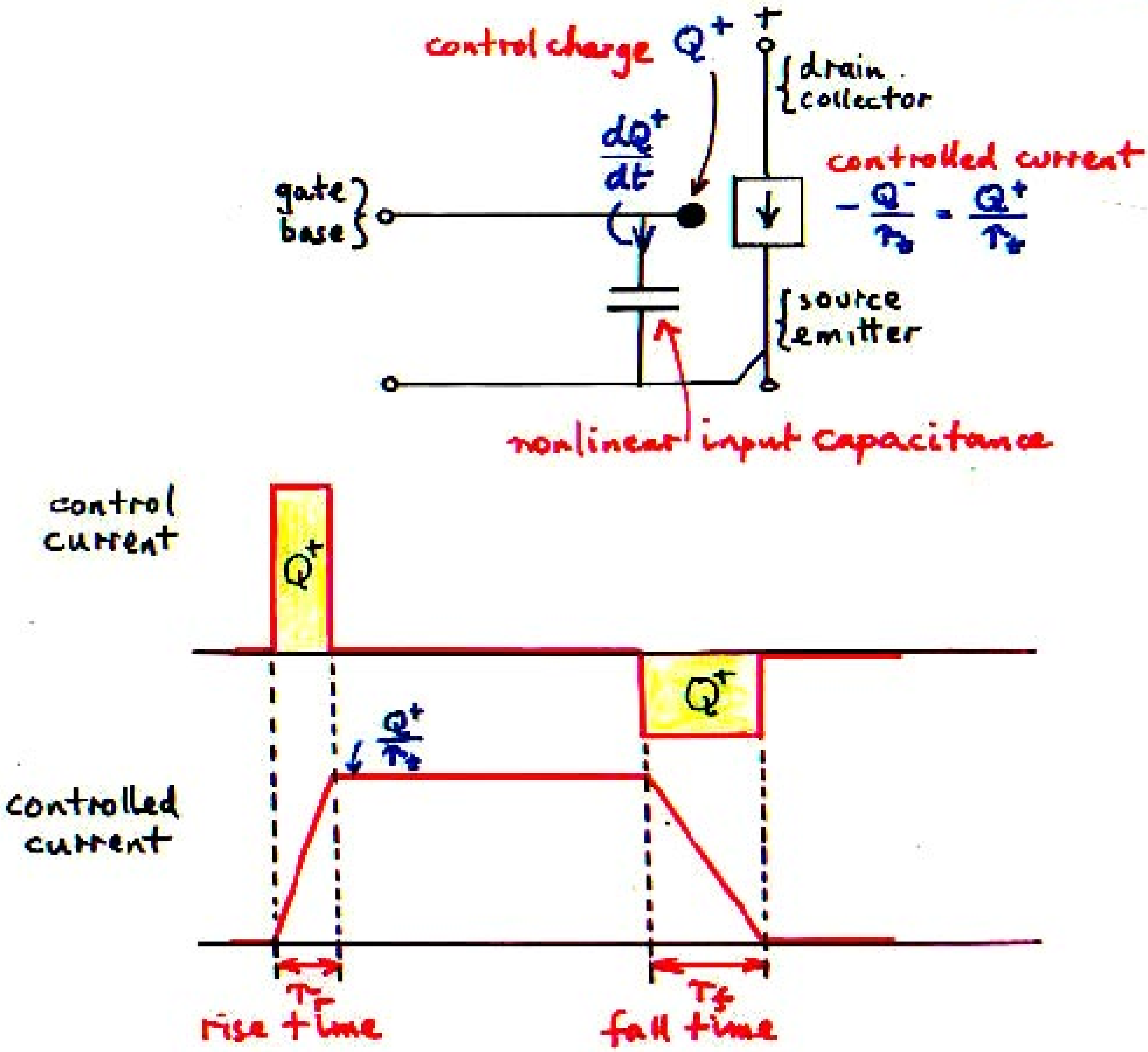
An Active Device is created when the control and collection functions are performed by two separate electrodes, as in

The FET, the Field Effect Transistor

MOSFET and BJT (and JFET and TUBE) are CHARGE-CONTROLLED DEVICES



The FET is a Charge-Controlled Device in that the drain, or output, current is controlled by the gate, or input, charge.

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The BJT, the Bipolar Junction Transistor, is also a Charge-Controlled Device, and its basic operation is exactly the same.

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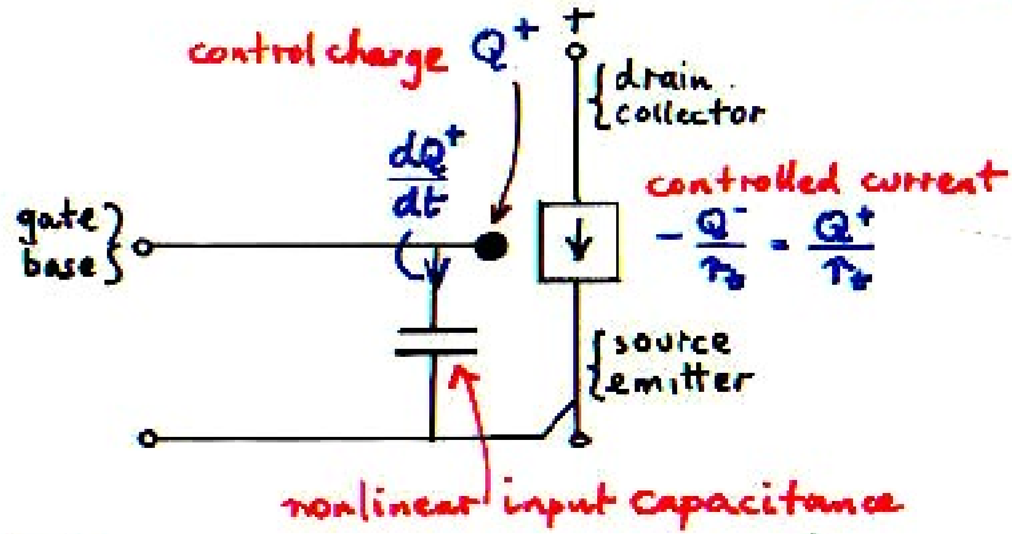
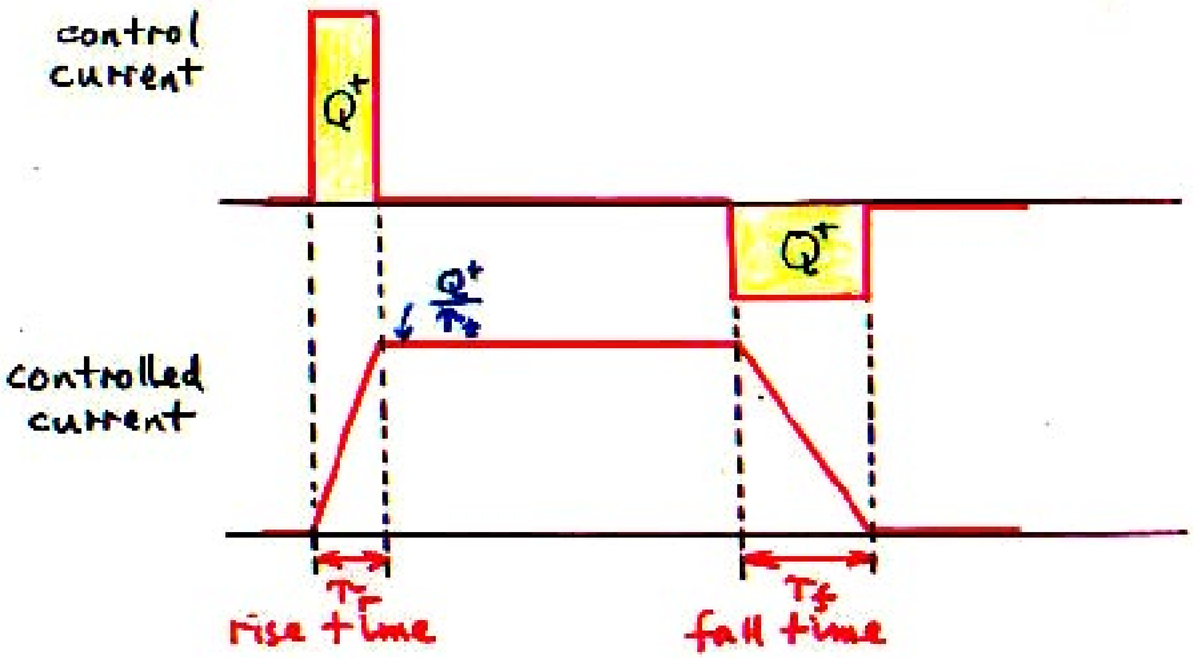
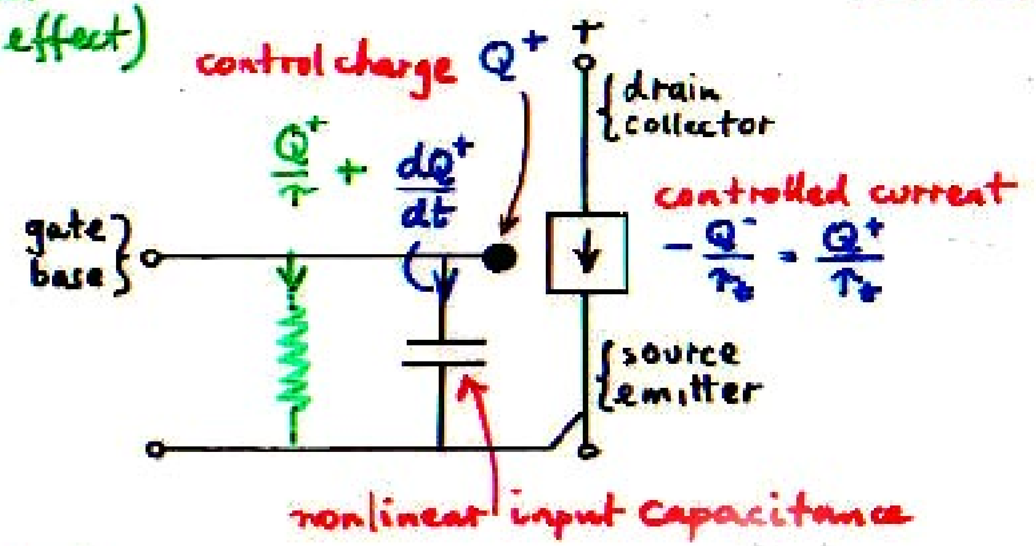
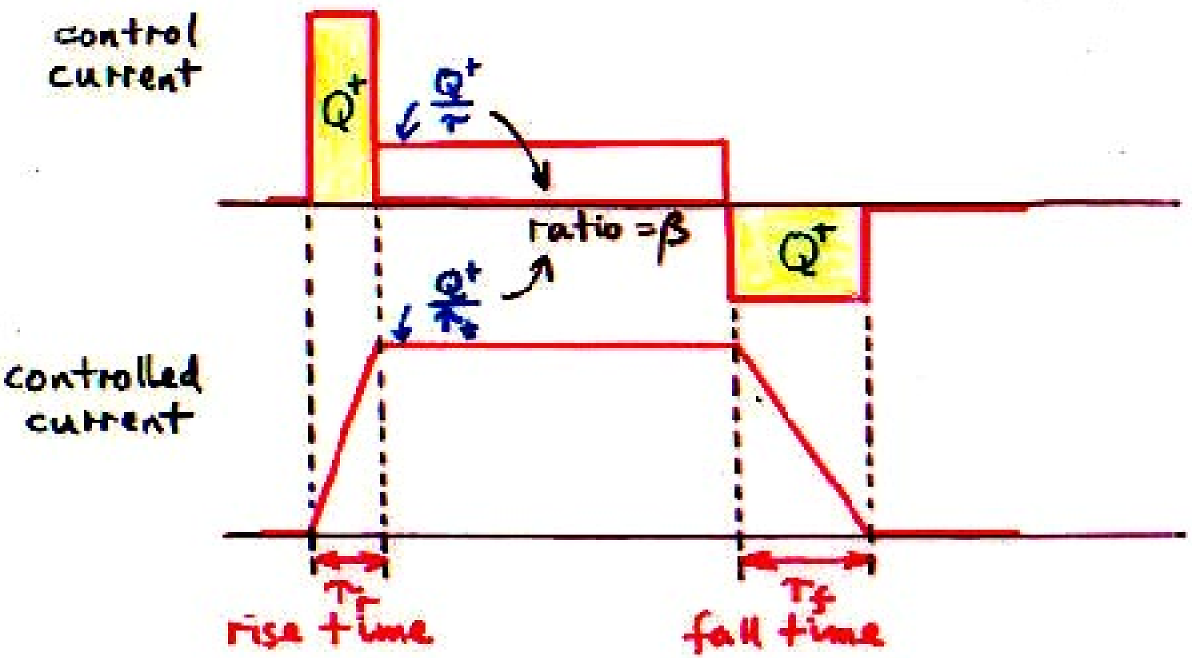




MOSFET and BJT (and JFET and TUBE) are **CHARGE-CONTROLLED DEVICES**

BJT requires a "maintenance" control current (second-order effect)





Principle of Charge-Controlled Devices:

The *rate of charge collection* at the output port (the output current) is controlled by the *amount* of charge placed on the input port.

These animations illustrate only the basic principle of Active Devices: they are all charge-controlled.

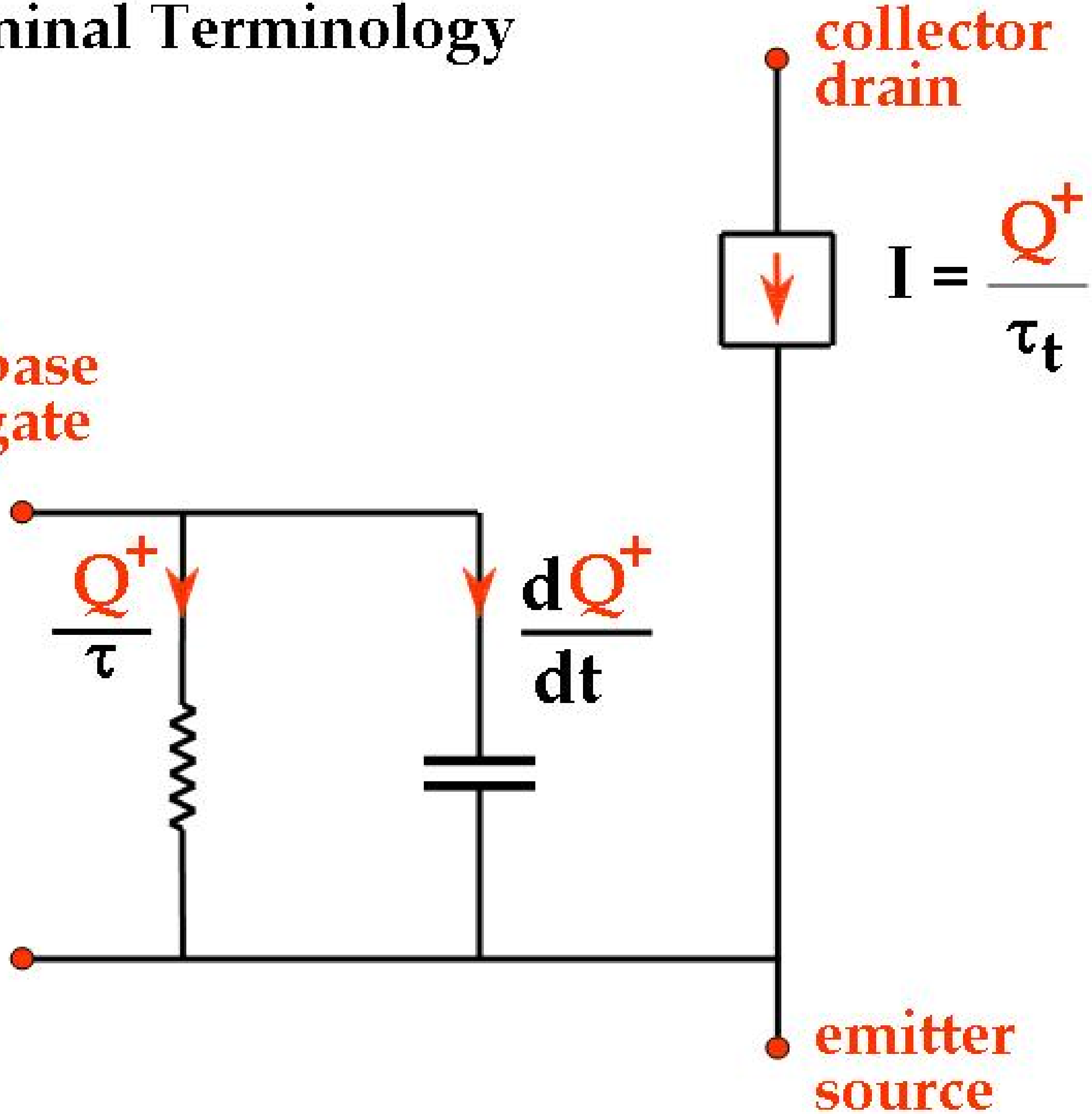
The voltage or current needed at the input to provide a given amount of controlled charge is, from a device point of view, a secondary consideration.

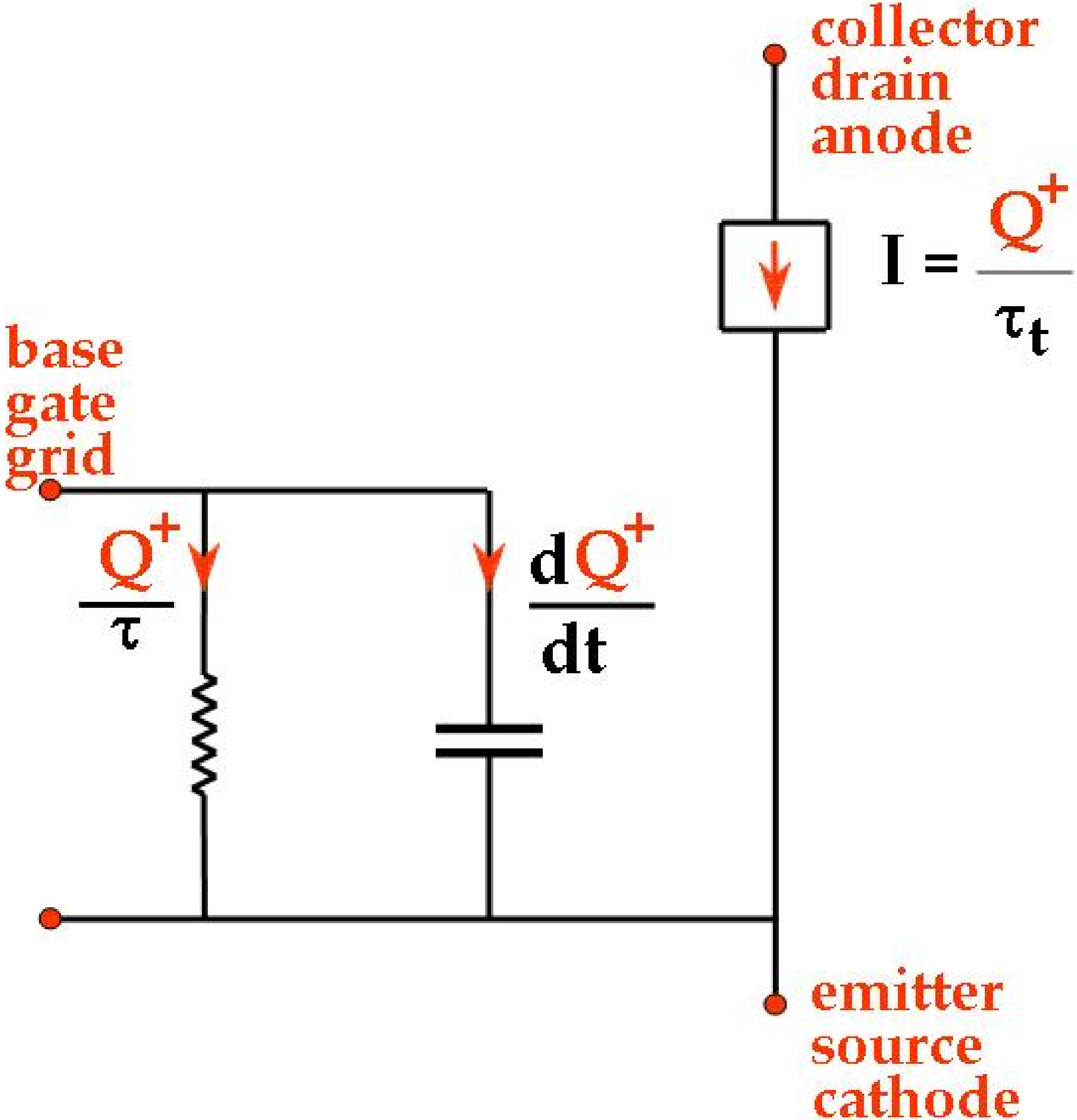
The presence of an input capacitance is inherent in the device.

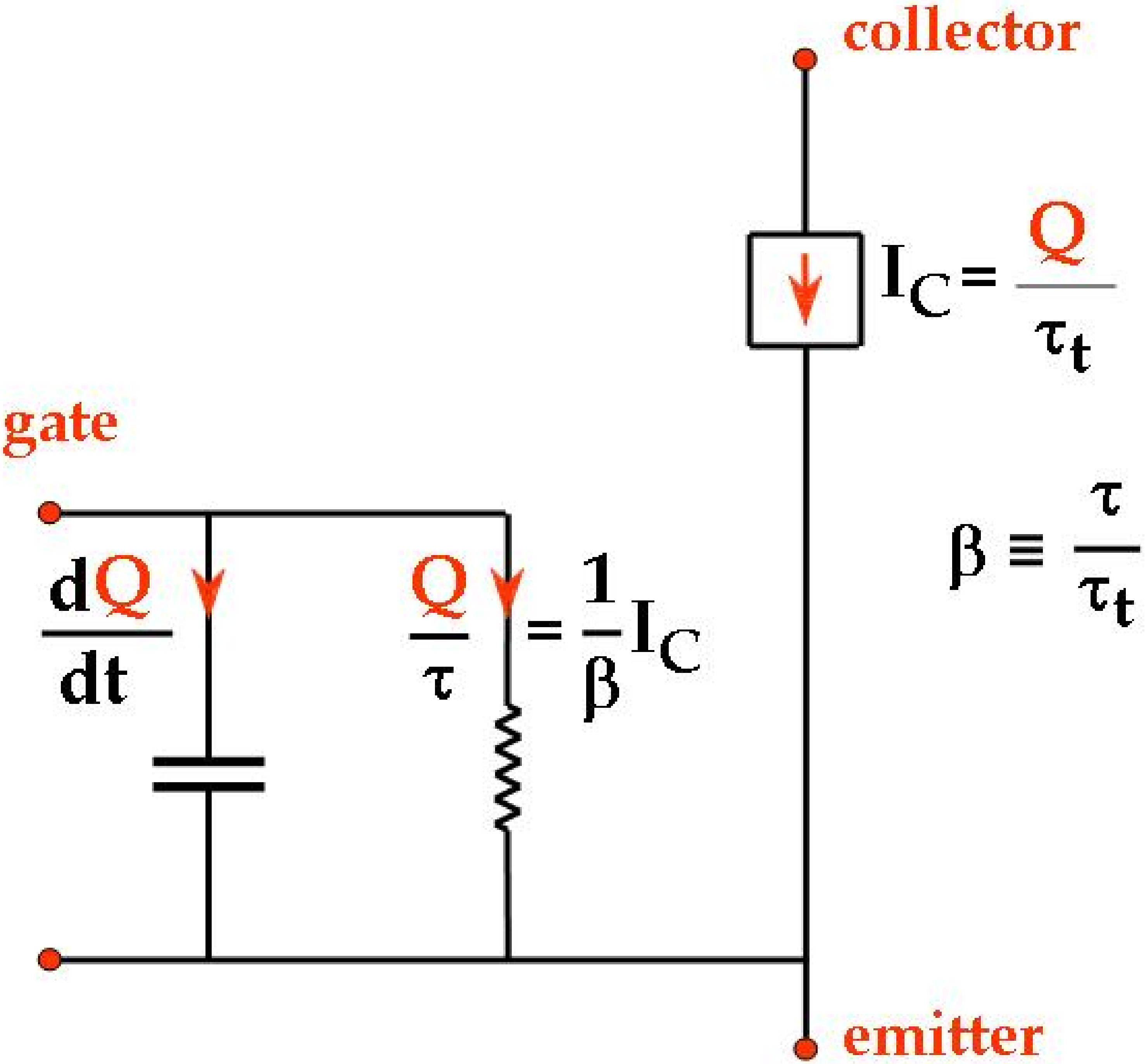
To make the device operate fast, the controlling charge must be supplied or withdrawn fast, requiring a large transient drive current. This is the same for the FET and for the BJT.

In the BJT, the controlling charge must be maintained, in the presence of recombination, by a relatively small dc current.

Terminal Terminology

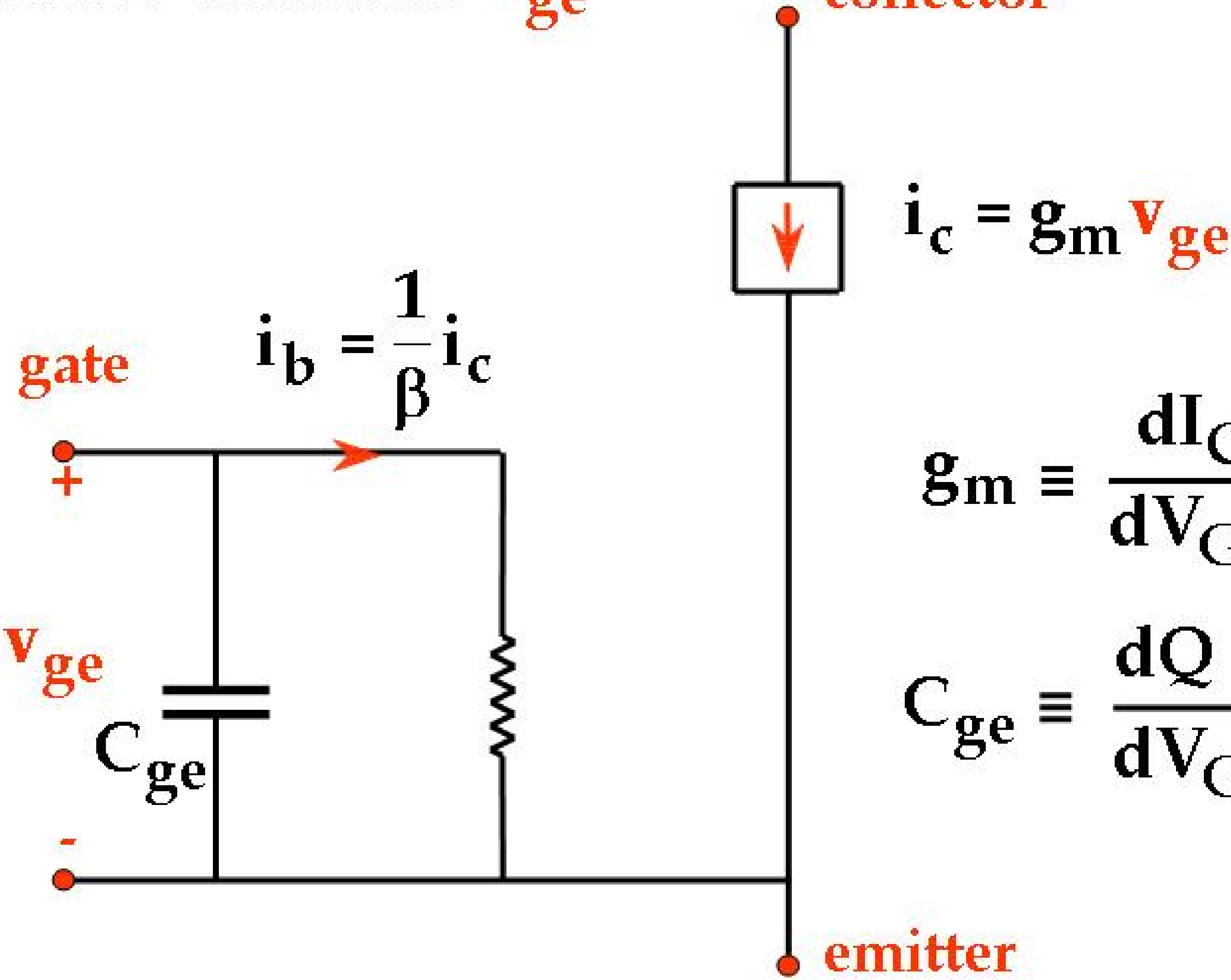



collector
drain
anode
$I = \frac{Q^+}{\tau_t}$
base
gate
grid
$\frac{Q^+}{\tau}$
$\frac{dQ^+}{dt}$
emitter
source
cathode



collector
$I_C = \frac{Q}{\tau_t}$
gate
$\beta \equiv \frac{\tau}{\tau_t}$
$\frac{dQ}{dt}$
$\frac{Q}{\tau} = \frac{1}{\beta} I_C$
emitter

Model 1: excitation v_{ge}

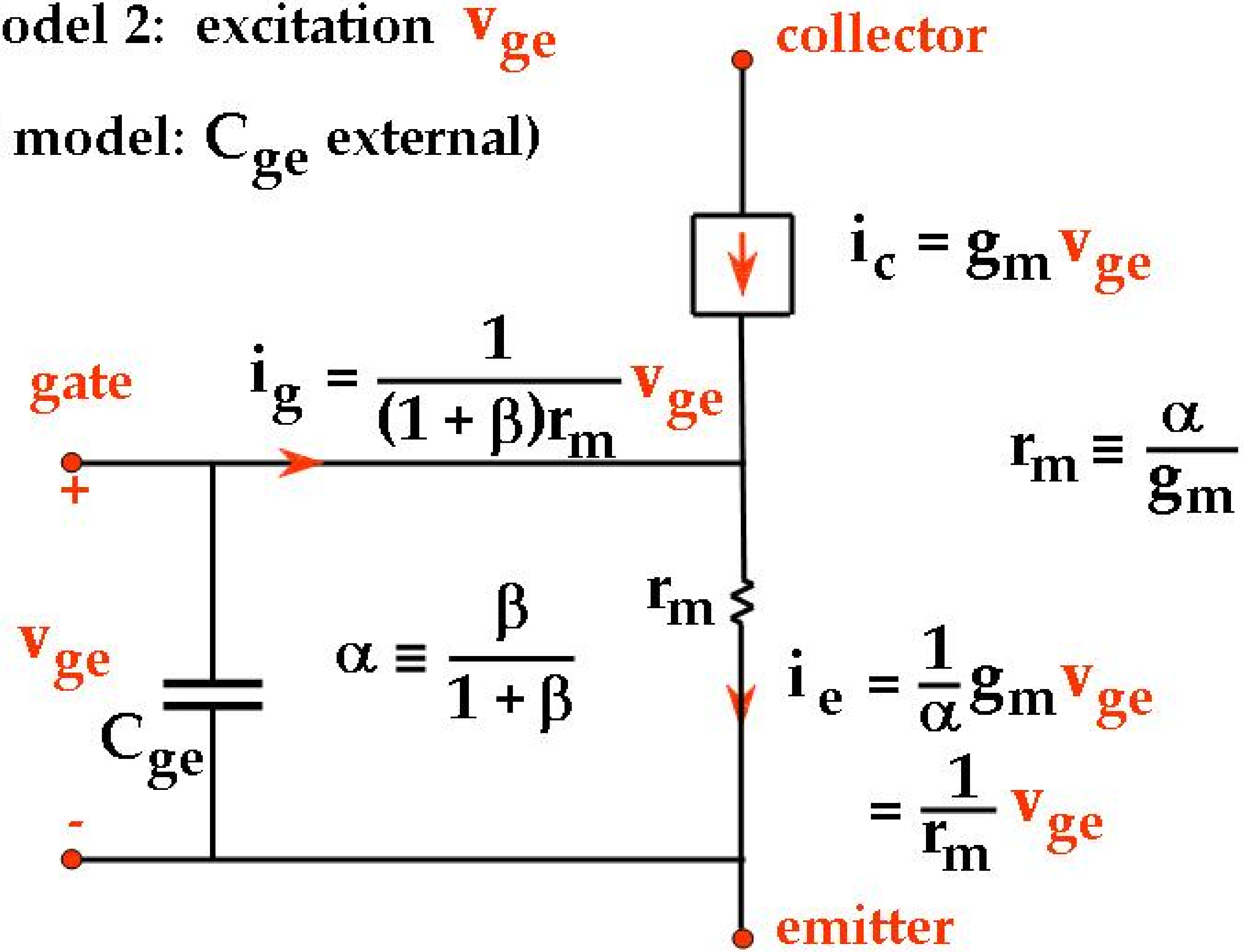


$$g_m \equiv \frac{dI_C}{dV_{GE}}$$

$$C_{ge} \equiv \frac{dQ}{dV_{GE}}$$

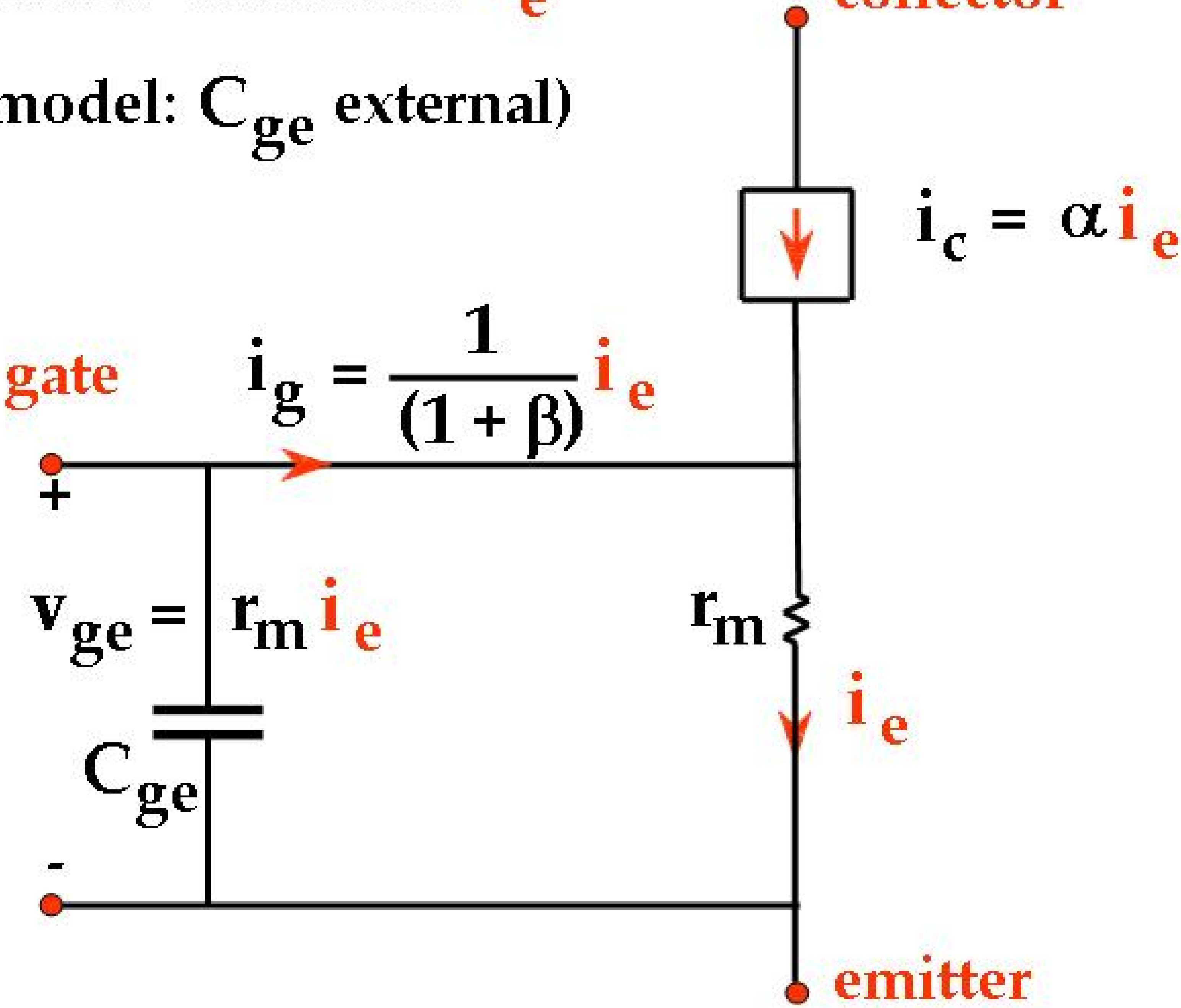
Model 2: excitation v_{ge}

(T model: C_{ge} external)



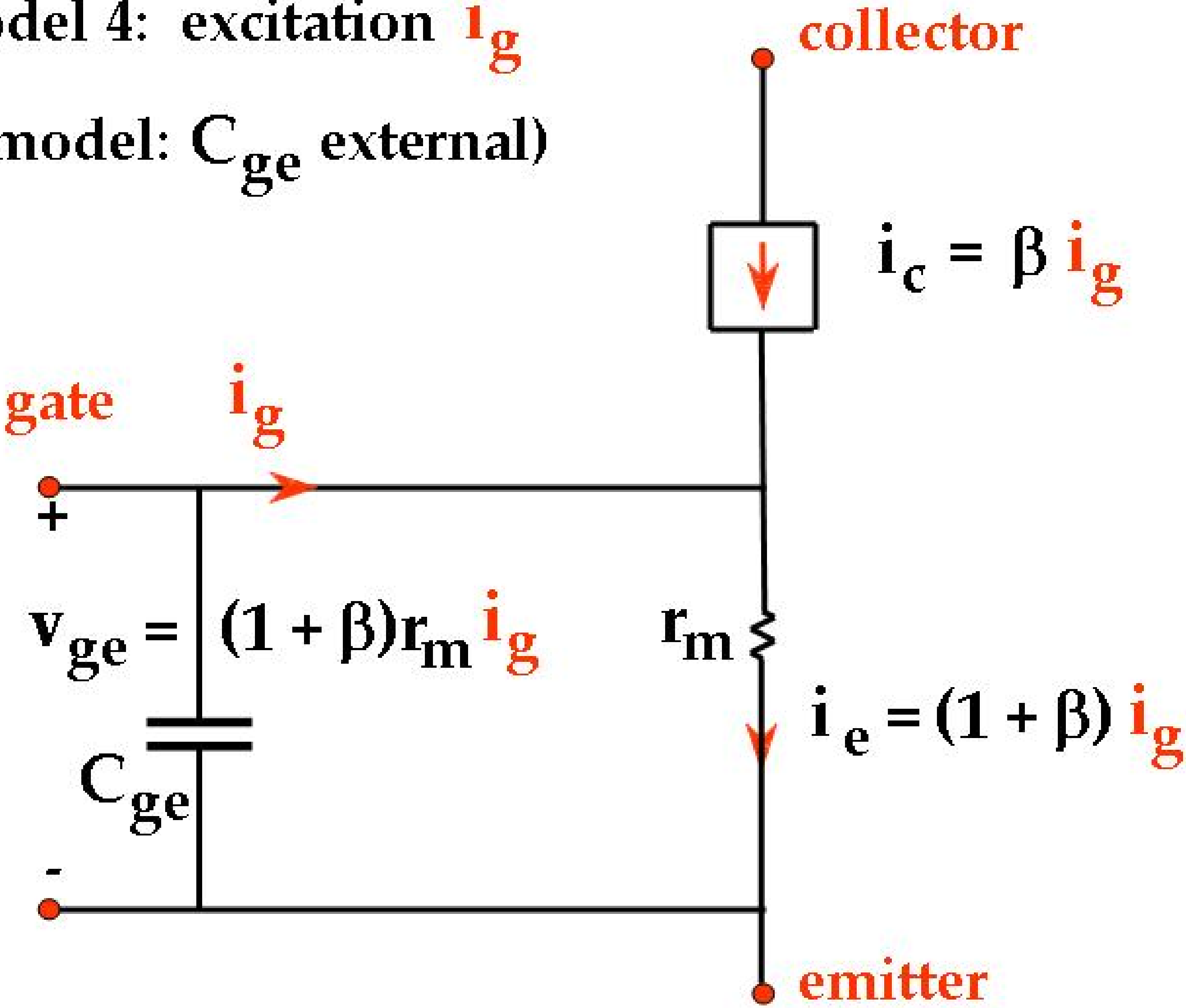
Model 3: excitation i_e

(T model: C_{ge} external)



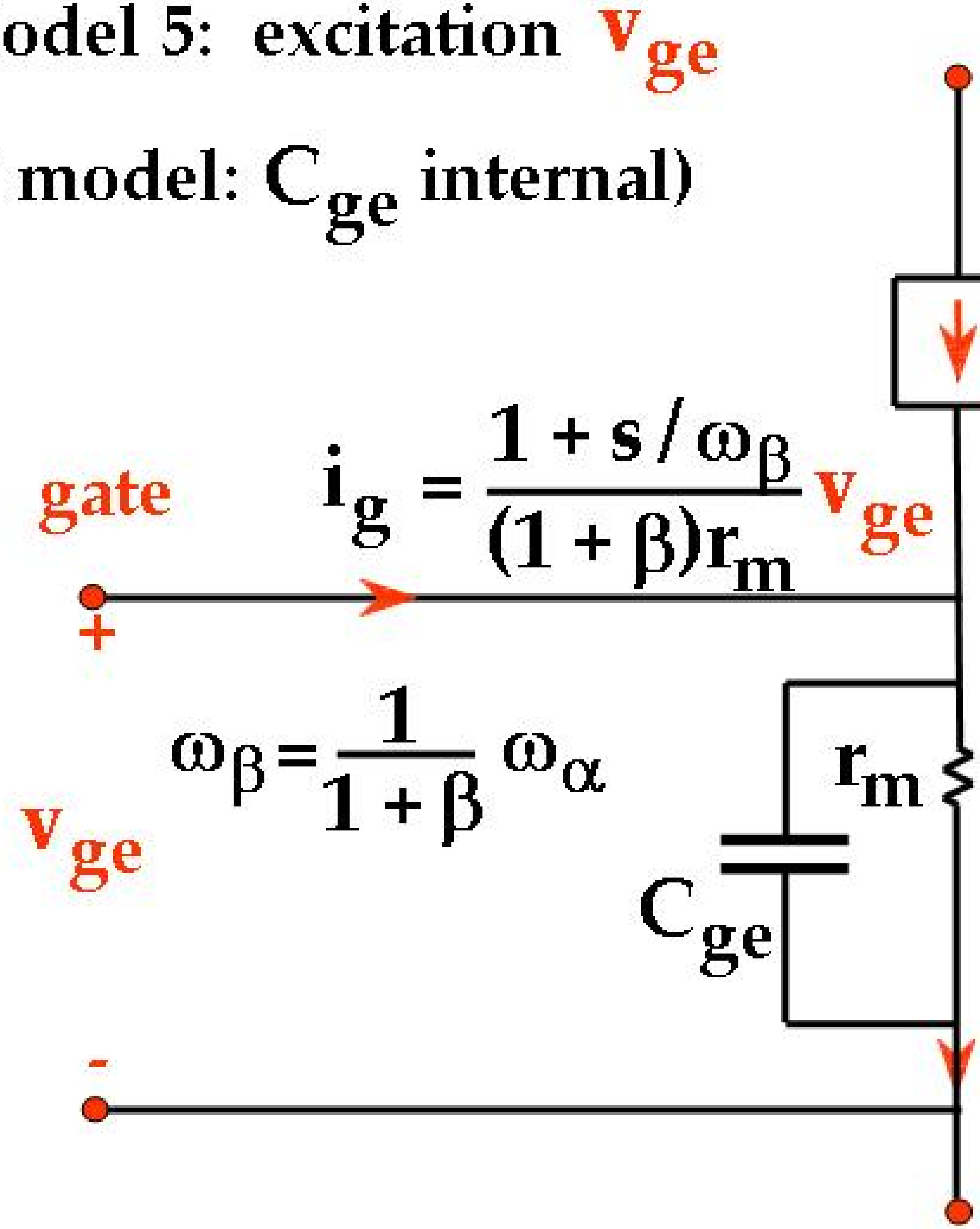
Model 4: excitation i_g

(T model: C_{ge} external)



Model 5: excitation v_{ge}

(T model: C_{ge} internal)



$$i_c = g_m v_{ge}$$

$$i_g = \frac{1 + s/\omega_\beta}{(1+\beta)r_m} v_{ge}$$

$$\omega_\alpha \equiv \frac{1}{C_{ge} r_m}$$

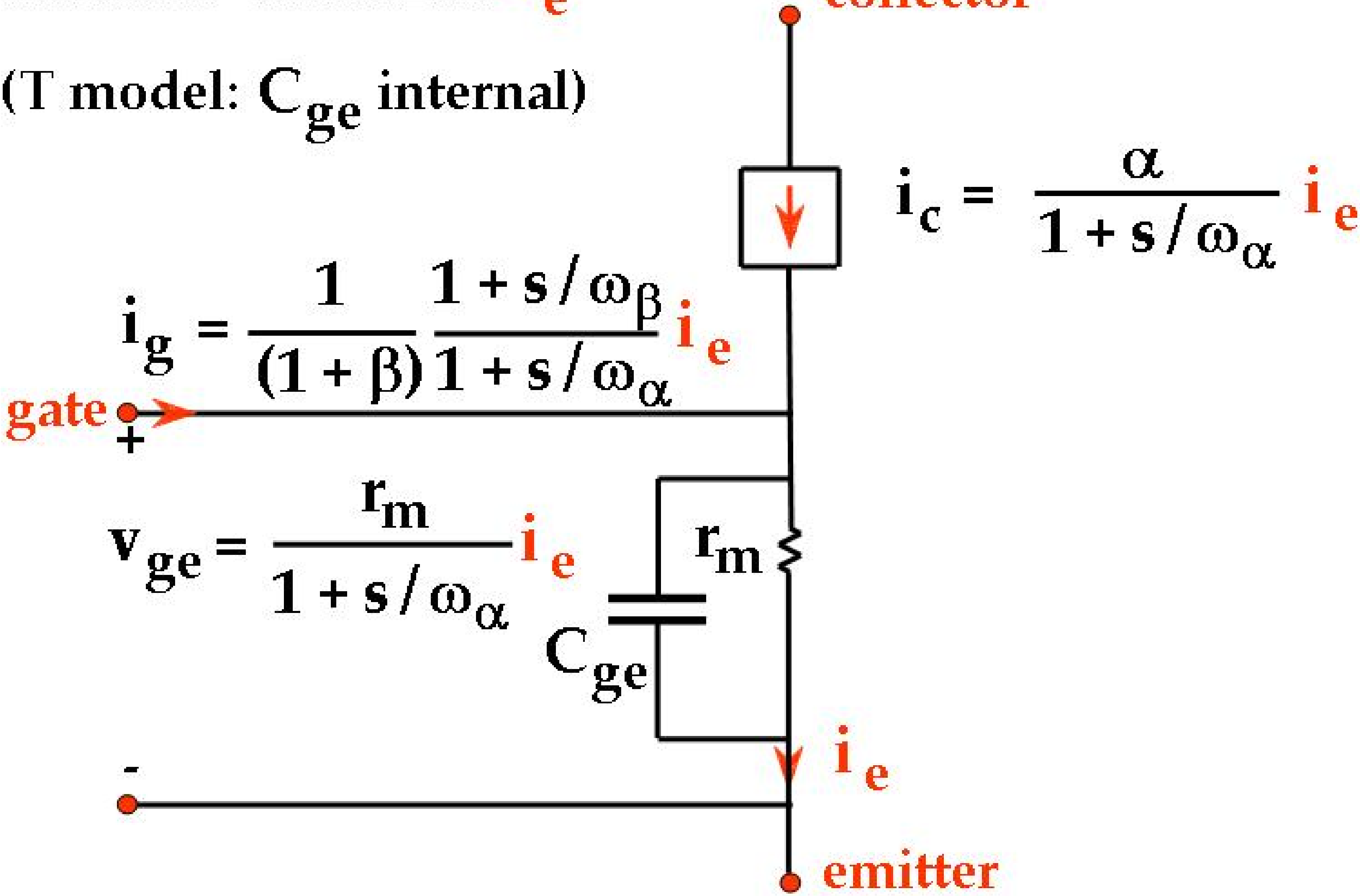
$$\omega_\beta = \frac{1}{1+\beta}\omega_\alpha$$

$$\omega_\beta \equiv \frac{1}{(1+\beta)C_{ge} r_m}$$

$$i_e = \frac{1 + s/\omega_\alpha}{r_m} v_{ge}$$

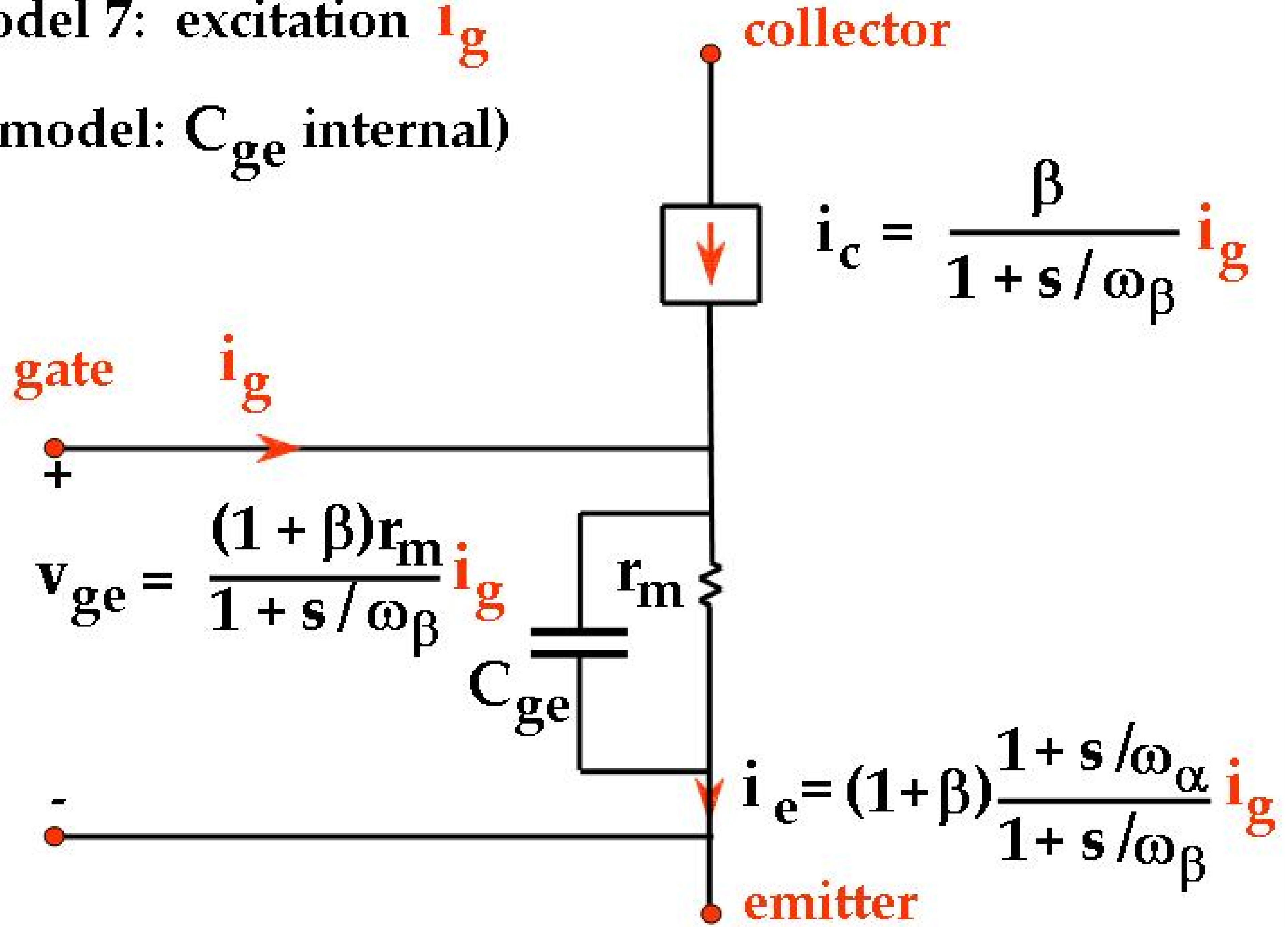
Model 6: excitation i_e

(T model: C_{ge} internal)



Model 7: excitation i_g

(T model: C_{ge} internal)



Dependence of transconductance $g_m \equiv dI_C / dV_{GE}$ upon nonlinearity, with offsets ignored:

TUBE: $I_C = CV_{GE}^{3/2}$ $\quad g_m = (3/2)CV_{GE}^{1/2}$

FET: $I_C = CV_{GE}^{2}$ $\quad g_m = 2CV_{GE}$

BJT: $I_C = \alpha C e^{V_{GE}/V_t}$ $\quad g_m = I_C / V_t$

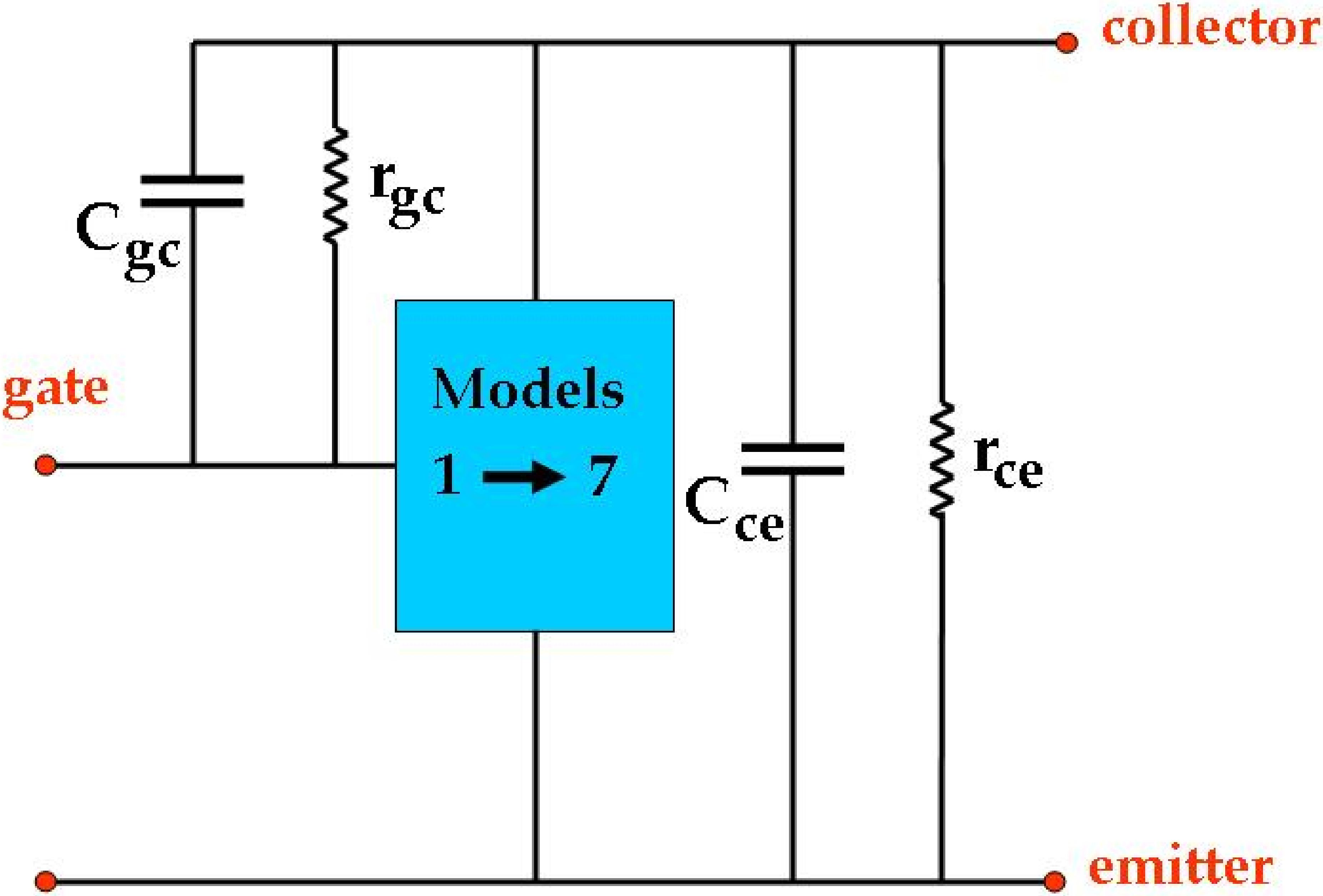
$r_m = \alpha / g_m = V_t / I_E$

where $V_t = kT/e$ is the thermal voltage

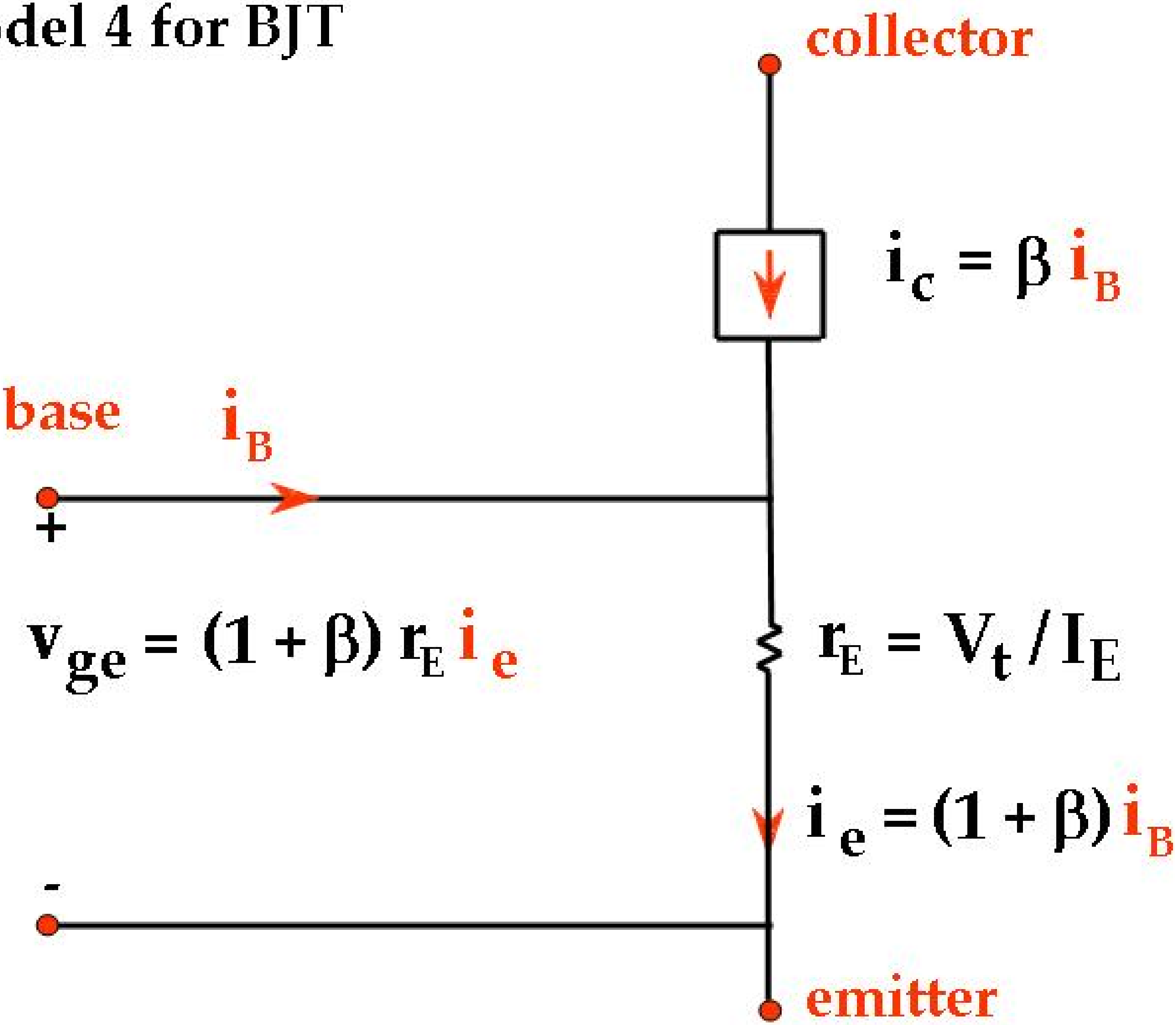
$= 25.7\text{mV} @ 25^{\circ}\text{C}$

The constants C are different, and depend upon device materials, structure, and geometry

Addition of some "parasitic" elements: the Pi Model



Model 4 for BJT



Model 3 for FET