Physical Explanations

AQL
Acceptable **Q**uality **L**evel (see chapter “Quality Data”)

B, b
Base, base terminal

C, c
Collector, collector terminal

C
Capacitances

The transistor equivalent circuit (see chapter “Transistor Equivalent Circuit”) shows the different capacitances in a transistor. Additionally, there are capacitances between terminals, inside as well as outside the package. All these capacitances have its effect only at high frequencies. Here, the actual operating capacitances are important, but not the equivalent circuit capacitances. They can be best explained with y coefficients.

C_i
Short-circuit input capacitance $C_{11} = C_i$
It is an imaginary part of the short–circuit input admittance y_{11} (= y_i) divided by a factor $j\omega$.

The values of capacitances are circuit-configuration dependent; therefore, a further subscript (e, b or c) is added with the concerned capacitance to designate the orientation.

C_{ib}
Short-circuit input capacitance in common-base configuration

$$C_{11b} = C_{ib} = \frac{1}{j\omega}\ \mathrm{Im}\ (y_{ib})$$

C_{ie}
Short-circuit input capacitance in common-emitter configuration

$$C_{11e} = C_{ie} = \frac{1}{j\omega}\ \mathrm{Im}\ (y_{ie})$$

C_{issg1}
Gate 1-input capacitance in common-source configuration

C_{issg2}
Gate 2-input capacitance in common-source configuration

C_o
Short-circuit output capacitance

C_{ob}
Short-circuit output capacitance in common-base configuration

$$C_{22b} = C_{ob} = \frac{1}{j\omega}\ \mathrm{Im}\ (y_{ob})$$

C_{oe}
Short-circuit output capacitance in common-emitter configuration.

$$C_{22e} = C_{oe} = \frac{1}{j\omega}\ \mathrm{Im}\ (y_{oe})$$

C_{oss}
Output capacitance in common-source configuration

C_{rss}
Feedback capacitance in common-source configuration

C_{rb}
Feedback capacitance in common-base configuration

$$C_{rb} = C_{12b} = \frac{1}{j\omega}\ \mathrm{Im}\ (y_{rb})$$

C_{re}
Feedback capacitance in common-emitter configuration

$$C_{re} = C_{12e} = \frac{1}{j\omega}\ \mathrm{Im}\ (y_{re})$$

Additional **capacitances** are given in the data sheet. They can be deducted from the direct measurements given below.

C_{cb}
Capacitance between collector and base without parasitic capacitances

C_{CBO}
Capacitance between collector and base with open emitter. It can be measured by applying reverse bias to its terminals.

The following relationship is also valid:

$$C_{CBO} \approx C_{oe} \approx C_{ob}$$

(Different configurations, but approximately the same values)

C_{eb}
Capacitance between emitter and base without parasitic capacitances

C_{EBO}
Capacitance between emitter and base having an open collector. Measurement is carried out by applying reverse bias to its terminals

The following relationship is also valid:

$$C_{EBO} \approx C_{ie} \approx C_{ib}$$

(Different configurations, but approximately the same values)

C_L
Load capacitance

C_p
Parallel capacitance
Package capacitance

D
Drain

d_{iM}
Signal-to-intermodulation ratio

E, e
Emitter

E_L
Inductive energy

F
Noise figure

For a given frequency and bandwidth, the noise figure is the ratio of the total noise power, p_2, delivered to the output termination, to the portion (G_p p_1) that is contributed by the input power, p_1, given from the signal source whose noise temperature is standard (T_0 = 290 K) at all frequencies

$$F = \frac{p_2}{G_p\ p_1}$$

If this ratio is given in decibel, it is valid that:

$$\frac{F}{dB} = 10\ \lg \frac{p_2}{G_p\ p_1}$$

The noise figure is given for a specified operating point, a specified generator (source) resistance and a specified frequency or frequency range

f
Frequency

Fc
Noise figure for mixer

fg, f_{-3dB}
Cut-off frequency

f_{hfe}
h_{fe}-cut-off frequency
(β-cut-off frequency, f_β)

The frequency at which the modulus of the current amplification factor (h_{fe}) has decreased below 0.707 times the frequency (1 kHz)

f_{IM}
Intermodulation frequency

f_{max}
Maximum frequency of oscillation

Frequency by which the power gain of a transistor assumes the value of one due to conjugately matching of input and output.

f_T
Gain bandwidth product, transition frequency

The product of the modulus of the common-emitter, small-signal short-circuit forward current transfer ratio, and the frequency of measurement f_M. This frequency is chosen because h_{fe} decreases at a slope of approximately 6 dB per octave.

The associated angular frequency

$$\omega_T = 2\ \pi\ f_T$$

is defined as the reciprocal value of transit time minority carriers through the base region.

g
Conductance

G, g
Gate

G_G
Generator conductance

g_i
Short-circuit input conductance

g_{ib}
Input conductance in common-base configuration, short circuit at output g_{ib} = Re (y_{ib})

g_{ie}
Input conductance in common-emitter configuration, short circuit at output g_{ie} = Re (y_{ie})

g_o
Short-circuit output conductance

g_{ob}
Output conductance in common-base configuration, short circuit at input g_{ob} = Re (y_{ob})

g_{oe}
Output conductance in common-emitter configuration short circuit at input g_{oe} = Re (y_{oe})

G_{pb}
Power gain in common-base configuration

G_{pe}
Power gain in common-emitter configuration

G_{ps}
Power gain in common-source configuration

g_r
Short-circuit reverse conductance

G_V
Unilateral gain

h_{FE}
DC forward-current transfer ratio in common-emitter configuration

It is the ratio of the collector current, I_C, to the base current, I_B, for specified values of V_{CE} and I_C.

It is also denoted by the symbol B.

h
The hybrid matrix is an arrangement of h parameters given as follows:

$$h = \begin{pmatrix} h_i & h_r \\ h_f & h_o \end{pmatrix} = \begin{pmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{pmatrix}$$

These h parameters are used mostly in the audio frequency range. They are valid only for a specified operating point and frequency. Usually, this frequency is 1 kHz and the corresponding h parameters are having real values only.

The following electrical characteristics can be calculated from the parameters mentioned above

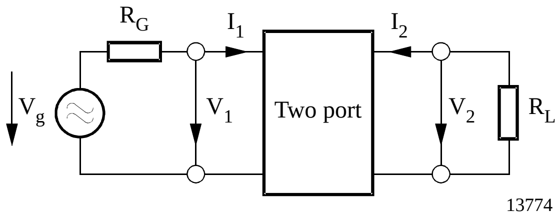

Figure 1.

Current amplification

$$G_i = \frac{\underline{I}_2}{\underline{I}_1} = \frac{h_{21}\ G_L}{h_{22} + G_L} = \frac{h_{21}}{1 + h_{22}\ IG_L}$$

Voltage amplification

$$G_u = \frac{\underline{V}_1}{\underline{V}_1} = \frac{-h_{21}}{h_{11}(h_{22} + G_L) - h_{12}\ h_{21}}$$

Input resistance

$$r_{in} = \frac{\underline{V}_1}{\underline{I}_1} = h_{11} - \frac{h_{12}\ h_{21}}{h_{22} + G_L}$$

Output conductance

$$g_{out} = \frac{\underline{I}_2}{\underline{V}_2} = h_{22} - \frac{h_{12}\ h_{21}}{h_{11} + R_G}$$

Power gain

$$G_p = \frac{P_{out}}{P_{in}} = G_L\ r_{in}\ |A_u|^2$$

$$= G_L \frac{{h_{21}}^2}{[h_{11}(h_{22} + G_L) - h_{12}\ h_{21}]\ (h_{22} + G_L)}$$

The h parameters are the coefficients of two-port network equations given in hybrid form:

$$\underline{V}_1 = h_i\ \underline{I}_1 + h_r\ \underline{V}_2 = h_{11}\ \underline{I}_1 + h_{12}\ \underline{V}_2$$

$$\underline{I}_2 = h_f\ \underline{I}_1 + h_0\ \underline{V}_2 = h_{21}\ \underline{I}_1 + h_{22}\ \underline{V}_2$$

h_i
Short-circuit input impedance

$$h_i = h_{11} = \left(\frac{\underline{V}_1}{\underline{I}_1}\right)\ \underline{V}_2 = 0$$

Parameter values are circuit-configuration dependent; therefore, a further subscript (e, b or c) is used to identify the circuit configuration.

h_{ib}
Short-circuit input resistance in common-base config-uration (small-signal value)

h_{ie}
Short-circuit input resistance in common-emitter configuration (small-signal value)

h_r
Open-circuit reverse-voltage transfer ratio

$$h_r = h_{12} = \left(\frac{\underline{V}_1}{\underline{V}_2}\right)\ \underline{I}_1 = 0$$

h_{rb}
Open-circuit reverse-voltage transfer ratio in common-base configuration (small-signal value)

h_{re}
Open-circuit reverse-voltage transfer ratio in common-emitter configuration (small-signal value)

h_f
Short-circuit forward-current transfer ratio

$$h_f = h_{21} = \left(\frac{\underline{I}_2}{\underline{I}_1}\right)\ \underline{V}_2 = 0$$

h_{fb}
Short-circuit forward-current transfer ratio in common-base configuration (small-signal value)

h_{fe}
Short-circuit forward-current transfer ratio in common-emitter configuration (small-signal value)

This is the ratio of the alternating collector current, i_c, to the alterning base current, i_b, for small signals whose output is short-circuited to a.c. This is also known as β.

In technical data sheets, this parameter is given with 1 kHz sine wave for a specified operating point. This quantity is also known as the current amplification factor.

h_o
Open-circuit output admittance

$$h_0 = h_{22} = \left(\frac{\underline{I}_1}{\underline{V}_{22}}\right) \underline{I}_1 = 0$$

h_{ob}
Open-circuit output conductance in common-base configuration (small-signal value)

h_{oe}
Open-circuit output conductance in common-emitter configuration (small-signal value)

I_B
DC base current

I_{BM}
Peak base current

I_C
DC collector current

I_{CBO}
Collector cut-off current, with open emitter

The cut-off current is the reverse current flowing through the junction(s) (base-emitter or base-collector) of a transistor. By applying reverse bias across its terminals, the third terminal is open-circuited or otherwise specified. This is also known as leakage current.

Collector-base cut-off current, I_{CBO}, and collector-base V_{CBO}, with open emitter, i.e., $I_E = 0$ A

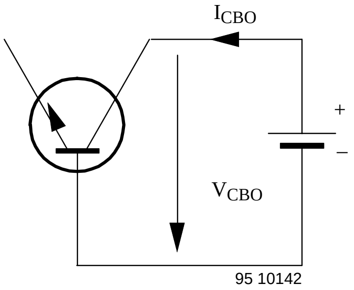

Figure 2.

I_{CEO}
Collector cut-off current, with open base

Collector-emitter, cut-off current, I_{CEO}, and collector-emitter voltage, V_{CEO}, with open base, i.e., $I_B = 0$

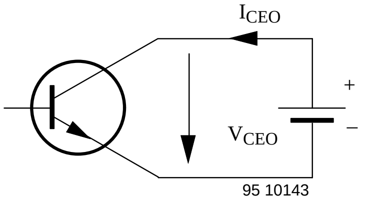

Figure 3.

I_{CER}
Collector cut-off current, with a resistor R_{BE} connected between base and emitter

Collector-emitter cut-off current, I_{CER}, and collector-emitter voltage, V_{CER}, having the resistance connected between base and emitter. The appropriate value of R_{BE} referring to V_{CER} is also given in the technical data sheets. For higher values of R_{BE}, the values of V_{CEO} and I_{CEO} are valid.

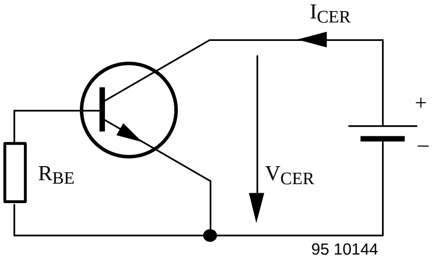

Figure 4.

I_{CES}
Collector cut-off current, short circuit between base and emitter

Collector cut-off current, $I_{CES} = I_{CBS}$, and collector-emitter voltage,
$V_{CES} = V_{CBS}$, with base emitter short-circuited

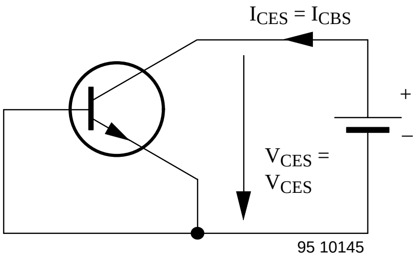

Figure 5.

I_{CEV}
Collector cut-off current with reverse base-emitter voltage

Collector-emitter cut-off current, I_{CEV}, and collector-emitter voltage, V_{CEV}, when the applied voltage between base and emitter is reverse biased

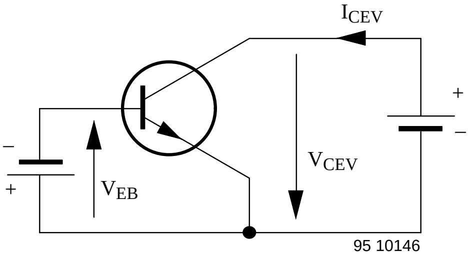

Figure 6.

I_{CEX}
Collector cut-off current with forward base-emitter voltage

Collector-emitter cut-off current, I_{CEX}, when the applied voltage between base and emitter is forward biased

The value of the base-emitter voltage, V_{BE}, is selected so that no appreciable base current flows.

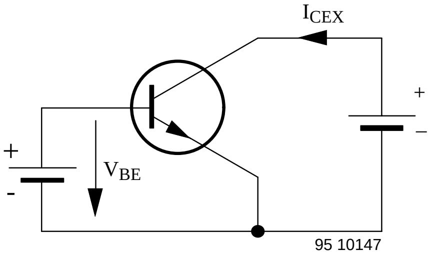

Figure 7.

I_{CM}
DC collector peak current

It is the maximum collector current with sine-wave operation, f ≥ 25 Hz, or pulse operation, *f* ≥ 25 Hz, having a duty cycle of $t_p/T \leq 0.5$

I_D, I_{DSS}
Drain current

I_E
Emitter current

I_{EBO}
Emitter cut-off current, with open collector

Emitter-base cut-off current, I_{EBO}, and emitter-base voltage, V_{EBO}, with open collector, i.e., $I_C = 0$

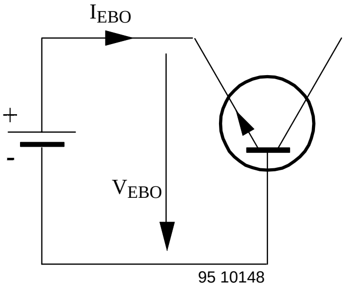

Figure 8.

$\pm I_{G1/2SM}$
Gate 1/gate 2-source peak current

$\pm I_{G1S/1SS}$
Gate 1-source current

$\pm I_{G2S/2SS}$
Gate 2-source current

I_I
Input current

I_K
Short-circuit current

I_Q
Output current

I_S
Supply current

K
Kelvin

l
Length, connecting lead length

L_S
Series inductance

M_A
Tightening torque

m
Degree of modulation

P
Power

P_I
Input power

P_q, P_Q
Output power

P_{tot}
Total power dissipation

It is the dispersion of the heat generated within a device when a current flows through it. The permissible power dissipation, $P_{totmax,}$ which is specified under absolute maximum ratings, is a function of T_{jmax}, T_{amb}, R_{thJA} and R_{thJC}. It is given as follows:

$$P_{totmax}\ (amb) = \frac{T_{jmax}-T_{amb}}{R_{thJA}}$$

or

$$P_{totmax}\ (package) = \frac{T_{jmax}-T_{case}}{R_{thJC}}$$

If the safe-operation conditions as given in the data sheets are observed, the power dissipation is limited (valid for special packages).

P_V
Power dissipation, general

$r_{bb'}$
Basic intrinsic resistance

R_{BE}
Resistance connected between base and emitter

r_F
DC forward resistance

r_f
Differential forward resistance

R_G
Generator resistance

r_i
Input resistance

R_L
Load resistance

r_p
Parallel resistance, damping resistance

r_o
Output resistance

R_{thCA}
Thermal resistance, channel ambient

R_{thJA}
Thermal resistance, junction ambient

R_{thJC}
Thermal resistance, junction case

s
Standing wave ratio (SWR)

S, s
Source

$|S_{21e}|$
Forward transmission factor

T
Period

T
Absolute temperature, Kelvin temperature
0 K = –273.15°C
Unit: K (Kelvin)

T
Temperature, measured in celsius
Unit: °C

t
Time

T_{amb}
Ambient temperature

If self-heating is significant:
Temperature of the surrounding air below the device under conditions of thermal equilibrium

If self-heating is insignificant:
Air temperature in the immediate surroundings of the device

T_{amb}
Ambient temperature range

As an absolute maximum rating:
The maximum permissible ambient temperature range

T_c
Channel temperature

T_{case}
Case temperature

The temperature measured at a specified point on the package of a semiconductor device

Unless otherwise stated, this temperature is given as the temperature of the mounting base for transistors with metal can

t_d
Delay time, see section “Switching Characteristics”

t_f
Fall time, see section “Switching Characteristics”

t_{fr}
Forward recovery time

T_j
Junction temperature

It is the spatial mean value of the temperature which the junction has acquired during operation. In the case of transistors, it is mainly the temperature of the collector junction because its inherent temperature is maximum

T_K
Temperature coefficient

The ratio of the relative change of an electrical quantity to the change in temperature (Δt) which causes it, under otherwise constant operating conditions

t_L
Connecting lead temperature in holder at a distance, I, from case

t_{off}
Turn-off time, see section “Switching Characteristics”

t_{on}
Turn-on time, see section “Switching Characteristics”

t_p
Pulse duration

$\frac{t_p}{T}$
Duty cycle

t_r
Rise time, see section “Switching Characteristics”

t_{rr}
Reverse recovery time

t_s
Storage time, see section “Switching Characteristics”

t_{sd}
Soldering temperature

Maximum permissible temperature for soldering with a specified distance from package and its duration. Refer to section “soldering instructions”

T_{stg}
Storage temperature range

The temperature range at which the device may be stored or transported without any applied voltage

V_{BB}
Base supply voltage

V_{BE}
Base emitter voltage

V_{BEsat}
Base saturation voltage

The base-emitter saturation voltage, V_{BEsat}, is the base-emitter voltage which belongs to the collector-emitter saturation voltage, V_{CEsat}

$V_{(BR)}$
Breakdown voltage

Reverse voltage at which an increase in voltage results in a sharp rise of the reverse current. It is given in the technical data sheets for a specified current

$V_{(BR)CBO}$
Breakdown voltage, collector-base, open emitter

$V_{(BR)CEO}$
Breakdown voltage, collector emitter, open base

Measurements with pulsed current collector source

With a switched-off inductive-load connected test circuit as shown in fig. 16 (see next page), it is set in breakdown position till the storage energy during switch-on has been discharged. This is when the ramp-shaped pulse current inflow at collector has reached its zero value.

Absolute maximum ratings of $V_{(BR)CEO}$ are defined with the test current, I_{test}, whereas the transistor has its lowest breakdown voltage value

The breakdown voltage and collector inductance has been dimensioned so that the load of breakdown energy is below the value of transistor failure

$V_{(BR)CEV}$
Collector-emitter breakdown voltage at a defined reverse voltage between base and emitter

$V_{(BR)DS}$
Drain-source breakdown voltage

$V_{(BR)EBO}$
Breakdown voltage, emitter-base, open collector

$V_{(BR)ECO}$
Breakdown voltage, emitter-collector, open base

$\pm V_{(BR)G1SS}$
Gate 1-source breakdown voltage

$\pm V_{(BR)G2SS}$
Gate 2-source breakdown voltage

V_{CB}
Collector-base voltage

V_{CBO}
Collector-base voltage, open emitter

Generally, reverse biasing is the voltage applied to any of the two terminals of a transistor in such a way that one of the junctions operates in reverse direction, whereas the third terminal (second junction) is specified separately

V_{CC}
Collector supply voltage

V_{CE}
Collector-emitter voltage

V_{CEO}
Collector-emitter voltage, open base

V_{CER}
Collector-emitter voltage with a resistor R_{BE} connected between base and emitter

V_{CES}
Collector-emitter voltage, short circuit between base and emitter

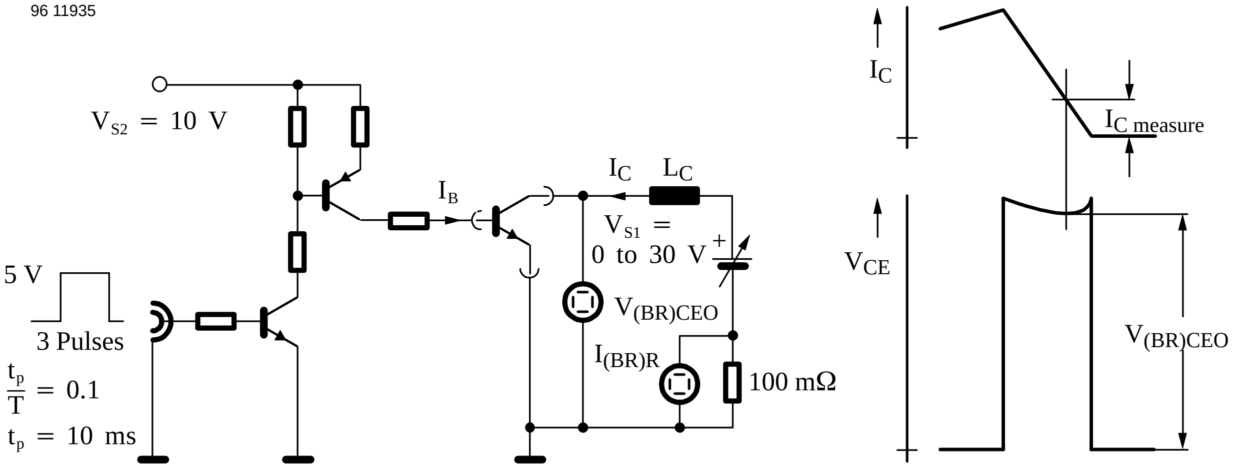

Figure 9.

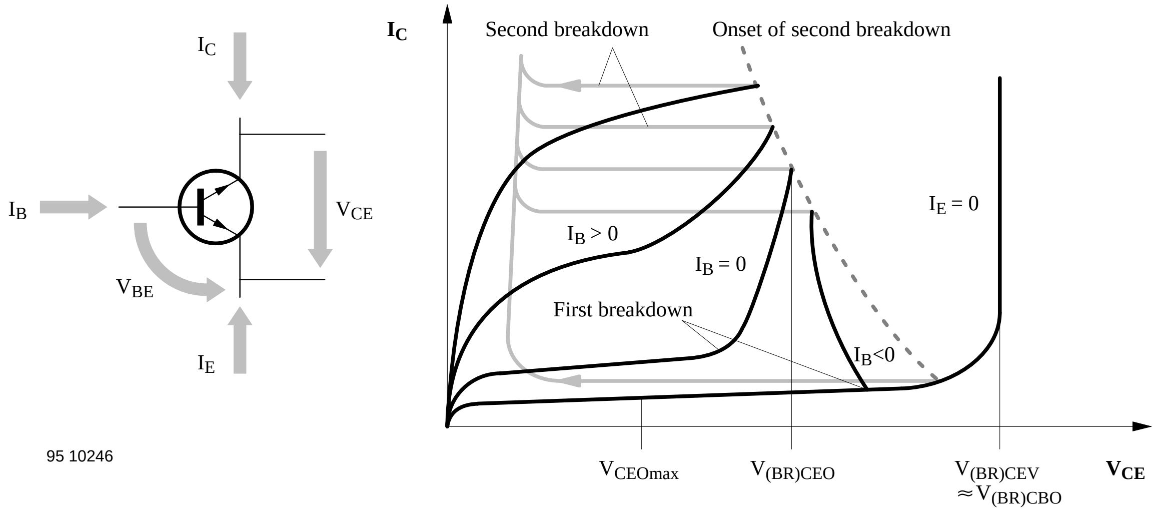

Figure 10. Typical voltage-breakdown behavior of a transistor

V_{CEsat}
Saturation voltage, collector emitter

The collector saturation voltage is the DC voltage between collector and emitter for specified saturation conditions.

The saturation voltage V_{CEsat} is given:

a) For a specified value of I_C where the base-emitter voltage equals the collector-emitter voltage, i.e., $V_{CB} = 0$ V

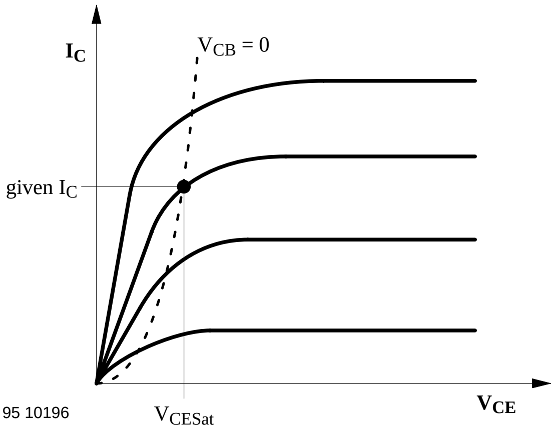

Figure 11.

b) For a specified value of I_C and I_B where the operating point is in the saturation region, i.e., $V_{CE} < V_{CB}$

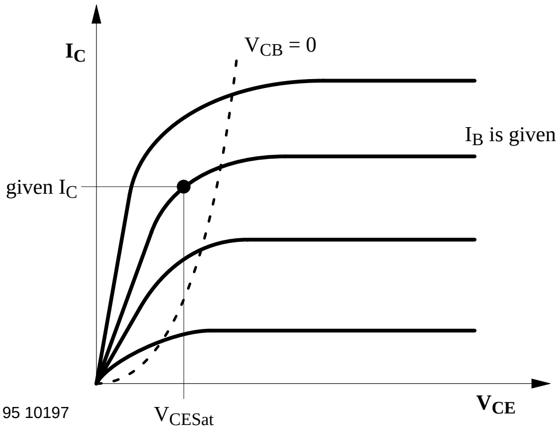

Figure 12.

c) For a specified value of the characteristic curve (I_B const.) which intersects the curve point $I_C' = K\ I_c$ ($K = 1.1$) and a specified value of the collector-emitter voltage ($V_{CE} = 1$ V)

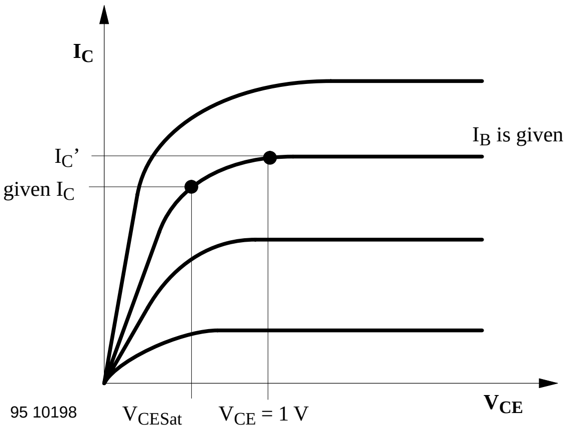

Figure 13.

$V_{CEsatHF}$
Collector-emitter HF saturation voltage

V_{CEV}
Collector-emitter voltage, with reverse base emitter voltage

V_{DS}
Drain source voltage, maximum

V_{EBO}
Emitter-base voltage, with open collector

V_F
Forward voltage

Emitter-base voltage due to the flow of the forward current at emitter-base juction

$V_{G1S(OFF)}$
Gate 1-source cut-off voltage

$V_{G2S(OFF)}$
Gate 2-source cut-off voltage

V_{HF}
RF voltage, RMS value

V_{HF}
RF voltage, peak value

V_n
Noise voltage (RMS value)

V_R
Reverse voltage

Voltage drop which results from the flow of the reverse current

An external voltage applied to a semiconductor PN or NP junction to reduce the flow of current across the junction and thereby widen the depletion region

V_S
Supply voltage

V_T
Voltage due to temperature

y
The admittance matrix is an arrangement of y parameters given as follows:

$$y = \begin{pmatrix} y_i & y_r \\ y_f & y_o \end{pmatrix} = \begin{pmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{pmatrix}$$

y parameters are the coefficients of two-port network equations given in admittance form:

$$\underline{I}_1 = y_i\ \underline{V}_1 + y_r\ \underline{V}_2 = y_{11}\ \underline{V}_1 + y_{12}\ \underline{V}_2$$

$$\underline{I}_1 = y_i\ \underline{V}_1 + y_r\ \underline{V}_2 = y_{11}\ \underline{V}_1 + y_{12}\ \underline{V}_2$$

Y_i

Short-circuit input admittance

$$y_i = y_{11} = \left(\frac{\underline{I}_1}{\underline{V}_1}\right) \quad \underline{V}_2 = 0$$

Parameter values are circuit-configuration dependent; therefore, a further subscript (e, b or c) is used to identify the circuit configuration

y_{ib}
Short-circuit input admittance in common-base configuration (small-signal value)

$y_{ib} = g_{ib} + j\ \omega\ C_{ib}$

y_{ie}
Short-circuit input admittance in common-emitter configuration (small-signal value)

$y_{ie} = g_{ie} + j\ \omega\ C_{ie}$

y_r
Short-circuit reverse-transfer admittance

$$y_r = y_{12} = \left(\frac{\underline{I}_1}{\underline{V}_2}\right) \quad \underline{V}_1 = 0$$

$|y_{rb}|$

Short-circuit reverse-transfer admittance in common-base configuration (small-signal value)

$$\begin{aligned} y_{rb} &= |y_{rb}|\ \exp\ \varphi_{rb} \\ &= g_{rb} + j\ \omega\ C_{rb} \end{aligned}$$

$|y_{re}|$

Short-circuit reverse-transfer admittance in common-emitter configuration (small-signal value)

$$\begin{aligned} y_{re} &= |y_{re}|\ \exp\ \varphi_{re} \\ &= g_{re} + j\ \omega\ C_{re} \end{aligned}$$

y_f
Short-circuit forward-transfer admittance

$$y_f = y_{21} = \left(\frac{\underline{I}_2}{\underline{V}_1}\right) \quad \underline{V}_2 = 0$$

$|y_{fb}|$
Short-circuit forward-transfer admittance in common-base configuration (small-signal value)

$y_{fb} = |y_{fb}|\ \exp\ \varphi_{fb}$

Short-circuit forward-transfer admittance in common-emitter configuration (small-signal value)

$y_{fe} = |y_{fe}|\ \exp\ \varphi_{fe}$
$|y_{fs}|$
Short-circuit forward admittance in a source configuration at a given operating point and frequency

y_o
Short-circuit output admittance

$$y_o = y_{22} = \left(\frac{\underline{I}_2}{\underline{V}_2}\right) \quad \underline{V}_1 = 0$$

Y_{ob}
Short-circuit output admittance in common-base configuration (small-signal value)

$y_{ob} = g_{ob} + j\ \omega\ C_{ob}$

y_{oe}
Short-circuit output admittance in common-emitter configuration (small-signal value)

$y_{oe} = g_{oe} + j\ \omega\ C_{oe}$

The following electrical characteristics can be calculated from the admittance parameters mentioned above.

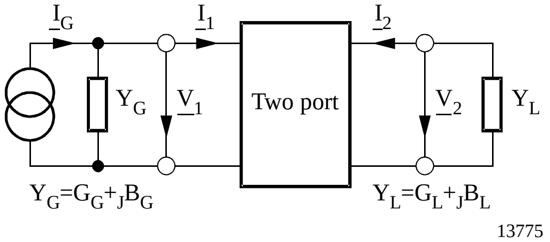

Figure 14.

Current amplification

$$G_i = \frac{\underline{I}_2}{\underline{I}_1} = \frac{y_{21}\quad Y_L}{y_{11}\ (y_{22} + Y_L) - y_{12}\, y_{21}}$$

Voltage amplification

$$G_u = \frac{\underline{V}_2}{\underline{V}_1} = \frac{-y_{21}}{y_{22} + Y_L}$$

Input admittance

$$y_{in} = \frac{\underline{I}_1}{\underline{V}_1} = y_{11} - \frac{y_{12}\ y_{21}}{y_{22} + Y_L}$$

Output admittance

$$y_{out} = \frac{\underline{I}_2}{\underline{V}_2} = y_{22} - \frac{y_{12}\ y_{21}}{y_{11} + Y_G}$$

Power gain

$$G_p = \frac{P_{out}\ G_L}{P_{in}\ g_{in}}\ |A_u|^2$$

$$= \frac{G_L}{g_{in}} \left| \frac{y_{21}}{y_{22} + Y_L} \right|^2$$

At AF in certain cases, and for RF throughout, the coefficients of y parameters or the equivalent circuit according to Giacoletto (see section “Transistor Equivalent Circuit’’) are used. The y coefficients are valid only for a specified operating point and a specified frequency with narrow (frequency) range.

The y parameters are sometimes given separately as real and imaginary values or according to its modulus and phase.

$$y_i = g_i + j\ \omega\ C_i$$

g_i
Short-circuit input conductance

C_i
Short-circuit input capacitance

$$y_r = g_r + j\omega C_r = |y_r|\ \exp\ (j\varphi_r)$$

g_r
Short-circuit reverse conductance

C_r
Short-circuit reverse capacitance

$|y_r|$
Modulus of the short-circuit reverse-transfer admittance

φ_r
Phase of the short-circuit reverse-transfer admittance

$$y_f = |y_f|\ \exp\ (j\ \varphi_f)$$

$|y_f|$
Modulus of the short-circuit forward-transfer admittance

φ_f
Phase of the short-circuit forward-transfer admittance

$$y_o = g_o + j\ \varphi\ C_o$$

g_o
Short-circuit output conductance

C_o
Short-circuit output capacitance

Y_G
Generator admittance

φ
Phase angle

φ_{fb}
Phase of the short-circuit forward transfer admittance y_{fb}

φ_{fe}
Phase of the short-circuit forward transfer admittance y_{fe}

φ_{rb}
Phase of the short-circuit reverse transfer admittance y_{rb}

Y_G
Generator admittance

φ
Phase angle

φ_{fb}
Phase of the short-circuit forward-transfer admittance y_{fb}

φ_{fe}
Phase of the short-circuit forward-transfer admittance y_{fb}

φ_{rb}
Phase of the short-circuit reverse-transfer admittance y_{rb}

φ_{re}
Phase of the short-circuit reverse-transfer admittance y_{re}

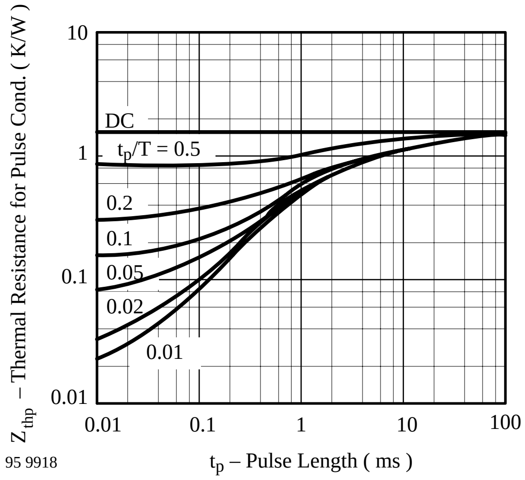

Figure 15.

Z_{thP}
Thermal impedance, pulse load
To determine the maximum power dissipation, P_{totmax}, of a transistor by repetitive rectangular pulse operation, the calculation is as follows:

$$P_{totM} = \frac{T_{jM} - T_{case}}{Z_{thP}}$$

whereas:

$$T_{jmax} \triangleq T_{jM} =$$

maximum (crest) permissible crystal temperature by repetitive pulse operation,

$$P_{totM} = \frac{T_{jmax} - T_{case}}{Z_{thP}}$$

Z_{thP} = thermal impedance, pulse operation,

$\frac{t_p}{T}$ as a parameter

When the calculation has been completed, $P_{tot\ max}$ should correspond with the maximum permissible operating range.

π
Efficiency

T_s
Storage-time constant

Switching Characteristics

By using a transistor as a switch, one has to bear in mind that during transition from off- to on-state, the signal does not respond instantaneously, even when abrupt changes in control values occur. The output signal is not only delayed but also distorted. These switching characteristics of a transistor are explained by means of an NPN transistor.

Figure 16 shows the basic circuit.

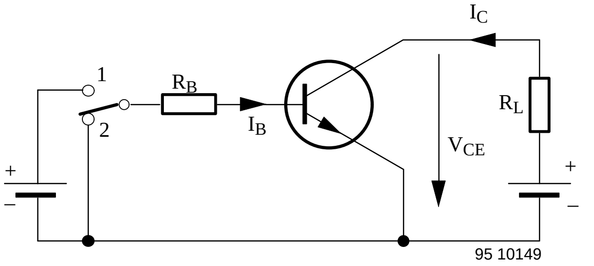

Figure 16.

The input (i.e., base current, i_B) and output (i.e., collector current, i_C) signals are shown in figure 17.

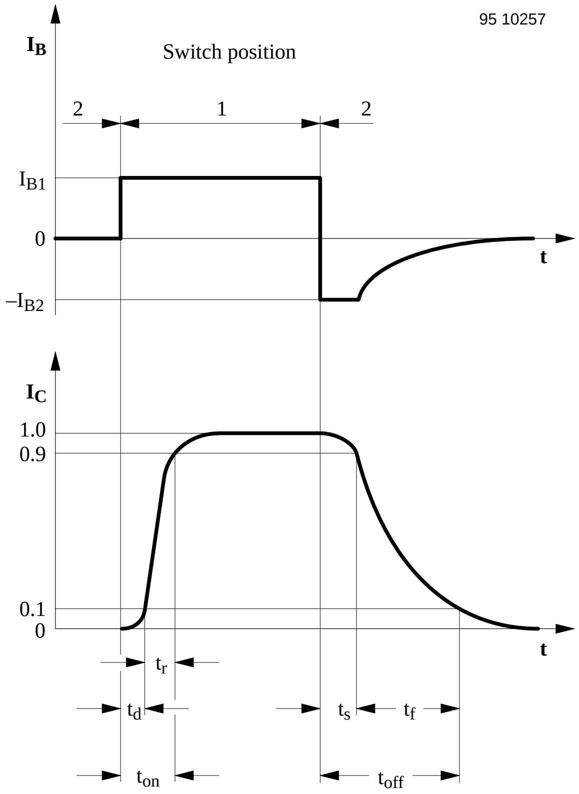

Figure 17.

The transient responses as shown in figure 17 are given as follows:

t_d : delay time

t_r : rise time

t_{on} ($t_d + t_r$) : turn-on time

t_s : storage time

t_f : fall time

t_{off} ($t_s + t_f$) : turn-off time

These switching characteristics depend on the transistor type and the circuit used. They are only valid if the slope of the control pulse is much greater than that of the collector current pulse. If the saturation factor is higher, the turn-on time is shorter, and the turn-off time is longer. The turn-off time is shorter if the on-off base current ratio is higher.