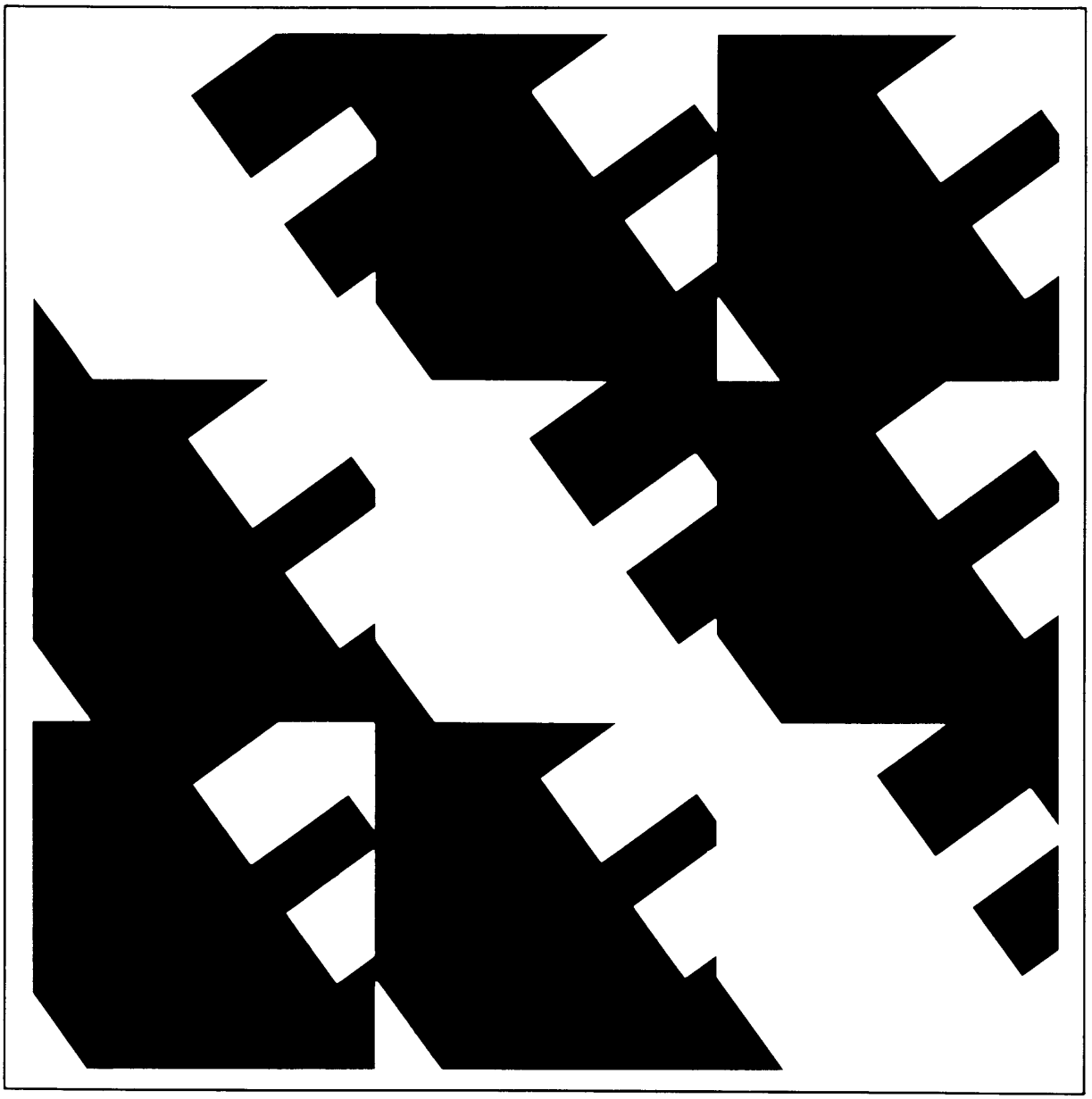
IEEE Standard Letter Symbols for Semiconductor Devices



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LETTER SYMBOLS FOR SEMICONDUCTOR DEVICES
(IEEE No. 255)

On pages 6 and 7:

All h, y, z, H, Y, and Z characters
should have been set in italic type

On page 8:

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should have been set in italic type

CONTENTS

INTRODUCTION

These Standards are supplementary to the IRE Standards on Abbreviations, Graphical Symbols, and Mathematical Signs—1948, Section 1. The usage conforms to Section 101, General Principles of Letter Symbol Standardization. This Standard provides a uniform system of letter symbols for electrical quantities and parameters as applied to semiconductor devices in the same way that Section 102 provides symbols for electron tubes. The Standard has been divided into three Sections:

1. Electrical quantities, dealing primarily with voltage, current, and time quantities.
2. Electrical parameters, dealing with the relationship between specific electrical quantities.
3. List of letter symbols in alphabetical order.

Electrical quantities at the device terminals are defined in Section 1. The electrical parameters of Section 2 are ratios of the terminal electrical quantities; i.e., they are two-terminal-pair open-and-short-circuit ratios. Numeric subscripts are used for those ratios throughout this Standard; letter subscripts may be used when convenient.

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LETTER SYMBOLS FOR SEMICONDUCTOR DEVICES

1. ELECTRICAL QUANTITIES

1.1 Quantity Symbols

1.1.1 Instantaneous values of current, voltage, and power, that vary with time, are represented by the lower-case letter of the proper symbol.

Examples: i, v, p

1.1.2 Maximum (peak), average (direct-current), and root-mean-square values of current, voltage, and power are represented by the upper-case letter of the appropriate symbol.

Examples: I, V, P

1.2 Subscripts for Quantity Symbols

1.2.1 Direct-current values and instantaneous total values are indicated by upper-case subscripts.

Examples: i_C, I_C, v_{EB}, V_{EB}, p_C, P_C

1.2.2 Alternating-component values are indicated by lower-case subscripts.

Examples: i_c, I_c, v_{eb}, V_{eb}, p_c, P_c

1.2.3 To distinguish between maximum (peak), average, and root-mean-square values, maximum values are represented by the addition of a subscript M or m, and average by (AV).

Note: Where this distinction is not necessary, the additional subscript may be omitted.

Examples: i_{cm}, I_{cm}, I_{CM}, $i_{C(AV)}$

1.2.4 Symbols to be used as subscripts. (For example, see Figure 1 and Basic Symbols Chart 1.2.5.)

E, e = emitter terminal
B, b = base terminal
C, c = collector terminal
J, j = terminal, general
A, a = anode terminal
K, k = cathode terminal
G, g = gate terminal
X, x = circuit node
M, m = maximum value
Min, min = minimum value
(AV) = average value

1.2.5 A final subscript may be used to identify the termination of the port other than the one to which the quantity is referred:

O = Open-circuit termination
S = Short-circuit termination
X = General termination
R = Resistive termination
V = Bias-Voltage termination

This subscript should be upper case if the other subscripts are upper case, and lower case if the other subscripts are lower case.

Example: I_{CBO}, I_{CES}, $V_{(BR)CER}$

1.2.6 Basic Symbols Chart (Table I)

TABLE I

SUBSCRIPTS	SYMBOLS	
	i, v, p	I, V, P
e b c j a k g	Instantaneous Value of Alternating Component	Root-Mean-Square Value of Alternating Component With additional subscript m, Maximum (peak) Value of Alternating Component
E B C J A K G	Instantaneous Total Value	Direct-current Value With additional subscript M, Maximum (Peak) Total Value With additional subscript (AV) Direct-current Value with Alternating Component

1.2.7 Examples of application of basic symbols chart.

I_E = emitter direct-current (no alternating component)

I_e = root-mean-square value of alternating component of emitter current

i_e = instantaneous value of alternating component of emitter current

i_E = instantaneous total value of emitter current

$I_{E(AV)}$ = average of emitter current with alternating component

I_{em} = maximum (peak) value of the alternating component of emitter current

I_{EM} = maximum total (peak) value of the emitter current

1.3 The Subscript Sequence Conforms to the Mathematical Convention for Writing Determinants from a Set of Fundamental Kirchhoff's Equations

1.3.1 The first subscript designates the terminal at which the current is measured, or where the terminal potential is measured with respect to the reference terminal, or circuit node, designated by the second subscript. (Conventional current flow into the terminal from the external circuit is positive.) When the reference terminal or circuit node is understood, the second subscript may be omitted where its use is not required to preserve the meaning of the symbol.

1.3.2 Supply voltage may be indicated by repeating the terminal subscript. The reference terminal may then be designated by the third subscript.

Examples: V_{EE}, V_{CC}, V_{BB}, V_{EEB}, V_{CCB}, V_{BBC}, V_{KK}

1.3.3 In devices having more than one terminal of the same type, the terminal subscripts are modified by adding a number following the subscript and on the same line.

Example: V_{B1-B2}

In multiple-unit devices, the terminal subscripts are modified by a number preceding the subscript.

Example: V_{1B-2B}

1.3.4 When necessary to distinguish between components of current or voltage, the symbols may be used as shown in Figure 1. The illustration shows a case where a small alternating component is developed in the collector circuit of a transistor.

2. ELECTRICAL PARAMETERS

2.1 Parameter Symbols

2.1.1 Value of four-pole matrix parameters, or other resistances, impedances, admittances, etc., inherent in the device, may be represented by the lower-case symbol with the proper subscripts.

Examples: h_{11b}, z_{21b}, y_{21b}, h_{11B}, h_{21e}

2.1.2 The four-pole matrix parameters of external circuits and of circuits in which the device forms only a part shall be represented by upper-case symbols with appropriate subscripts.

Examples: H_{11}, Z_{22}, Y_{21}, Y_{12}

2.2 Subscript for Parameter Symbols

2.2.1 Static[1] values of parameters are indicated by the upper-case subscript.

Examples: h_{11B}, z_{21B}, y_{22c}

[1]The static value is the slope of the line from the origin to the operating point on the appropriate characteristic curve, i.e., the quotient of the appropriate electrical quantities at the operating point.

2.2.2 Small-signal values of parameters are indicated by the lower-case subscript.

Examples: h_{11b}, z_{21b}, y_{22c}

2.2.3 The first subscript or subscript pair, in matrix notation, identifies the element of the four-pole matrix.

11 or i = input
22 or o = output
21 or f = forward transfer
12 or r = reverse transfer

Examples: $V_1 = h_{11} I_1 + h_{12} V_2$ $\quad V_i = h_i I_i + h_r V_o$
$I_2 = h_{21} I_1 + h_{22} V_2$ $\quad I_o = h_f I_i + h_o V_o$

Note 1: Voltage and current symbols in matrix notations are designated with a single-digit subscript 1 = input and subscript 2 = output.

Note 2: The quantities and parameters in these equations may be complex.

2.2.4 The subscript following the numeric pair identifies the circuit configuration. When the common terminal is understood, it may be omitted.

e = emitter terminal, common
b = base terminal, common
c = collector terminal, common
j = general terminal, common
a = anode terminal, common
k = cathode terminal, common
g = gate terminal, common

Examples: (common-base transistor)

$I_1 = y_{11b} V_{1b} + y_{12b} V_{2b}$ $\quad I_i = y_{ib} V_{ib} + y_{rb} V_{ob}$
$I_2 = y_{21b} V_{1b} + y_{22b} V_{2b}$ $\quad I_o = y_{fb} V_{ib} + y_{ob} V_{ob}$

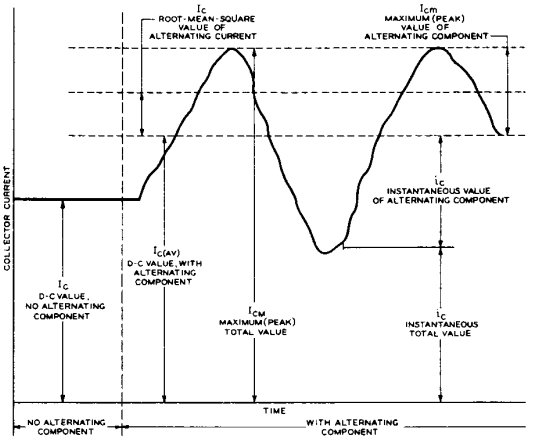

Figure 1
ILLUSTRATION OF PROPER SYMBOL USAGE

2.2.5 The subscript "o" or "s" following the subscript identifying circuit configuration for a two-port parameter identifies the termination of the port opposite from the one to which the parameter is referred:

o = opposite port open-circuited
s = opposite port short-circuited

This subscript should be upper case if the other subscripts are upper case and should be lower case if the other subscripts are lower case.

Example: C_{11bs}, C_{oeo}

3. LETTER SYMBOLS IN ALPHABETICAL ORDER

The following list has been compiled according to the conventions set forth in Sections 1 and 2 of this Standard. In many of the symbols that follow only the direct-current versions are listed, e.g., I_{CBO}. Other symbols are easily generated by application of the rules of Sections 1 and 2.

C_{11s}, C_{11bs}, C_{11cs}, C_{11es}, C_{ibs}, C_{ies}, C_{ics} — The capacitance measured across the input terminals with the output terminals short-circuited to alternating current.

Note: The use of the upper-case symbol is an exception to the rules set forth in Section 2.1.1.

C_{22o}, C_{22bo}, C_{22co}, C_{22eo}, C_{obo}, C_{oco}, C_{oeo} — The capacitance measured across the output terminals with the input open-circuited to alternating current.

Note: The use of the upper-case symbol is an exception to the rules set forth in Section 2.1.1.

f_{h21b}, f_{h21e}, f_{h21c} — The lowest frequency at which the magnitude of the parameter indicated by the subscript is 0.707 of its low-frequency value.

Note: The use of the symbol f_α is not recommended.

f_{max} — The maximum frequency of oscillation of the device.

f_1 — The frequency at which the modulus of the common-emitter small-signal short-circuit forward current transfer ratio, $|h_{21e}|$, has decreased to unity.

f_T — The product of the modulus of the common-emitter small-signal short-circuit forward current transfer ratio, $|h_{21e}|$, multiplied by the frequency of measurement when this latter is sufficiently high so that the modulus of h_{21e} is decreasing with a slope approximately 6 decibels per octave.

Note: This is the frequency at which the modulus of h_{21e} is extrapolated to unity.

h_{21B}, h_{21E}, h_{21C}, h_{FB}, h_{FE}, h_{FC} — The static value of the short-circuit forward current transfer ratio.

Note: Use of the symbols α_{FB}, α_{FC}, α_{FE} is not recommended.

h_{21b}, h_{21e}, h_{21c}, h_{fb}, h_{fe}, h_{fc} — The small-signal short-circuit forward current transfer ratio.

Note: Use of the symbols α_{fb}, α_{fc}, α_{fe} is not recommended.

h_{11B}, h_{11E}, h_{11C}, h_{IB}, h_{IE}, h_{IC} — The static value of the short-circuit input resistance.

h_{11b}, h_{11e}, h_{11c}, h_{ib}, h_{ie}, h_{ic} — The small-signal value of the short-circuit input impedance.

h_{22B}, h_{22E}, h_{22C}, h_{OB}, h_{OE}, h_{OC} — The static value of the open-circuit output conductance.

h_{22b}, h_{22e}, h_{22c}, h_{ob}, h_{oe}, h_{oc} — The small-signal value of the open-circuit output admittance.

h_{12B}, h_{12E}, h_{12C}, h_{RB}, h_{RE}, h_{RC} — The static value of the open-circuit reverse voltage transfer ratio.

h_{12b}, h_{12e}, h_{12c}, h_{rb}, h_{re}, h_{rc} — The small-signal value of the open-circuit reverse voltage transfer ratio.

$Re(h_{11b})$, $Re(h_{21b})$, $Re(h_{22b})$ — Real part of the small-signal value of the parameter within the parenthesis.

$Im(h_{11b})$, $Im(h_{21b})$, $Im(h_{22b})$ — Imaginary part of the small-signal value of the parameter within the parenthesis.

I_{FO}, I_{RO} — The current through the collector junction in a PNPN type switch when the switch is in the forward (reverse) blocking state and the gate terminal, if any, is open-circuited.

I_{AGO}, I_{GAO}, I_{GKO}, I_{KGO}, I_{CBO}, I_{CEO}, I_{EBO}, I_{ECO}, I_{BEO}, I_{BCO} — The current into the terminal indicated by the first subscript when it is biased in the reverse direction with respect to the reference terminal and the other terminal is open-circuited.

I_{FS}, I_{RS} — The current through the collector junction in a PNPN type switch when it is in the forward (reverse) blocking state and the gate terminal is short-circuited to the terminal of the adjacent region.

I_{AGS}, I_{GKSG}, I_{KGS}, I_{GASG}, I_{CBS}, I_{CES}, I_{EBS}, I_{ECS}, I_{BES}, I_{BCS} — The current into the terminal indicated by the first subscript when it is biased in the reverse direction with respect to the reference terminal and the other terminal is short-circuited to the terminal indicated by the subscript following the subscript S.

Note: When the last subscript is omitted, the other terminal is short-circuited to the reference terminal.

I_{FX}, I_{RX} — The current through the collector junction in a PNPN type switch when the switch is in the forward (reverse) blocking state and the gate terminal is returned to the terminal of the adjacent region through a stated impedance and/or bias voltage.

Note: When the return is through a resistance, the subscript "X" should be replaced by the subscript "R." When the return is through a stated bias voltage, the subscript "X" should be replaced by the subscript "V."

I_{AGX}, I_{GKXG}, I_{KGX}, I_{GAXG}, I_{CBX}, I_{CEX}, I_{EBX}, I_{ECX}, I_{BEX}, I_{BCX} — The current into the terminal indicated by the first subscript when it is biased in the reverse direction with respect to the reference terminal and the other terminal is returned to the terminal indicated by the subscript following the subscript "X" through a stated impedance and/or bias voltage.

Note: When the last subscript is omitted, the other terminal is returned to the reference terminal. When the return is through a resistance, the subscript "X" should be replaced by the subscript "R." When the return is through a stated bias voltage, the subscript "X" should be replaced by the subscript "V."