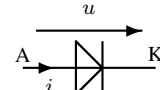
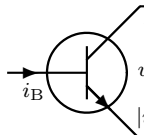
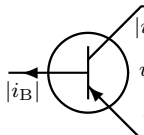
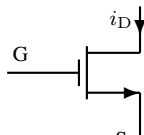
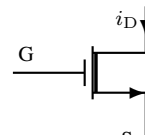
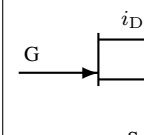
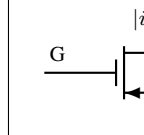
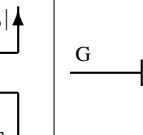
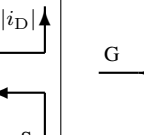


DIODI		<i>pn</i> - liitos APLAC VT=25.86496647m BV ≈ U _Z + 0,7 V Diode D 1 2 IS=10f N=1 VT BV = ∞	
Virtayhtälö	$i = I_S (e^{u/(nU_T)} - 1)$	$\frac{dI}{dT} \Big _{U \text{ on vakio}} \approx q \frac{1,2 V - U}{nkT^2} I$	$U_T = \frac{kT}{q}$
Jännite	$u = nU_T \ln \frac{i+I_S}{I_S} \approx 0,7V$	$\frac{dU}{dT} \Big _{I \text{ on vakio}} \approx n \frac{U-1,2 V}{T}$	$k = 1,380658 \cdot 10^{-23} \text{ J/K}$
Dynaaminen resistanssi	$r_d = \frac{nU_T}{I}$		$q = 1,60217733 \cdot 10^{-19} \text{ As}$

BJT	<i>npn-transistori</i>	<i>pnp-transistori</i>	
$u_{BE} = U_{BE} + u_{be}$ $u_{CE} = U_{CE} + u_{ce}$ $i_B = I_B + i_b$ $i_C = I_C + i_c$ $ i_E = i_B + i_C $			
	$u_{CE} = u_{BE} - u_{BC}$ Itseisarvomerkkejä ei tarvita, jos suunnat valitaan kuvan mukaisesti; IEC määrittelee virtojen suunnat sisäänpäin.	$u_{EC} = u_{EB} - u_{CB}$ Itseisarvomerkkejä ei tarvita, jos suunnat valitaan kuvan mukaisesti; IEC määrittelee virtojen suunnat sisäänpäin.	
Virtavahvistus	$u_{CE} \geq 0,3 \text{ V}; i_C = \beta i_B = \alpha i_E $	$\alpha = \alpha_F = \frac{\beta}{\beta+1} \quad \beta = \beta_F = \frac{\alpha}{1-\alpha}$	
Jännite	$u_{BE} = U_T \ln \frac{i_C+I_S}{I_S} \approx 0,7 \text{ V}$	$U_T = \frac{kT}{q}$	$u_{EB} = U_T \ln \frac{ i_C +I_S}{I_S} \approx 0,7 \text{ V}$
(Ebers-Moll) $i_C =$	$I_S (e^{u_{BE}/U_T} - 1) - \frac{I_S}{\alpha_R} (e^{u_{BC}/U_T} - 1)$	$I_S (e^{u_{EB}/U_T} - 1) - \frac{I_S}{\alpha_R} (e^{u_{CB}/U_T} - 1)$	
(Ebers-Moll) $i_B =$	$\frac{I_S}{\beta} (e^{u_{BE}/U_T} - 1) + \frac{I_S}{\beta_R} (e^{u_{BC}/U_T} - 1)$	$\frac{I_S}{\beta} (e^{u_{EB}/U_T} - 1) + \frac{I_S}{\beta_R} (e^{u_{CB}/U_T} - 1)$	
(Ebers-Moll) $ i_E =$	$\frac{I_S}{\alpha} (e^{u_{BE}/U_T} - 1) - I_S (e^{u_{BC}/U_T} - 1)$	$\frac{I_S}{\alpha} (e^{u_{EB}/U_T} - 1) - I_S (e^{u_{CB}/U_T} - 1)$	
(Ebers-Moll) B-E	$I_S e^{u_{BE}/U_T} = i_C + I_S + \frac{i_C - \beta i_B}{\beta \alpha_R - \beta - 1}$	$I_S e^{u_{EB}/U_T} = i_C + I_S + \frac{ i_C - \beta i_B }{\beta \alpha_R - \beta - 1}$	
(Ebers-Moll) B-C	$I_S e^{u_{BC}/U_T} = I_S + \alpha_R \frac{i_C - \beta i_B}{\beta \alpha_R - \beta - 1}$	$I_S e^{u_{CB}/U_T} = I_S + \alpha_R \frac{ i_C - \beta i_B }{\beta \alpha_R - \beta - 1}$	
Dyn. resistanssi, Early-j.	$U_A > 0$	$r_\pi = \frac{U_T}{ I_B } \quad r_e = \frac{U_T}{ I_E } \quad r_o = \frac{ U_A }{ I_C }$	$U_A < 0$
Transkonduktanssi	$g_m = \frac{ I_C }{U_T} = \frac{\beta}{r_\pi} \quad i_c = g_m u_\pi = g_m r_\pi i_b = \beta i_b \quad u_\pi = u_{be}$		
APLAC (E-M)	Trans T C B E NPN BETA=99 AF=0.99 AR=0.5 VT DIODE_BE IS N DIODE_BC IS N		

Avaus/Sulku/Liitos-FET	e-nmosfet	d-nmosfet	njfet	e-pmosfet	d-pmosfet	pjfet
$u_{GS} = U_{GS} + u_{gs}$ $u_{DS} = U_{DS} + u_{ds}$ $i_D = I_D + i_d$ $i_G = 0$						
Kynnys-/kuristusjännite	$U_t > 0$	$U_t < 0$	$U_t = U_P < 0$	$U_t < 0$	$U_t > 0$	$U_t = U_P > 0$
Johtavuusparametri <i>K</i>	$k \frac{W}{L} = \frac{1}{2} k' \frac{W}{L} = \frac{1}{2} \mu_n C_{OX} \frac{W}{L} \quad I_{DSS}/U_P^2$			$k \frac{W}{L} = \frac{1}{2} k' \frac{W}{L} = \frac{1}{2} \mu_p C_{OX} \frac{W}{L} \quad I_{DSS}/U_P^2$		
Saturaatioalue (SAT)	$u_{DS} \geq u_{GS} - U_t$			$u_{DS} \leq u_{GS} - U_t$		
Triodialue (TRI)	$u_{DS} \leq u_{GS} - U_t$			$u_{DS} \geq u_{GS} - U_t$		
Sulkualue ($i_D = 0$)	$u_{GS} \leq U_t$			$u_{GS} \geq U_t$		
Johtavuustila	$u_{GS} \geq U_t$			$u_{GS} \leq U_t$		
Kanavan jännite	$u_{DS} \geq 0$			$u_{DS} \leq 0$		
SAT-alue	$i_G = 0$	$ i_D = i_S = K(u_{GS} - U_t)^2 (1 + \lambda u_{DS})$		$\lambda = \frac{1}{U_A}$	Huom. suunta yllä	
TRI-alue	$i_G = 0$	$ i_D = i_S = K [2(u_{GS} - U_t)u_{DS} - u_{DS}^2]$			Huom. suunta yllä	
Ohminen alue	$i_G = 0$	$ i_D = i_S = \frac{ u_{DS} }{r_{DS}} \approx 2K(u_{GS} - U_t)u_{DS}$			kun $ u_{DS} $ on pieni	
Transkondukt., Early-j.	$U_A > 0$	$g_m = 2K U_{GS} - U_t = 2\sqrt{K I_D }$		$r_o \approx \frac{ U_A }{ I_D }$	$U_A < 0$	
APLAC (enh./depl.)	Mosfet Q D G S B N(P) L=0.1m W=0.1m KP UO ($\mu_{n(p)}/\text{[cm}^2/\text{Vs})$) COX VTO LAMBDA=0 $K = \frac{1}{2} kP \frac{W}{L}$					
APLAC (jfet)	Jfet Q D G S N(P) VTO=-2 LAMBDA=0 BETA (= K)					