

FIGURES FOR CHAPTER 7

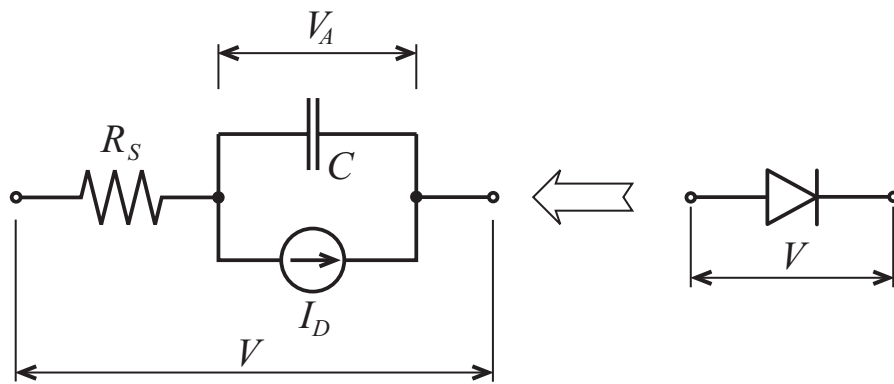
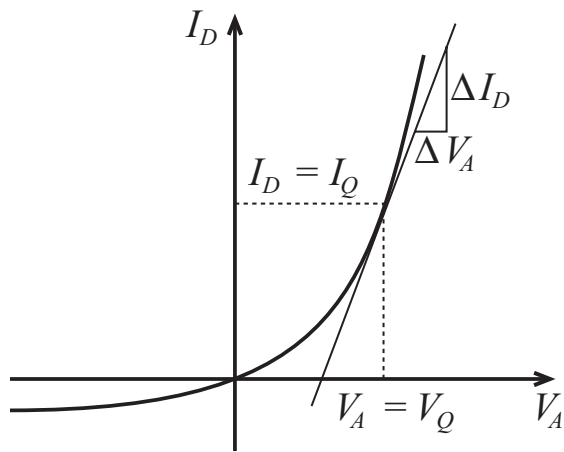


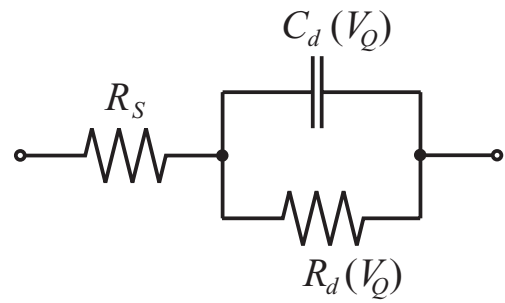
Figure 7-1 Large-scale diode model.

Table 7-1 Diode model parameters and their corresponding SPICE parameters

Symbol	SPICE	Description	Typical values
I_S	IS	saturation current	1 fA–10 μ A
n	N	emission coefficient	1
τ_T	TT	transit time	5 ps–500 μ s
R_S	RS	ohmic resistance	0.1–20 Ω
V_{diff}	VJ	barrier voltage	0.6–0.8 V (<i>pn</i>) 0.5–0.6 V (Schottky)
C_{J0}	CJ0	zero-bias junction capacitance	5–50 pF (<i>pn</i>) 0.2–5 pF (Schottky)
m	M	grading coefficient	0.2–0.5
W_g	EG	bandgap energy	1.11 eV (Si) 0.69 eV (Si-Schottky)
p_t	XTI	saturation current temperature coefficient	3 (<i>pn</i>) 2 (Schottky)



(a) tangent approximation at Q-point



(b) linear circuit model.

Figure 7-2 Small-signal diode model.

Table 7-2 Diode model parameters for different temperatures

$T, ^\circ\text{K}$	250	300	350	400
$W_g(T), \text{eV}$	1.128	1.115	1.101	1.086
$I_s(T), \text{A}$	5.1×10^{-19}	5.0×10^{-15}	3.3×10^{-12}	3.8×10^{-10}
V_Q, V	0.979	0.898	0.821	0.748
R_d, Ω	0.5	0.6	0.7	0.8
C_d, pF	999.5	832.9	713.9	624.7

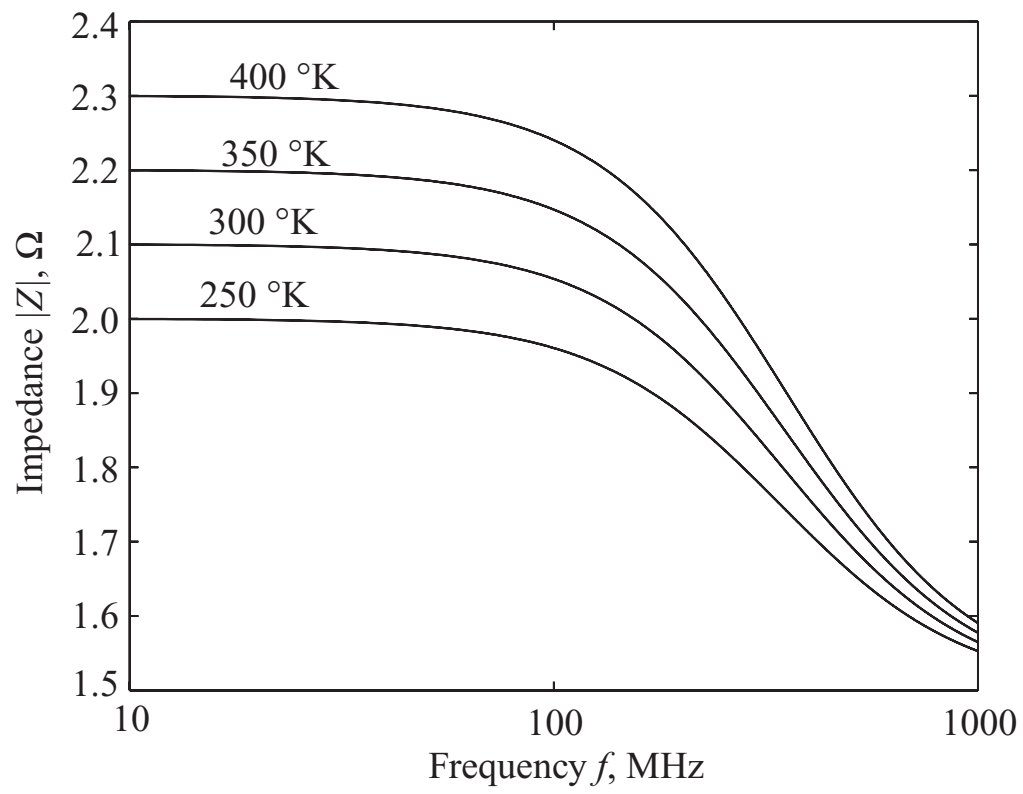
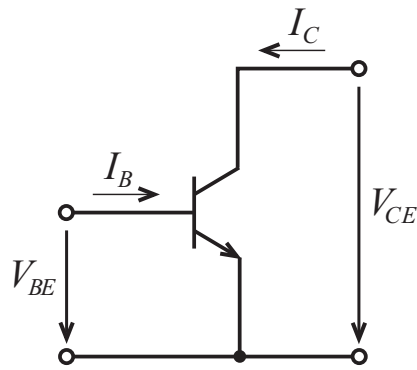
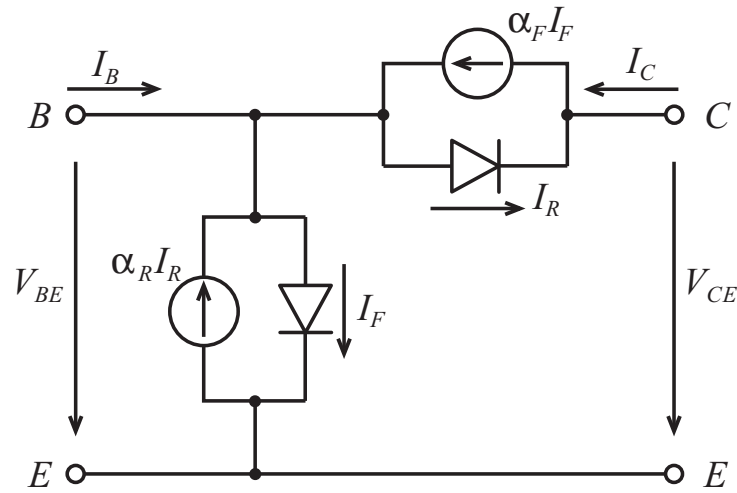


Figure 7-3 Frequency behavior of the diode impedance for different junction temperatures.



(a) Voltage and current convention for *npn* transistor



(b) Ebers-Moll circuit model

Figure 7-4 Large-signal Ebers-Moll circuit model.

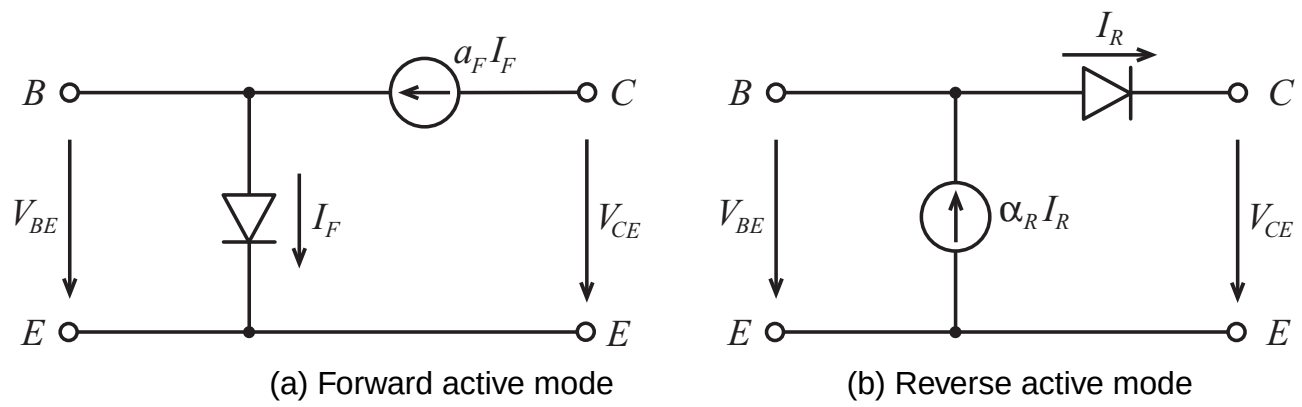
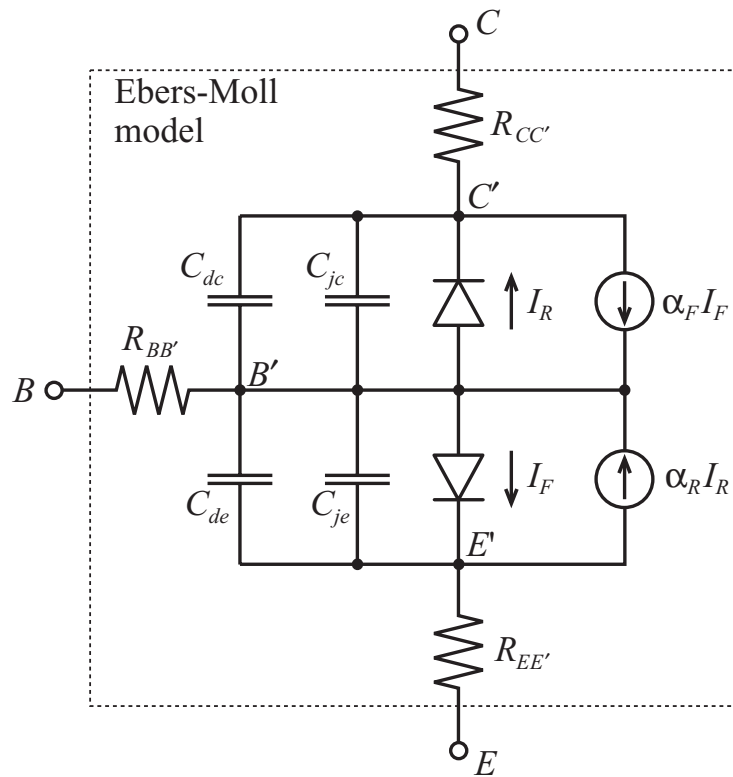
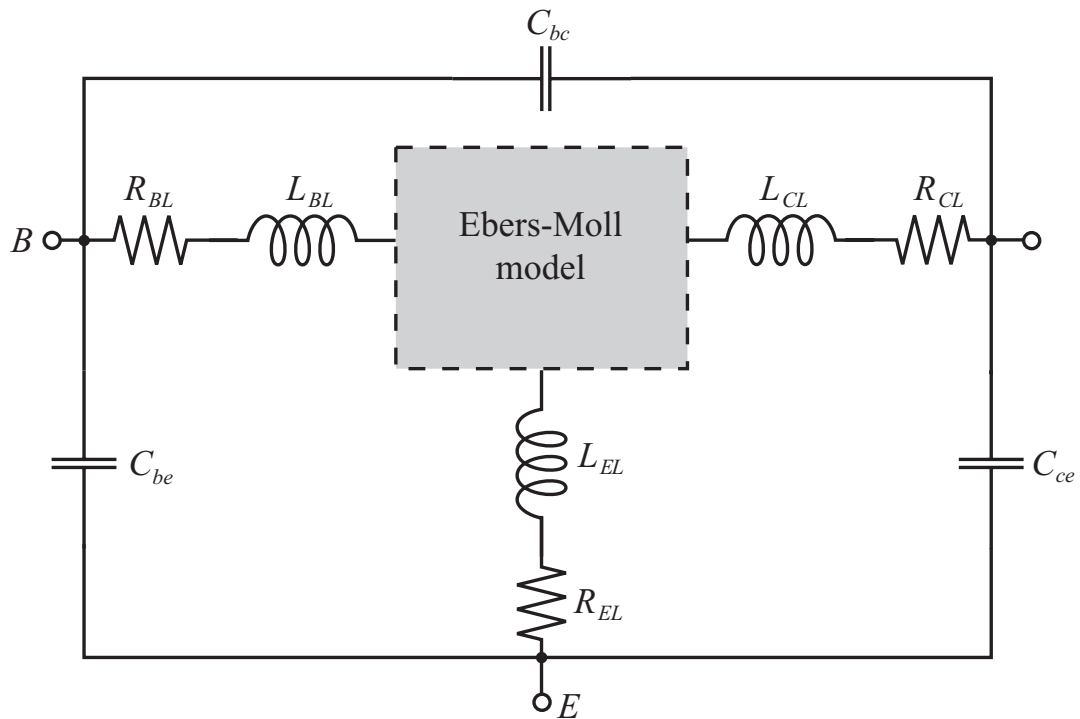


Figure 7-5 Simplified Ebers-Moll equations for forward and reverse active modes.



(a) Dynamic Ebers-Moll chip model



(b) RF model with parasitic terminal effects

Figure 7-6 Dynamic Ebers-Moll model and parasitic element refinements.

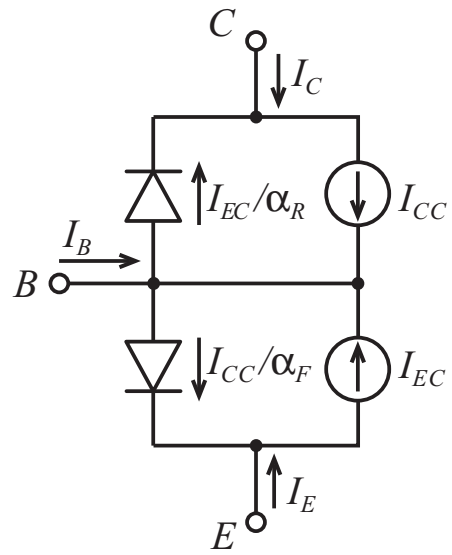


Figure 7-7 Transport representation of static Ebers-Moll injection model.

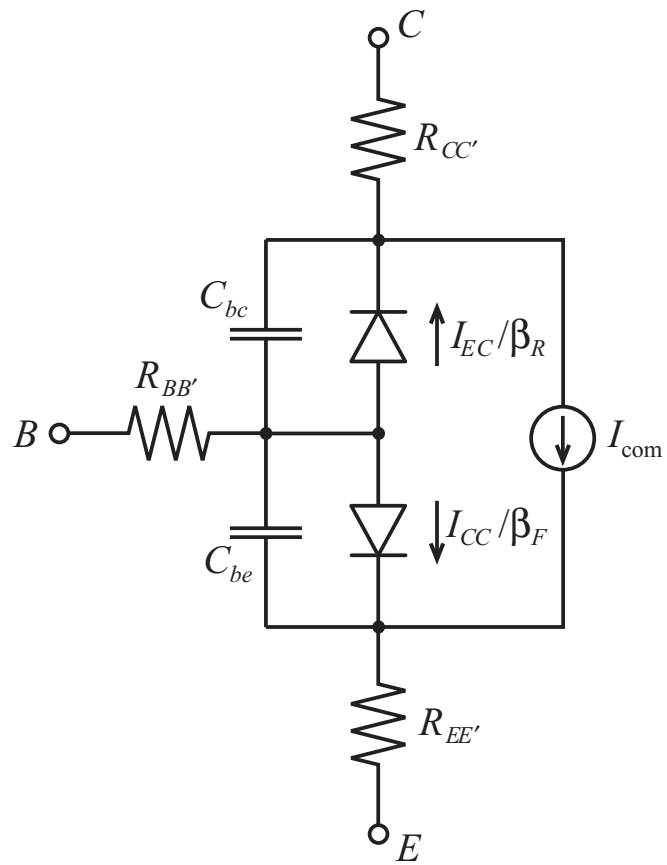


Figure 7-8 Dynamic Ebers-Moll transport model with single current source.

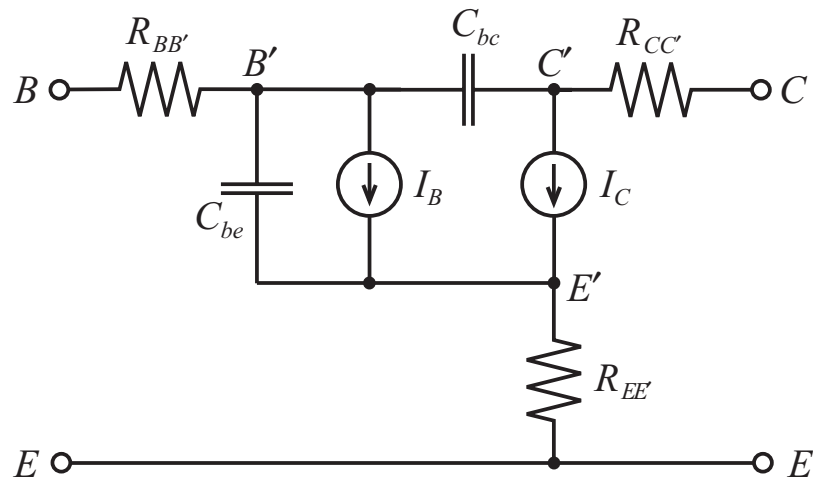


Figure 7-9 Large-signal BJT model in forward active mode.

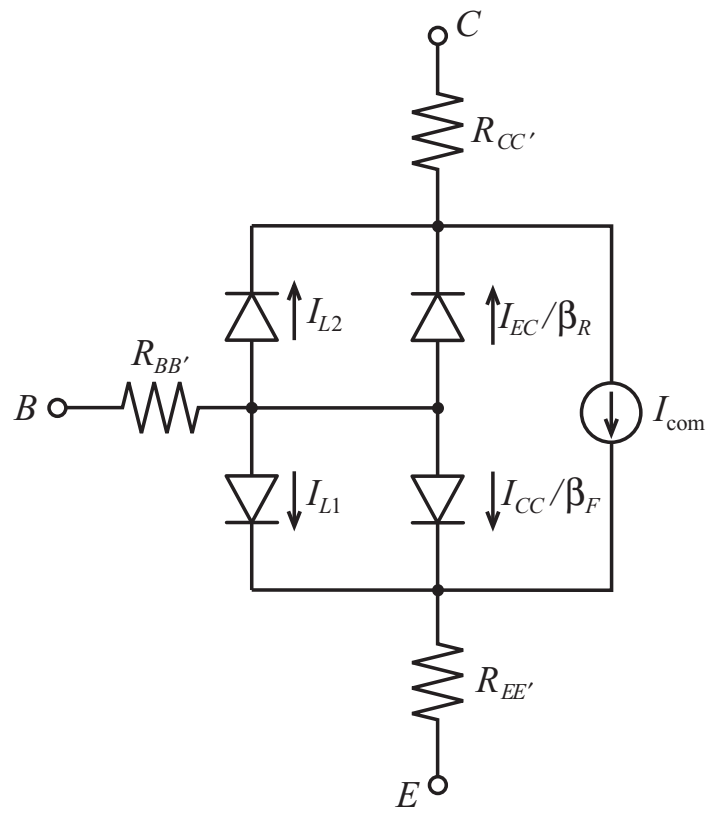


Figure 7-10 Static Gummel-Poon model.

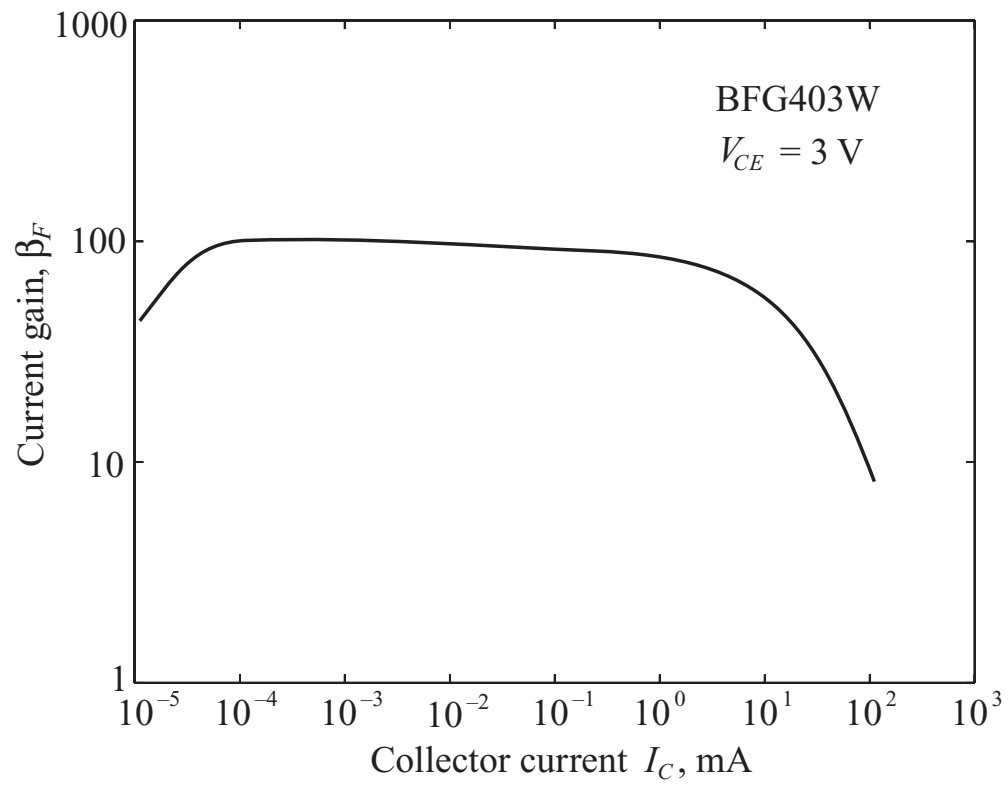


Figure 7-11 Typical dependency of β_F on the collector current I_C for a fixed collector-emitter voltage V_{CE} .

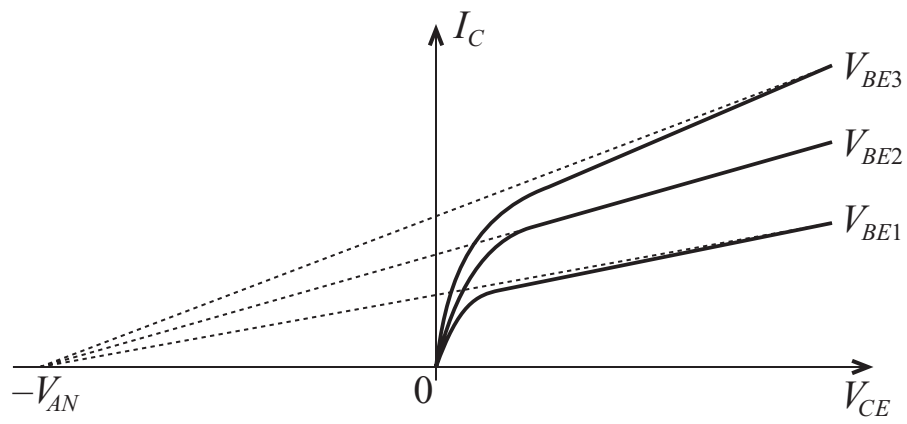


Figure 7-12 Collector current dependence on V_{CE} and its approximation through the Early voltage V_{AN} .

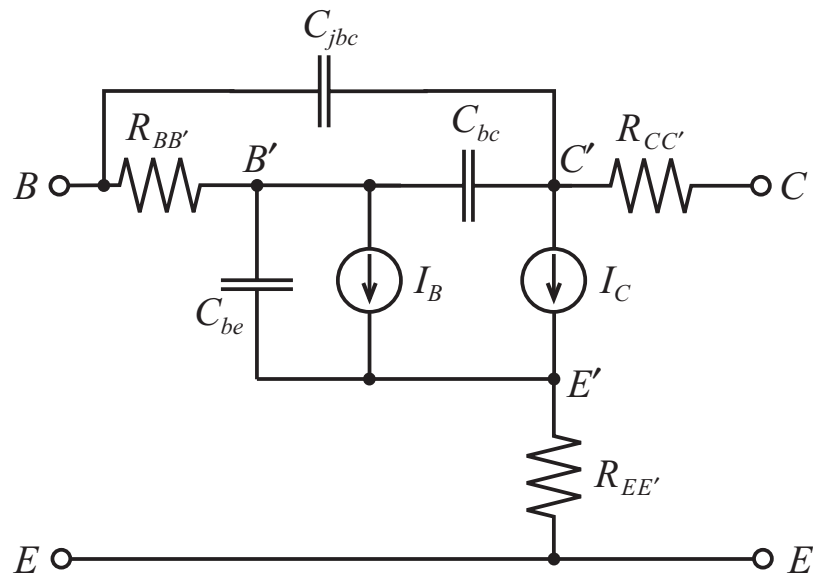


Figure 7-13 Large-signal Gummel-Poon model in normal active mode.

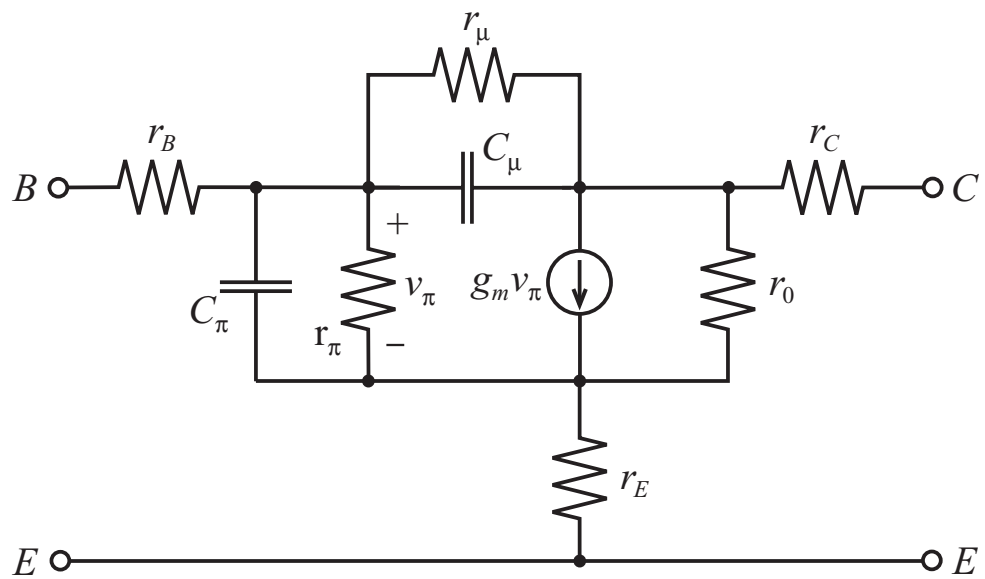


Figure 7-14 Small-signal hybrid- π Ebers-Moll BJT model.

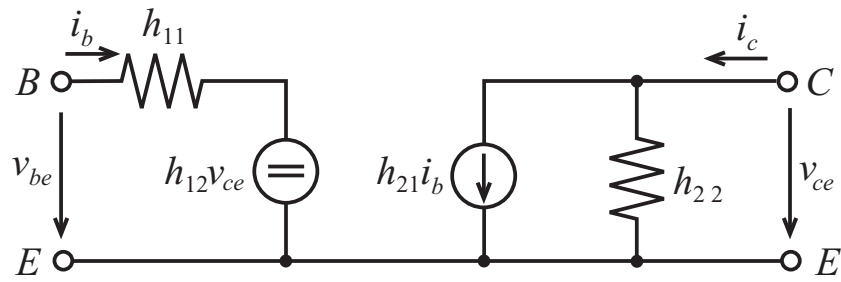


Figure 7-15 Generic h -parameter BJT representation with two sources.

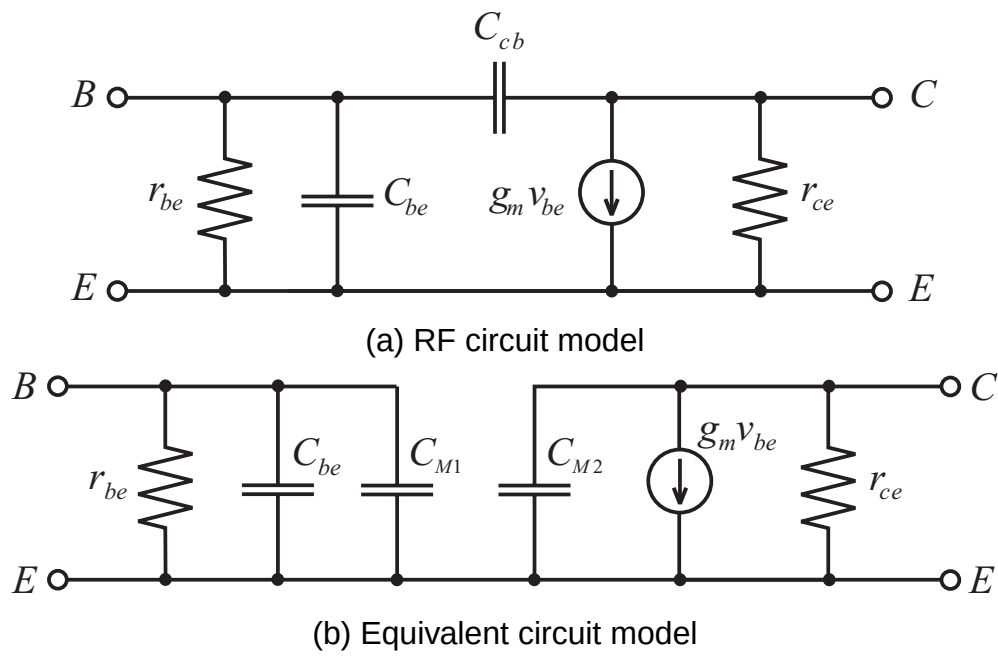
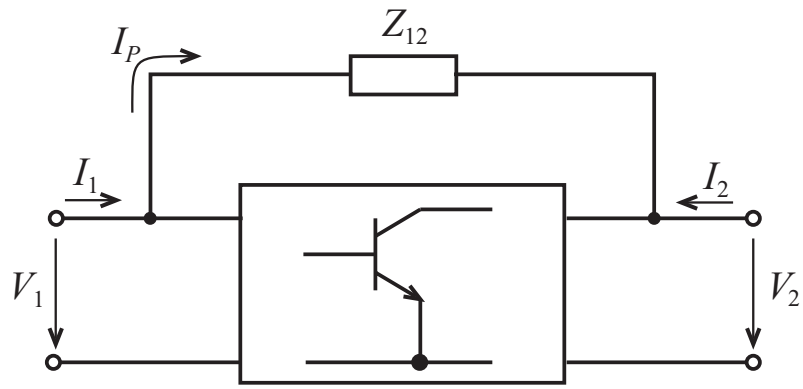
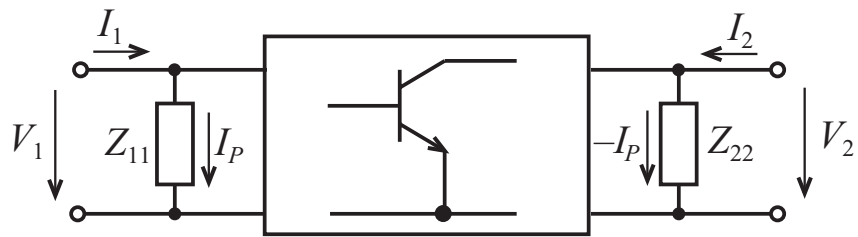


Figure 7-16 RF small-signal circuit model and converted circuit model using the Miller effect.

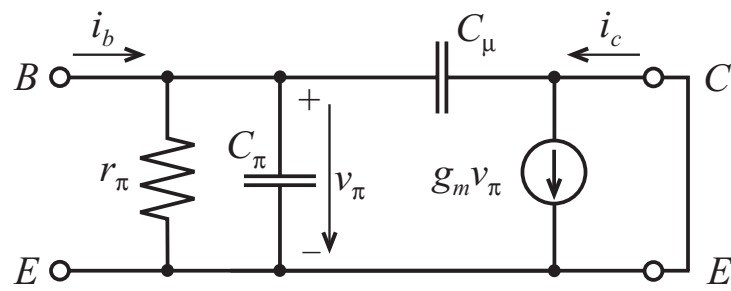


(a) Circuit with feedback impedance Z_{12}

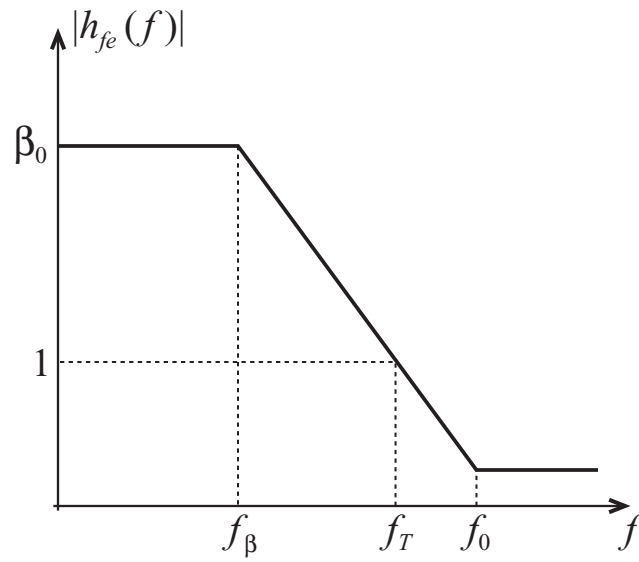


(b) Equivalent form

Figure 7-17 Miller transformation of feedback impedance.



(a) Short-circuit hybrid- π model



(b) Amplification versus frequency behavior

Figure 7-18 Short-circuit current gain of BJT model.

Table 7-3 Parameters of the BJT transistor

Symbol	Description	Typical value
β_F	forward current gain	145
I_S	saturation current	5.5 fA
V_{AN}	forward Early voltage	30 V
τ_F	forward transition time	4 ps
C_{JC0}	base-collector junction capacitance at zero applied junction voltage	16 fF
C_{JE0}	base-emitter junction capacitance at zero applied junction voltage	37 fF
m_C	collector capacitance grading coefficient	0.2
m_E	emitter capacitance grading coefficient	0.35
$V_{\text{diff}_{BE}}$	base-emitter diffusion potential	0.9 V
$V_{\text{diff}_{BC}}$	base-collector diffusion potential	0.6 V
r_B	base body resistance	125 Ω
r_C	collector body resistance	15 Ω
r_E	emitter body resistance	1.5 Ω
L_B	base lead inductance	1.1 nH
L_C	collector lead inductance	1.1 nH
L_E	emitter lead inductance	0.5 nH

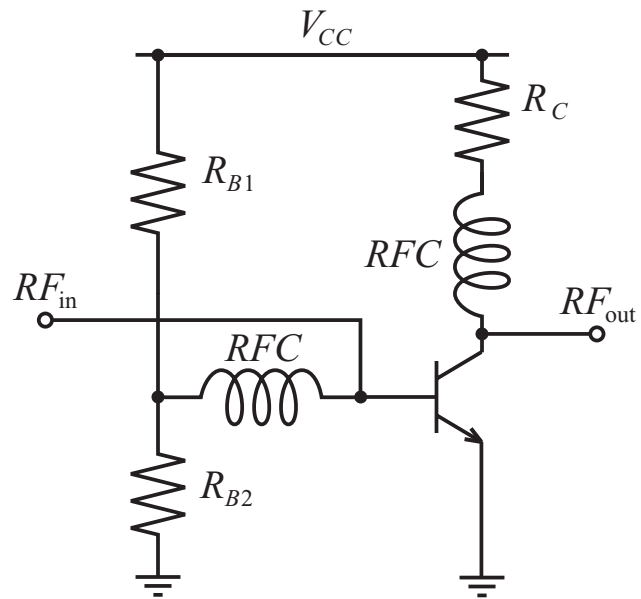


Figure 7-19 Biasing a BJT in common-emitter configuration.

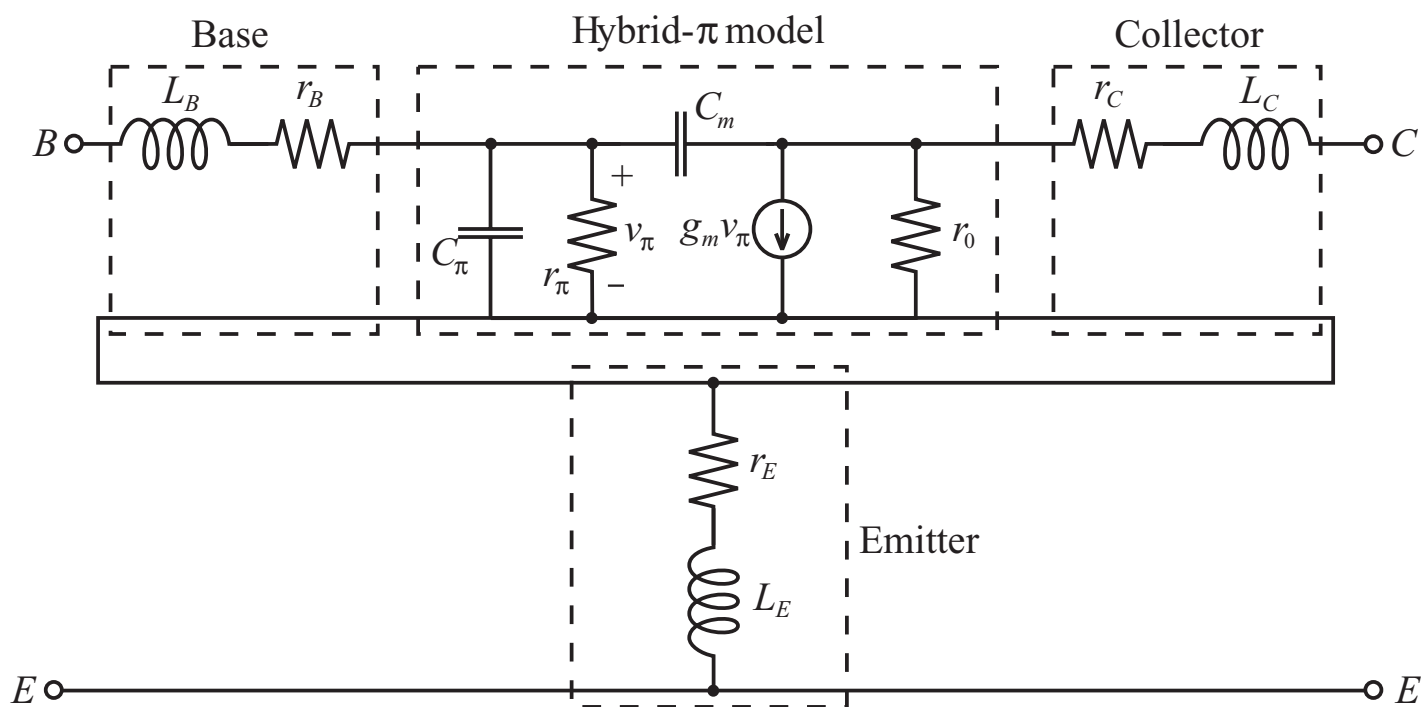
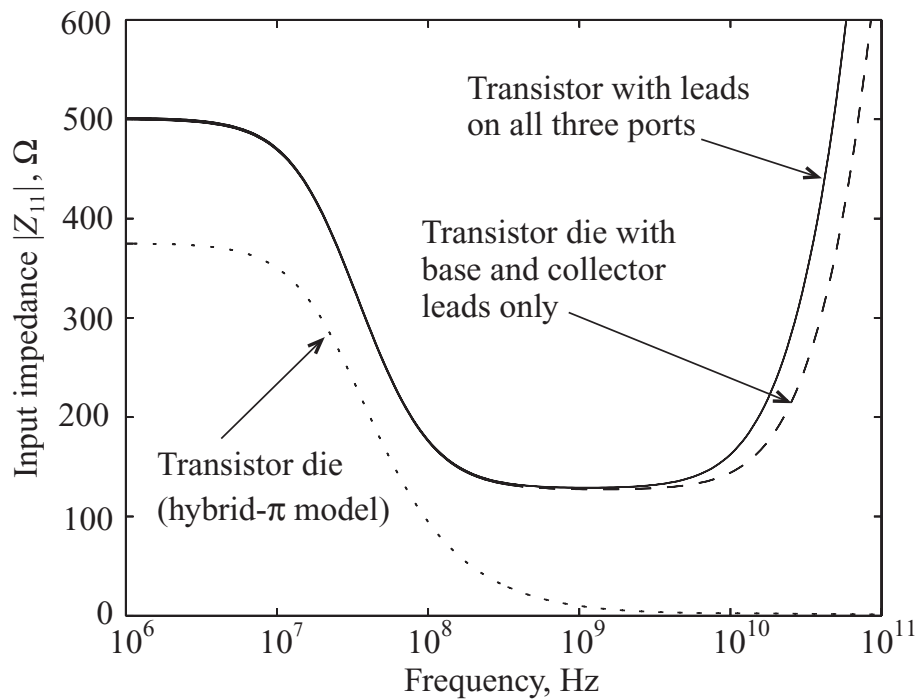
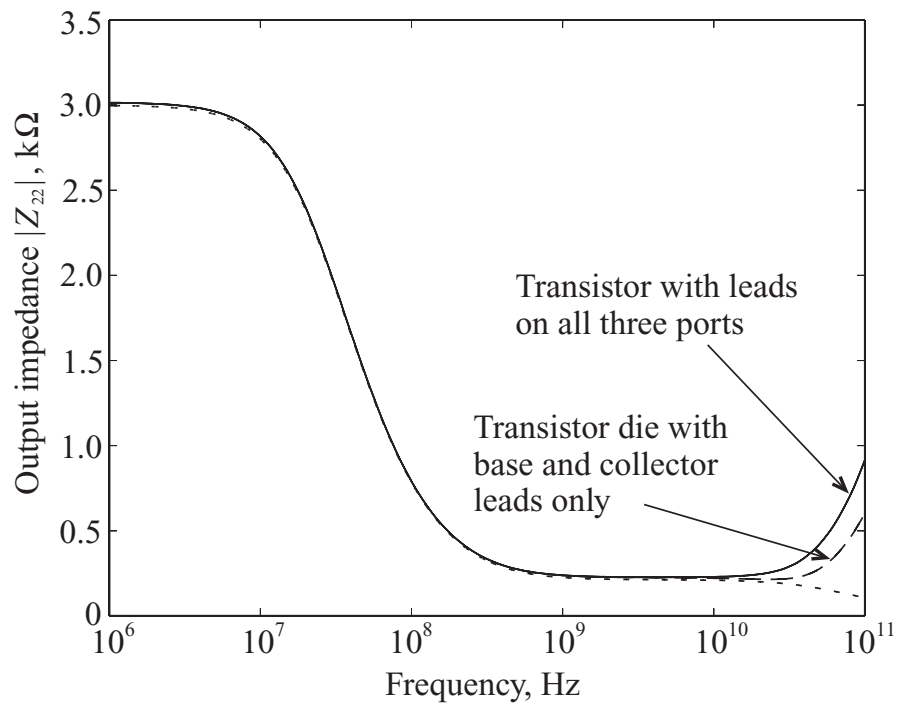


Figure 7-20 Complete transistor model divided into four two-port networks.



(a) Input impedance of the transistor



(b) Output impedance of the transistor

Figure 7-21 Input and output impedances as a function of frequency.

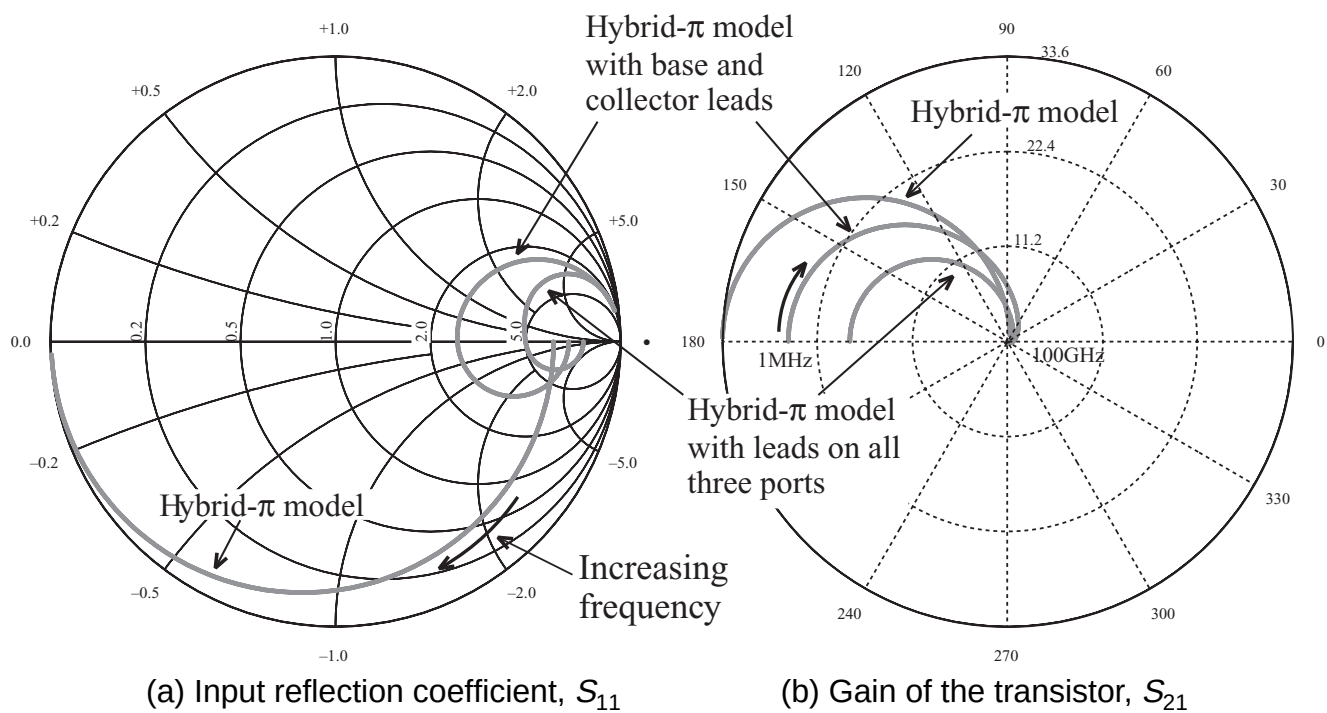


Figure 7-22 S_{11} and S_{21} responses of a BJT for various model configurations.

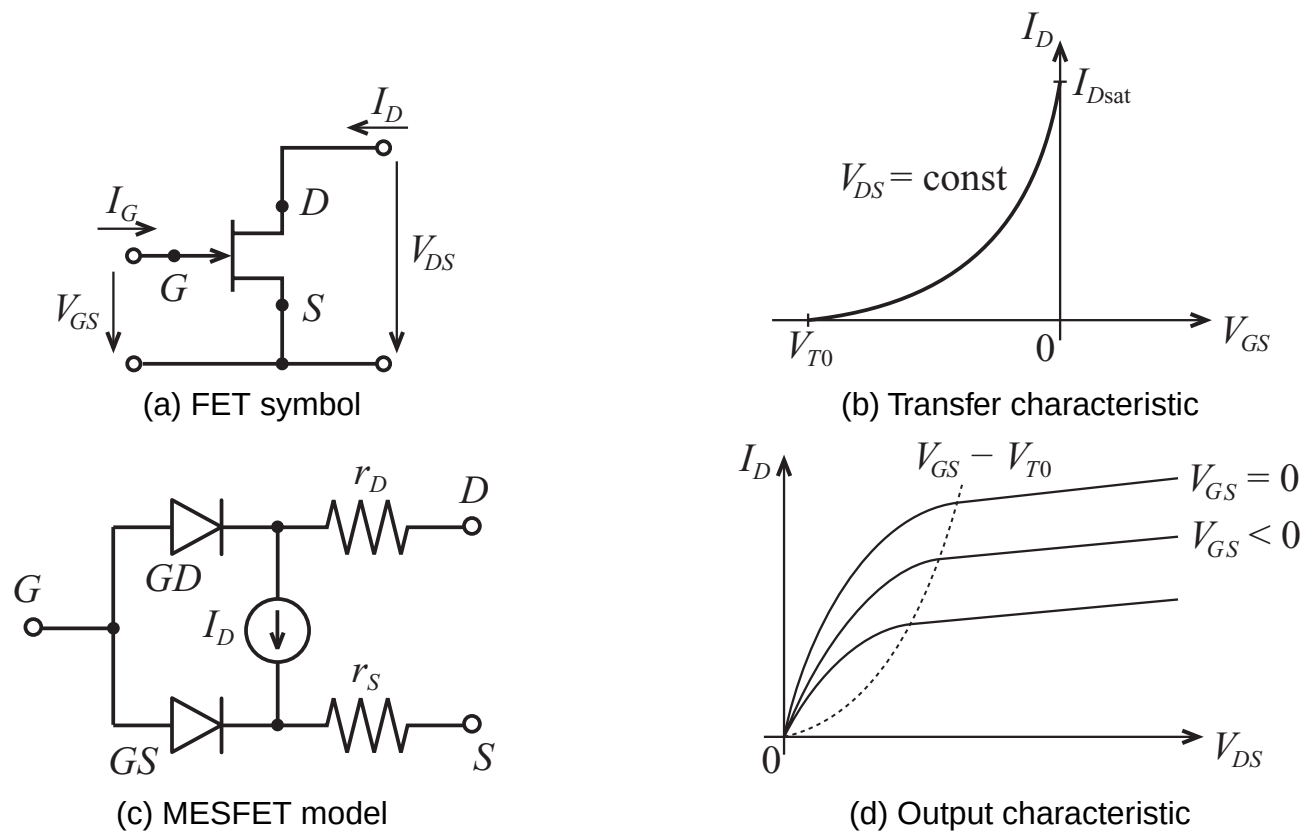


Figure 7-23 Static n -channel MESFET model.

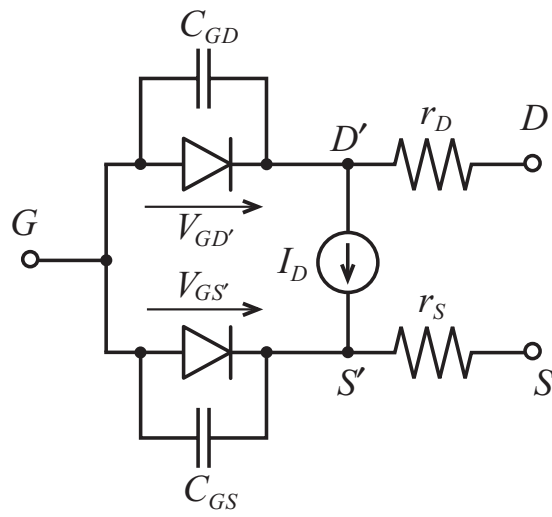
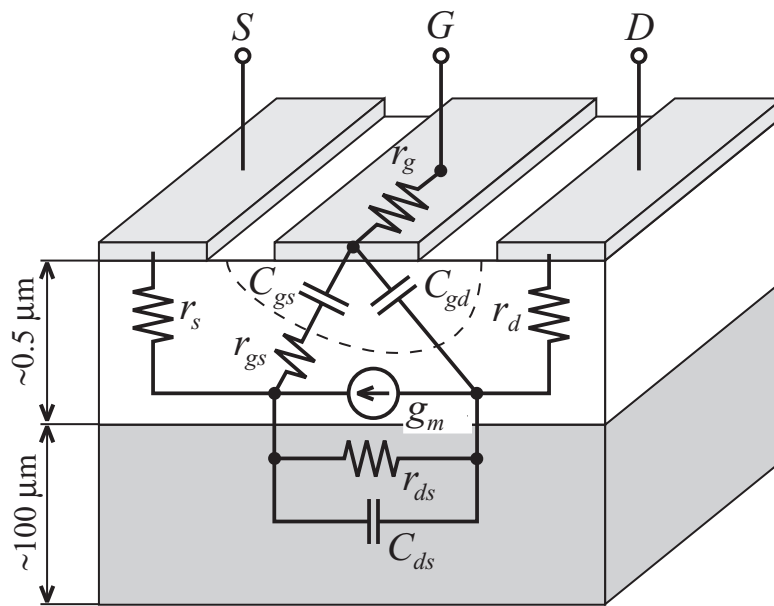


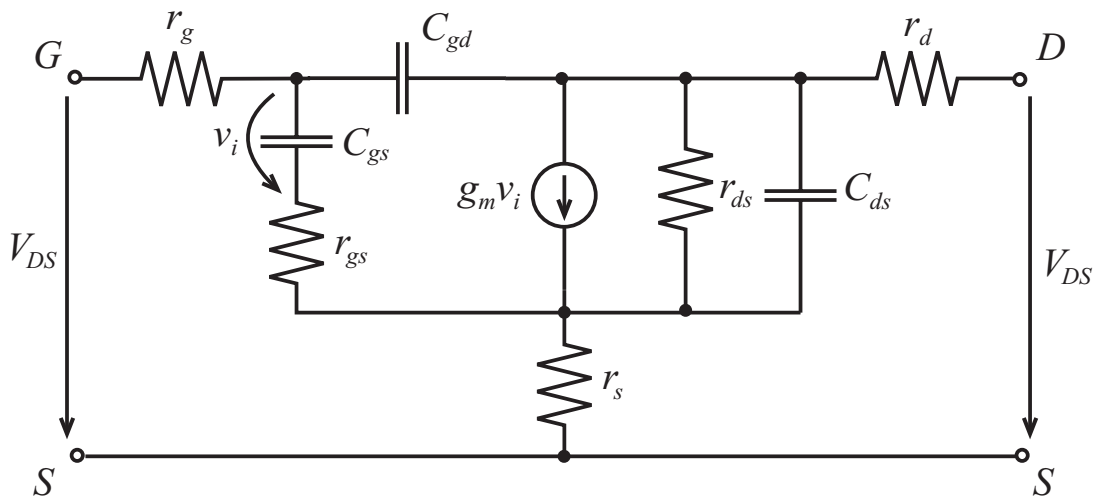
Figure 7-24 Dynamic FET model.

Table 7-4 SPICE modeling parameters for a MESFET

Symbol	SPICE	Description
V_{T0}	VTO	Threshold voltage
λ	LAMBDA	Channel-length modulation coefficient
β	BETA	Conduction parameter
C_{GD}	CGD	Zero-bias gate-to-drain capacitance
C_{GS}	CGS	Zero-bias gate-to-source capacitance
r_D	RD	Drain resistance
r_S	RS	Source resistance



(a) Idealized MESFET device structure



(b) Circuit model

Figure 7-25 Small-signal MESFET model.

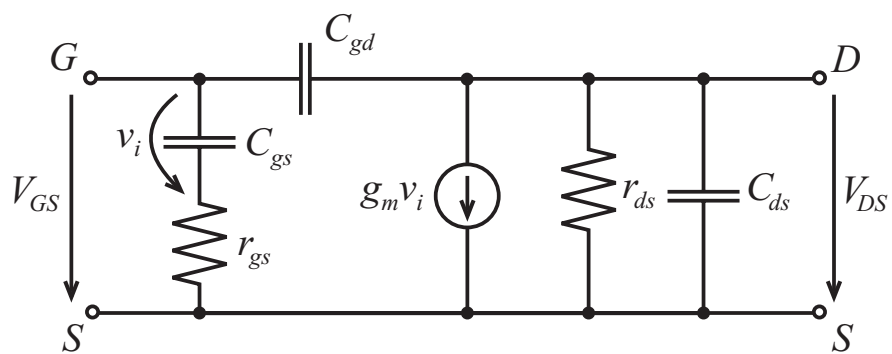


Figure 7-26 High-frequency FET model.

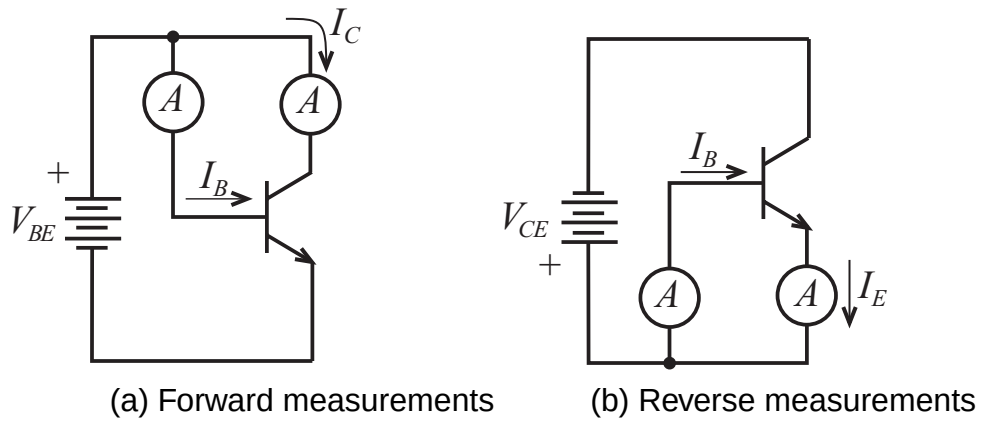


Figure 7-27 Forward and reverse measurements to determine Ebers-Moll BJT model parameters.

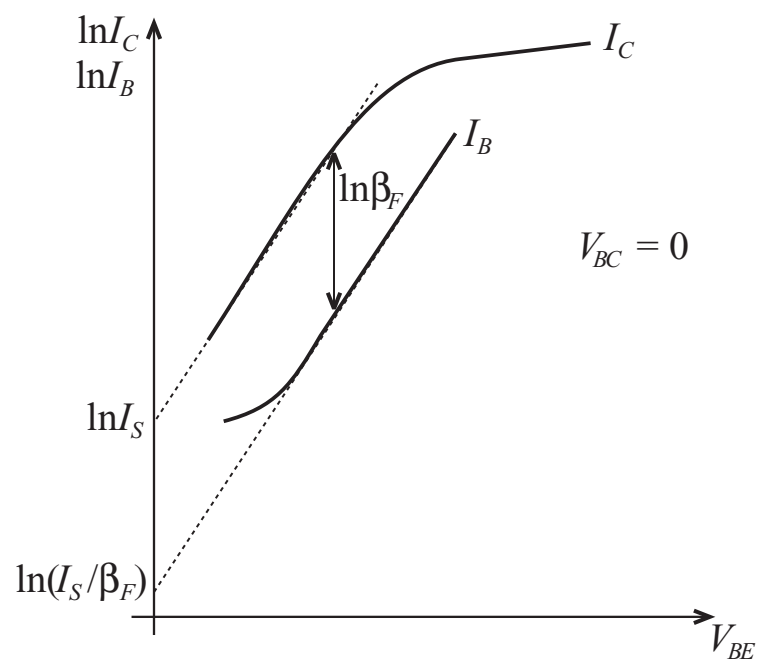


Figure 7-28 I_C and I_B versus V_{BE} .

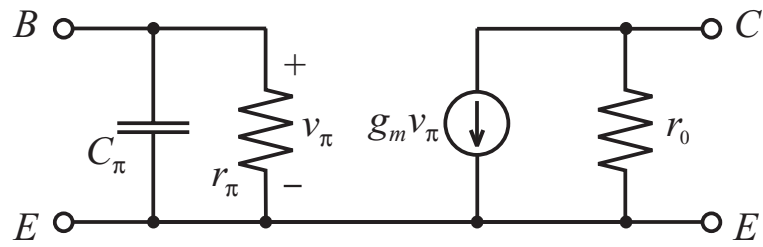


Figure 7-29 Small-signal, low-frequency h -parameter representation.

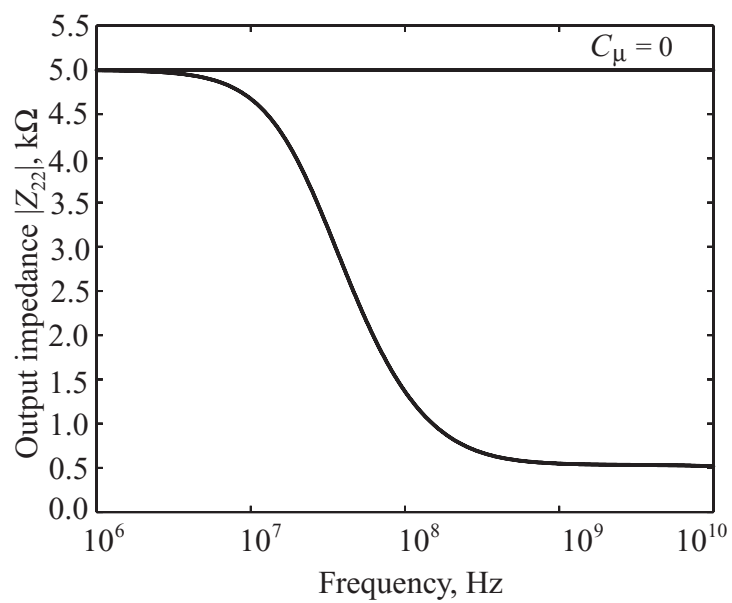
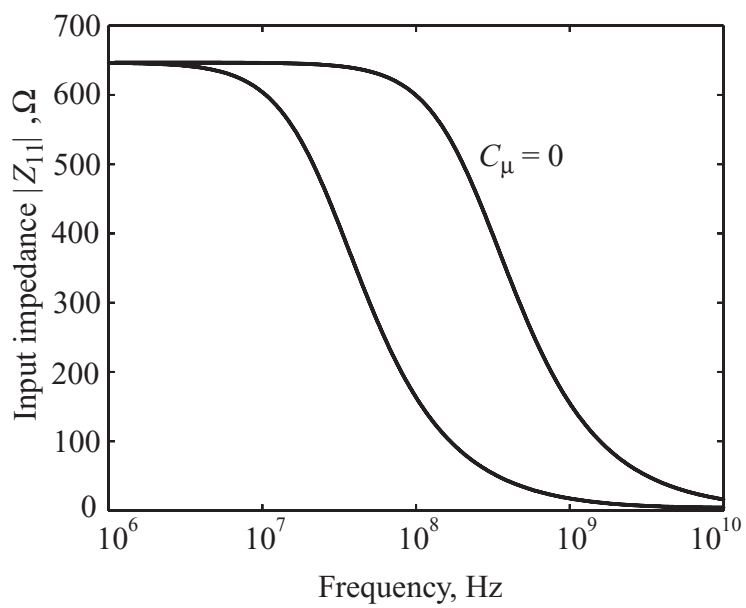
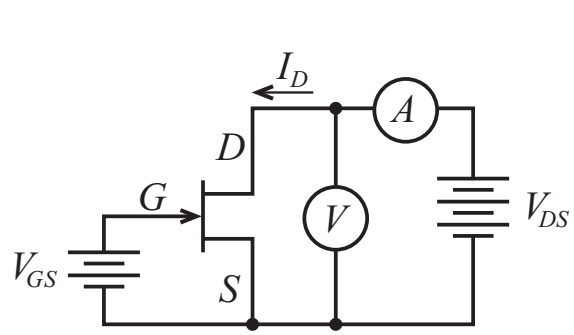
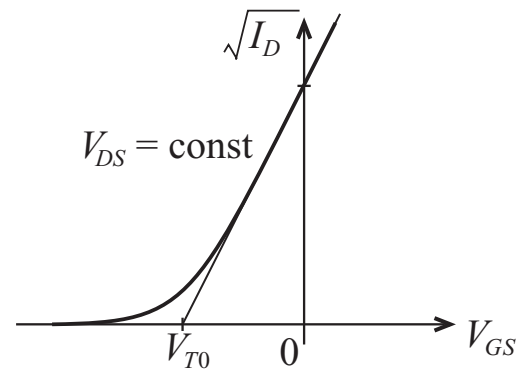


Figure 7-30 Input and output impedances with and without feedback.



(a) Measurement arrangement



(b) I_D versus V_{GS} transfer characteristic

Figure 7-31 Generic measurement arrangement and transfer characteristics in saturation region.

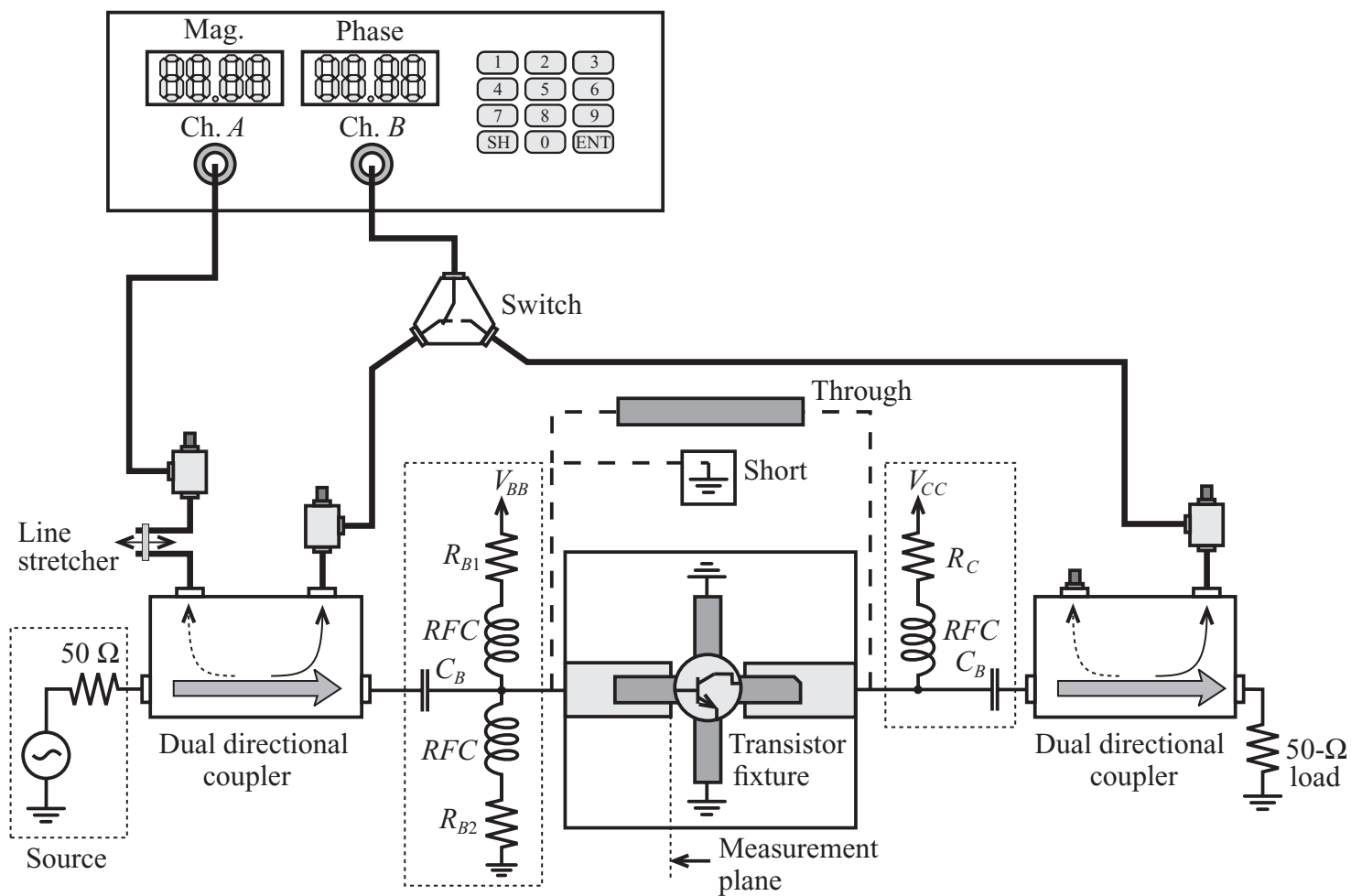


Figure 7-32 Recording of S-parameters with a vector voltmeter.

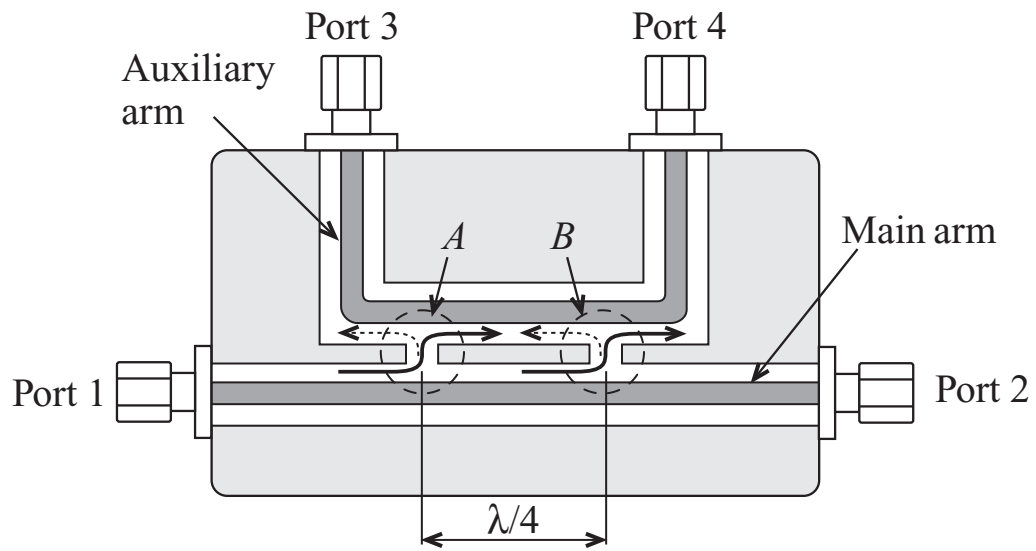


Figure 7-33 Cross-sectional view of directional coupler and signal path adjustment.

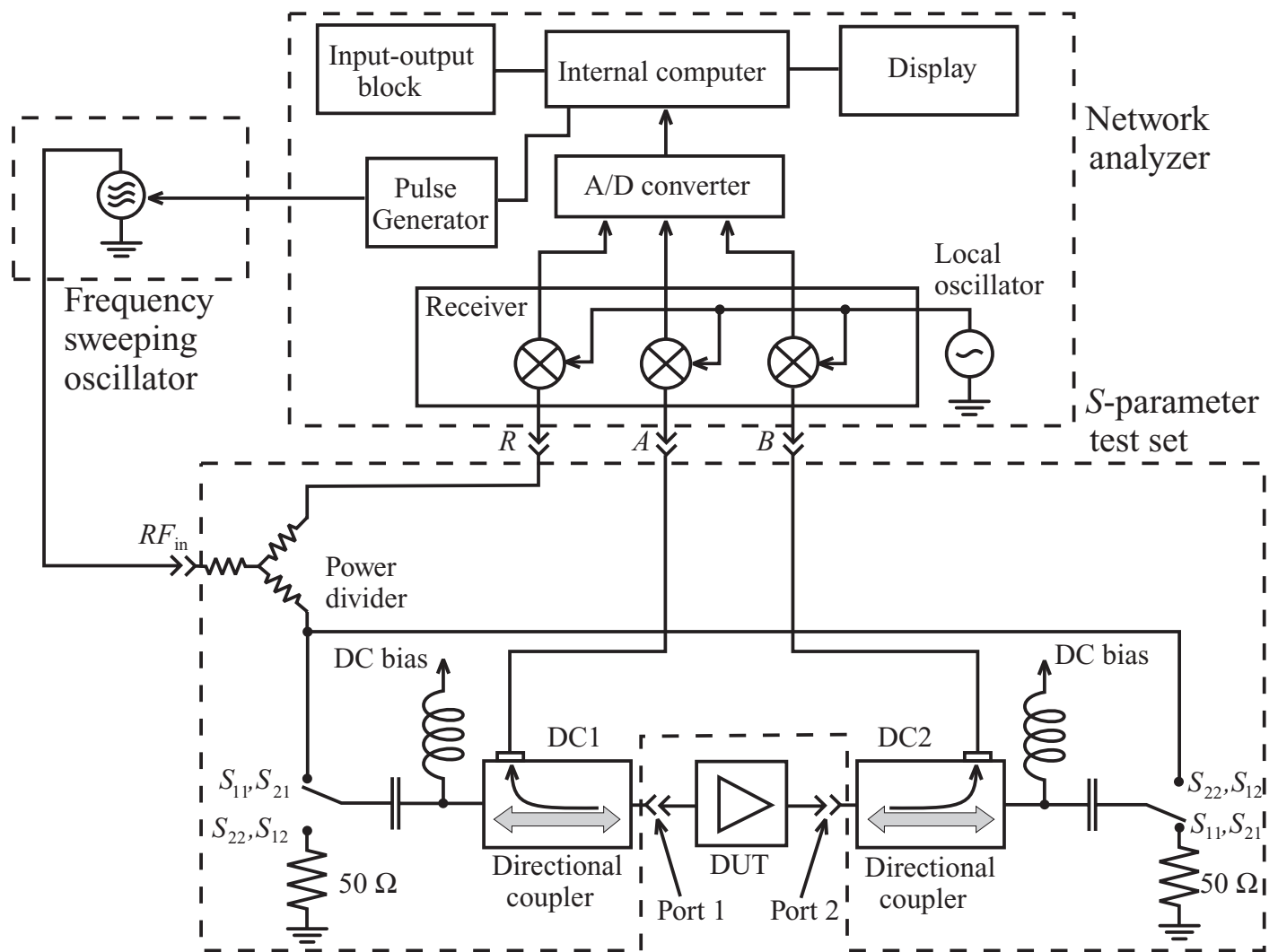


Figure 7-34 Block diagram of a network analyzer with S-parameter test set.