Scilab Textbook Companion for Electronic Devices And Circuits by B. Kumar And S. B. Jain[1]

Created by
Vivek Sharma
Bachelor of Engineering
Instrumentation Engineering
N. S. I. T.
College Teacher
Mr. Satish Chand Tiwari
Cross-Checked by
TechPassion

July 31, 2019

[1]Funded by a grant from the National Mission on Education through ICT, http://spoken-tutorial.org/NMEICT-Intro. This Textbook Companion and Scilab codes written in it can be downloaded from the "Textbook Companion Project" section at the website http://scilab.in

Book Description

Title: Electronic Devices And Circuits

Author: B. Kumar And S. B. Jain

Publisher: PHI Learning Pvt. Ltd., New Delhi

Edition: 1

Year: 2007

ISBN: 978-81-203-2981-2

Scilab numbering policy used in this document and the relation to the above book.

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

AP Appendix to Example(Scilab Code that is an Appednix to a particular Example of the above book)

For example, Exa 3.51 means solved example 3.51 of this book. Sec 2.3 means a scilab code whose theory is explained in Section 2.3 of the book.

Contents

List of Scilab Codes 4

1 Semiconductor Physics 6

2 The p n Junction Diode 10

3 Application of Diodes 23

4 Bipolar Junction Transistors 60

5 BJT Biasing and Stability 68

6 BJT Ampilifiers 81

7 Field Effect Transistors Characteristics and Biasing 89

8 FET Amplifiers 99

9 Multistage Amplifiers 103

10 Frequency Response of Amplifiers 112

11 Feedback Amplifiers 133

12 Oscillators 152

13 Power Amplifiers and Voltage Regulators **154**

List of Scilab Codes

Exa 1.1	Electron concentration	6
Exa 1.2	Intrinsic Silicon	6
Exa 1.3	Extrinsic n type Silicon	7
Exa 1.4	Contact difference of potential	8
Exa 1.7	Potential barrier	8
Exa 2.1	Ideal diodes	10
Exa 2.2	Change in diode voltage	11
Exa 2.3	Germanium diode	12
Exa 2.4	Diode current	13
Exa 2.5	Change in diode voltage	14
Exa 2.6	Value of R	14
Exa 2.7	Solving a circuit with diode	15
Exa 2.8	Output voltage	16
Exa 2.9	Circuit parameters	16
Exa 2.11	Solving a circuit with diode	17
Exa 2.12	Diode small signal model	19
Exa 2.13	Barrier capacitance	20
Exa 2.14	Change in capacitance	20
Exa 2.18	Diffusion length	21
Exa 2.19	Two diodes in series	22
Exa 3.4	Full wave rectifier	23
Exa 3.5	Full wave bridge rectifier	24
Exa 3.6	Centre tapped full wave rectifier	25
Exa 3.7	Full scale reading	26
Exa 3.8	Full scale reading	26
Exa 3.10	Minimum and maximum value of zener diode current	26
Exa 3.11	Safe voltage range	27

Exa 3.12	Voltage regulator	28
Exa 3.13	Range of load current	29
Exa 3.14	Zener diode	29
Exa 3.15	Zener diode regulator	30
Exa 3.16	Zener diode	31
Exa 3.17	Avalanche diode	31
Exa 3.18	Zener diode	32
Exa 3.19	Zener diode	33
Exa 3.20	Regulation range of zener diode	34
Exa 3.21.a	Clipping circuits	35
Exa 3.21.b	Range of load current	38
Exa 3.22	Transfer characteristics	42
Exa 3.23	Clipping circuit	43
Exa 3.24	Transfer characteristics	45
Exa 3.25	Clipping circuit	47
Exa 3.26	Range of load current	49
Exa 3.27	Range of load current	50
Exa 3.28	Transfer characteristics	51
Exa 3.29	Output voltage	53
Exa 3.30	EX30	54
Exa 3.31	Output waveform	55
Exa 3.32	Clamping circuit	56
Exa 3.33	Clamping circuit	57
Exa 4.1	Value of Collector Current	60
Exa 4.2	CE transistor	60
Exa 4.3	CE transistor	61
Exa 4.4	Region of Operation	62
Exa 4.5	Saturation region	63
Exa 4.6	Output voltages	64
Exa 4.7	pnp transistor	65
Exa 4.8	Solving a circuit with transistor	65
Exa 5.1	Fixed bias circuit	68
Exa 5.2	Determination of Q point	68
Exa 5.3	Self biased circuit	69
Exa 5.4	Amplifier circuit	70
Exa 5.5	Determination of Q point	71
Exa 5.6	Amplifier circuit	71
Exa 5.7	Amplifier circuit	72

Exa 5.8	Q point voltage	73
Exa 5.9	Stability factor	73
Exa 5.10	Self bias circuit	74
Exa 5.11	Stability factor	75
Exa 5.12	Variation of collector current	76
Exa 5.13	Current mirror	77
Exa 5.14	Widlar current source	78
Exa 5.15	Current Repeaters	78
Exa 5.16	Output current	79
Exa 5.17	Current mirror	79
Exa 5.18	Modified current mirror	80
Exa 6.2	Bipolar Junction Transistor	81
Exa 6.3	Hybrid h parameter model	81
Exa 6.4	Bipolar Junction Transistor	82
Exa 6.5	Simplified h parameter model	83
Exa 6.6	Hybrid pi model	84
Exa 6.7	CC amplifier	85
Exa 6.8	Voltage gain	86
Exa 6.9	Hybrid pi model	86
Exa 6.10	re model	87
Exa 7.1	Transfer curve of FET	89
Exa 7.2	NMOS transistor	89
Exa 7.3	n channel JFET	91
Exa 7.4	Self bias configuration	91
Exa 7.5	Operating point	93
Exa 7.6	n channel enhancement type MOSFET	95
Exa 7.7	Operating point of MOSFET	96
Exa 8.1	Transconductance	99
Exa 8.2	Fixed bias CS amplifier	99
Exa 8.3	Self bias CS amplifier	100
Exa 8.4	JFET source follower	100
Exa 8.5	Common gate JFET amplifier	101
Exa 8.6	E MOSFET amplifier	102
Exa 9.1	CE CC configuration	103
Exa 9.2	Two stage amplifier	104
Exa 9.3	CC CE composite pair	106
Exa 9.4	FET cascade	107
Exa 9.5	Three stage amplifier	107

Exa 9.6	FET and BJT cascade	109
Exa 9.7	Darlington emitter follower	109
Exa 9.8	Cascode circuit	110
Exa 10.1	Bode plots	112
Exa 10.2	Bode plots	116
Exa 10.3	Pole of transfer function	117
Exa 10.4	Low frequency response	118
Exa 10.5	Single pole model	118
Exa 10.7	Upper half power frequency	119
Exa 10.12	Dominant pole approximation	120
Exa 10.13	Cascode amplifier	122
Exa 10.15	Capacitances of transistor	123
Exa 10.16	Common emitter stage	123
Exa 10.17	Time constant method	124
Exa 10.18	Gain bandwidth product	125
Exa 10.19	Approximation of fH	126
Exa 10.20	Low and high 3 dB frequency	127
Exa 10.21	Dominant pole approximation	129
Exa 10.23	Time constant method	130
Exa 11.1	Feedback network	133
Exa 11.2	Amount of feedback	133
Exa 11.3	Second harmonic distortion	134
Exa 11.4	Closed loop parameters	135
Exa 11.5	Noise reduction	136
Exa 11.6	Non inverting configuration	136
Exa 11.7	Upper 3 dB frequency	137
Exa 11.9	Desensitivity	138
Exa 11.11	Transfer ratio	139
Exa 11.12	Gain with feedback	140
Exa 11.13	Transfer ratio	140
Exa 11.15	Small signal gain	141
Exa 11.16	Closed loop parameters	142
Exa 11.17	Feedback in MOSFETs	144
Exa 11.18	Open and closed loop gain	145
Exa 11.19	Closed loop parameters	146
Exa 11.20	Closed loop parameters	147
Exa 11.21	Voltage gain	149
Exa 11.22	Feedback in FETs	150

Exa 12.1	Phase shift oscillator	152
Exa 12.2	Wien Bridge oscillator	153
Exa 12.3	Hartley oscillator	153
Exa 13.1	Series fed amplifier	154
Exa 13.2	Transformer turn ratio	155
Exa 13.3	Class A amplifier	155
Exa 13.4	Class B push pull amplifier	155
Exa 13.5	Class B output stage	156
Exa 13.6	Thermal considerations	157

List of Figures

3.1 Clipping circuits 36
3.2 Clipping circuits 36
3.3 Range of load current 38
3.4 Range of load current 39
3.5 Transfer characteristics 41
3.6 Transfer characteristics 41
3.7 Clipping circuit 43
3.8 Clipping circuit 44
3.9 Transfer characteristics 45
3.10 Clipping circuit 46
3.11 Clipping circuit 47
3.12 Range of load current 48
3.13 Range of load current 49
3.14 Range of load current 51
3.15 Transfer characteristics 52
3.16 Output voltage 53
3.17 EX30 54
3.18 EX30 55
3.19 Output waveform 56
3.20 Clamping circuit 57
3.21 Clamping circuit 58

7.1 Transfer curve of FET 90

7.2 Self bias configuration 92
7.3 Operating point 93
7.4 n channel enhancement type MOSFET 95
7.5 Operating point of MOSFET 97

10.1 Bode plots 113
10.2 Bode plots 113
10.3 Bode plots 115
10.4 Bode plots 115

Chapter 1

Semiconductor Physics

Scilab code Exa 1.1 Electron concentration

```
// Example 1.1: Electron concentration
clc, clear
V=0.1; // Voltage in volts
I=5e-3; // Current in ampere
l_a=7e8; // Length to cross-sectional area ratio in
    metre inverse
mu=0.05; // Electron mobility in metre square per
    volt second
q=1.6e-19; // Charge on an electron in coulombs
n=(l_a*I)/(V*q*mu); //Electron concentration in
    inverse metres cube
n=n*1e-6; //Electron concentration in inverse
    centimetres cube
disp(n,"Electon concentration (cm^-3) = ");
```

Scilab code Exa 1.2 Intrinsic Silicon

```
// Example 1.2: Electric field intensity, Voltage
```

```
clc, clear
l=3e-3; // Length of the bar in metres
a=50*10*1e-12; // Cross-sectional area in metres
    square
I=2e-6; // Current in amperes
rho=2.3e3; // Resistivity in ohm metres
E=I*rho/a; // Electric field intensity in volt per
    metres
V=E*l; // Voltage across the bar in volt
disp(E,"Electic field intensity (V/m) = ");
disp(V,"Voltage across the bar (V) = ");
```

Scilab code Exa 1.3 `Extrinsic n type Silicon`

```
// Example 1.3: Electron concentration, Hole
    concentration, Conductivity, Voltage
clc, clear
l=3e-3; // Length on Si sample in metres
a=5e-9; // Cross-sectional area of Si sample in
    metres square
ND=5e20; // Donor concentration in inverse metres
    cube
I=2e-6; // Current flowing through the bar in
    amperes
ni=1.45e16; // Intrinsic carrier concentration in
    inverse metres cube
mu_n=0.15; // Mobility of electrons in metres square
     per volt second
q=1.6e-19; // Charge on an electron in coulombs
n=ND; // Electron concentration in inverese metres
    cube
p=ni*ni/n; // Hole concentration in inverese metres
    cube
sigma=q*n*mu_n;  // Conductivity of Si sample in
    inverse ohm metres
```

```
V=(I*l)/(a*sigma); // Voltage across the bar in
    volts
n=n*1e-6; // Electron concentration in inverese
    centimetres cube
p=p*1e-6; // Hole concentration in inverese
    centimetres cube
sigma=sigma*0.01; // Conductivity of Si sample in
    inverse ohm centimetres
disp(n,"Electron concentration (cm^-3) = ");
disp(p,"Hole concentration (cm^-3) = ");
disp(sigma,"Conductivity of Si sample (ohm^-1 cm^-1)
     = ");
disp(V,"Voltage across the bar (V) = ");
```

Scilab code Exa 1.4 Contact difference of potential

```
// Example 1.4: Contact difference of potential
clc, clear
N=5e22; // Number of acceptor or donor atoms per
    metres cube of step graded p-n junction
ni=1.45e16; // Intrinsic carrier concentration in
    inverse metres cube
VT=25e-3; // Voltage equivalent to temperatue at
    room temperature in volts
Vo=VT*log(N^2/ni^2); // Contact difference of
    potential in volts
Vo=Vo*1e3; // Contact difference of potential in
    milivolts
disp(Vo,"Contact difference of potential (mV) = ");
```

Scilab code Exa 1.7 Potential barrier

```
// Example 1.7: Potential barrier
```

```
clc, clear
rho_p=0.05; // Resistivity of p side of step-graded
    junction in ohm metres
rho_n=0.025; // Resistivity of n side of step-graded
     junction in ohm metres
mu_p=475e-4; // Mobility of holes in metres square
    per volt second
mu_n=1500e-4; // Mobility of holes in metres square
    per volt second
ni=1.45e16; // Intrinsic carrier concentration in
    atoms per metres cube
q=1.6e-19; // Charge on an electron in coulombs
VT=25e-3; // Voltage equivalent to temperatue at
    room temperature in volts
NA=1/(q*mu_p*rho_p); // Acceptor concentration in
    atoms per metres cube
ND=1/(q*mu_n*rho_n); // Donor concentration in atoms
     per metres cube
Vo=VT*log(NA*ND/ni^2); // Contact difference of
    potential in volts
Vo=Vo*1e3; // Contact difference of potential in
    milivolts
disp(Vo,"Contact difference of potential (mV) = ");
```

Chapter 2

The p n Junction Diode

Scilab code Exa 2.1 Ideal diodes

```
// Example 2.1: (a) I,Vo
//              (b) I,Vo
clc, clear

disp("Part (a)");
// Applying Thevnin's theorem at XX', in Fig. 2.5(a)
Vth=15*20e3/(10e3+20e3); // Thevnin equivalent
   voltage in volts
Zth=10e3*20e3/(10e3+20e3); // Thevnin equivalent
   resistance in ohms
// From the figure 2.5(c)
I=Vth/(Zth+20e3); // Labelled current in amperes
Vo=I*20e3; // Labelled voltage in volts
I=I*1e3; // Labelled current in miliamperes
disp(I,"Labelled current I (mA) = ");
disp(Vo,"Labelled voltage Vo (V) = ");

disp("Part (b)");
// Applying Thevnin's theorem at XX' and YY', in Fig
   . 2.5(b)
Vth1=15*10e3/(10e3+10e3); // Thevnin equivalent
```

```
voltage at XX' in volts
Zth1=10e3*10e3/(10e3+10e3); // Thevnin equivalent resistance at YY' in ohms
Vth2=5; // Thevnin equivalent voltage at YY' in volts
Zth2=5e3; // Thevnin equivalent resistance at YY' in ohms
// From the figure 2.5(d)
I=0; // Labelled current in amperes
Vo=5-7.5; // Labelled voltage in volts
disp(I,"Labelled current I = ");
disp(Vo,"Labelled voltage Vo (V) = ");
```

Scilab code Exa 2.2 Change in diode voltage

```
// Example 2.2: Change in diode voltage
clc, clear
ID1=1; // Let the initial diode current be 1 A
ID2=15*ID1; // Final diode current
VT=25e-3; // Voltage equivalent to temperatue at room temperature in volts
eta=1; // for Ge
deltaVD=eta*VT*log(ID2/ID1); // Change in diode voltage in volts
deltaVD=deltaVD*1e3; // Change in diode voltage in milivolts
disp(deltaVD,"Change in diode voltage (for Ge) (mV) = ");
eta=2; // for Si
deltaVD=eta*VT*log(ID2/ID1); // Change in diode voltage in volts
deltaVD=deltaVD*1e3; // Change in diode voltage in milivolts
disp(deltaVD,"Change in diode voltage (for Si) (mV) = ");
```

Scilab code Exa 2.3 Germanium diode

```
// Example 2.3: (a) Voltage
//              (b) Ratio of current in forward bias to that in reverse bias
//              (c) Forward current
clc, clear

disp("Part (a)");
eta=1; // for Ge
T=300; // Room temperature in kelvins
VT=T/11600; // Voltage equivalent to temperatue at room temperature in volts
IS=1; // Let reverse saturation current be 1 A
I=-0.9*IS; // Reverse current
V=eta*VT*log(1+(I/IS)); // Voltagei in volts
V=V*1e3; // Voltage in milivolts
disp(V,"Voltage (mV) = ");

disp("Part (b)");
V=0.05; // Voltage in volts
If_Ir=(%e^(V/(eta*VT))-1)/(%e^(-V/(eta*VT))-1); // Ratio of current in forward bias to that in reverse bias
disp(If_Ir,"Ratio of current in forward bias to that in reverse bias = ");

disp("Part (c)");
IS=10e-6; // Reverse saturation current in amperes
V=0.1; // Voltage in volts
ID=IS*(%e^(V/(eta*VT))-1); // Forward current for 0.1 V in amperes
ID=ID*1e6; // Forward current for 0.1 V in micro-amperes
```

```
disp(ID,"Forward current for 0.1 V ( A ) = ");
V=0.2; // Voltage in volts
ID=IS*(%e^(V/(eta*VT))-1); // Forward current for 0.1 V in amperes
ID=ID*1e3; // Forward current for 0.1 V in miliamperes
disp(ID,"Forward current for 0.1 V (mA) = ");
V=0.3; // Voltage in volts
ID=IS*(%e^(V/(eta*VT))-1); // Forward current for 0.1 V in amperes
disp(ID,"Forward current for 0.1 V (A) = ");
```

Scilab code Exa 2.4 Diode current

```
// Example 2.4 (a) Current
//             (b) Current
//             (C) Current
clc, clear
IS=10e-6; // Reverse saturation current in amperes
eta=1; // for Ge
VT=25e-3; // Voltage equivalent to temperatue at room temperature in volts

disp("Part (a)");
VD=-24; // Reverse bias in volts
ID=IS*(%e^(VD/(eta*VT))-1); // Current in amperes
ID=ID*1e6; // Current in micro-amperes
disp(ID,"Current ( A ) = ");

disp("Part (b)");
VD=-0.02; // Reverse bias in volts
ID=IS*(%e^(VD/(eta*VT))-1); // Current in amperes
ID=ID*1e6; // Current in micro-amperes
disp(ID,"Current ( A ) = ");

```

```
disp("Part (c)");
VD=0.3; // Forward bias in volts
ID=IS*(%e^(VD/(eta*VT))-1); // Current in amperes
disp(ID,"Current (A) = ");
```

Scilab code Exa 2.5 `Change in diode voltage`

```
// Example 2.2: Change in diode voltage
clc, clear
T=300; // Operating temperature in kelvins
VT=T/11600; // Voltage equivalent to temperatue at
   room temperature in volts
ID1=1; // Let the initial diode current be 1 A
ID2=10*ID1; // Final diode current
eta=1; // for Ge
deltaVD=eta*VT*log(ID2/ID1); // Change in diode
   voltage in volts
deltaVD=deltaVD*1e3; // Change in diode voltage in
   milivolts
disp(deltaVD,"Change in diode voltage (for Ge) (mV)
   = ");
eta=2; // for Si
deltaVD=eta*VT*log(ID2/ID1); // Change in diode
   voltage in volts
deltaVD=deltaVD*1e3; // Change in diode voltage in
   milivolts
disp(deltaVD,"Change in diode voltage (for Si) (mV)
   = ");
```

Scilab code Exa 2.6 `Value of R`

```
// Example 2.6: R
clc, clear
```

```
// In the circuit given in Fig. 2.7
V=50e-3; // Output voltage
VD1=0.7; // Voltage across diode 1 in volts
I1=10e-3; // Current through diode 1 at 0.7 V in amperes
VD2=0.8; // Voltage across diode 2 in volts
I2=100e-3; // Current through diode 2 at 0.8 V in amperes
eta_VT=(VD2-VD1)/log(I2/I1); // Product of   and VT
I=10e-3/(%e^(V/eta_VT)+1); // Current through diode 1 in amperes
R=V/I;
disp(R,"R (  ) = ");
```

Scilab code Exa 2.7 Solving a circuit with diode

```
// Example 2.7: Current, Diode voltage
clc, clear
VDD=5; // Applied voltage in volts
VD=0.7; // Diode voltage in volts
I1=1e-3; // Current in amperes at diode voltage = 0.7 V
R=1000; // R in ohms
deltaVD=0.1; // Change in diode voltage in volts for every decade change in current
ratioI=10; // Decade change in current
eta_VT=deltaVD/log(ratioI); // Product of   and VT
ID=(VDD-VD)/R; // Diode current in amperes
VD2=VD+eta_VT*log(ID/I1); // Diode voltage in volts
ID=ID*1e3; // Diode current in miliamperes
disp(ID,"Diode current (mA) = ");
disp(VD2,"Diode voltage (v) = ");
```

Scilab code Exa 2.8 Output voltage

```
// Example 2.8: (a) Output voltage
//              (b) Output voltage
//              (c) Output voltage
clc, clear

disp("Part (a)");
// Since both the diodes are in OFF state
Vo=5; // Output voltage in volts
disp(Vo,"Output voltage (V) = ");

disp("Part (b)");
//Since diode D1 is in OFF state and diode D2 is in
    ON state
// From Fig. 2.16(C)
I=(5-0.6)/(4.7e3+300); // Current flowing through
    the diode D2 in amperes
Vo=5-I*4.7e3; // Output voltage in volts
disp(Vo,"Output voltage (V) = ");

disp("Part (c)");
// Since both diodes are in ON state
// Applying KVL in Fig. 2.16(d)
I=(5-0.6)/(2*4.7e3+300); // Current flowing through
    diode D1 or diode D2 in amperes
Vo=5-2*I*4.7e3; // Output voltage in volts
disp(Vo,"Output voltage (V) = ");
```

Scilab code Exa 2.9 Circuit parameters

```
// Example 2.9 (a) Output voltage, Diode currents
//             (b) Output voltage, Diode currents
clc, clear
Vy=0.7; // Cut-in voltage in volts
```

```
// In the Fig. 2.17
R1=5e3;
R2=10e3;

disp("Part (a)");
// Since diode D1 is OFF and diode D2 is ON
ID2=(5-Vy-(-5))/(R1+R2); // Current through diode D2 in amperes
Vo=5-ID2*R1; // Output voltage
ID2=ID2*1e3; // Current through diode D2 in miliamperes
disp(Vo,"Output voltage (V) =");
disp(0,"Current through diode D1 =");
disp(ID2,"Current through diode D2 (mA) =");

disp("Part (b)");
// Since both the diodes are ON
VA=4-Vy; // In the fig.
Vo=VA+Vy; // Output voltage
ID2=(5-Vo)/R1; // Current through diode D2 in amperes
IR2=(VA-(-5))/R2; // Current through diode R2 in amperes
ID1=IR2-ID2; // Current through diode D1 in amperes
ID1=ID1*1e3; // Current through diode D1 in miliamperes
ID2=ID2*1e3; // Current through diode D2 in miliamperes
disp(Vo,"Output voltage (V) =");
disp(ID1,"Current through diode D1 (mA) =");
disp(ID2,"Current through diode D2 (mA) =");
```

Scilab code Exa 2.11 `Solving a circuit with diode`

```
// Example 2.11 (a) Alternating component of voltage acroos load resistance
//              (b) Total voltage across load resistance
//              (c) Total current
clc, clear
T=293; // Operating temperature in kelvins
VT=T/11600; // Voltage equivalent to temperatue at room temperature in volts
// In the Fig. 2.21(a)
VAA=9; // in volts
Vm=0.2; // in volts
RL=2e3; // Load resistance in ohms
Vy=0.6; // Cut−in voltage in volts
Rf=10; // Forward resistance of diode in ohms
eta=2;

disp("Part (a)")
// From DC model in Fig. 2.21(b)
IDQ=(VAA-Vy)/(RL+Rf); // DC current through diode or load resistance in amperes
rd=eta*VT/IDQ; // Dynamic resistance in ohms
// This dynamic resistance is used in AC model in Fig. 2.21(c)
Vom=Vm*RL/(RL+rd); // Amplitude of alternating component of the voltage across load resistance in volts
disp(Vom,"Amplitude of alternating component of the voltage across load resistance (V) =");
disp("Therefore, the alternating component of the voltage across load resistance is 0.199 sin  t  V");

disp("Part (b)");
VDQ=IDQ*RL; // DC component of voltage across load resistance in volts
disp(VDQ,"DC component of voltage across load resistance (V) =");
```

```
disp("Therefore, total voltage across load resistance is (8.36 + 0.199 sin  t ) V");

disp("Part (C)");
IDQ=IDQ*1e3; // DC current through load resistance in miliamperes
idm=Vm/(RL+rd); // Amplitude of alternating component of the current across load resistance in amperes
idm=idm*1e3; // Amplitude of alternating component of the current across load resistance in miliamperes
disp(IDQ,"DC component of current across load resistance (mA) =");
disp(idm,"Amplitude of alternating component of the current across load resistance (mA) =");
disp("Therefore, total current across load resistance is (4.18 + 0.099 sin  t ) mA");
```

Scilab code Exa 2.12 `Diode small signal model`

```
//Example 2.12: (b) Vo
//              (c) I
clc, clear

disp("Part (b)");
// In the Fig. 2.22 (a)
vs=10e-3; // in volts
Rs=1e3; // in ohms
eta=2;
VT=25e-3; // Voltage equivalent to temperatue at room temperature in volts
I=1e-3; // in amperes
Vo=vs*eta*VT/(eta*VT+I*Rs); // in volts
Vo=Vo*1e3; // in milivolts
```

```
disp(Vo,"Vo for I= 1 mA (mV) =");
I=0.1e-3; // in amperes
Vo=vs*eta*VT/(eta*VT+I*Rs); // in volts
Vo=Vo*1e3; // in milivolts
disp(Vo,"Vo for I= 0.1 mA (mV) =");
I=1e-6; // in amperes
Vo=vs*eta*VT/(eta*VT+I*Rs); // in volts
Vo=Vo*1e3; // in milivolts
disp(Vo,"Vo for I= 1  A  (mV) =");

disp("Part (c)");
Vo=vs/2; // in volts
I=eta*VT*(vs-Vo)/(Vo*Rs); // in amperes
I=I*1e6; // in micro−amperes
disp(I,"I ( A ) =");
```

Scilab code Exa 2.13 Barrier capacitance

```
// Example 2.13: Barrier capacitance
clc, clear
A=1e-3*1e-3; // Area of p−n junction in metres square
W=2e-6; // Space charge thickness in metres
E=16; // Dielectric constant of Ge
Eo=1/(36*%pi*1e9); // Absolute permittivity of air
C=E*Eo*A/W; // Barrier capacitance in farads
C=C*1e12; // Barrier capacitance in pico−farads
disp(C,"Barrier capacitance (pF) =");
```

Scilab code Exa 2.14 Change in capacitance

```
// Example 2.14: (a) Change in capacitance
//               (b) Change in capacitance
```

```
clc, clear
C=4e-12; // Depletion capacitance in farads
V=4; // in volts
K=C*sqrt(V); // a constant

disp("Part (a)");
V=4+0.5; // in volts
C_new=K/sqrt(V); // in farads
deltaC=C_new-C; // Change in capacitande in farads
deltaC=deltaC*1e12; // Change in capacitande in pico
    -farads
disp(deltaC,"Change in capacitance (pF) =");

disp("Part (b)");
V=4-0.5; // in volts
C_new=K/sqrt(V); // in farads
deltaC=C_new-C; // Change in capacitande in farads
deltaC=deltaC*1e12; // Change in capacitande in pico
    -farads
disp(deltaC,"Change in capacitance (pF) =");
```

Scilab code Exa 2.18 `Diffusion length`

```
// Example 2.18: Diffusion length
clc, clear
I=1e-3; // Forward bias current in amperes
C=1e-6; // Diffusion capacitance in farads
Dp=13; // Diffusion constant for Si
eta=2; // for Si
VT=26e-3; // Voltage equivalent to temperatue at
    room temperature in volts
Lp=sqrt(C*Dp*eta*VT/I); // Diffusion length in
    metres
Lp=Lp*1e2; // Diffusion length in centimetres
disp(Lp,"Diffusion length (cm) =");
```

Scilab code Exa 2.19 Two diodes in series

```
// Example 2.19 (a) Vd1 and Vd2
//              (b) Current in the circuit
clc, clear
eta_VT=0.026; // Product of    and VT

disp("Part (a)");
// From the Fig. 2.19(a)
Is=5e-6; // Reverse saturation current through diode
    D2 in amperes
Id1=Is; // Forward current through diode D1 in
   amperes
Vd1=eta_VT*log(1+(Id1/Is)); // in volts
Vd2=5-Vd1; // in volts
disp(Vd1,"Vd1 (V) =");
disp(Vd2,"Vd2 (V) =");

disp("Part (b)");
// From the Fig. 2.19(b)
Vz=4.9; // Zener voltage in volts
Vd1=5-Vz; // in volts
I=Is*(%e^(Vd1/eta_VT)-1); // Current in the circuit
   in amperes
I=I*1e6; // Current in the circuit in micro-amperes
disp(I,"Current in the circuit ( A ) =");
```

Chapter 3

Application of Diodes

Scilab code Exa 3.4 Full wave rectifier

```
// Example 3.4: (a) DC load current
//              (b) DC power in load
//              (c) Rectification efficiency
//              (d) Percentage regulation
//              (e) PIV of each diode
clc, clear
Vrms=40; // Input in volts
Rf=1; // Forward conduction resistance of diodes in
   ohms
RL=29; // Load resistance in ohms
Vmax=Vrms*sqrt(2); // in volts
Imax=Vmax/(Rf+RL); // in amperes

disp("Part (a)");
Idc=2*Imax/%pi; // DC load current in amperes
disp(Idc,"DC load current (A) =");

disp("Part (b)");
Pdc=Idc^2*RL; // DC power in load in watts
disp(Pdc,"DC power in load (W) =");

```

```
disp("Part (c)");
Pac=Vrms^2/(Rf+RL); // AC power in load
eta=Pdc/Pac; // Rectification efficiency
disp(eta,"Rectification efficiency =");

disp("Part (d)");
reg=Rf*100/RL; // Percentage regulation
disp(reg,"Percentage regulation (%) =");

disp("Part (e)");
PIV=2*Vmax; // in volts
disp(PIV,"PIV for each diode (V) =");
```

Scilab code Exa 3.5 Full wave bridge rectifier

```
// Example 3.5: (a) DC voltage at load
//              (b) PIV rating of each diode
//              (c) Maximum current through each
    diode
//              (d) Required power rating
clc, clear
Vrms=120; // Input voltage in volts
RL=1e3; // Load resistance in ohms
Vy=0.7; // Cut-in voltage in volts

disp("Part (a)");
Vmax=Vrms*sqrt(2); // in volts
Imax=(Vmax-2*Vy)/RL; // in amperes
Idc=2*Imax/%pi; // in amperes
Vdc=Idc*RL; // in volts
disp(Vdc,"DC voltage at load (V) =");

disp("Part (b)");
disp(Vmax,"PIV rating of each diode (V) =");

```

```
disp("Part (c)");
Imax=Imax*1e3; // in miliamperes
disp(Imax,"Maximum current through each diode (mA) = ");

disp("Part (d)");
Pmax=Vy*Imax; // Required power rating in mili−watts
disp(Pmax,"Required power rating (mW) =");
```

Scilab code Exa 3.6 Centre tapped full wave rectifier

```
// Example 3.6: (a) Peak value of current
//              (b) DC value of current
//              (c) Ripple factor
//              (d) Rectification efficiency
clc, clear
// From the Fig. 2.16
RL=1e3; // Load resistance in ohms
rd=10; // Forward bias dynamic resistance of diodes in ohms
Vmax=220; // Amplitude of input voltage in volts

disp("Part (a)");
Imax=Vmax/(rd+RL); // Peak value of current in amperes
disp(Imax,"Peak value of current (A) =");

disp("Part (b)");
Idc=2*Imax/%pi; // DC value of current in amperes
disp(Idc,"DC value of current (A) =");

disp("Part (C)");
ripl=sqrt((Imax/(Idc*sqrt(2)))^2-1);
disp(ripl,"Ripple factor =");

```

```
disp("Part (d)");
eta=8/(%pi^2*(1+(rd/RL))); // Rectification
   efficiency
disp(eta,"Rectification efficiency =");
```

Scilab code Exa 3.7 Full scale reading

```
// Example 3.7: Full scale reading
clc, clear
Idc=1e-3; // in amperes
Rf=10; // in ohms
RL=5e3; // in ohms
Vrms=Idc*(RL+Rf)*%pi/(2*sqrt(2)); // Full-scale
   deflection in volts
disp(Vrms,"Full-scale deflection (V) =");
```

Scilab code Exa 3.8 Full scale reading

```
// Example 3.8: Full-scale reading
clc, clear
Idc=5e-3; // in amperes
Rf=40; // in ohms
RL=20e3; // in ohms
Vrms=Idc*(RL+Rf)*%pi/(2*sqrt(2)); // Full-scale
   deflection in volts
disp(Vrms,"Full-scale deflection (V) =");
```

Scilab code Exa 3.10 Minimum and maximum value of zener diode current

```
// Example 3.10: Minimum and maximum value of zener
   diode current
clc, clear
// From the Fig. 3.33
Vsmin=120; // in volts
Vsmax=170; // in volts
Vz=50; // in volts
Rs=5e3; // in ohms
RLmin=5e3; // in ohms
RLmax=10e3; // in ohms
ILmin=Vz/RLmax; // in amperes
ILmax=Vz/RLmin; // in amperes
Izmin=((Vsmin-Vz)/Rs)-ILmax; // Minimum value of
   zener diode current in amperes
Izmin=Izmin*1e3; // Minimum value of zener diode
   current in miliamperes
Izmax=((Vsmax-Vz)/Rs)-ILmin; // Maximum value of
   zener diode current in amperes
Izmax=Izmax*1e3; // Maximum value of zener diode
   current in miliamperes
disp(Izmin,"Minimum value of zener diode current (mA
   ) =");
disp(Izmax,"Maximum value of zener diode current (mA
   ) =");
```

Scilab code Exa 3.11 Safe voltage range

```
// Example 3.11: (a) V
//               (b) Voltage range of V
clc, clear
Vz=50; // Zener voltage in volts
Izmin=1e-3; // in amperes
Izmax=5e-3; // in amperes

disp("Part (a)");
```

```
ILmin=0;
Rs=5e3; // in ohms
V=Vz+Rs*(Izmax+ILmin); // in volts
disp(V,"V (V) =");

disp("Part (b)");
IL=(50/15)*1e-3; // in amperes
Vmin=Vz+Rs*(Izmin+IL); // in volts
Vmax=Vz+Rs*(Izmax+IL); // in volts
disp(Vmin,"Vmin (V) =");
disp(Vmax,"Vmax (V) =");
```

Scilab code Exa 3.12 Voltage regulator

```
// Example 3.12: Zener diode current, Power
   dissipation in zener diode and resistor
clc, clear
// In the Fig. 3.35
Vz=6.8; // in volts
R=100; // in ohms

disp("Normal situation");
Vs=9; // in volts
I=(Vs-Vz)/R; // in amperes
Pzener=I*Vz; // in watts
Presistor=I^2*R; // in watts
I=I*1e3; // in miliamperes
Pzener=Pzener*1e3; // in miliwatts
Presistor=Presistor*1e3; // in miliwatts
disp(I,"Zener diode current (mA) =");
disp(Pzener,"Power dissipation in zener diode (mW) =
   ");
disp(Presistor,"Power dissipation in resistor (mW) =
   ");

```

```
disp("Aberrant situation");
Vs=15; // in volts
I=(Vs-Vz)/R; // in amperes
Pzener=I*Vz; // in watts
Presistor=I^2*R; // in watts
I=I*1e3; // in miliamperes
Pzener=Pzener*1e3; // in miliwatts
Presistor=Presistor*1e3; // in miliwatts
disp(I,"Zener diode current (mA) =");
disp(Pzener,"Power dissipation in zener diode (mW) =
   ");
disp(Presistor,"Power dissipation in resistor (mW) =
   ");
```

Scilab code Exa 3.13 `Range of load current`

```
// Example 3.13: Range of load current
clc, clear
Vz=5; // in volts
Izmin=50e-3; // in amperes
Izmax=1; // in amperes
Vmin=7.5; // in volts
Vmax=10; // in volts
Rs=4.75; // in ohms
ILmin=((Vmax-Vz)/Rs)-Izmax; // in amperes
ILmin=ILmin*1e3; // in miliamperes
ILmax=((Vmin-Vz)/Rs)-Izmin; // in amperes
ILmax=ILmax*1e3; // in miliamperes
disp(ILmin,"ILmin (mA) =");
disp(ILmax,"ILmax (mA) =");
```

Scilab code Exa 3.14 `Zener diode`

```
// Exmaple 3.14: Load−current range, Series resistance in redesigned circuit
clc, clear
// In Fig. 3.37
Vz=6.8; // in volts
Izk=0.1e-3; // in amperes
Vs=10; // in volts
Rs=1e3; // in ohms
ILmax=((Vs-Vz)/Rs)-Izk; // in amperes
ILmax=ILmax*1e3; // in miliamperes
disp(0,"ILmin =");
disp(ILmax,"ILmax (mA) =");

disp("Redesigned Part")
RL=1e3; // in ohms
Izk=Izk*10; // in amperes
I=Izk+(Vz/RL); // in amperes
R=(Vs-Vz)/I; // in ohms
disp(R,"Series resistance ( ) =");
```

Scilab code Exa 3.15 Zener diode regulator

```
// Example 3.15: (a) Series resistance
//               (b) Power dissipation rating of zener diode
clc, clear
// In Fig. 3.38
Vz=6; // in volts
ILmin=0;
ILmax=0.5; // in amperes
Vmin=8; // in volts
Vmax=10; // in volts
Izmin=0;

disp("Part (a)");
```

```
Rs=(Vmin-Vz)/(ILmax+Izmin); // Series resistance in ohms
disp(Rs,"Series resistance (  ) =");

disp("Part (b)");
Izmax=((Vmax-Vz)/Rs)-ILmin; // in amperes
Pzmax=Vz*Izmax; // in watts
disp(Pzmax,"Power dissipation rating of zener diode (W) =");
```

Scilab code Exa 3.16 Zener diode

```
// Example 3.16: Series resistance R, Maximum zener current
clc, clear
// In Fig. 3.39
Vz=7.2; // in volts
ILmin=12e-3; // in amperes
ILmax=100e-3; // in amperes
Vs=20; // in volts
Izmin=10e-3; // in amperes
Rs=(Vs-Vz)/(ILmax+Izmin); // Series resistance in ohms
disp(Rs,"Series resistance (  ) =");
// For ILmin=0
Izmax=((Vs-Vz)/Rs); // in amperes
Izmax=Izmax*1e3; // in miliamperes
disp(Izmax,"Maximum zener current (mA) =");
```

Scilab code Exa 3.17 Avalanche diode

```
// Example 3.17: (a) R, maximum possible value of load current
```

```
//                    (b) Range of V
clc, clear
Vz=50; // Diode voltage in volts
Izmin=5e-3; // in amperes
Izmax=40e-3; // in amperes

disp("Part (a)");
ILmin=0;
V=200; // Input voltage in volts
R=(V-Vz)/(Izmax-ILmin); // in ohms
ILmax=((V-Vz)/R)-Izmin; // in amperes
Rk=R*1e-3; // in kilo-ohms
ILmax=ILmax*1e3; // in miliamperes
disp(Rk,"R( k  ) =");
disp(ILmax,"Maximum possible value of load current (mA) =");

disp("Part (b)");
IL=25e-3;
Vmin=Vz+R*(Izmin+IL); // in volts
Vmax=Vz+R*(Izmax+IL); // in volts
disp(Vmin,"Minimum value of V (V) =");
disp(Vmax,"Maximum value of V (V) =");
```

Scilab code Exa 3.18 Zener diode

```
// Example 3.18: R, ILmax, Power rating of zener diode
clc, clear
// In Fig. 3.41
Vz=6; // in volts
V=22; // in volts
Izmin=10e-3; // in amperes
Izmax=40e-3; // in amperes
ILmin=0;
```

```
R=(V-Vz)/(Izmax-ILmin); // in ohms
ILmax=((V-Vz)/R)-Izmin; // in amperes
P=Izmax*Vz; // Power rating of zener diode in watts
ILmax=ILmax*1e3; // in miliamperes
P=P*1e3; // Power rating of zener diode in mili-watts
disp(R,"R(  ) =");
disp(ILmax,"ILmax (mA) =");
disp(P,"Power rating of zener diode (mW) =");
```

Scilab code Exa 3.19 Zener diode

```
// Example 3.19: (a) VL,IL,Iz,IR
//               (b) RL for maximum power dissipation for zener diode
//               (c) Maximum value of RL for zener diode to remain ON
clc, clear
// From Fig. 3.42
Vs=25; // in volts
Rs=220; // in ohms
Vz=10; // in volts
Pzmax=400; // in mili-watts
Izmax=Pzmax/Vz; // in miliamperes
Izmin=Izmax*10/100; // in miliamperes

disp("Part (a)");
RL=180; // in ohms
VL=Vz; // in volts
IL=Vz/RL; // in amperes
IL=IL*1e3; // in miliamperes
IR=(Vs-Vz)/Rs; // in amperes
IR=IR*1e3; // in miliamperes
Iz=IR-IL; // in miliamperes
disp(VL,"VL (V) =");
```

```
disp(IL,"IL (mA) =");
disp(Iz,"Iz (mA) =");
disp(IR,"IR (mA) =");

disp("Part (b)");
RL=Vz*1e3/(IR-Izmax); // in ohms
disp(RL,"RL for maximum power dissipation for zener diode ( ) =");

disp("Part (c)");
RL=Vz*1e3/(IR-Izmin); // in ohms
disp(RL,"Maximum value of RL for zener diode to remain ON ( ) =");
disp("If Izmin=0");
RL=Vz*1e3/IR; // in ohms
disp(RL,"Maximum value of RL for zener diode to remain ON ( ) =");
```

Scilab code Exa 3.20 Regulation range of zener diode

```
// Example 3.20: Range and average watage of Rs
clc, clear
// From Fig. 3.43
Vsmin=20; // in volts
Vsmax=30; // in volts
RLmin=1; // in ohms
RLmax=10; // in ohms
Izmin=10e-3; // in amperes
Pzmax=50; // in watts
Vz=10; // in volts
ILmin=Vz/RLmax; // in amperes
ILmax=Vz/RLmin; // in amperes
Izmax=Pzmax/Vz; // in amperes
Rs1=(Vsmin-Vz)/(ILmax+Izmin); // in ohms
Rs2=(Vsmax-Vz)/(ILmin+Izmax); // in ohms
```

```
disp(Rs1,"Rs <= ");
disp(Rs2,"Rs >= ");
disp("To meet the load current variation from 1 A to
    10 A a zener of specification Izmin = 0.01 A to
   Izmax = 5 A cannot meet the requirement for any
   value of Rs")
// Let
RLmin=1e3; // in ohms
RLmax=10e3; // in ohms
ILmin=Vz/RLmax; // in amperes
ILmax=Vz/RLmin; // in amperes
Rsmin=(Vsmax-Vz)/(ILmin+Izmax); // in ohms
Rsmax=(Vsmin-Vz)/(ILmax+Izmin); // in ohms
disp(Rsmin,"Minimum value of Rs (  ) =");
disp(Rsmax,"Maximum value of Rs (  ) =");
Rs=4; // in ohms
W=Rs*(ILmax+Izmax)^2; // in watts
disp(W,"Average wattage of Rs (W) =");
```

Scilab code Exa 3.21.a `Clipping circuits`

```
// Example 3.21: (a) Transfer characteristics and
   output
//               (b) Transfer characteristics and
   output
clc, clear
Vy=0.6; // in volts
Rf=100; // in ohms
t=[-40:0.001:40];
vin=40*sin(2*%pi*t/80); // Input voltage in volts

```

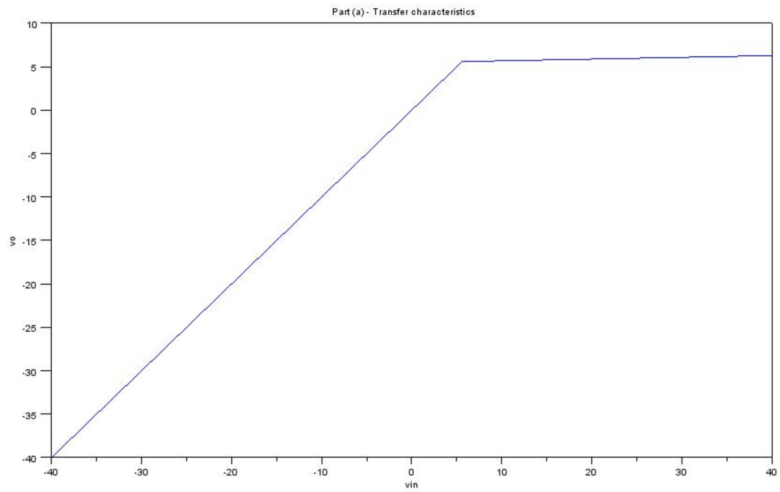

Figure 3.1: Clipping circuits

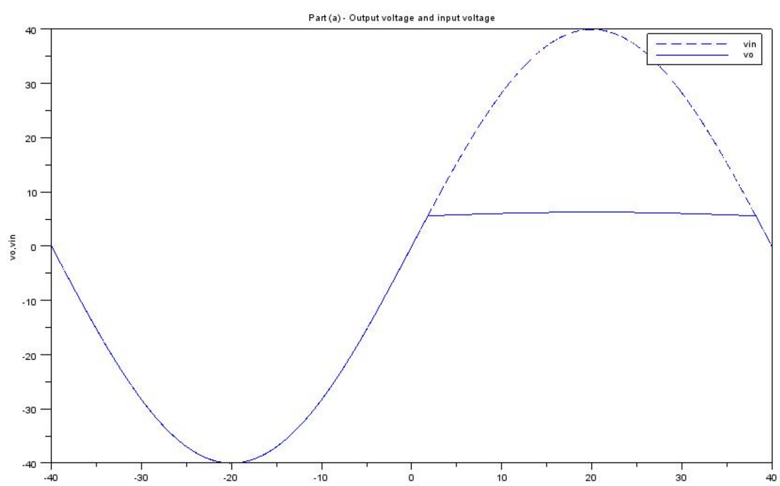

Figure 3.2: Clipping circuits

```
// Part (a)
// From Fig. 3.49(a)
// Sketching of transfer characteristics
for i=1:length(vin)
    if vin(i)<5.6 then
        vo(i)=vin(i); // in volts
    else
        ID=(vin(i)-5.6)/(4.9e3+Rf); // in amperes
        vo(i)=vin(i)-ID*4.9e3; // in volts
    end
end
plot(vin,vo);
xtitle("Part (a) - Transfer characteristics","vin","vo");
// Sketching of output
scf(1);
plot(t,vin,"--");
plot(t,vo);
xtitle("Part (a) - Output voltage and input voltage"," t ","vo,vin");
legend("vin","vo");

// Part (b)
// From Fig. 3.49(b)
// Sketching of transfer characteristics
for i=1:length(vin)
    if vin(i)>-0.6 then
        vo(i)=vin(i); // in volts
    else
        ID=(vin(i)+0.6)/(9.9e3+Rf); // in amperes
        vo(i)=vin(i)-ID*9.9e3; // in volts
    end
end
scf(2);
plot(vin,vo);
xtitle("Part (b) - Transfer characteristics","vin","vo");
// Sketching of output
```

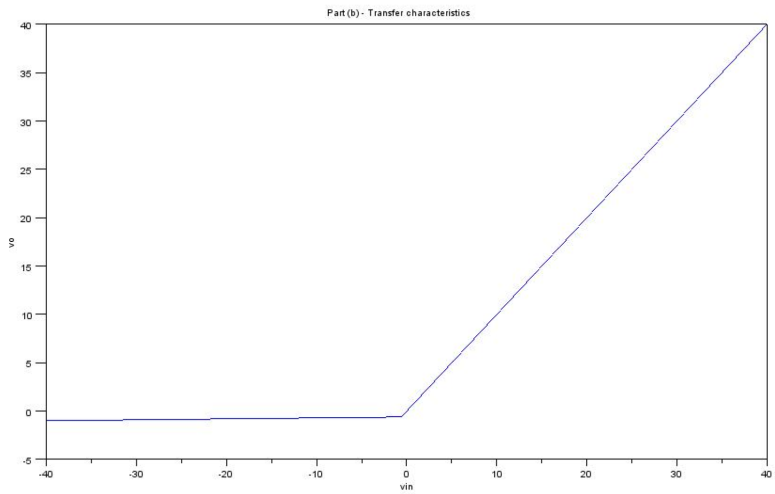

Figure 3.3: Range of load current

```
scf(3);
plot(t,vin,"--");
plot(t,vo);
xtitle("Part (b) - Output voltage and input voltage"
    ," t ","vo,vin");
legend("vin","vo");
```

Scilab code Exa 3.21.b Range of load current

```
// Example 3.21: (a) Transfer characteristics and
    output
//                (b) Transfer characteristics and
    output
```

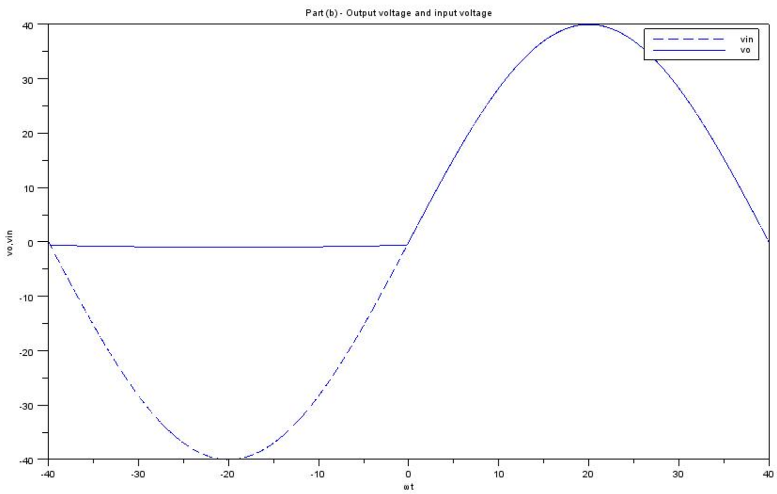

Figure 3.4: Range of load current

```
clc, clear
Vy=0.6; // in volts
Rf=100; // in ohms
t=[-40:0.001:40];
vin=40*sin(2*%pi*t/80); // Input voltage in volts

// Part (a)
// From Fig. 3.49(a)
// Sketching of transfer characteristics
for i=1:length(vin)
    if vin(i)<5.6 then
        vo(i)=vin(i); // in volts
    else
        ID=(vin(i)-5.6)/(4.9e3+Rf); // in amperes
        vo(i)=vin(i)-ID*4.9e3; // in volts
    end
end
plot(vin,vo);
xtitle("Part (a) - Transfer characteristics","vin","
```

```
    vo");
// Sketching of output
scf(1);
plot(t,vin,"--");
plot(t,vo);
xtitle("Part (a) - Output voltage and input voltage"
    ," t ","vo,vin");
legend("vin","vo");

// Part (b)
// From Fig. 3.49(b)
// Sketching of transfer characteristics
for i=1:length(vin)
    if vin(i)>-0.6 then
        vo(i)=vin(i); // in volts
    else
        ID=(vin(i)+0.6)/(9.9e3+Rf); // in amperes
        vo(i)=vin(i)-ID*9.9e3; // in volts
    end
end
scf(2);
plot(vin,vo);
xtitle("Part (b) - Transfer characteristics","vin","
    vo");
// Sketching of output
scf(3);
plot(t,vin,"--");
plot(t,vo);
xtitle("Part (b) - Output voltage and input voltage"
    ," t ","vo,vin");
legend("vin","vo");
```

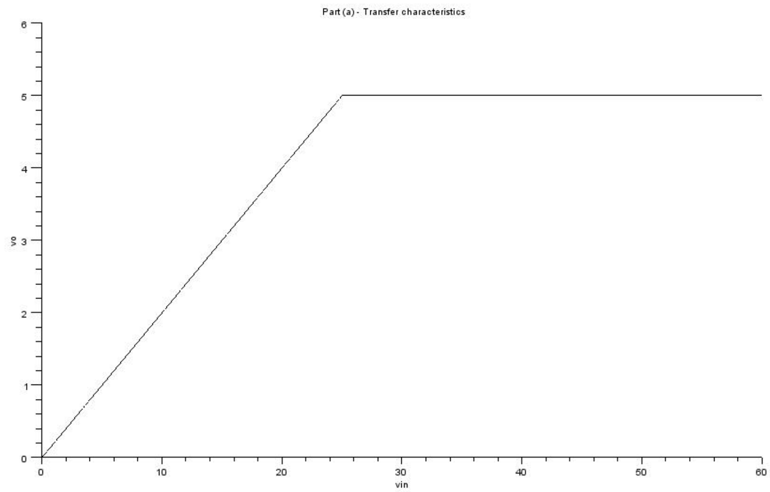

Figure 3.5: Transfer characteristics

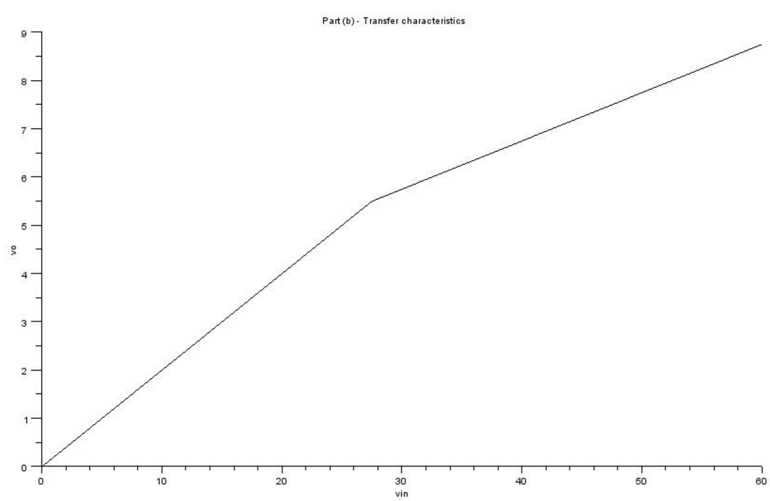

Figure 3.6: Transfer characteristics

Scilab code Exa 3.22 Transfer characteristics

```
// Example 3.22: (a) Transfer characteristics
//                (b) Transfer characteristics
clc, clear
t=[0:0.1:20]; // in mili-seconds
vin=30*t/10; // Input voltage in volts
// From Fig. 3.52(b)

// Part {a}
// Sketching of transfer characteristics
for i=1:length(vin)
    if vin(i)>25 then
        vo(i)=5; // in volts
    else
        IL=vin(i)/(200+50); // in amperes
        vo(i)=IL*50; // in volts
    end
end
plot2d(vin,vo,rect=[0,0,60,6]);
xtitle("Part (a) - Transfer characteristics","vin","
   vo");

// Part (b)
// Sketching of transfer characteristics
Vy=0.5; // in volts
Rf=40; // in ohms
VA=5+0.5; // in volts
for i=1:length(vin)
    if vin(i)<27.5 then
        IL=vin(i)/(200+50); // in amperes
        vo(i)=IL*50; // in volts
    else
        IL=(vin(i)+27.5)/500; // in amperes
        vo(i)=IL*50; // in volts
    end
end
scf(1);
```

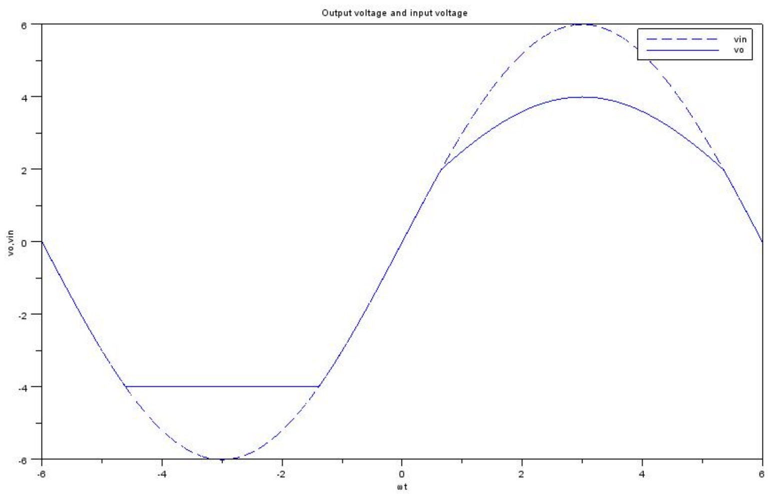

Figure 3.7: Clipping circuit

```
plot2d(vin,vo);
xtitle("Part (b) - Transfer characteristics","vin","
   vo");
```

Scilab code Exa 3.23 `Clipping circuit`

```
// Example 3.23: Output voltage and transfer
   characteristic curve
clc, clear
t=[-6:0.001:6];
vin=6*sin(2*%pi*t/12); // Input voltage in volts
// Sketching of output voltage
for i=1:length(vin)
```

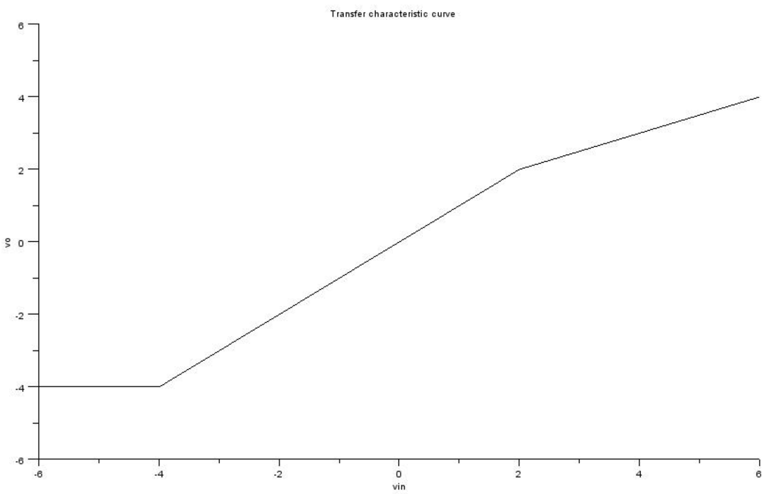

Figure 3.8: Clipping circuit

```
    if vin(i)>=2 then
        // From Fig. 3.54(b), D1 ON and D2 OFF
        I1=(vin(i)-2)/(10e3+10e3); // in amperes
        vo(i)=vin(i)-I1*10e3; // in volts
    elseif vin(i)>=-4 then
        // both D1 and D2 OFF
        vo(i)=vin(i);
    else
        // From Fig. 3.54(c), D1 OFF and D2 ON
        vo(i)=-4; // in volts
    end
end
plot(t,vin,"--");
plot(t,vo);
xtitle("Output voltage and input voltage"," t ","vo,
   vin");
legend("vin","vo");
// Sketching of transfer characteristic curve
scf(1);
```

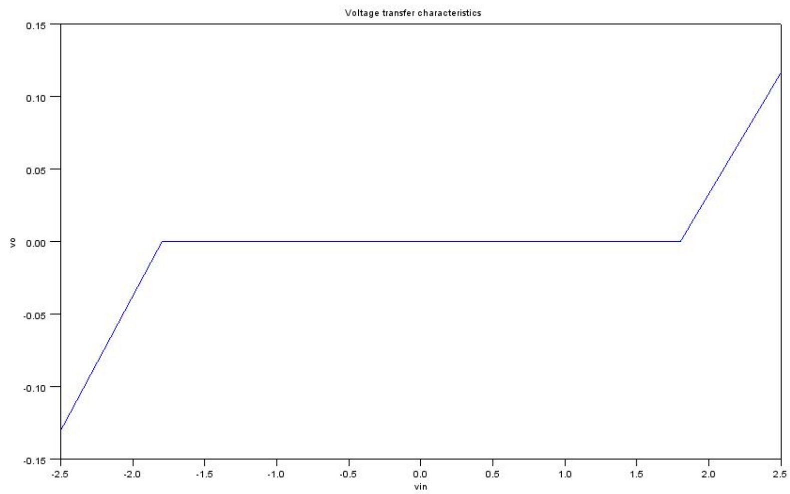

Figure 3.9: Transfer characteristics

```
plot2d(vin,vo,rect=[-6,-6,6,6]);
xtitle("Transfer characteristic curve","vin","vo");
```

Scilab code Exa 3.24 Transfer characteristics

```
// Example 3.24: Voltage transfer characteristics
clc, clear
vin=[-2.5:2.5]; // Input voltage in volts
// Obtaining thevnin's equivalent circuit on LHS of
   XX'
V_th=vin*7.5e3/(7.5e3+15e3); // in volts
R_th=15e3*7.5e3/(15e3+7.5e3); // in ohms
// Sketching of voltage transfer characteristics
// From thevnin's equivalent circuit in Fig. 3.55(b)
for i=1:length(vin)
```

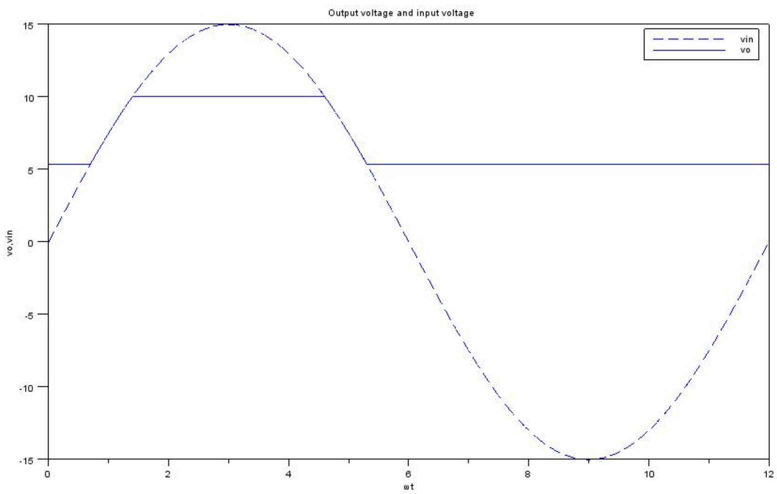

Figure 3.10: Clipping circuit

```
    if vin(i)>1.8 then
        I1=(V_th(i)-0.6)/(5e3+R_th); // in amperes
        vo(i)=I1*5e3; // in volts
    elseif vin(i)>-1.8 then
        vo(i)=0;
    else
        I2=(V_th(i)+0.6)/(4e3+R_th); // in amperes
        vo(i)=I2*5e3; // in volts
    end
end
plot(vin,vo);
xtitle("Voltage transfer characteristics","vin","vo");
```

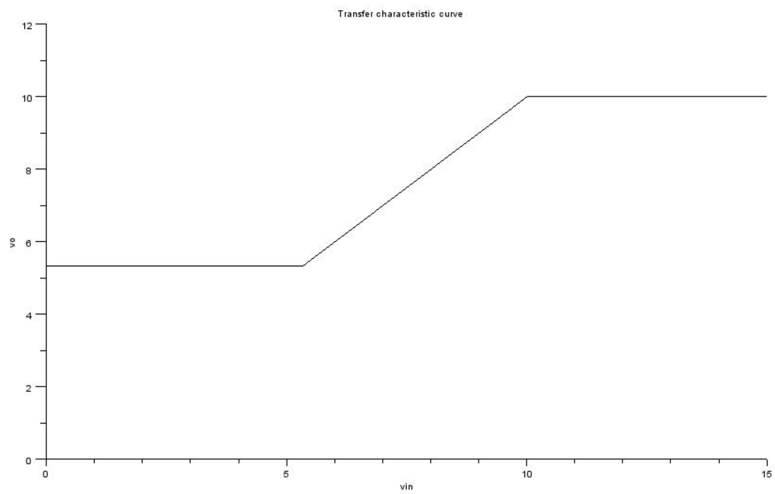

Figure 3.11: Clipping circuit

Scilab code Exa 3.25 `Clipping circuit`

```
// Example 3.25: (a) Output voltage waveform
//               (b) Transfer curve
clc, clear
t=[0:0.001:12];
vin=15*sin(2*%pi*t/12); // Input voltage in volts
// From Fig. 3.56(a)
// Sketching of output voltage waveform
for i=1:length(vin)
    if vin(i)<16/3 then
        // D1 OFF and D2 ON
        I2=(10-3)/(20e3+10e3); // in amperes
        vo(i)=10-I2*20e3; // in volts
    elseif vin(i)<=10 then
        // both D1 and D2 ON
```

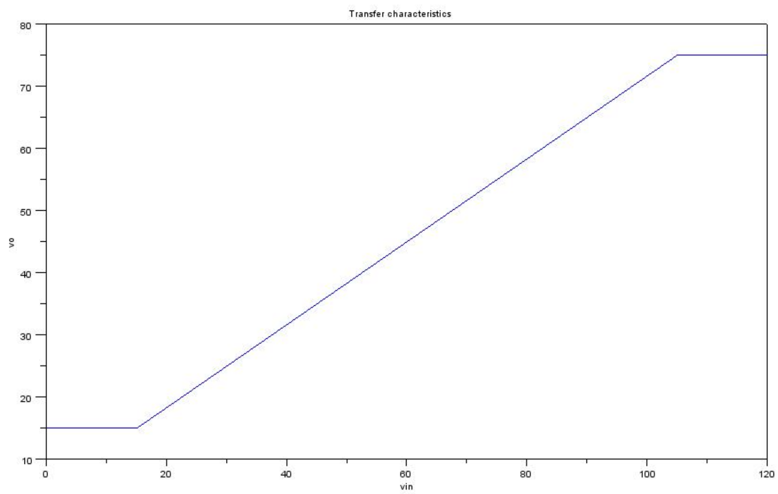

Figure 3.12: Range of load current

```
        vo(i)=vin(i);
    else
        // D1 ON and D2 OFF
        vo(i)=10; // in volts
    end
end
plot(t,vin,"--");
plot(t,vo);
xtitle("Output voltage and input voltage"," t ","vo,
   vin");
legend("vin","vo");
// Sketching of transfer curve
scf(1);
plot2d(vin,vo,rect=[0,0,15,12]);
xtitle("Transfer characteristic curve","vin","vo");
```

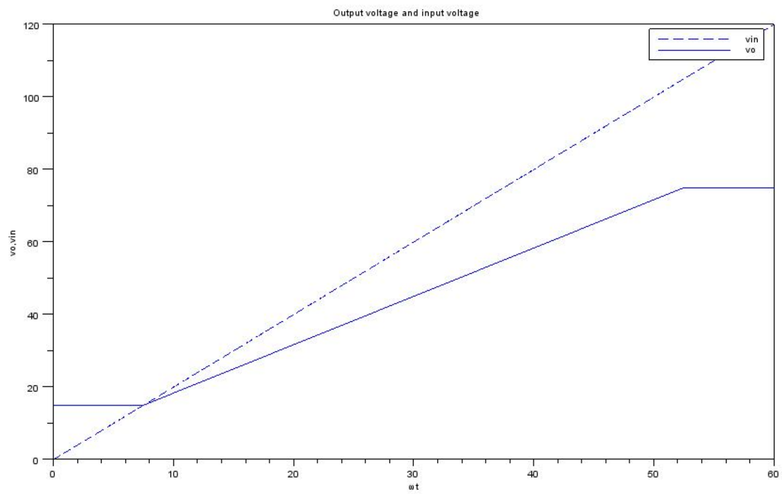

Figure 3.13: Range of load current

Scilab code Exa 3.26 `Range of load current`

```
// Example 3.26: Transfer characteristics and output
    and input voltage
clc, clear
T=60; // Let T = 60 seconds
t=[0:T];
vin=120*t/T; // Input voltage in volts
// From Fig. 3.57(a)
// Sketching of transfer characteristics
for i=1:length(vin)
    if vin(i)<=15 then
        // Both D1 and D2 OFF
        vo(i)=15; // in volts
```

```
    elseif vin(i)<=105 then
        // D1 OFF and D2 ON
        I2=(vin(i)-15)/(100e3+200e3); // in amperes
        vo(i)=vin(i)-I2*100e3; // in volts
    else
        // Both D1 and D2 ON
        vo(i)=75; // in volts
    end
end
plot(vin,vo);
xtitle("Transfer characteristics","vin","vo");
// Sketching of output
scf(1);
plot(t,vin,"--");
plot(t,vo);
xtitle("Output voltage and input voltage"," t ","vo,
   vin");
legend("vin","vo");
```

Scilab code Exa 3.27 Range of load current

```
// Example 3.27: vo vs vin
clc, clear
vin=[0:50]; // Input voltage in volts
// Sketching of vo vs vin
for i=1:length(vin)
    if vin(i)<3 then
        // From Fig. 3.58(b), D1 ON, D2 and D3 OFF
        I1=6/(5e3+5e3); // in amperes
        vo(i)=I1*5e3; // in volts
    elseif vin(i)<9 then
        // From Fig. 3.58(c), D1 and D3 ON, D2 OFF
        // Applying Kirchoff's laws
```

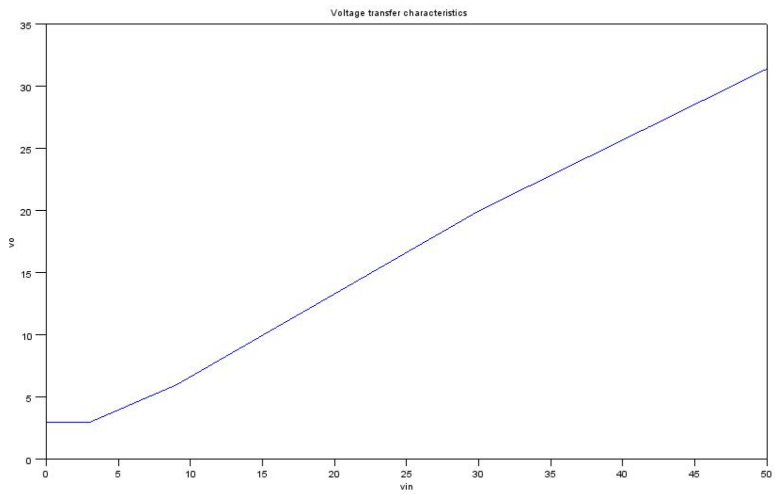

Figure 3.14: Range of load current

```
            vo(i)=0.5*vin(i)+1.5; // in volts
        elseif vin(i)<30 then
            // From Fig. 3.58(d), D3 ON, D1 and D2 OFF
            I3=vin(i)/(2.5e3+5e3); // in amperes
            vo(i)=I3*5e3; // in volts
        else
            // From Fig. 3.58(e), D2 and D3 ON, D1 OFF
            // Applying Kirchoff's laws
            vo(i)=4*vin(i)/7+20/7; // in volts
        end
end
plot(vin,vo);
xtitle("Voltage transfer characteristics","vin","vo"
    );
```

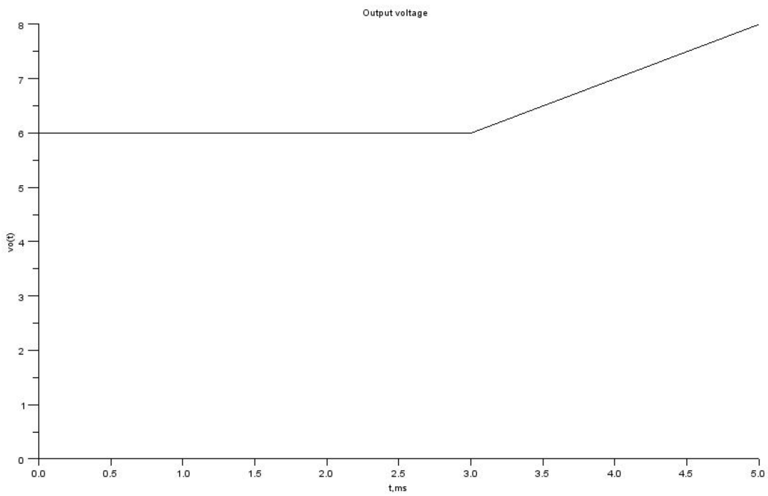

Figure 3.15: Transfer characteristics

Scilab code Exa 3.28 `Transfer characteristics`

```
// Example 3.28: Output voltage
clc, clear
t=[0:5]; // in seconds
vs=10*t/5; // Input voltage in volts
// Output voltage
for i=1:length(vs)
    if vs(i)<6 then
        // Diode is OFF
        vo(i)=6; // in volts
    else
        // From Fig. 3.65(c), Diode is ON
        I=(vs(i)-6)/(200+200); // in amperes
        vo(i)=6+I*200; // in volts
    end
end
plot2d(t,vo,rect=[0,0,5,8]);
xtitle("Output voltage","t,ms","vo(t)");
```

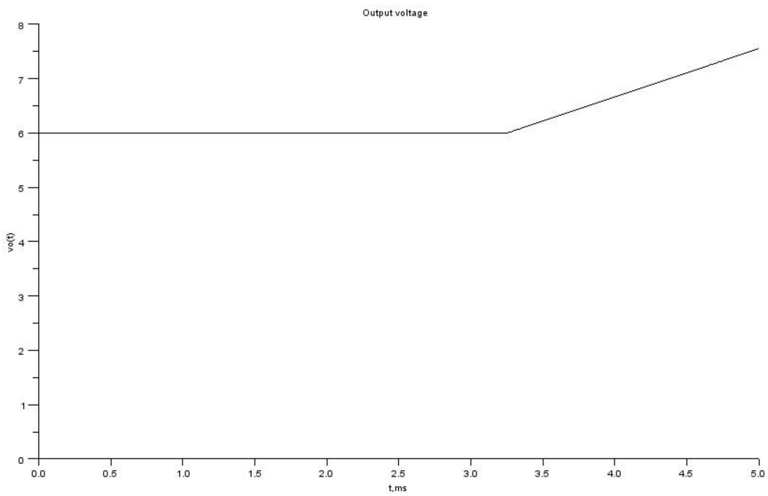

Figure 3.16: Output voltage

Scilab code Exa 3.29 `Output voltage`

```
// Example 3.29: Output voltage
clc, clear
Vy=0.5; // in volts
Rf=50; // in ohms
t=[0:5]; // in seconds
vs=10*t/5; // Input voltage in volts
// Output voltage
for i=1:length(vs)
    if vs(i)<6.5 then
        // Diode is OFF
        vo(i)=6; // in volts
    else
```

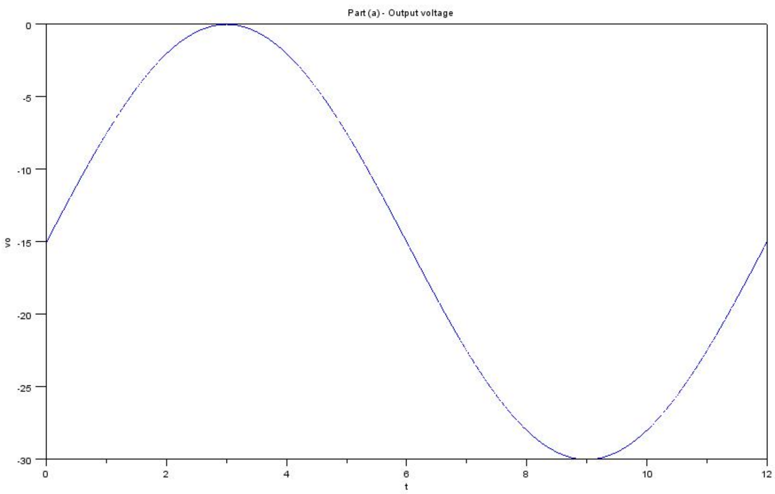

Figure 3.17: EX30

```
        // From Fig. 3.66(a), Diode is ON
        I=(vs(i)-6.5)/(200+Rf+200); // in amperes
        vo(i)=6+I*200; // in volts
    end
end
plot2d(t,vo,rect=[0,0,5,8]);
xtitle("Output voltage","t,ms","vo(t)");
```

Scilab code Exa 3.30 EX30

```
// Example 3.30: (a) Output waveform
//               (b) Output waveform
clc, clear
```

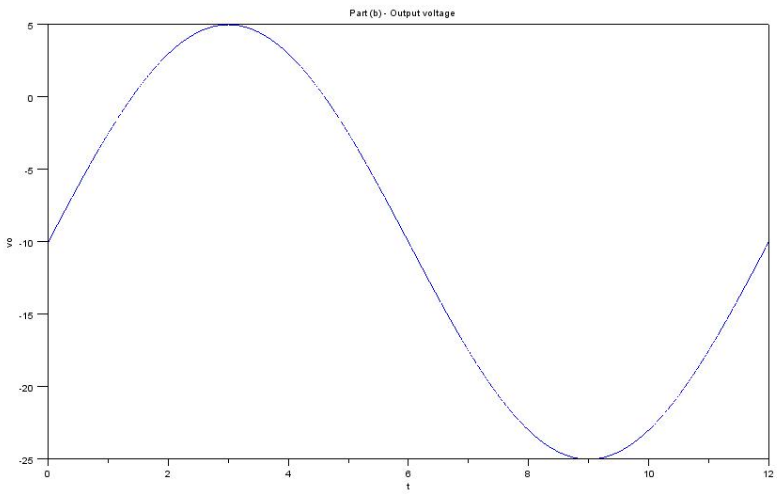

Figure 3.18: EX30

```
t=[0:0.001:12];
vin=15*sin(2*%pi*t/12); // Input voltage in volts

// Part (a), From Fig. 3.67(a)
vo=vin-15; // in volts
plot(t,vo);
xtitle("Part (a) - Output voltage","t","vo");

// Part(b), From Fig. 3.67(b)
vo=vin-10; // in volts
scf(1);
plot(t,vo);
xtitle("Part (b) - Output voltage","t","vo");
```

Scilab code Exa 3.31 `Output waveform`

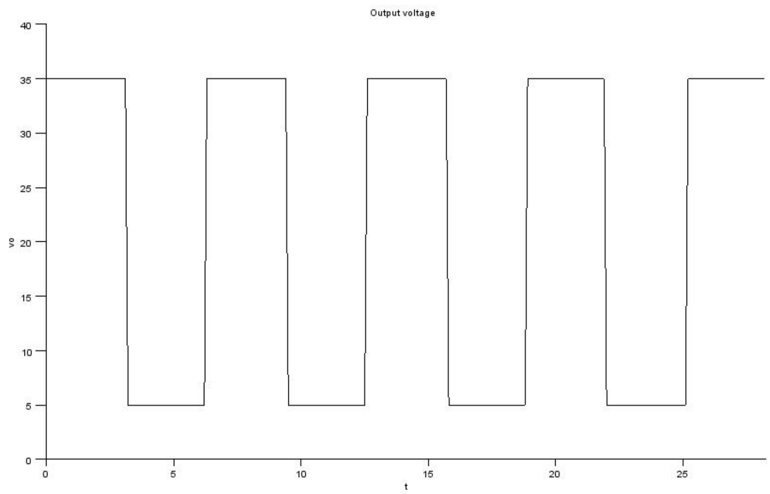

Figure 3.19: Output waveform

```
// Example 3.31: Output voltage
clc, clear
t=[0:0.1:9*%pi];
vin=15*squarewave(t)-5; // Input wave in volts
vo=vin+25; // in volts
plot2d(t,vo,rect=[0,0,9*%pi,40]);
xtitle("Output voltage","t","vo");
```

Scilab code Exa 3.32 Clamping circuit

```
// Example 3.32: Output voltage
clc, clear
t1=[0:20];
vin1=t1;
t2=[20:60];
```

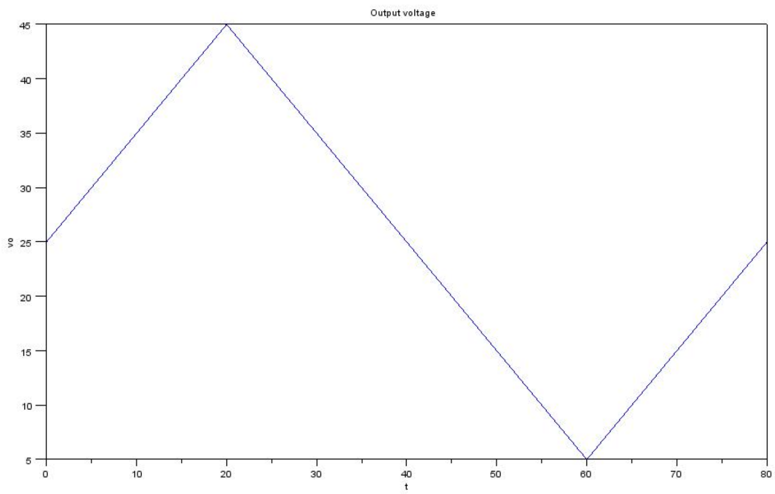

Figure 3.20: Clamping circuit

```
vin2=40-t2;
t3=[60:80];
vin3=-80+t3;
t=[t1 t2 t3];
vin=[vin1 vin2 vin3]; // Input wave in volts
vo=vin+25; // in volts
plot(t,vo);
xtitle("Output voltage","t","vo");
```

Scilab code Exa 3.33 `Clamping circuit`

```
// Example 3.33: vo
clc, clear
t=[0:0.001:12];
vin=10*sin(2*%pi*t/4); // Input voltage in volts
```

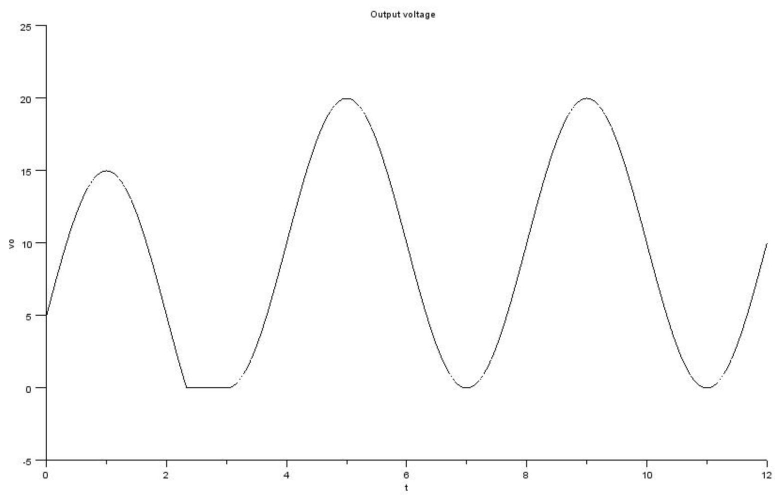

Figure 3.21: Clamping circuit

```
// From Fig. 3.73
vint=vin+5;
for i=1:length(vint)
    if vint(i)>0 then
        // Diode is OFF
        vo(i)=vint(i); // in volts
    else
        break;
    end
end
for i=i:length(vint)
    if vint(i)==-5 then
        break;
    else
        // Diode is ON
        vo(i)=0;
    end
end
for i=i:length(vint)
```

```
    // Capacitor is charged to 5 V
    vo(i)=vint(i)+5; // in volts
end
plot2d(t,vo,rect=[0,-5,12,25]);
xtitle("Output voltage","t","vo");
```

Chapter 4

Bipolar Junction Transistors

Scilab code Exa 4.1 `Value of Collector Current`

```
// Example 4.1: New value of Ic
clc, clear
VA=100; // Early voltage in volts
VCE_old=1; // in volts
Ic_old=1e-3; // in amperes
VCE_new=11; // in volts
ro=VA/Ic_old; // Output resistance in ohms
Ic_new=(VCE_new-VCE_old+Ic_old*ro)/ro; // in amperes
Ic_new=Ic_new*1e3; // in miliamperes
disp(Ic_new,"New value of Ic (mA) =");
```

Scilab code Exa 4.2 `CE transistor`

```
// Example 4.2: Region of operation , All the node
   voltages and currents
clc, clear
betaf=100; // Current gain
disp("Let us assume that the transistor is in active
    region.");
```

```
VBE_active=0.7; // in volts
// From the equivalent circuit in Fig. 4.18(b)
VCC=10; // in volts
VBB=4; // in volts
RE=3.3e3; // in ohms
RC=5e3; // in ohms
VE=VBB-VBE_active; // in volts
// Writing KVL for base emitter loop and putting Ic=
    F *Ib
IB=VE/((1+betaf)*RE); // in amperes
IB=IB*1e3; // in miliamperes
IC=betaf*IB; // in miliamperes
IE=IB+IC; // in miliamperes
VC=VCC-IC*RC*1e-3; // in volts
disp(VC,"VC (V) =");
disp(VE,"VE (V) =");
disp(VBB,"VB (V) =");
disp(IC,"IC (mA) =");
disp(IE,"IE (mA) =");
disp(IB,"IB (mA) =");
disp("Since the base is at 4 V and the collector is
   at 5.05 V, so the collector junction is reverse
   biased by 1.05 V. The transistor is indeed in
   forward active region as assumed.")
```

Scilab code Exa 4.3 CE transistor

```
// Example 4.3: Region of operation , Node currents
   and voltages
clc, clear
betaf=100; // Current gain
disp("Let us assume that the transistor is in active
    region.");
VBE_active=0.7; // in volts
// From Fig. 4.19
```

```
VCC=10; // in volts
VBB=5; // in volts
RB=100e3; // in ohms
RE=2e3; // in ohms
RC=2e3; // in ohms
// Writing KVL to the base circuit and putting Ic=
    F *Ib
IB=(VBB-VBE_active)/(RB+(1+betaf)*RE); // in amperes
IB=IB*1e3; // in miliamperes
IC=betaf*IB; // in miliamperes
IE=IB+IC; // in miliamperes
VB=VBB-IB*RB*1e-3; // in volts
VE=IE*RE*1e-3; // in volts
VC=VCC-IC*RC*1e-3; // in volts
disp(VC,"VC (V) =");
disp(VE,"VE (V) =");
disp(VB,"VB (V) =");
disp(IC,"IC (mA) =");
disp(IE,"IE (mA) =");
disp(IB,"IB (mA) =");
disp("Since base voltage VB is 3.6 V and collector
   is at 7.2 V, so collector-base junction is
   reverse biased by 3.6 V. Thus our assumption that
    the transistor is in active region is valid.")
```

Scilab code Exa 4.4 Region of Operation

```
// Example 4.4: Region of operation
clc, clear
betaf=100; // Current gain
disp("Let us assume that the transistor is in
   saturation region.");
VBE_sat=0.8; // in volts
VCE_sat=0.2; // in volts
// From Fig. 4.21
```

```
VCC=10; // in volts
VBB=5; // in volts
RB=50e3; // in ohms
RC=2e3; // in ohms
// From the base loop
IB=(VBB-VBE_sat)/RB; // in amperes
IB=IB*1e3; // in miliamperes
IC_sat=(VCC-VCE_sat)/RC; // in amperes
IC_sat=IC_sat*1e3; // in miliamperes
IB_min=IC_sat/betaf; // in miliamperes
disp(IB_min,"Minimum IB required to saturate the
    transistor (mA) =");
disp(IB,"IB in the circuit (mA) =");
disp("Since IB in the circuit is calculated as 0.084
    mA, so it is greater than IB,min. Thus the
    transistor is indeed in saturation mode.")
```

Scilab code Exa 4.5 Saturation region

```
// Example 4.5: Value of RB so as to drive the
    transistor into saturation
clc, clear
bta=50; // Current gain
VBE_sat=0.8; // in volts
VCE_sat=0.2; // in volts
// From Fig. 4.22
VCC=10; // in volts
VBB=5; // in volts
RC=1e3; // in ohms
IC_sat=(VCC-VCE_sat)/RC; // in amperes
IB_min=IC_sat/bta; // Minimum base current in
    amperes to saturate the transistor
// Then base current can be taken as
IB=10*IB_min; // in amperes
RB=(VBB-VBE_sat)/IB; // in ohms
```

```
RB=RB*1e-3; // in kilo-ohms
disp(RB,"Value of RB so as to drive the transistor
   into saturation (k  ) =");
```

Scilab code Exa 4.6 Output voltages

```
// Example 4.6: Vo1, Vo2
clc, clear
betaf=100; // Current gain
disp("Let us assume that the transistor is in active
    region.");
VBE_active=-0.7; // in volts
// From Fig. 4.23
VCC=-10; // in volts
VEE=10; // in volts
VBB=2.5; // in volts
RE=6.8e3; // in ohms
RB=100e3; // in ohms
RC=10e3; // in ohms
// Writing KVL for base-emitter circuit and putting
   Ic= F *Ib
IB=(VEE-VBB+VBE_active)/(RB+(1+betaf)*RE); // in
   amperes

IC=betaf*IB; // in amperes
IE=IB+IC; // in amperes
Vo1=VCC+IC*RC; // in volts
Vo2=VEE-IE*RE; // in volts
VB=VBB+IB*RB; // in volts
disp(Vo1,"Vo1 (V) =");
disp(Vo2,"Vo2 (V) =");
disp(VB,"Voltage at base (V) =")
disp("As base voltage, VB is 3.36 V and voltage at
   collector is -1.4 V, collector base junction is
   reverse biased. Thus the transistor is indeed in
```

```
    active region as assumed.")
```

Scilab code Exa 4.7 pnp transistor

```
// Example 4.7: Value of RC to obtain VC = +5 V
clc, clear
betaf=50; // Current gain
disp("Let us assume that the transistor is in active
    region.");
disp("When current gain = 50")
VBE_active=-0.7; // in volts
// From Fig. 4.24
VC=5; // in volts
VEE=10; // in volts
RB=100e3; // in ohms
// Writing KVL for base circuit and putting Ic=  F *
   Ib
IB=(VEE+VBE_active)/RB; // in amperes
IC=IB*betaf; // in amperes
RC=VC/IC; // in ohms
RC=RC*1e-3; // in kilo-ohms
disp(RC,"Value of RC to obtain VC = +5 V ( k  ) =");
disp("When current gain = 100");
IC=IB*100; // in amperes
VC=IC*RC*1e3; // in volts
disp(VC,"Collector voltage (V) =");
disp("Since collector voltage is greater than the
   base voltage, the transistor goes into saturation
    as collector junction gets forward biased.");
```

Scilab code Exa 4.8 Solving a circuit with transistor

```
// Example 4.8: :Labelled voltages and currents
```

```
clc, clear
betaf=100; // Current gain
disp("Let us assume that the transistor is in active region.");
VBE_active=-0.7; // in volts
// From Fig. 4.25(a)
VCC=-10; // in volts
VEE=10; // in volts
RE=6.8e3; // in ohms
RC=10e3; // in ohms
R1=300e3; // in ohms
R2=180e3; // in ohms
// Applying Thevnin's theorem at point B
R_th=R1*R2/(R1+R2); // in ohms
V_th=VEE-(R2*(VEE-VCC)/(R1+R2)); // in volts
// From the Thevnin equivalent circuit in Fig. 4.25(b)
// Writing KVL for base-emitter circuit and putting Ic= F *Ib
IB=(VEE-V_th+VBE_active)/(R_th+(1+betaf)*RE); // in amperes
IB=IB*1e3; // in miliamperes
IC=betaf*IB; // in miliamperes
IE=IB+IC; // in miliamperes
VC=VCC+IC*RC*1e-3; // in volts
VE=VEE-IE*RE*1e-3; // in volts
VB=V_th+IB*R_th*1e-3; // in volts
I1=(VEE-VB)/R2; // in amperes
I1=I1*1e3; // in miliamperes
I2=I1+IB; // in miliamperes
disp(IC,"IC (mA) =");
disp(IE,"IE (mA) =");
disp(IB,"IB (mA) =");
disp(I1,"I1 (mA) =");
disp(I2,"I2 (mA) =");
disp(VC,"VC (V) =");
disp(VE,"VE (V) =");
disp(VB,"VB (V) =");
```

Chapter 5

BJT Biasing and Stability

Scilab code Exa 5.1 Fixed bias circuit

```
// Example 5.1: RB, RC
clc, clear
IB=40e-6; // in amperes
VCE=6; // in volts
VCC=12; // in volts
betaf=80;
VBE=0.7; // in volts
RB=(VCC-VBE)/IB; // in ohms
RC=(VCC-VCE)/(betaf*IB); // in ohms
RB=RB*1e-3; // in kilo-ohms
RC=RC*1e-3; // in kilo-ohms
disp(RB,"RB (k ) =");
disp(RC,"RC (k ) =");
```

Scilab code Exa 5.2 Determination of Q point

```
// Example 5.2: VCEQ, ICQ
clc, clear
```

```
VBE=0.7; // in volts
betaf=50;
// From Fig. 5.11(a)
VCC=18; // in volts
R1=82e3; // in ohms
R2=22e3; // in ohms
RC=5.6e3; // in ohms
RE=1.2e3; // in ohms
// Using Thevnin's theorem to obtain equivalent
    circuit given in Fig. 5.11(b)
VBB=R2*VCC/(R1+R2); // in volts
RB=R1*R2/(R1+R2); // in ohms
IB=(VBB-VBE)/(RB+(1+betaf)*RE); // in amperes
IC=betaf*IB; // in amperes
VCE=VCC-IC*(RC+RE)-IB*RE; // in volts
IC=IC*1e3; // in mili-amperes
disp(VCE,"VCEQ (V) =");
disp(IC,"ICQ (mA) =");
```

Scilab code Exa 5.3 Self biased circuit

```
// Example 5.3: R1, R2, RC, RE
clc, clear
IC=1e-3; // in amperes
VCC=12; // in volts
betaf=100;
VBE=0.7; // in volts
// As suggested in the design constraints, allocate
    1/3VCC to RC, another 1/3VCC to R2 leaving 1/3VCC
     for VCEQ.
VB=4; // in volts
VE=VB-VBE; // in volts
// Neglecting base current,
RE=VE/IC; // in ohms
// Select the current through R1R2 equal to 0.1IC
```

```
R1_plus_R2=VCC/(0.1*IC); // in ohms
R2=VB*R1_plus_R2/VCC; // in ohms
R1=R1_plus_R2-R2; // in ohms
RC=VCC/(3*IC); // in ohms
R1=R1*1e-3; // in kilo-ohms
R2=R2*1e-3; // in kilo-ohms
RC=RC*1e-3; // in kilo-ohms
RE=RE*1e-3; // in kilo-ohms
disp(R1,"R1 (k ) =");
disp(R2,"R2 (k ) =");
disp(RC,"RC (k ) =");
disp(RE,"RE (k ) =");
```

Scilab code Exa 5.4 Amplifier circuit

```
// Example 5.4: VCEQ, ICQ
clc, clear
VBE=0.7; // in volts
betaf=45;
// From Fig. 5.14
VEE=9; // in volts
RB=100e3; // in ohms
RC=1.2e3; // in ohms
// Applying KVL in the clockwise direction base
   emitter loop
IB=(VEE-VBE)/RB; // in amperes
IC=betaf*IB; // in amperes
// Writing KVL for the collector loop
VCE=VEE-IC*RC; // in volts
IC=IC*1e3; // in mili-amperes
disp(VCE,"VCEQ (V) =");
disp(IC,"ICQ (mA) =");
```

Scilab code Exa 5.5 Determination of Q point

```
// Example 5.5: VCEQ, ICQ
clc, clear
VBE=0.7; // in volts
betaf=120;
// From Fig. 5.15
VCC=20; // in volts
VEE=20; // in volts
R1=8.2e3; // in ohms
R2=2.2e3; // in ohms
RC=2.7e3; // in ohms
RE=1.8e3; // in ohms
// Using Thevnin's theorem to obtain equivalent circuit given in Fig. 5.16(b)
RB=R1*R2/(R1+R2); // in ohms
// From Fig. 5.16(a)
I=(VCC+VEE)/(R1+R2); // in amperes
VBB=I*R2-VEE; // in volts
// Writing KVL for the base emitter loop and putting Ic= F *Ib gives
IB=(VEE+VBB-VBE)/(RB+(1+betaf)*RE); // in amperes
IC=betaf*IB; // in amperes
// KVL for the collector loop gives
VCE=VCC+VEE-IC*(RC+RE)-IB*RE; // in volts
IC=IC*1e3; // in mili-amperes
disp(VCE,"VCEQ (V) =");
disp(IC,"ICQ (mA) =");
```

Scilab code Exa 5.6 Amplifier circuit

```
// Example 5.6: RF so that IE=+2 mA
clc, clear
IE=2e-3; // in amperes
VBE=0.7; // in volts
```

```
betaf=49;
// From Fig. 5.17
VCC=12; // in volts
RB=25e3; // in ohms
RC=2e3; // in ohms
I1=VBE/RB; // in amperes
IB=IE/(1+betaf); // in amperes
// KVL for the indicated loop gives
RF=(VCC-RC*(I1+(1+betaf)*IB)-VBE)/(I1+IB); // in ohms
RF=RF*1e-3; // in kilo-ohms
disp(RF,"RF so that IE=+2 mA (k  ) =");
```

Scilab code Exa 5.7 `Amplifier circuit`

```
// Example 5.7: RCQ, RE
clc, clear
VCEQ=3; // in volts
VBE=0.7; // in volts
betaf=200;
// From Fig. 5.18(a)
VCC=6; // in volts
VEE=6; // in volts
R1=90e3; // in ohms
R2=90e3; // in ohms
// Using Thevnin's theorem to obtain equivalent circuit given in Fig. 5.18(b)
RB=R1*R2/(R1+R2); // in ohms
VBB=R2*(VCC+VEE)/(R1+R2); // in volts
// In the output loop
x=VEE-VCEQ; // x = (IC+IB)RE in volts
// Applying KVL in the base emitter loop
IB=(VEE-VBE-x)/RB; // in amperes
IC=betaf*IB; // in amperes
// In the output loop
```

```
RC=VCC/IC; // in ohms
RE=x/(IC+IB); // in ohms
RC=RC*1e-3; // in kilo-ohms
RE=RE*1e-3; // in kilo-ohms
disp(RC,"RC (k ) =");
disp(RE,"RE (k ) =");
```

Scilab code Exa 5.8 Q point voltage

```
// Example 5.8: VCEQ
clc, clear
VBE=-0.7; // in volts
betaf=120;
// From Fig. 5.19(a)
VCC=18; // in volts
R1=47e3; // in ohms
R2=10e3; // in ohms
RC=2.4e3; // in ohms
RE=1.1e3; // in ohms
// Using Thevnin's theorem to obtain equivalent
    circuit given in Fig. 5.19(b)
VBB=R2*VCC/(R1+R2); // in volts
RB=R1*R2/(R1+R2); // in ohms
// Applying KVL in the base emitter loop and putting
    Ic= F *Ib
IB=(VBB+VBE)/(RB+(1+betaf)*RE); // in amperes
IC=betaf*IB; // in amperes
// In the collector emitter loop
VCE=-VCC+IC*(RC+RE)+IB*RE; // in volts
disp(VCE,"VCEQ (V) =");
```

Scilab code Exa 5.9 Stability factor

```
// Example 5.9 :(i) RB
//             (ii) Stability factor
//            (iii) IC at 100 C
clc, clear
bta=50;
VBE=0.7; // in volts
VCE=5; // in volts
// From Fig. 5.21
VCC=24; // in volts
RC=10e3; // in ohms
RE=500; // in ohms

disp("Part (i)");
// Applying KVL to the collector emitter circuit and putting Ic= F *Ib
IB=(VCC-VCE)/((RC+RE)*(bta+1)); // in amperes
IC=bta*IB; // at 25 C in amperes
RB=(VCE-VBE)/IB; // in ohms
RB=RB*1e-3; // in kilo-ohms
disp(RB,"RB (k ) =")

disp("Part (ii)");
S=(1+bta)/(1+bta*(RC+RE)/(RC+RE+RB*1e3)); // Stability factor
disp(S,"Stability factor =");

disp("Part (iii)");
// From Table 5.1
del_ICO=(20-0.1)*1e-9; // in amperes
del_IC=S*del_ICO; // in amperes
IC=IC+del_IC; // at 100 C in amperes
IC=IC*1e3; // at 100 C in mili-amperes
disp(IC,"IC at 100 C (mA) =");
```

Scilab code Exa 5.10 `Self bias circuit`

```
// Example 5.10: (i) S(ICO) for RB/RE=10 and change in IC
//                (ii) S(VBE) for RB = 240 k , RE = 1 k  and change in IC
clc, clear
bta=100;

disp("Part (i)");
RB_RE=10; // RB/RE
S_ICO=(1+bta)*(1+RB_RE)/(1+bta+RB_RE);
// From Table 5.1
del_ICO=(20-0.1)*1e-9; // in amperes
del_IC=S_ICO*del_ICO; // in amperes
del_IC=del_IC*1e6; // in micro-amperes
disp(S_ICO,"S(ICO) for RB/RE=10");
disp(del_IC,"Change in IC ( A ) =");

disp("Part (ii)");
RB=240e3; // in kilo-ohms
RE=1e3; // in kilo-ohms
S_VBE=-bta/(RB+(1+bta)*RE);
// From Table 5.1
del_VBE=0.48-0.65; // in volts
del_IC=S_VBE*del_VBE; // in amperes
del_IC=del_IC*1e6; // in micro-amperes
disp(S_VBE,"S(VBE) for (RB = 240 k , RE = 1 k ) =");
disp(del_IC,"Change in IC ( A ) =");
```

Scilab code Exa 5.11 Stability factor

```
// Example 5.11: S( ), IC at 100 C
clc, clear
IC=2e-3; //  at 25 C in amperes
// From Table 5.1
```

```
bta1=50; // at 25 C
bta2=80; // at 100 C
RB_RE=10; // RB/RE
S=IC*(1+RB_RE)/(bta1*(1+bta2+RB_RE));
del_bta=bta2-bta1;
del_IC=S*del_bta; // in amperes
IC=IC+del_IC; //  at 100 C  in amperes
IC=IC*1e3; //  at 100 C  in mili-amperes
disp(S,"S(   ) =");
disp(IC,"IC at 100 C  (mA) =");
```

Scilab code Exa 5.12 Variation of collector current

```
// Example 5.12: Variation of IC over the temperature range -65 C  to 175 C
clc, clear
RB_RE=2; // RB/RE
RE=4.7e3; // in ohms
IC=2e-3; // at 25 C  in amperes
// From Table 5.1
bta=50; // at 25 C
S_ICO=(1+bta)*(1+RB_RE)/(1+bta+RB_RE);
S_VBE=-bta/(RE*(1+bta+RB_RE));
// From Table 5.1
bta1=20; // at -65 C
bta2=120; // at 175 C
S_bta1=IC*(1+RB_RE)/(bta*(1+bta1+RB_RE)); // For 25 C  to -65 C
S_bta2=IC*(1+RB_RE)/(bta*(1+bta2+RB_RE)); // For 25 C  to 175 C
// From Table 5.1

// For 25 C  to -65 C
del_ICO=(0.2e-3-0.1)*1e-9; // in amperes
del_VBE=0.85-0.65; // in volts
```

```
del_bta=bta1-bta;
del_IC=S_ICO*del_ICO+S_VBE*del_VBE+S_bta1*del_bta; // in amperes
IC1=IC+del_IC; // at -65 C in amperes
IC1=IC1*1e3; // at -65 C in mili-amperes
disp(IC1,"IC at -65 C (mA) =");

// For 25 C to 175 C
del_ICO=(3.3e3-0.1)*1e-9; // in amperes
del_VBE=0.30-0.65; // in volts
del_bta=bta2-bta;
del_IC=S_ICO*del_ICO+S_VBE*del_VBE+S_bta2*del_bta; // in amperes
IC2=IC+del_IC; // at 175 C in amperes
IC2=IC2*1e3; // at 175 C in mili-amperes
disp(IC2,"IC at 175 C (mA) =");
```

Scilab code Exa 5.13 `Current mirror`

```
// Example 5.13: (i) R1
//               (ii) R1 for IC = 10  A
clc, clear
IC=1e-3; // in amperes
VCC=10; // in volts
bta=125;
VBE=0.7; // in volts

disp("Part (i)");
R1=bta*(VCC-VBE)/((bta+2)*IC); // in ohms
R1=R1*1e-3; // in kilo-ohms
disp(R1,"R1 (k ) =");

disp("Part (i)");
IC=10e-6; // in amperes
R1=bta*(VCC-VBE)/((bta+2)*IC); // in ohms
```

```
R1=R1*1e-3; // in kilo-ohms
disp(R1,"R1 for (IC = 10  A ) ( k  ) =");
```

Scilab code Exa 5.14 `Widlar current source`

```
// Example 5.14: R1, RE
clc, clear
Io=10e-6; // in amperes
VCC=10; // in volts
bta=125;
VBE=0.7; // in volts
VT=25e-3; // in volts
// Let
I_ref=1e-3; // in amperes
R1=(VCC-VBE)/I_ref; // in ohms
R1=R1*1e-3; // in kilo-ohms
RE=VT*log(I_ref/Io)/((1+1/bta)*Io); // in ohms
RE=RE*1e-3; // in kilo-ohms
disp(R1,"R1 ( k  ) =");
disp(RE,"RE ( k  ) =");
```

Scilab code Exa 5.15 `Current Repeaters`

```
// Example 5.11: IC1, IC2, IC3
clc, clear
bta=125;
VBE=0.7; // in volts
VT=25e-3; // Voltage equivalent to temperatue at room temperature in volts
// From Fig. 5.27
VC=9; // in volts
RC=30; // in kilo-ohms
RE=1.94; // in kilo-ohms
```

```
I_ref=(VC-VBE)/RC; // in mili-amperes
IC=I_ref*bta/(3+bta); // in mili-amperes
for i=0.01:0.001:0.5
    if abs(VT*log(IC/i)/(i*(1+1/bta))-RE)<=0.1 then
        break;
    end
end
disp(IC,"IC1 (mA) =");
disp(IC,"IC2 (mA) =");
disp(i,"IC3 (mA) =");
```

Scilab code Exa 5.16 Output current

```
// Example 5.16: Io
clc, clear
bta=100;
VBE=0.7; // in volts
// From Fig. 5.30
// Writing KVL for the indicated loop
I_ref=(10-VBE)/10; // in mili-amperes
Io=bta*I_ref/(2*(1+bta)); // in mili-amperes
disp(Io,"Io (mA) =");
```

Scilab code Exa 5.17 Current mirror

```
// Example 5.17: (i) IC1 and IC2
//                (ii) RC so that Vo = 6 V
clc, clear
bta=200;
// From Fig. 5.31

disp("Part (i)");
I_ref=(12-0.7)/15; // in amperes
```

```
I1=0.7/2.8; // in amperes
IC=(I_ref-I1)*bta/(bta+2); // in mili-amperes
disp(IC,"IC1 (mA) =");
disp(IC,"IC2 (mA) =");

disp("Part (ii)");
Vo=6; // in volts
RC=(12-Vo)/IC; // in kilo-ohms
disp(RC,"RC so that (Vo = 6 V) (k  ) =");
```

Scilab code Exa 5.18 Modified current mirror

```
// Example 5.18: Emitter current in transistor Q3
clc, clear
bta=100;
VBE=0.75; // in volts
// From Fig. 5.32
I=(10-VBE)/4.7; // in mili-amperes
IE=I/2; // in mili-amperes
disp(IE,"Emitter current in transistor Q3 (mA) =");
```

Chapter 6

BJT Ampilifiers

Scilab code Exa 6.2 `Bipolar Junction Transistor`

```
// Example 6.2: r  , gm
clc, clear
IBQ=7.6e-6; // in amperes
bta=104;
VT=25e-3; // Voltage equivalent to temperatue at room temperature in volts
ICQ=IBQ*bta; // in amperes
gm=ICQ/VT; // in ampere per volt
gm=gm*1e3; // in mili-ampere per volt
r_pi=bta/gm; // in kilo-ohms
disp(r_pi,"r  (k  ) =");
disp(gm,"gm (mA/V) =");
```

Scilab code Exa 6.3 `Hybrid h parameter model`

```
// Example 6.3: AI, Ri, AV, AVs, Ro, Ro'
clc, clear
hie=1e3; // in ohms
```

```
hfe=100;
hre=2e-4;
hoe=20e-6; // in amperes per volt
RC=5e3; // in ohms
Rs=1e3; // in ohms
// From Table 6.3
AI=-hfe/(1+hoe*RC);
Ri=hie+hre*AI*RC; // in ohms
AV=AI*RC/Ri;
AVs=AV*Ri/(Ri+Rs);
Yo=hoe-hfe*hre/(hie+Rs); // in ohms inverse
Ro=1/Yo; // in ohms
Ro_dash=Ro*RC/(Ro+RC); // in ohms
Ri=Ri*1e-3; // in kilo-ohms
Ro=Ro*1e-3; // in kilo-ohms
Ro_dash=Ro_dash*1e-3; // in kilo-ohms
disp(AI,"AI =");
disp(Ri,"Ri (k ) =");
disp(AV,"AV =");
disp(AVs,"AVs =");
disp(Ro,"Ro (k ) =");
disp(Ro_dash,"Ro'' (k ) =");
```

Scilab code Exa 6.4 Bipolar Junction Transistor

```
// Example 6.4: AI', AVs, Ri,eff, Ro, Ro'
clc, clear
hie=2e3; // in ohms
hfe=50;
hre=2e-4;
hoe=20e-6; // in amperes per volt
// From Fig. 6.22(a)
Rs=2e3; // in ohms
R1=90e3; // in ohms
R2=10e3; // in ohms
```

```
RC=5e3; // in ohms
// From the Table 6.3
RB=R1*R2/(R1+R2); // in ohms
AI=-hfe/(1+hoe*RC);
Ri=hie+hre*AI*RC; // in ohms
Ri_eff=RB*Ri/(RB+Ri); // in ohms
AI_dash=AI*RB/(RB+Ri);
AVs=AI*RC*Ri_eff/(Ri*(Rs+Ri_eff));
Rs_eff=Rs*RB/(Rs+RB); // in ohms
Yo=hoe-hfe*hre/(hie+Rs_eff); // in ohms inverse
Ro=1/Yo; // in ohms
Ro_dash=Ro*RC/(Ro+RC); // in ohms
Ri_eff=Ri_eff*1e-3; // in kilo-ohms
Ro=Ro*1e-3; // in kilo-ohms
Ro_dash=Ro_dash*1e-3; // in kilo-ohms
disp(AI_dash,"AI'' =");
disp(AVs,"AVs =");
disp(Ri_eff,"Ri,eff (k ) =");
disp(Ro,"Ro (k ) =");
disp(Ro_dash,"Ro'' (k ) =");
```

Scilab code Exa 6.5 Simplified h parameter model

```
// Example 6.5: AI, AVs, Ri, Ro'
clc, clear
hie=4e3; // in ohms
hfe=200;
// From Fig. 6.27(a)
Rs=5e3; // in ohms
R1=90e3; // in ohms
R2=10e3; // in ohms
RC=5e3; // in ohms
RE=1e3; // in ohms
// From Fig 6.27(b)
RB=R1*R2/(R1+R2); // in ohms
```

```
Ri=hie+(1+hfe)*RE; // in ohms
Ri_eff=RB*Ri/(RB+Ri); // in ohms
AI=-hfe*RB/(RB+Ri);
AVs=-hfe*RC*Ri_eff/(Ri*(Rs+Ri_eff));
Ro_dash=RC; // in ohms
Ri=Ri*1e-3; // in kilo-ohms
Ro_dash=Ro_dash*1e-3; // in kilo-ohms
disp(AI,"AI =");
disp(AVs,"AVs =");
disp(Ri,"Ri (k ) =");
disp(Ro_dash,"Ro'' (k ) =");
```

Scilab code Exa 6.6 Hybrid pi model

```
// Example 6.6: AI, Ri, AVs
clc, clear
bta=100;
VBE=0.7; // Cut-in voltage in volts
VT=25e-3; // Voltage equivalent to temperatue at
    room temperature in volts
// From Fig. 6.33
RB=100e3; // in ohms
RC=3e3; // in ohms
VBB=3; // in volts

// DC analysis
// From dc equivalent circuit in Fig. 6.34(a)
IBQ=(VBB-VBE)/RB; // in amperes
ICQ=bta*IBQ; // in amperes
gm=ICQ/VT; // in ampere per volt
r_pi=bta/gm; // in ohms

// AC analysis
// From ac equivalent circuit using approximate
    hybrid-   model in Fig. 6.34(b)
```

```
AI=-bta;
Ri=RB+r_pi; // in ohms
AVs=-bta*RC/(RB+r_pi);
Ri=Ri*1e-3; // in kilo-ohms
disp(AI,"AI =");
disp(Ri,"Ri (k ) =");
disp(AVs,"AVs =");
```

Scilab code Exa 6.7 CC amplifier

```
// Example 6.7: (a) Load resistance RE to make Ri 500 k
//              (b) AV, Ro, Ro'
clc, clear
IC=2e-3; // in amperes
Rs=5e3; // Source resistance in ohms
bta=125;
VT=25e-3; // Voltage equivalent to temperatue at room temperature in volts

disp("Part (a)");
Ri=500e3; // in ohms
gm=IC/VT; // in mho
r_pi=bta/gm; // in ohms
RE=(Ri-r_pi)/(1+bta); // in ohms
REk=RE*1e-3; // in kilo-ohms
disp(REk,"RE (k ) =");

disp("Part (b)");
AV=(1+bta)*RE/(Rs+Ri);
Ro=(Rs+r_pi)/(1+bta); // in ohms
Ro_dash=Ro*RE/(Ro+RE); // in ohms
disp(Ro,"Ro ( ) =");
disp(Ro_dash,"Ro'' ( ) =");
```

Scilab code Exa 6.8 Voltage gain

```
// Example 6.8: Ri, AVs
clc, clear
IC=0.2e-3; // in amperes
bta=125;
Rs=2e3; // in ohms
RE=100; // in ohms
RC=5e3; // in ohms
VT=25e-3; // Voltage equivalent to temperatue at room temperature in volts
gm=IC/VT; // in mho
r_pi=bta/gm; // in ohms
Ri=r_pi+(1+bta)*RE; // in ohms
AVs=-bta*RC/(Rs+r_pi+(1+bta)*RE);
Ri=Ri*1e-3; // in kilo-ohms
disp(Ri,"Ri ( k  ) =");
disp(AVs,"AVs =");
```

Scilab code Exa 6.9 Hybrid pi model

```
// Example 6.9: r  , AI, Ri, AVs, Ro, Ro'
clc, clear
bta=200;
VT=25e-3; // Voltage equivalent to temperatue at room temperature in volts
// From Fig. 6.39
VBE=0.7; // Cut-in voltage in volts
VCC=9; // in volts
RB=200e3; // in ohms
RC=2e3; // in ohms

```

```
// DC analysis
// From dc equivalent circuit in Fig. 6.40(a)
// Writing KVL from collector to base loop
IB=(VCC-VBE)/(RB+(1+bta)*RC); // in amperes
ICQ=bta*IB;  // in amperes
gm=ICQ/VT; // in mho
r_pi=bta/gm; // in ohms

// AC analysis
// From ac equivalent circuit using Miller's theorem in Fig. 6.40(b)
// Assuming AV >> 1
RL=RB*RC/(RB+RC); // Effective load resistance in ohms
// Using hybrid-  model and approximate resulta given in Table 6.5 for CE amplifier stage, we have
AI=-bta;
AV=-bta*RL/r_pi;
Ro=%inf;
r_pi=r_pi*1e-3; // in kilo-ohms
RL=RL*1e-3; // in kilo-ohms
disp(r_pi,"r  (k  ) =");
disp(AI,"AI =");
disp(AV,"AVs =");
disp(Ro,"Ro =");
disp(RL,"Ro'' (k  ) =");
```

Scilab code Exa 6.10 `re model`

```
// Example 6.10: Ri,eff, Ro, AV, AI
clc, clear
bta=200;
ro=50e3; // in ohms
VBE=0.7; // Cut-in voltage in volts
```

```
VT=25e-3; // Voltage equivalent to temperatue at room temperature in volts
// From Fig. 6.44
VCC=16; // in volts
R1=90e3; // in ohms
R2=10e3; // in ohms
RC=2.2e3; // in ohms
RE=0.68e3; // in ohms

// DC analysis
// From the Thevnin's equivalent circuit in Fig. 6.45(a)
RB=R1*R2/(R1+R2); // in ohms
VBB=VCC*R2/(R1+R2); // in volts
// From the base loop
IB=(VBB-VBE)/(RB+(1+bta)*RE); // in amperes
IE=(1+bta)*IB; // in amperes
re=VT/IE; // in ohms

// AC analysis
Ri=bta*re+(1+bta)*RE; // in ohms
Ri_eff=RB*Ri/(RB+Ri); // in ohms
AI=-bta*RB/(RB+bta*(re+RE));
AV=-RC/RE;
Ri_eff=Ri_eff*1e-3; // in kilo-ohms
disp(Ri_eff,"Ri,eff (k ) =");
disp(%inf,"Ro =");
disp(AI,"AI =");
disp(AV,"AVs =");
```

Chapter 7

Field Effect Transistors Characteristics and Biasing

Scilab code Exa 7.1 `Transfer curve of FET`

```
// Example 7.1: Transfer curve
clc, clear
IDSS=12; // in mili-amperes
VP=-5; // in volts
// Plotting transfer curve
VGS=[0:-0.01:VP]; // Gate source voltage in volts
// Using Shockley's equation
ID=IDSS*(1-VGS/VP)^2; // Drain current in mili-
    amperes
plot(VGS,ID);
xtitle("Transfer Curve","VGS (V)","ID (mA)");
```

Scilab code Exa 7.2 `NMOS transistor`

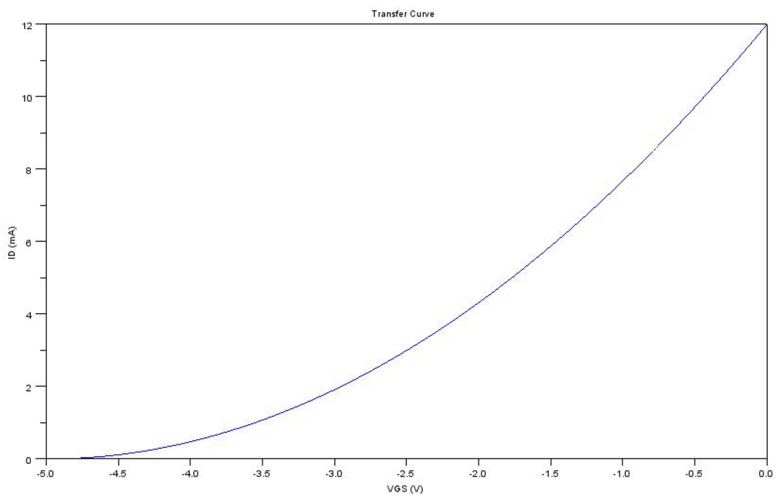

Figure 7.1: Transfer curve of FET

```
// Example 7.2: (a) Region of operation
//              (b) Region of operation
//              (c) Region of operation
clc, clear
VT=2; // in volts
VGS=3; // in volts
disp(VGS-VT,"VGS - VT (V)");

disp("Part (a)");
disp(0.5,"VDS (V) =");
disp("Since VDS < VGS - VT, therefore transistor is in ohmic region.");

disp("Part (b)");
disp(1,"VDS (V) =");
disp("Since VDS = VGS - VT, therefore transistor is in saturation region.");

disp("Part (c)");
```

```
disp(5,"VDS (V) =");
disp("Since VDS > VGS - VT, therefore transistor is
    in saturation region.");
```

Scilab code Exa 7.3 n channel JFET

```
// Example 7.3: IDQ, VDSQ
clc, clear
IDSS=12; // in mili-amperes
VP=-4; // in volts
// From Fig. 7.28
VDD=12; // in volts
RD=1.2; // in kilo-ohms
// Since IG=0
VGS=-1.5; // in volts
// Using Shockley's equation
ID=IDSS*(1-VGS/VP)^2; // Drain current in mili-
    amperes
VDS=VDD-ID*RD; // in volts
disp(ID,"IDQ (mA) =");
disp(VDS,"VDSQ (V) =");
```

Scilab code Exa 7.4 Self bias configuration

```
// Example 7.4: VDSQ, IDSQ, VD, VS
clc, clear
IDSS=6e-3; // in amperes
VP=-6; // in volts
// From Fig. 7.31
VDD=12; // in volts
RD=2.2e3; // in ohms
```

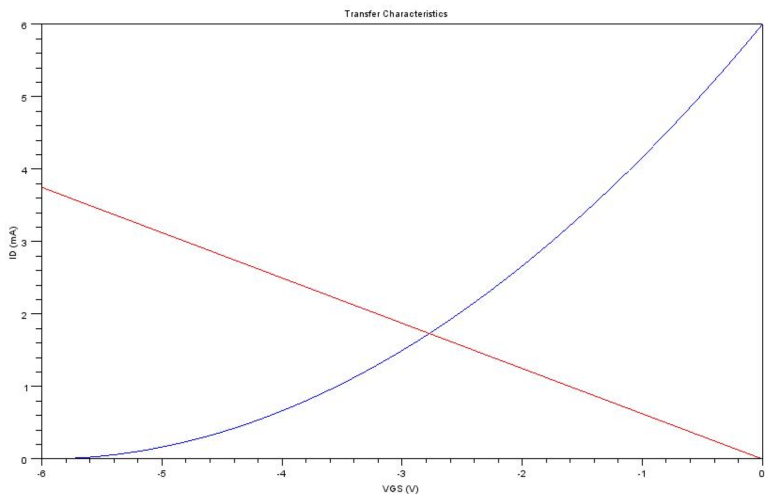

Figure 7.2: Self bias configuration

```
RS=1.6e3; // in ohms
// Plotting transfer characteristics
VGS=[0:-0.01:VP]; // Gate source voltage in volts
// Using Shockley's equation
ID=IDSS*(1-VGS/VP)^2; // Drain current in amperes
ID=ID*1e3; // Drain current in mili-amperes
plot(VGS,ID);
xtitle("Transfer Characteristics","VGS (V)","ID (mA)
  ");
// Plotting bias line
// From gate source circuit
ID=-VGS/RS; // Source current in amperes
ID=ID*1e3; // Source current in mili-amperes
plot(VGS,ID,"RED");
// Intersection of transfer characteristics with the
   bias curve
// Putting VGS = -ID*RS in Shockley's equation and
  solving, we get ID^2*RS^2 + (2*RS*VP - VP^2/IDSS)
  *ID + VP^2
```

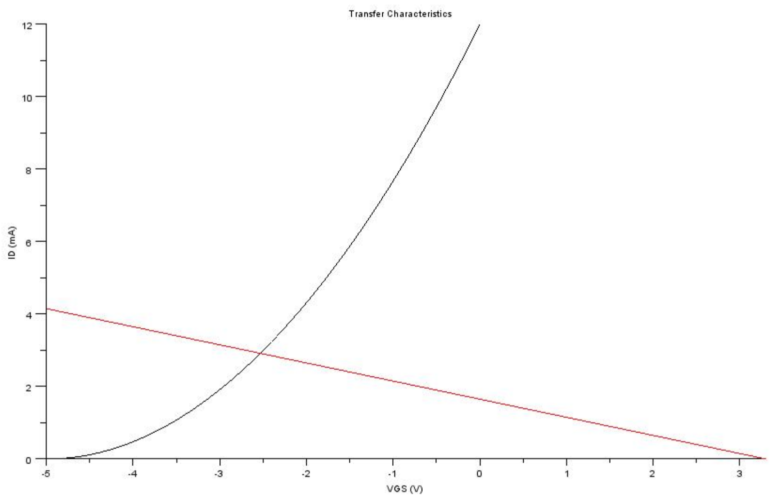

Figure 7.3: Operating point

```
// Solving the equation
p_eq = poly([VP^2 (2*RS*VP-VP^2/IDSS) RS^2],"x","coeff");
p_roots= roots(p_eq);
IDQ=p_roots(1); // in amperes
// Writing the KVL for the output loop
VDSQ=VDD-IDQ*(RD+RS); // in volts
VS=IDQ*RS; // in volts
VD=VDSQ+VS; // in volts
IDQ=IDQ*1e3; // in mili-amperes
disp(VDSQ,"VDSQ (V) =");
disp(IDQ,"IDQ (mA) =");
disp(VD,"VD (V) =");
disp(VS,"VS (V) =");
```

Scilab code Exa 7.5 Operating point

```
// Example 7.5: Operating point
clc, clear
VP=-5; // in volts
IDSS=12e-3; // in amperes
// From Fig. 7.34(a)
VDD=18; // in volts
R1=400; // in kilo-ohms
R2=90; // in kilo-ohms
RD=2e3; // in ohms
RS=2e3; // in ohms
// Applying Thevnin's theorem to obtain simplified circuit in Fig. 7.34(b)
VGG=VDD*R2/(R1+R2); // in volts
// Plotting transfer characteristics
VGS=[VGG:-0.01:VP]; // Gate source voltage in volts
// Using Shockley's equation
ID=IDSS*(1-VGS/VP)^2; // Drain current in amperes
ID=ID*1e3; // Drain current in mili-amperes
plot2d(VGS,ID,rect=[-5,0,3,12]);
xtitle("Transfer Characteristics","VGS (V)","ID (mA)");
// Plotting bias line
// From the KVL for the gate-loop
ID=(-VGS+VGG)/RS; // Source current in amperes
ID=ID*1e3; // Source current in mili-amperes
plot(VGS,ID,"RED");
// Intersection of transfer curve with the bias curve
// Putting VGS = VGG-ID*RS in Shockley's equation and solving, we get
// ID^2*RS^2 + (2*RS*VP - 2*VGG*RS - VP^2/IDSS)*ID + (VGG-VP)^2
// Solving the equation
p_eq = poly([(VGG-VP)^2 (2*RS*VP-2*VGG*RS-VP^2/IDSS) RS^2],"x","coeff");
p_roots= roots(p_eq);
```

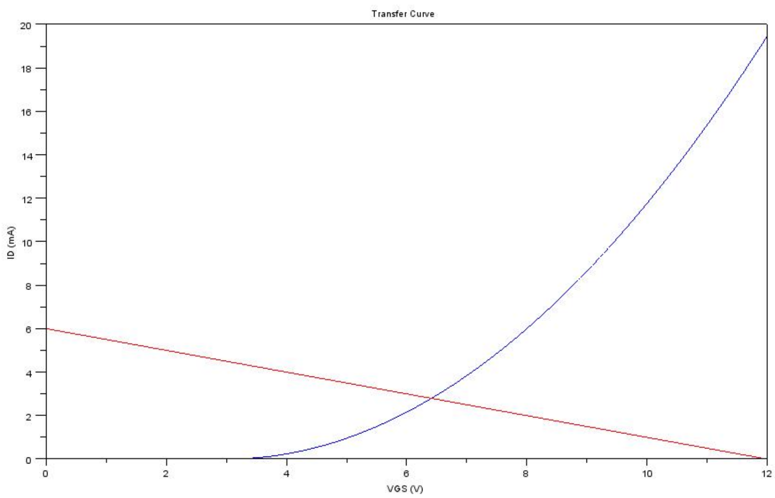

Figure 7.4: n channel enhancement type MOSFET

```
IDQ=p_roots(1); // in amperes
// Writing the KVL for the drain source loop
VDSQ=VDD-IDQ*(RD+RS); // in volts
IDQ=IDQ*1e3; // in mili-amperes
disp(VDSQ,"VDSQ (V) =");
disp(IDQ,"IDQ (mA) =");
```

Scilab code Exa 7.6 `n channel enhancement type MOSFET`

```
// Example 7.6: VDSQ, IDQ
clc, clear
ID=6e-3; // in amperes
VGS=8; // in volts
VT=3; // in volts
// From Fig. 7.37(a)
```

```
VDD=12; // in volts
RD=2e3; // in ohms
// Plotting transfer curve
k=ID/(VGS-VT)^2; // in amperes per volt square
VGS=[3:0.01:VDD]; // Gate source voltage in volts
ID=k*(VGS-VT)^2; // Drain current in amperes ............ (i)
ID=ID*1e3; // Drain current in mili-amperes
plot(VGS,ID);
xtitle("Transfer Curve","VGS (V)","ID (mA)");
// Plotting bias line
// From the simplified dc equivalent circuit in Fig. 7.37(b)
VGS=[0:0.01:VDD]; // Gate source voltage in volts
ID=(VDD-VGS)/RD; // Source current in amperes
ID=ID*1e3; // Source current in mili-amperes
plot(VGS,ID,"RED");
// Intersection of transfer curve with the bias curve
// Putting VGS = VDD-ID*RD in equation (i) and solving, we get ID^2*RD^2 + (2*RD*VT - 2*VDD*RD - 1/k)*ID + (VDD-VT)^2
// Solving the equation
p_eq = poly([(VDD-VT)^2 (2*RD*VT-2*VDD*RD-1/k) RD^2],"x","coeff");
p_roots= roots(p_eq);
IDQ=p_roots(1); // in amperes
VGSQ=VDD-IDQ*RD; // in volts
IDQ=IDQ*1e3; // in mili-amperes
disp(VGSQ,"VDSQ (V) =");
disp(IDQ,"IDQ (mA) =");
```

Scilab code Exa 7.7 Operating point of MOSFET

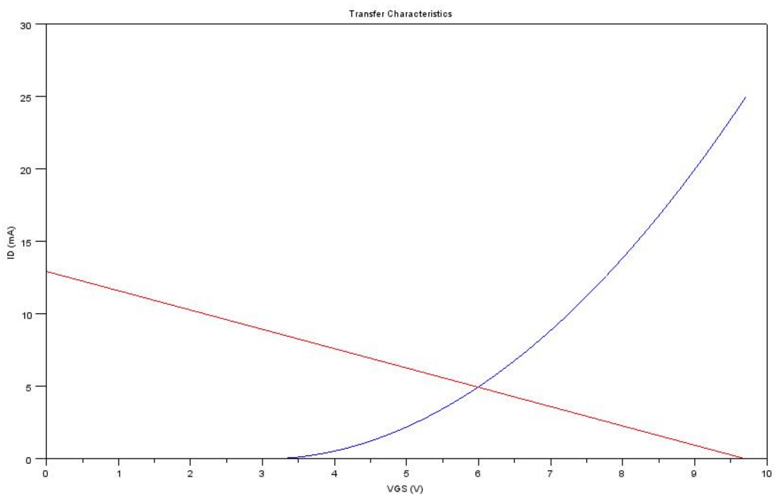

Figure 7.5: Operating point of MOSFET

```
// Example 7.7: IDQ, VDSQ, VGSQ
clc, clear
ID=5e-3; // in amperes
VGS=6; // in volts
VT=3; // in volts
// From Fig. 7.39(a)
VDD=24; // in volts
R1=10; // in mega-ohms
R2=6.8; // in mega-ohms
RD=2.2e3; // in ohms
RS=0.75e3; // in ohms
// Applying Thevnin's theorem to obtain simplified
    circuit in Fig. 7.39(b)
VGG=VDD*R2/(R1+R2); // in volts
// Plotting transfer characteristics
k=ID/(VGS-VT)^2; // in amperes per volt square
VGS=[3:0.01:VGG]; // Gate source voltage in volts
ID=k*(VGS-VT)^2; // Drain current in amperes
    ............ (i)
```

```
ID=ID*1e3; // Drain current in mili-amperes
plot(VGS,ID);
xtitle("Transfer Characteristics","VGS (V)","ID (mA)");
// Plotting bias line
VGS=[0:0.01:VGG]; // Gate source voltage in volts
// Writing KVL for the gate-source loop
ID=(VGG-VGS)/RS; // Source current in amperes
ID=ID*1e3; // Source current in mili-amperes
plot(VGS,ID,"RED");
// Intersection of transfer curve with the bias curve
// Putting VGS = VGG-ID*RD in equation (i) and solving, we get ID^2*RS^2 + (2*RS*VT - 2*VGG*RS - 1/k)*ID + (VGG-VT)^2
// Solving the equation
p_eq = poly([(VGG-VT)^2 (2*RS*VT-2*VGG*RS-1/k) RS^2],"x","coeff");
p_roots= roots(p_eq);
IDQ=p_roots(1); // in amperes
VGSQ=VGG-IDQ*RS; // in volts
// From the output circuit
VDSQ=VDD-IDQ*(RD+RS); // in volts
IDQ=IDQ*1e3; // in mili-amperes
disp(IDQ,"IDQ (mA) =");
disp(VDSQ,"VDSQ (V) =");
disp(VGSQ,"VGSQ (V) =");
```

Chapter 8

FET Amplifiers

Scilab code Exa 8.1 Transconductance

```
// Example 8.1: gm
clc, clear
IDSS=12; // in mili-amperes
Vp=-5; // in volts
VGS=-1.5; // in volts
gmo=2*IDSS/abs(Vp); // in mili-Siemens
gm=gmo*(1-VGS/Vp); // in mili-Siemens
disp(gm,"gm (mS) =");
```

Scilab code Exa 8.2 Fixed bias CS amplifier

```
// Example 8.2: Voltage gain
clc, clear
gm=2; // in mili-ampere per volt
rd=10; // in kilo-ohms
// From Fig. 8.7
RD_eff=10*10/(10+10); // in kilo-ohms
AV=-gm*rd*RD_eff/(rd+RD_eff); // Voltage gain
disp(AV,"Voltage gain =");
```

Scilab code Exa 8.3 Self bias CS amplifier

```
// Example 8.3: gm,  , Ri, Ro, AV
clc, clear
VGSQ=-2.6; // in volts
IDSS=8; // in mili-amperes
Vp=-6; // in volts
rd=50; // in kilo-ohms
// From Fig. 8.11
RD=3.3; // in kilo-ohms
RG=1; // in mega-ohms
RS=1; // in kilo-ohms
gmo=2*IDSS/abs(Vp); // in mili-ampere per volt
gm=gmo*(1-VGSQ/Vp); // in mili-ampere per volt
mu=rd*gm; //
Ro=(rd+(1+mu)*RS)*RD/(RD+rd+(1+mu)*RS); // in kilo-
    ohms
AV=-mu*RD/(RD+rd+(1+mu)*RS);
disp(gm,"gm (mA/V) =");
disp(mu,"  =");
disp(RG,"Ri (M ) =");
disp(Ro,"Ro (k ) =");
disp(AV,"AV =");
```

Scilab code Exa 8.4 JFET source follower

```
// Example 8.4: AV, Ri, Ro
clc, clear
IDSS=16; // in mili-amperes
Vp=-4; // in volts
rd=40; // in kilo-ohms
```

```
// From Fig. 8.14
RS=2.2; // in kilo-ohms
// Using dc analysis
VGSQ=-2.8; // in volts
gmo=2*IDSS/abs(Vp); // in mili-ampere per volt
gm=gmo*(1-VGSQ/Vp); // in mili-ampere per volt
mu=rd*gm; // Amplification factor
AV=mu*RS/(rd+(1+mu)*RS);
Ri=10; // in mega-ohms
Ro=rd*RS/(rd+(1+mu)*RS); // in kilo-ohms
disp(AV,"AV =");
disp(Ri,"Ri (M ) =");
disp(Ro,"Ro (k ) =");
```

Scilab code Exa 8.5 Common gate JFET amplifier

```
// Example 8.5: AV, Ri, Ro
clc, clear
VGSQ=-1.8; // in volts
rd=40; // in kilo-ohms
IDSS=8; // in mili-amperes
Vp=-2.8; // in volts
// From Fig. 8.16
RD=3.3; // in kilo-ohms
RS=1.5; // in kilo-ohms
gmo=2*IDSS/abs(Vp); // in mili-Siemens
gm=gmo*(1-VGSQ/Vp); // in mili-Siemens
mu=rd*gm; // Amplification factor
AV=(1+mu)*RD/(rd+RD);
Ri_dash=(RD+rd)/(1+mu); // in kilo-ohms
Ri=Ri_dash*RS/(Ri_dash+RS); // in kilo-ohms
Ro=rd*RD/(rd+RD);
disp(AV,"AV =");
disp(Ri,"Ri (k ) =");
disp(Ro,"Ro (k ) =");
```

Scilab code Exa 8.6 E MOSFET amplifier

```
// Example 8.6: gm, Ri, Ro, AV
clc, clear
VGSQ=8; // in volts
VT=3; // in volts
k=0.3e-3;
// From Fig. 8.18
RF=10e6; // in ohms
RD=2.2e3; // in ohms
gm=2*k*(VGSQ-VT); // in Siemens
Ri=RF/(1+gm*RD); // in ohms
Ro=RF*RD/(RF+RD); // in ohms
AV=-gm*Ro;
gm=gm*1e3; // in mili-Siemens
Ri=Ri*1e-6; // in mega-ohms
Ro=Ro*1e-3; // in kilo-ohms
disp(gm,"gm (mS) =");
disp(AV,"AV =");
disp(Ri,"Ri ( M  ) =");
disp(Ro,"Ro ( k  ) =");
```

Chapter 9

Multistage Amplifiers

Scilab code Exa 9.1 CE CC configuration

```
// Exmaple 9.1: Overall voltage gain , Overall
   current gain
clc , clear
bta=100;
r_pi=0.5; // in kilo-ohms
// From Fig. 9.4
Rs=2; // in kilo-ohms
RC=2; // in kilo-ohms
RE=5; // in kilo-ohms
// As the first stage ia a CE amplifier stage
AV1=-bta*RC/(Rs+r_pi); // Voltage gain of first
   amplifier
// The second stage is a CC amplifier
AV2=(1+bta)*RE/(Rs+r_pi+(1+bta)*RE); // Voltage gain
    of second amplifier
AV=AV1*AV2; // Overall voltage gain
AI=Rs*AV/RE; // Overall current gain
disp(AV,"Overall voltage gain =");
disp(AI,"Overall current gain =");
```

Scilab code Exa 9.2 Two stage amplifier

```
// Example 9.2: Overall voltage gain , Current gain ,
    Input impedance , Output impedance
clc , clear
bta=100;
VBE=0.7; // in volts
VT=25e-3; // Voltage equivalent to temperatue at
    room temperature in volts
// From Fig . 9.7
R1=22; // in kilo-ohms
R2=3.3; // in kilo-ohms
RC1=6; // in kilo-ohms
RE1=0.5; // in kilo-ohms
R3=16; // in kilo-ohms
R4=6.2; // in kilo-ohms
RC2=2; // in kilo-ohms
RE2=1; // in kilo-ohms
RL=10; // in kilo-ohms


// DC analysis

// From simplified dc equivalent circuit for stage 1
     in Fig . 9.8(a)
RB1=R1*R2/(R1+R2); // in kilo-ohms
VBB1=15*R2/(R1+R2); // in volts
IB1=(VBB1-VBE)/(RB1+(1+bta)*RE1); // in mili-amperes
IC1=bta*IB1; // in mili-amperes
gm1=IC1/VT; // in mili-Siemens
r_pi1=bta/gm1; // in kilo-ohms

// From simplified dc equivalent circuit for stage 2
     in Fig . 9.8(b)
```

```
RB2=R3*R4/(R3+R4); // in kilo-ohms
VBB2=15*R4/(R3+R4); // in volts
IB2=(VBB2-VBE)/(RB2+(1+bta)*RE2); // in mili-amperes
IC2=bta*IB2; // in mili-amperes
gm2=IC2/VT; // in mili-Siemens
r_pi2=bta/gm2; // in kilo-ohms


// AC analysis

// Applying Thevnin theorem at 1-1' in ac equivalent circuit in Fig. 9.9 to obtain equivalent circuit of stage 1 in Fig. 9.10(a)
RL1=RC1*RB2/(RC1+RB2); // Effective load for first stage in kilo-ohms
AV1=-bta*RL1/r_pi1; // Voltage gain of first stage

// Using the Thevnin's equivalent of first stage the equivalent circuit of second stage is shown in Fig. 9.10(b)
RL2=RC2*RL/(RC2+RL); // Effective load for second stage in kilo-ohms
AV2=-bta*RL2/(RL1+r_pi2); // Voltage gain of second stage

Io_Ic2=-RC2/(RC2+RL); // Io/Ic2
Ic2_Ib2=-bta; // Ic2/Ib2
//From simplified diagram in Fig. 9.11
Ib2_Ic1=-RL1/(RL1+r_pi2); // Ib2/Ic1
Ic1_Ib1=-bta; // Ic1/Ib1
Ib1_Ii=RB1/(RB1+r_pi1); // Ib1/Ii

AV=AV1*AV2; // Overall voltage gain
AI=Io_Ic2*Ic2_Ib2*Ib2_Ic1*Ic1_Ib1*Ib1_Ii; // Overall current gain
Ri=RB1*r_pi1/(RB1+r_pi1); // Input impedance in kilo-ohms
Ro=RC2*RL/(RC2+RL); // Output impedance in kilo-ohms
```

```
disp(AV,"Overall voltage gain =");
disp(AI,"Overall current gain =");
disp(Ri,"Imput impedance (k ) =");
disp(Ro,"Output impedance (k ) =");
```

Scilab code Exa 9.3 CC CE composite pair

```
// Example 9.3: Voltage gain
clc, clear
bta=150;
VA=130; // in volts
IC=100; // in micro-amperes
Rs=50; // in kilo-ohms
RC=250; // in kilo-ohms
VT=25; // Voltage equivalent to temperatue at room temperature in mili-volts
gm=IC/VT; // in mili-Siemens
ro=VA/IC; // in Megaohms
ro=ro*1e3; // in kilo-ohms
r_pi=bta/gm; // in kilo-ohms
// From ac equivalent circuit of the first CC stage using hybrid-  model in Fig. 9.13(a)
// Voltage gain of CC stage
AV1=(1+bta)*ro/(Rs+r_pi+(1+bta)*ro); // Voltage gain of first stage
Ro1=(Rs+r_pi)/(1+bta); // in kilo-ohms
Ro1_dash=ro*Ro1/(ro+Ro1); // in kilo-ohms
// From the ac equivalent circuit of second stage in Fig. 9.13(b)
RL=ro*RC/(ro+RC); // Effective load for second stage in kilo-ohms
AV2=-bta*RL/(Ro1_dash+r_pi); // Voltage gain of second stage
AV=AV1*AV2; // Overall voltage gain
disp(AV,"Voltage gain =");
```

Scilab code Exa 9.4 `FET cascade`

```
// Example 9.4: (i) Voltage gain, Input impedance, Output impedance
//                 (ii) Output voltage
clc, clear
gm=2.5; // in mili-Siemens
// From Fig. 9.14(a)
RG=3; // in Mega-ohms
RD=2.2; // in kilo-ohms

disp("Part (i)");
AV1=-gm*RD; // Voltage gain of both individual stages
AV=AV1^2; // Overall voltage gain
disp(AV,"Voltage gain =");
disp(RG,"Input impedance (M  ) =");
disp(RD,"Output impedance (k  ) =");

disp("Part (ii)");
Vi=10; // in mili-volts
RD_dash=RD*10/(RD+10); // Effective load of secong stage in kilo-ohms
// Now the gain of second stage
AV2=-gm*RD_dash;
AV=AV1*AV2; // Overall voltage gain
Vo=Vi*AV; // Output voltage in mili-volts
disp(Vo,"Output voltage (mV) =");
```

Scilab code Exa 9.5 `Three stage amplifier`

```
// Example 9.5: (i) Gain of each stage
//              (ii) Overall voltage gain
//             (iii) Output resistance Ro'
clc, clear
gm=1 // in mili-mho
rd=40; // in kilo-ohms
// From Fig. 9.14(b)
RD1=40 // in kilo-ohms
RS1=2 // in kilo-ohms
RD2=10 // in kilo-ohms
RS3=5 // in kilo-ohms
mu=rd*gm; // Amplification factor

disp("Part (i)");
AV1=-mu*RD1/(rd+RD1+(1+mu)*RS1); // Voltage gain of first stage (CS amplifier with RS1)
AV2=-mu*RD2/(rd+RD2); // Voltage gain of second stage (CS amplifier stage)
AV3=mu*RS3/(rd+(1+mu)*RS3); // Voltage gain of third stage (CD amplifier stage)
disp(AV1,"Voltage gain of first stage (CS amplifier with RS1) =");
disp(AV2,"Voltage gain of second stage (CS amplifier stage) =");
disp(AV3,"Voltage gain of third stage (CD amplifier stage) =");

disp("Part (ii)");
AV=AV1*AV2*AV3; // Overall voltage gain
disp(AV,"Overall voltage gain =");

disp("Part (iii)");
// Last stage is a CD amplifier, therefore
Ro=rd/(1+mu); // in kilo-ohms
Ro_dash=Ro*RS3/(Ro+RS3); // in kilo-ohms
disp(Ro_dash,"Output resistance (k ) =");
```

Scilab code Exa 9.6 `FET and BJT cascade`

```
// Example 9.6: Input impedance, Output impedance, Voltage gain
clc, clear
gm=2.5; // in mili-Siemens
r_pi=1.3; // in kilo-ohms
bta=200;
// From Fig. 9.14(c)
Ri2=15*4.7*1.3/(15*4.7+15*1.3+4.7*1.3); // Input impedance of second stage in kilo-ohms
RD_dash=1.8*Ri2/(1.8+Ri2); // Effective load for the first stage in kilo-ohms
AV1=-gm*RD_dash; // Voltage gain of the loaded 1st stage
AV2=-bta*2.7/r_pi; // Voltage gain of the 2nd stage
AV=AV1*AV2; // Overall voltage gain
disp(10,"Input impedance (M ) =");
disp(2.7,"Output impedance (k ) =");
disp(AV,"Voltage gain =");
```

Scilab code Exa 9.7 `Darlington emitter follower`

```
// Example 9.7: AV, Ri, Ro
clc, clear
RE=0.5; // in kilo-ohms
Rs=50; // in kilo-ohms
Ic1=15e-3; // in mili-amperes
Ic2=1; // in mili-amperes
VA=100; // in volts
bta=150;
```

```
VT=25e-3; // Voltage equivalent to temperatue at room temperature in volts
// For Q1
gm1=Ic1/VT; // in mili-mho
r_pi1=bta/gm1; // in kilo-ohms
ro1=VA/Ic1; // in kilo-ohms
// For Q2
gm2=Ic2/VT; // in mili-mho
r_pi2=bta/gm2; // in kilo-ohms
ro2=VA/Ic2; // in kilo-ohms
// From ac equivalent circuit in Fig. 9.17
RE2=ro2*RE/(ro2+RE); // Effective load for stage Q2 in kilo-ohms
Ri2=r_pi2+(1+bta)*RE2; // Input resistance for second stage in kilo-ohms
AV2=(1+bta)*RE2/Ri2; // Voltage gain of the second stage
RE1=ro1*Ri2/(ro1+Ri2); // Effective load for the first stage in kilo-ohms
Ri1=r_pi1+(1+bta)*RE1; // Input resistance for first stage in kilo-ohms
AV1=(1+bta)*RE1/Ri1; // Voltage gain of first stage
AV=AV1*AV2; // Overall voltage gain
Ro=ro2*(r_pi2+ro1)/(ro2*(1+bta)+r_pi2+ro1); // Output resistance in kilo-ohms
Ri1=Ri1*1e-3; // in Mega-ohms
disp(AV,"AV =");
disp(Ri1,"Ri ( M ) =");
disp(Ro,"Ro ( k ) =");
```

Scilab code Exa 9.8 Cascode circuit

```
// Example 9.8:Gain
clc, clear
IC=1; // in mili-amperes
```

```
bta=120;
VT=25e-3; // Voltage equivalent to temperatue at
    room temperature in volts
// From Fig. 9.20
RC=6; // in kilo-ohms
AV1=-1; // Voltage gain of CE stage (from Eqn. 9.35)
gm=IC/VT; // in mili-mho
AV2=gm*RC; // Voltage gain of CB stage
AV=AV1*AV2; // Overall voltage gain
disp(AV,"Gain =");
```

Chapter 10

Frequency Response of Amplifiers

Scilab code Exa 10.1 Bode plots

```
// Example 10.1: Asymptotic magnitude and phase
   response curves
clc, clear
w=[0:70];
// Asymptotic magnitude response curve
for i=1:length(w)
    a(i)=32;
    if w(i)<10 then
        b(i)=0;
        c(i)=0;
    elseif w(i)<50
        b(i)=14*(w(i)-10)/40;
        c(i)=0;
    else
        b(i)=20*log10(w(i)/10);
```

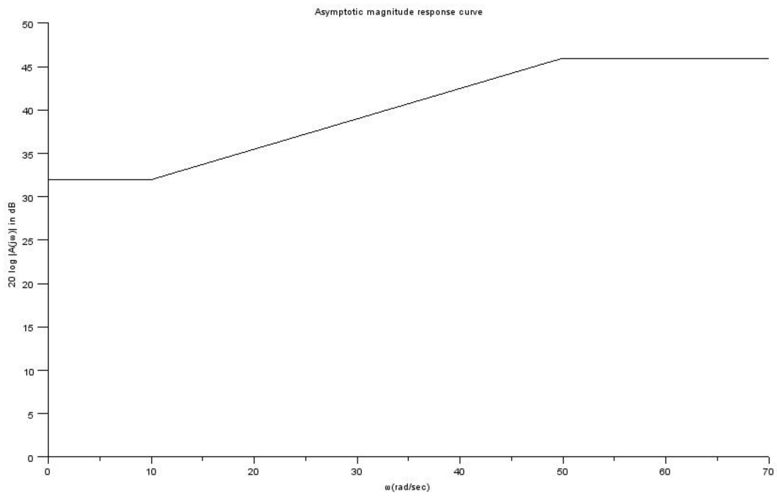

Figure 10.1: Bode plots

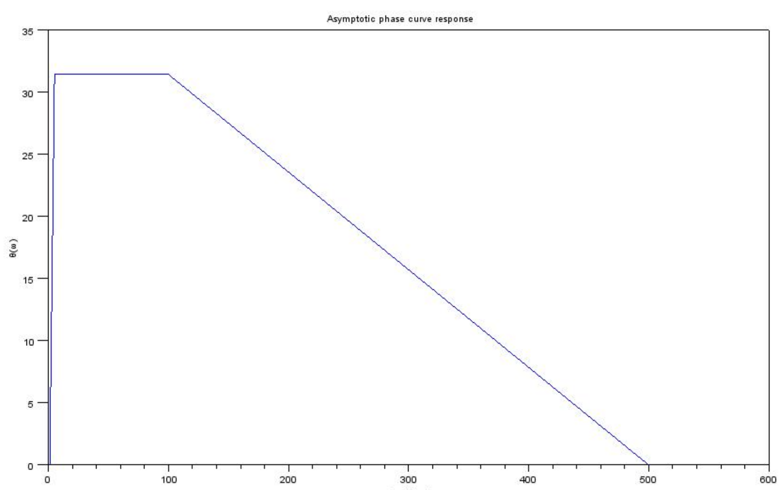

Figure 10.2: Bode plots

```
        c(i)=-20*log10(w(i)/50);
    end
end
A=a+b+c;
plot2d(w,A,rect=[0,0,70,50]);
xtitle("Asymptotic magnitude response curve"," (rad/sec)","20 log |A(j )| in dB");
// Asymptotic phase response curve
scf(1);
w=[1:600];
for i=1:length(w)
    if w(i)<1 then
        theta1(i)=0;
    elseif w(i)<5
        theta1(i)=31.45*(w(i)-1)/4;
        theta2(i)=0;
    elseif w(i)<100
        theta1(i)=45*log10(w(i)/10);
        theta2(i)=-45*log10(w(i)/50);
    elseif w(i)<500
        theta1(i)=90;
        theta2(i)=-58.55-31.45*(w(i)-100)/400;
    else
        theta1(i)=90;
        theta2(i)=-90;
    end
end
theta=theta1+theta2;
plot(w,theta);
xtitle("Asymptotic phase curve response"," (rad/sec)"," ( )")
```

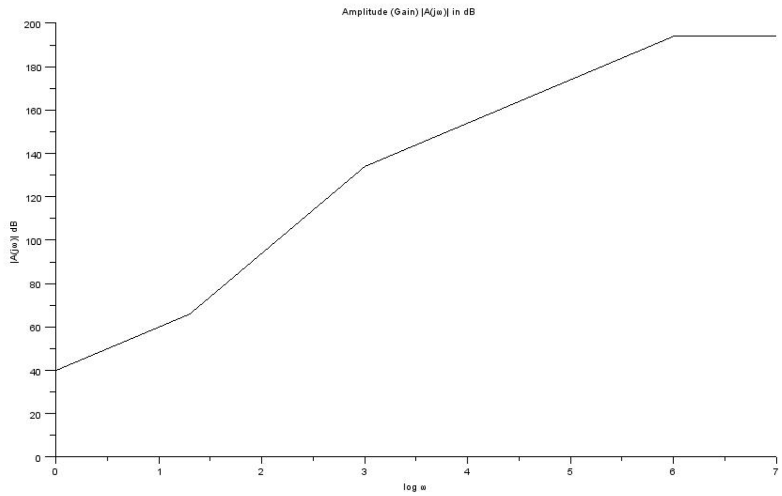

Figure 10.3: Bode plots

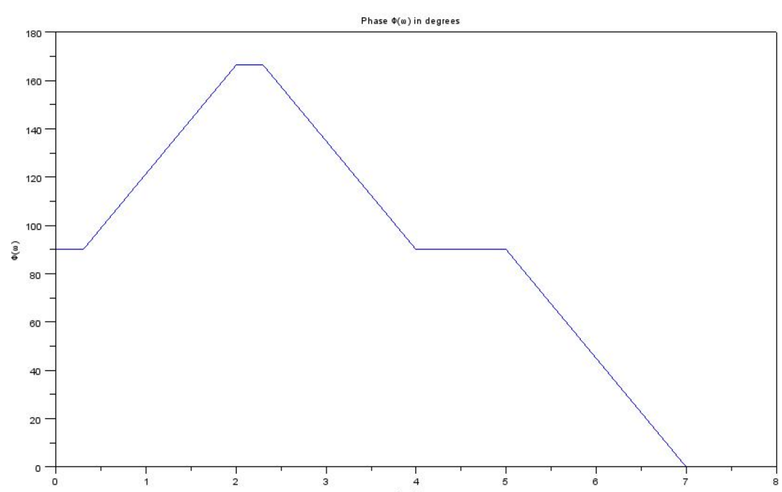

Figure 10.4: Bode plots

Scilab code Exa 10.2 `Bode plots`

```
// Example 10.2: Bode's plots
clc, clear
w=[0:0.1:8];
// Asymptotic magnitude response curve
for i=1:length(w)
    a(i)=40;
    if w(i)<1.3 then
        b(i)=20*w(i);
        c(i)=0;
        d(i)=0;
        e(i)=0;
    elseif w(i)<3
        b(i)=20*w(i);
        c(i)=20*(w(i)-1.3);
        d(i)=0;
        e(i)=0;
    elseif w(i)<6
        b(i)=20*w(i);
        c(i)=20*(w(i)-1.3);
        d(i)=-20*(w(i)-3);
        e(i)=0;
    else
        b(i)=20*w(i);
        c(i)=20*(w(i)-1.3);
        d(i)=-20*(w(i)-3);
        e(i)=-20*(w(i)-6);
    end
end
A=a+b+c+d+e;
plot2d(w,A,rect=[0,0,7,200]);
xtitle("Amplitude (Gain) |A(j  )| in dB","log   ","|
   A(j  )| dB");
// Asymptotic phase response curve
scf(1);
for i=1:length(w)
    thetab=90;
```

```
    if w(i)<0.3 then
        thetac(i)=0;
        thetad(i)=0;
        thetae(i)=0;
    elseif w(i)<2
        thetac(i)=45*(w(i)-0.3);
        thetad(i)=0;
        thetae(i)=0;
    elseif w(i)<2.3
        thetac(i)=45*(w(i)-0.3);
        thetad(i)=-45*(w(i)-2);
        thetae(i)=0;
    elseif w(i)<4
        thetac(i)=90;
        thetad(i)=-45*(w(i)-2);
        thetae(i)=0;
    elseif w(i)<5
        thetac(i)=90;
        thetad(i)=-90;
        thetae(i)=0;
    elseif w(i)<7
        thetac(i)=90;
        thetad(i)=-90;
        thetae(i)=-45*(w(i)-5);
    else
        thetac(i)=90;
        thetad(i)=-90;
        thetae(i)=-90;
    end
end
theta=thetab+thetac+thetad+thetae;
plot(w,theta);
xtitle("Phase   (   ) in degrees","log10   ","   (   )"
   )
```

Scilab code Exa 10.3 Pole of transfer function

```
// Example 10.3: CS, Zero frequency
clc, clear
gm=1e-3; // in mho
fL=10; // in hertz
// From Fig. 10.10
RS=6e3; // in ohms
I=RS/(1+RS*gm); // Impedance seen by CS in ohms
CS=1/(2*%pi*fL*I); // in farads
CS=CS*1e6; // in micro-farads
disp(CS,"CS ( F ) =");
disp("Here at f = 0 Hz, CS has infinite reactance.");
disp("Therefore, zero frequency fzero = 0 Hz here, i.e. the voltage transfer function is zero at DC.");
```

Scilab code Exa 10.4 Low frequency response

```
// Example 10.4: fT, fb
clc, clear
b_o=160;
f=50; // in Mega-hertz
b_jw=8;
wb=sqrt((2*%pi*f)^2*b_jw^2/(b_o^2-b_jw^2)); // in Mega-rad/sec
fb=wb/(2*%pi); // in Mega-hertz
fT=fb*b_o; // in Mega-hertz
disp(fT,"fT (MHz) =");
disp(fb,"fb (MHz) =");
```

Scilab code Exa 10.5 Single pole model

```
// Example 10.5: C
clc, clear
IC=1e-3; // in amperes
b_o=120;
b_jw=10;
f=25e6; // in hertz
C_mu=1e-12; // in farads
VT=25e-3; // Voltage equivalent to temperatue at
    room temperature in volts
wb=sqrt((2*%pi*f)^2*b_jw^2/(b_o^2-b_jw^2)); // in
    rad/sec
wT=wb*b_o; // in hertz
gm=IC/VT; // in mho
C_pi=gm/wT-C_mu; // in farads
C_pi=C_pi*1e12; // in pico-farads
disp(C_pi,"C   (pF) =");
```

Scilab code Exa 10.7 Upper half power frequency

```
// Example 10.7: (a) Midband gain, Upper half-power
    frequency
//                (b) Zi
clc, clear
ICQ=1e-3; // in amperes
RS=300; // in ohms
RC=1.2e3; // in ohms
bta=125;
fT=300e6; // in hertz
C_mu=0.5e-12; // in farads
VT=25e-3; // Voltage equivalent to temperatue at
    room temperature in volts

disp("Part (a)");
gm=ICQ/VT; // in mho
r_pi=bta/gm; // in ohms
```

```
// To find C_pi
C_pi=gm/(2*%pi*fT)-C_mu; // in farads
AVo=-bta*RC/(RS+r_pi); // Midband gain
disp(AVo,"Midband gain =");
R_pi0=RS*r_pi/(RS+r_pi);
a1=R_pi0*C_pi+(R_pi0+RC*(1+gm*R_pi0))*C_mu; // in seconds
a2=R_pi0*RC*C_pi*C_mu; // in seconds
p1=1/a1; // in rad/sec
p2=a1/a2; // in rad/sec
disp(p2/p1,"p2/p1 =");
disp("Since p2/p1 >> 8, therefore dominant-pole approximation holds good.");
wH=p1*1e-6; // in M rad/sec
disp(wH,"Upper half-power frequency (M rad/sec) =");

disp("Part (b)");
CM=C_pi+C_mu*(1+gm*RC); // in farads
Zi=r_pi/(1+%i*wH*1e6*CM*r_pi); // in ohms
disp(Zi,"Zi (  ) =");
```

Scilab code Exa 10.12 Dominant pole approximation

```
// Example 10.12: (a) Approximate value of fH
//                (b) Approximate location of the closest non-dominant pole
clc, clear
RS=600; // in ohms
RC1=1.5e3; // in ohms
RC2=600; // in ohms
r_pi1=1.2e3; // in ohms
gm1=0.1; // in mho
C1=24.5e-12; // in farads
C_pi1=C1; // in farads
C2=0.5e-12; // in farads
```

```
C_mu1=C2; // in farads
r_pi2=2.4e3; // in ohms
gm2=0.05; // in mho
C3=19.5e-12; // in farads
C_pi2=C3; // in farads
C4=0.5e-12; // in farads
C_mu2=C4; // in farads

function[c]=parallel(a,b)
    c=a*b/(a+b);
endfunction

disp("Part (a)");
R11_0=parallel(RS,r_pi1); // in ohms
R33_0=parallel(RC1,r_pi2); // in ohms
R22_0=R11_0*(1+gm1*R33_0)+R33_0; // in ohms
R44_0=R33_0*(1+gm2*RC2)+RC2; // in ohms
a1=R11_0*C1+R22_0*C2+R33_0*C3+R44_0*C4; // in
   seconds
fH=1/(2*%pi*a1); // in hertz
fH=fH*1e-6; // in Mega-hertz
disp(fH,"fH (MHz) =");

disp("Part (b)");
R33_1=R33_0; // in ohms
R44_1=R44_0; // in ohms
// From Fig. 10.61(a)
R22_1=R33_0; // in ohms
// From Fig. 10.61(b)
R44_3=RC2; // in ohms
// From Fig. 10.61(c)
R33_2=parallel(parallel(r_pi2,RC2),parallel(1/gm1,
   R11_0));
R44_2=R33_2*(1+gm2*RC2)+RC2; // in ohms
a2=R11_0*C1*R22_1*C2+R11_0*C1*R33_1*C3+R11_0*C1*
   R44_1*C4+R22_0*C2*R33_2*C3+R22_0*C2*R44_2*C4+
   R33_0*C3*R44_3*C4; // in seconds
p2=a1/a2;
```

```
f2=p2/(2*%pi); // in hertz
f2=f2*1e-6; // in Mega-hertz
disp(f2,"Approximate location of the closest non-
    dominant pole (MHz) =");
```

Scilab code Exa 10.13 Cascode amplifier

```
// Example 10.13: (a) fH for cascode amplifier
//                (b) fH for common -emitter stage
clc, clear
RC1=1.5e3; // in ohms
RC2=RC1;
RS=300; // in ohms
r_pi=2e3; // in ohms
gm=0.05; // in mho
bta=100;
C_pi=19.5e-12; // in farads
C_mu=0.5e-12; // in farads

disp("Part (a)");
R_pi1=RS*r_pi/(RS+r_pi); // in ohma
Ri2=r_pi/(1+bta); // in ohms
RL1=RC1*Ri2/(RC1+Ri2); // in ohms
a11=R_pi1*C_pi+(R_pi1*(1+gm*RL1)+RL1)*C_mu; // in
    seconds
a12=C_pi/gm+C_mu*RC2; // in seconds
a1=a11+a12; // in seconds
fH=1/(2*%pi*a1); // in hertz
fH=fH*1e-6; // in Mega-hertz
disp(fH,"fH for cascode amplifier (MHz) =");

disp("Part (b)");
a1=R_pi1*C_pi+(R_pi1*(1+gm*RC1)+RC1)*C_mu; // in
    seconds
fH=1/(2*%pi*a1); // in hertz
```

```
fH=fH*1e-6; // in Mega-hertz
disp(fH,"fH for common-emitter stage (MHz) =");
```

Scilab code Exa 10.15 Capacitances of transistor

```
// Example 10.15: (a) CB and CL
//                (b) Zero introduced by CE
clc, clear
RE=1.5e3; // in ohms
Rs=600; // in ohms
bta=100;
r_pi=1e3; // in ohms
fL=50; // in hertz

disp("Part (a)");
fLB=fL/2; // in hertz
fLE=fLB; // in hertz
CB=1/(2*%pi*fLB*(Rs+r_pi)); // in farads
CB=CB*1e6; // in micro-farads
function[c]=parallel(a,b)
    c=a*b/(a+b);
endfunction
CE=1/(2*%pi*fLE*parallel(RE,(Rs+r_pi)/(1+bta))); // in farads
CE=CE*1e6; // in micro-farads
disp(CB,"CB ( F ) =");
disp(CE,"CE ( F ) =");

disp("Part (b)");
fE=1e6/(2*%pi*RE*CE); // in hertz
disp(fE, "fE (Hz) =");
```

Scilab code Exa 10.16 Common emitter stage

```
// Example 10.16: AVo, fH
clc, clear
RC=1.5e3; // in ohms
Rs=0.6e3; // in ohms
// From Fig. 10.69
C_pi=19.5e-12; // in farads
r_pi=1e3; // in ohms
C_mu=0.5e-12; // in farads
gm=0.1; // in mho
bta=r_pi*gm;
AVo=-bta*RC/(Rs+r_pi);
R_pi=Rs*r_pi/(Rs+r_pi); // in ohms
R_mu=R_pi+(1+gm*R_pi)*RC; // in ohms
a1=R_pi*C_pi+R_mu*C_mu; // in seconds
a2=R_pi*C_pi*R_mu*C_mu; // in seconds
p2_pi=a1^2/a2; // p2/p1
disp("Since p2/pi >> 8, therefore dominant-pole
    approximation holds good.");
fH=1/(2*%pi*a1); // in hertz
fH=fH*1e-6; // in Mega-hertz
disp(AVo,"AVo =");
disp(fH,"fH (MHz) =");
```

Scilab code Exa 10.17 Time constant method

```
// Example 10.17: (b) a1, a2
clc, clear
RS=0.3e3; // in ohms
r_pi=2e3; // in ohms
RC=0.6; // in ohms
gm=0.1e-3; // in mho
C_pi=19.5e-12; // in farads
C_mu=0.5e-12; // in farads
R_pi=RS*r_pi/(RS+r_pi); // in ohms
a1=C_pi*R_pi+C_mu*(R_pi+RC+gm*R_pi*RC); // in
```

```
    seconds
a1=a1*1e9; // in nano-seconds
a2=C_pi*R_pi*C_mu*RC; // in seconds square
disp(a1,"a1 (ns) =");
disp(a2,"a2 (sec square) =");
```

Scilab code Exa 10.18 Gain bandwidth product

```
// Example 10.18: Upper 3 dB frequency
clc, clear
r_pi1=1.4e3; // in ohms
r_pi2=2.8e3; // in ohms
gm1=0.15; // in mho
gm2=0.05; // in mho
C_pi1=20e-12; // in farads
C_pi2=25e-12; // in farads
C_mu1=0.5e-12; // in farads
C_mu2=C_mu1 // in farads
bta1=gm1*r_pi1;
bta2=gm2*r_pi2;
// From Fig. 10.71
RS=600; // in ohms
RC1=1.5e3; // in ohms
RL2=600; // in ohms
// From ac model in Fig. 10.72
R_pi1=RS*r_pi1/(RS+r_pi1); // in ohms
RL1=RC1*r_pi2/(RC1+r_pi2); // in ohms
R_mu1=R_pi1+RL1+gm1*RL1*R_pi1; // in ohms
R_pi2=RL1; // in ohms
R_mu2=R_pi2+RL2+gm2*RL2*R_pi2; // in ohms
a11=C_pi1*R_pi1+C_mu1*R_mu1; // in seconds
a12=C_pi2*R_pi2+C_mu2*R_mu2; // in seconds
a1=a11+a12; // in seconds
fH1=1/(2*%pi*a11); // in hertz
fH2=1/(2*%pi*a12); // in hertz
```

```
fH=1/(2*%pi*a1); // in hertz
fH1=fH1*1e-6; // in Mega-hertz
fH2=fH2*1e-6; // in Mega-hertz
fH=fH*1e-6; // in Mega-hertz
AV1=-bta1*RC1/(RS+r_pi1); // Gain of first stage
AV2=-bta2*RL2/(RC1+r_pi2); // Gain of second stage
AV=AV1*AV2; // Gain of cascade
disp(fH,"Upper 3 dB frequency (MHz) =");
disp("Bandwidth:");
disp(fH1,"Stage 1 only (MHz) =");
disp(fH2,"Stage 2 only (MHz) =");
disp(fH,"Cascade (MHz) =");
disp("Gain:");
disp(abs(AV1),"Stage 1 only =");
disp(abs(AV2),"Stage 2 only =");
disp(AV,"Cascade =");
disp("Gain-bandwidth product:");
disp(fH1*abs(AV1)*1e6,"Stage 1 only (MHz) =");
disp(fH2*abs(AV2)*1e6,"Stage 2 only (MHz) =");
disp(fH*AV*1e6,"Cascade (MHz) =");
```

Scilab code Exa 10.19 Approximation of fH

```
// Example 10.19: Approximate value of fH
clc, clear
btaf=150;
VA=120; // in volts
fT=400e6; // in hertz
C_mu=0.5e-12; // in farads
ICQ=100e-6; // in amperes
RS=50e3; // in ohms
RC=250e3; // in ohms
VT=25e-3; // Voltage equivalent to temperatue at
   room temperature in volts
gm=ICQ/VT; // in mho
```

```
r_pi=btaf/gm;   // in ohms
ro=VA/ICQ; // in ohms
C_pi=btaf/(2*%pi*fT*r_pi)-C_mu; // in farads
function[c]=parallel(a,b)
    c=a*b/(a+b);
endfunction
// From AC model in Fig. 10.73
Ri=r_pi+(1+btaf)*parallel(ro,r_pi); // in ohms
R_mu1=parallel(RS,Ri); // in ohms
// From Fig. 10.75(b)
R=(50+36.36)/(1+145); // in ohms
R_pi1=parallel(r_pi,R); // in ohms
R_pi2=parallel(r_pi,parallel((RS+r_pi)/(1+btaf),ro)); // in ohms
RL=parallel(ro,RC); // in ohms
R_mu2=R_pi2*(1+gm*RL)+RL; // in ohms
a1=R_mu1*C_mu+R_pi1*C_pi+R_pi2*C_pi+R_mu2*C_mu; // in seconds
fH=1/(2*%pi*a1); // in hertz
fH=fH*1e-3; // in kilo-hertz
disp(fH,"Approximate value of fH (kHz) =");
```

Scilab code Exa 10.20 Low and high 3 dB frequency

```
// Example 10.20: (a) Low 3 dB frequency
//                (b) High 3 dB frequency
clc, clear
// From Fig. 10.76
C_gd1=2e-12; // in farads
C_gs1=5e-12; // in farads
gm1=10e-3; // in mho
C1=1e-6; // in farads
C_gd2=2e-12; // in farads
C_gs2=5e-12; // in farads
gm2=10e-3; // in mho
```

```
C2=10e-6; // in farads
// From low-frequency equivalent cicuit in Fig. 10.77
RS=0.2e3; // in ohms
RG1=50e3; // in ohms
RS1=0.25e3; // in ohms
RS2=0.15e3; // in ohms
RD2=5e3; // in ohms
R=10e3; // in ohms
C3=5.3e-6; // in farads

function[c]=parallel(a,b)
    c=a*b/(a+b);
endfunction

disp("Part (a)");
// From low-frequency equivalent cicuit in Fig. 10.77
tau1=C1*(RS+RG1); // in seconds
R_22=RD2+R; // in ohms
tau2=C2*R_22; // in seconds
R_33=parallel(RS2,1/gm2); // in ohms
tau3=C3*R_33; // in ohms
fL=(1/tau1+1/tau2+1/tau3)/(2*%pi); // in hertz
disp(fL,"Low 3 dB frequency (Hz) =");

disp("Part (b)");
// From high frequency equivalent cicuit in Fig. 10.78
R_gd1=parallel(RS,RG1); // in ohms
// From Fig. 10.79
R_gs1=(R_gd1+RS1)/(1+gm1*RS1); // in ohms
R_gs2=parallel(RS1,1/gm2); // in ohms
R_gd2=R_gs2+parallel(RD2,R)+R_gs2*parallel(RD2,R)*gm2; // in ohms
a1=C_gd1*R_gd1+C_gs1*R_gs1+C_gs2*R_gs2+C_gd2*R_gd2; // in seconds
fH=1/(2*%pi*a1); // in hertz
```

```
fH=fH*1e-6; // in Mega-hertz
disp(fH,"High 3 dB frequency (MHz) =");
```

Scilab code Exa 10.21 Dominant pole approximation

```
// Example 10.21: (a) AVo, Approximate value of fH
//                (b) Frequency of the nearest non-
    dominant pole
clc, clear
gm=1e-3; // in mho
Rd=40e3; // in ohms
Cgs=5e-12; // in farads
Cgd=1e-12; // in farads
Cds=1e-12; // in farads

function[c]=parallel(a,b)
    c=a*b/(a+b);
endfunction

disp("Part (a)");
RS=5e3; // in ohms
RD1=40e3; // in ohms
RD2=10e3; // in ohms
// From AC model of cascade amplifier in Fig. 10.80
Rds1=40e3; // in ohms
Rds2=40e3; // in ohms
R11_0=RS; // in ohms
RL1=parallel(Rds1,RD1); // in ohms
R22_0=RS+RL1+gm*RS*RL1; // in ohms
R33_0=RL1; // in ohms
RL2=parallel(Rds2,RD2); // in ohms
R44_0=RL1+RL2+gm*RL1*RL2; // in ohms
R55_0=RL2; // in ohms
C1=Cgs; // in farads
C2=Cgd; // in farads
```

```
C3=Cds+Cgs; // in farads
C4=Cds; // in farads
C5=Cds; // in farads
a1=C1*R11_0+C2*R22_0+C3*R33_0+C4*R44_0+C5*R55_0; // in seconds
fH=1/(2*%pi*a1); // in hertz
fH=fH*1e-6; // in Mega-hertz
AVo=gm*RL1*gm*RL2;
disp(AVo,"AVo =");
disp(fH,"Approximate value of fH (MHz) =");

disp("Part (b)");
R22_1=RL1; // in ohms
R33_1=RL1; // in ohms
R44_1=R44_0; // in ohms
R55_1=RL2; // in ohms
R33_2=parallel(RL1,parallel(1/gm,RS)); // in ohms
R44_2=R33_2+RL2+gm*R33_2*RL2; // in ohms
R55_2=R55_0; // in ohms
R44_3=RL2; // in ohms
R55_3=RL2; // in ohms
R55_4=parallel(RL1,parallel(1/gm,RL2)); // in ohms
a2=R11_0*C1*(R22_1*C2+R33_1*C3+R44_1*C4+R55_1*C5)+R22_0*C2*(R33_2*C3+R44_2*C4+R55_2*C5)+R33_0*C3*(R44_3*C4+R55_3*C5)+R44_0*C4*R55_4*C5; // in seconds
p2=a1/a2;
f=p2/(2*%pi); // in hertz
f=f*1e-6; // in Mega-hertz
disp(f,"Frequency of the nearest non-dominant pole (MHz) =");
```

Scilab code Exa 10.23 Time constant method

```
// Example 10.23: Value of fH for the cascade
```

```
clc, clear
bta=100;
r_pi1=0.5e3; // in ohms
r_pi2=0.5e3; // in ohms
r_pi3=1e3; // in ohms
fT=200e6; // in hertz
C_mu=1e-12; // in farads
// From Fig. 10.85
RS=2e3; // in ohms
RE1=5e3; // in ohms
RC2=2e3; // in ohms
RC3=1e3; // in ohms
RE3=100; // in ohms

function[c]=parallel(a,b)
    c=a*b/(a+b);
endfunction

// From Fig. 10.86
Ro1=parallel(RE1,(RS+r_pi1)/(1+bta)); // in ohms
gm2=bta/r_pi2; // in mho
gm3=bta/r_pi3; // in mho
C_pi2=bta/(2*%pi*fT*r_pi2)-C_mu; // in farads
C_pi3=bta/(2*%pi*fT*r_pi3)-C_mu; // in farads

// From Fig. 10.87
C1=C_pi2; // in farads
C2=C_mu; // in farads
C3=C_pi3; // in farads
C4=C_mu; // in farads
R11_0=parallel(Ro1,r_pi1); // in ohms
RL1=parallel(RC2,r_pi3+(1+bta)*RE3); // in ohms
R22_0=R11_0+RL1*(1+gm2*R11_0); // in ohms

// From Fig. 10.88
R_dash=2.1e3/(1+10); // in ohms
R33_0=parallel(RC2,R_dash); // in ohms

```

```
// From Fig. 10.89
R44_0=(3+2*98/13.1)*1e3; // in ohms

a1=R11_0*C1+R22_0*C2+R33_0*C3+R44_0*C4; // in
    seconds
fH=1/(2*%pi*a1); // in hertz
fH=fH*1e-6; // in Mega-hertz
disp(fH,"Value of fH for the cascade (MHz) =");
```

Chapter 11

Feedback Amplifiers

Scilab code Exa 11.1 `Feedback network`

```
// Example 11.1: Open−loop gain , Return ratio ,
   Reverse transmission    of feedback circuit
clc, clear
// Let A be open−loop gain and B be return ratio
// For A, B 10% higher , −1.1A + 55.11B = −50.1
// For A, B 10% lower , −0.9A + 44.91B = −49.9
// Solving the two equations
a=[-1.1 55.11; -0.9 44.91];
b=[-50.1; -49.9];
c=inv(a)*b;
A=c(1,1);
B=c(2,1);
disp(A,"Open−loop gain =");
disp(B,"Return ratio =");
disp(B/A,"Reverse transmission    of the feedback
   circuit =");
```

Scilab code Exa 11.2 `Amount of feedback`

```
// Example 11.2: Necessary amount of feedback, Gain without feedback
clc, clear
// Let A be gain without feedback and b be necessary amount of feedback
// AOL can assume values A, 1.1A, 0.9A, i.e. 10% variation
// For AOL = 1.1A yields, 50.01 + 1.1A(50.01b -1) = 0
// When AOL = 0.9A, 49.99 + 0.9A(49.99b - 1) = 0
// Solving the two equations
a=[1.1*50.01 -1.1; 0.9*44.99 -0.9];
b=[-50.01; -49.99];
c=inv(a)*b;
d=c(1,1); // A*b
A=c(2,1);
b=d/A;
disp(b,"Necessary amount of feedback =");
disp(A,"Gain without feedback =");
```

Scilab code Exa 11.3 Second harmonic distortion

```
// Example 11.3: (a) Output voltage
//               (b) Input voltage
clc, clear
B1=36; // Fundamental output in volts
B2=7*B1/100; // Second-harmonic distortion in volts
Vs=0.028; // Input in volts
A=B1/Vs; // Gain

disp("Part (a)");
b=1.2/100; // Amount of feedback in volts
B1f=B1/(1+b*A); // Fundamental output with feedback in volts
B2f=B2/(1+b*A); // Second-harmonic distortion with
```

```
   feedback in volts
disp(B1f,"Fundamental output with feedback (V) =");
disp(B2f,"Second-harmonic distortion with feedback (
   V) =");

disp("Part (b)");
B1f=36; // Fundamental output with feedback in volts
B2f=1*B1f/100; // Second-harmonic distortion with
   feedback in volts
T=B2/B2f-1; // Return ratio
AF=A/(1+T); // Feedback gain
Vs=B1f/AF; // Input voltage in volts
disp(Vs,"Input voltage (V) =");
```

Scilab code Exa 11.4 Closed loop parameters

```
// Example 11.4: Closed loop parameters
clc, clear
Av=1000;
bta=0.01;
Zin=1; // in kilo-ohms
Zo=420; // in ohms
fL=1.5; // in kilo-hertz
fH=501.5; // in kilo-hertz
disp("Closed loop parameters :");
T=Av*bta; // Return ratio
// From Fig. 11.18
Af=Av/(1+T); // Closed loop gain
Zif=Zin*(1+T); // Closed loop input impedance in
   kilo-ohms
Zof=Zo/(1+T); // Closed loop output impedance in
   ohms
fLf=fL/(1+T); // Closed loop lower 3 dB frequency in
    kilo-hertz
fHf=fH*(1+T); // Closed loop upper 3 dB frequency in
```

```
    kilo−hertz
disp(Af,"Gain =");
disp(Zif,"Input impedance (k  ) =");
disp(Zof,"Output impedance (  ) =");
disp(fLf,"Lower 3 dB frequency (kHz) =");
disp(fHf,"Upper 3 dB frequency (kHz) =");
```

Scilab code Exa 11.5 Noise reduction

```
// Example 11.5: Output signal voltage, Output noise
    voltage, Improvement in S/N ratio
clc, clear
A1=1;
Vs=1; // in volts
Vn=1; // in volts
A2=100;
bta=1;
Vos=Vs*A1*A2/(1+bta*A1*A2); // Output signal voltage
    in volts
Von=Vn*A1/(1+bta*A1*A2); // Output noise voltage in
    volts
SNRi=20*log10(Vs/Vn); // Input S/N ratio in dB
SNRo=20*log10(Vos/Von); // Output S/N ratio in dB
SNR=SNRo-SNRi; // Improvement in S/N raio in dB
disp(Vos,"Output signal voltage (V) =");
disp(Von,"Output noise voltage (V) =");
disp(SNR,"Improvement in S/N ratio (dB) =");
```

Scilab code Exa 11.6 Non inverting configuration

```
// Example 11.6: (b) R2/R1
//               (c) Amount of feedback in decibels
//               (d) Vo, Vf, Vi
```

```
//                  (e) Decrease in Af
clc, clear

disp("Part (b)");
A=1e4;
Af=10;
bta=(A/Af-1)/A; // Feedback factor
R2_R1=1/bta-1; // R2/R1
disp(R2_R1,"R2/R1 =");

disp("Part (c)");
dB=20*log10(1+A*bta); // Amount of feedback in
    decibels
disp(dB,"Amount of feedback (dB) =");

disp("Part (d)");
Vs=1; // in volts
Vo=Af*Vs; // in volts
Vf=bta*Vo; // in volts
Vi=Vs-Vf; // in volts
disp(Vo,"Vo (V) =");
disp(Vf,"Vf (V) =");
disp(Vi,"Vi (V) =");

disp("Part (e)");
A=80*A/100; // Decreased A
Af_dash=A/(1+A*bta); // Decreased Af
C=(Af-Af_dash)*100/Af; // Percentage decrease in Af
disp(C,"Percentage decrease in Af (%) =");
```

Scilab code Exa 11.7 Upper 3 dB frequency

```
// Example 11.7: Low frequency gain, Upper 3 dB
    frequency
clc, clear
```

```
// Without feedback
AM=1e4; // Low frequency values of A
wH=100; // Upper 3 dB frequency in hertz
// With feedback
R1=1; // in kilo-ohms
R2=9; // in kilo-ohms
bta=R1/(R1+R2); // Feedback factor
AfM=AM/(1+bta*AM); // Low frequency gain
wHf=wH*(1+bta*AM); // Upper 3 dB frequency in hertz
wHf=wHf*1e-3; // Upper 3 dB frequency in kilo-hertz
disp("For closed loop amplifier :");
disp(AfM,"Low frequency gain =");
disp(wHf,"Upper 3 dB frequency (kHz) =");
```

Scilab code Exa 11.9 Desensitivity

```
// Example 11.9: (a) RE
//               (b) RL
//               (c) R1F
//               (d) Quiescent collector current
clc, clear
GmF=1; // Transconductance gain in mili-amperes per volts
AVF=-4; // Voltage gain
D=50; // Desensitivity factor
RS=1; // in kilo-ohms
btao=150;
AoL=GmF*D; // Open loop mutual conductance in mili-amperes per volts

disp("Part (a)");
RE=(D-1)/AoL; // in kilo-ohms
disp(RE,"RE ( k    ) =");

disp("Part (b)");
```

```
RL=-AVF/GmF; // in kilo-ohms
disp(RL,"RL ( k  ) =");

disp("Part (c)");
r_pi=btao/AoL-RS-RE; // in kilo-ohms
R1F=RS+r_pi+(1+btao)*RE; // in kilo-ohms
disp(R1F,"R1F ( k  ) =");

disp("Part (d)");
VT=26e-3; // Voltage equivalent to temperatue at room temperature in volts
IC=btao*VT/r_pi; // in mili-amperes
disp(IC,"IC (mA) =");
```

Scilab code Exa 11.11 Transfer ratio

```
// Example 11.11: (a) Amplifier type
//                (b) Input resistance , Output resistance , Transfer ratio
clc, clear
r_pi=1e3; // in ohms
gm=0.1; // in mho

disp("Part (a)");
disp("It ia a CB-CE cascade , configuration. It has low input and high output impedance and hence corresponds to a current  amplifier.");

disp("Part (b)");
// From low frequency equivalent circuit in Fig. 11.40
btao=gm*r_pi;
Rin=r_pi/(1+btao); // Input resistance in ohms
Rout=%inf; // Output resistance (= ro of Q2)
Ai=gm*gm*Rin*3e3*1e3/(3e3+1e3); // Transfer ratio
```

```
disp(Rin,"Input resistance (      ) =");
disp(Rout,"Output resistance =");
disp(Ai,"Transfer ratio =");
```

Scilab code Exa 11.12 Gain with feedback

```
// Example 11.12: (b) AF
clc, clear
AV=4000;
bta=1/300;
RS=2; // in kilo-ohms
RE=RS; // in kilo-ohms
RC=6; // in kilo-ohms
btao=200;
r_pi=4; // in kilo-ohms

disp("Part (b)");
x=-AV*-btao*RC/(r_pi+RS);
AF=x/(1+x*bta);
disp(AF,"AF =");
```

Scilab code Exa 11.13 Transfer ratio

```
// Example 11.13: (a) Amplifier type
//                 (b) Input resistance, Output
    resistance, Transfer ratio
clc, clear
r_pi=1e3; // in ohms
gm=0.1; // in mho

disp("Part (a)");
disp("Q1 is a common collector and Q2 is common
    emitter stage. Hence the given circuit is cascade
```

```
    of cc and CE stages. As the Rin of a CC is high
    and the Ro of the CE is low, therefore, the given
    circuit approximates a voltage amplifier. If RL
    is chosen a low resistance, the amplifier can be
    considered a voltage-to-current converter.")

function[c]=parallel(a,b)
    c=a*b/(a+b);
endfunction

disp("Part (b)");
// From the Fig. 11.42
RE1=3e3; // in ohms
RC2=0.6e3; // in ohms
btao=gm*r_pi;
Ri2=r_pi; // in ohms
Ri1=r_pi+(1+btao)*parallel(RE1,Ri2); // Input
    resistance in ohms
Rout=RC2; // Output resistance (= ro of Q2)
AV1=(1+btao)*RE1/(r_pi+(1+btao)*RE1);
Ro1=parallel(RE1,r_pi/(1+btao)); // in ohms
AV2=-btao*RC2/(Ro1+r_pi);
AV=AV1*AV2;
Ri1=Ri1*1e-3; // in kilo-ohms
Rout=Rout*1e-3; // in kilo-ohms
disp(Ri1,"Input resistance (    ) =");
disp(Rout,"Output resistance =");
disp(AV,"Transfer ratio =");
```

Scilab code Exa 11.15 Small signal gain

```
// Example 11.15: Small signal gain, Input
    resistance, Output resistance
clc, clear
btao=100;
```

```
r_pi=1e3; // in ohms
ICQ=2.5e-3; // in amperes
VT=25e-3; // in volts
gm=ICQ/VT; // Transconductance in mho
r_pi=btao/gm; // Incremental resistance of emitter-base diode in ohms
// From ac model without feedback in Fig. 11.47
RS=10e3; // in ohms
RF=47e3; // in ohms
RC=4.7e3; // in ohms
function[c]=parallel(a,b)
    c=a*b/(a+b);
endfunction
AoL=-gm*parallel(RF,RC)*parallel(RS,parallel(RF,r_pi)); // in ohms
bta=1/RF;
T=-bta*AoL; // Return ratio
AF=AoL/(1+T); // in ohms
AVF=AF/RS; // Small signal gain
RID=parallel(RF,r_pi); // in ohms
RID_dash=parallel(RID,RS); // in ohms
RIF_dash_I=RID_dash/(1+T); // in ohms
RIF_I=RS*RIF_dash_I/(RS-RIF_dash_I); // in ohms
RIF_dash_V=RS+RIF_I; // in ohms
RoD_dash=parallel(RF,RC); // in ohms
RoF_dash=RoD_dash/(1+T); // in ohms
RoF=RoF_dash*RC/(RC-RoF_dash); // in ohms
disp(RoF);
RIF_dash_V=RIF_dash_V*1e-3; // in kilo-ohms
RoF=RoF*1e-3; // in kilo-ohms
disp(AVF,"Small signal gain =");
disp(RIF_dash_V,"Input resistance ( k    ) =");
disp(RoF,"Output resistance ( k    ) =");
```

Scilab code Exa 11.16 `Closed loop parameters`

```
// Example 11.16: (a) AF, T
//                (b) R1F, RoF
clc, clear
btao=150;
ICQ=1.5e-3; // in amperes
VT=25e-3; // Voltage equivalent to temperatue at room temperature in volts
// From circuit without feedback but with loading in Fig. 11.50
RS=2e3; // in ohms
RE1=0.1e3; // in ohms
RF=6.2e3; // in ohms
RC1=4.3e3; // in ohms
RC2=1.2e3; // in ohms
RL=4.7e3; // in ohms

function[c]=parallel(a,b)
    c=a*b/(a+b);
endfunction

disp("Part (a)");
gm=ICQ/VT; // Transconductance in mho
r_pi=btao/gm; // Incremental resistance of emitter-base diode in ohms
AV1=-btao*RC1/(RS+r_pi+(1+btao)*parallel(RE1,RF));
AV2=-btao*parallel(RC2,parallel(RF+RE1,RL))/(RC1+r_pi);
AoL=AV1*AV2;
bta=-RE1/(RE1+RF);
T=-bta*AoL;
AF=AoL/(1+T);
disp(AF,"AF =");
disp(T,"T =");

disp("Part (b)");
RID=r_pi+(1+btao)*parallel(RE1,RF); // in ohms
RID_dash=RS+RID; // in ohms
RIF_dash=RID_dash*(1+T); // in ohms
```

```
RIF=RIF_dash-RS; // in ohms
RoD=parallel(RC2,RF+RE1); // in ohms
RoD_dash=parallel(RoD,RL); // in ohms
RoF_dash=RoD_dash/(1+T); // in ohms
RoF=RL*RoF_dash/(RL-RoF_dash); // in ohms
RIF=RIF*1e-3; // in kilo-ohms
disp(RIF,"RIF ( k    ) =");
disp(RoF,"RoF (      ) =");
```

Scilab code Exa 11.17 Feedback in MOSFETs

```
// Example 11.17: (a) T, AoL, AF
//                (b) RoF
clc, clear
gm=1e-3; // in mho
rd=20e3; // in ohms

function[c]=parallel(a,b)
    c=a*b/(a+b);
endfunction

disp("Part (a)");
// From the ac equivalent circuit in Fig. 11.52
RF=10e3; // in ohms
RD1=10e3; // in ohms
RL=10e3; // in ohms
ro=20e3; // in ohms
RS=parallel(0.47e3,RF); // in ohms
RL2=parallel(ro,parallel(10.47e3,RL)); // in ohms
mu=rd*gm; // Amplification factor
AV1=-mu*RD1/(RD1+rd+(1+mu)*RS);
AV2=-gm*RL2;
AoL=AV1*AV2;
bta=-0.47/(10+0.47); // Feedback factor
T=-bta*AoL;
```

```
AF=AoL/(1+T);
disp(T,"T =");
disp(AoL,"AoL =");
disp(AF,"AF =");

disp("Part (b)");
RoD=parallel(ro,10.47e3); // in ohms
TSC=0; // for RL=0, T=0
ToC=bta*AV1*gm*RoD;
// By Blackman's relation
RoF=RoD*(1+TSC)/(1+ToC); // in ohms
RoF=RoF*1e-3; // in kilo-ohms
disp(RoF,"RoF (k ) =");
```

Scilab code Exa 11.18 Open and closed loop gain

```
// Example 11.18: T, AoL, AF
clc, clear
function[c]=parallel(a,b)
    c=a*b/(a+b);
endfunction
ICQ1=0.25e-3; // in amperes
ICQ2=-0.5e-3; // in amperes
bta1=200;
VA1=125; // in volts
bta2=150;
VT=25e-3; // Voltage equivalent to temperatue at
   room temperature in volts
gm1=ICQ1/VT; // in mho
gm2=abs(ICQ2)/VT; // in mho
r_pi1=bta1/gm1; // in ohms
r_pi2=bta2/gm2; // in ohms
ro1=VA1/ICQ1; // in ohms
// From ac equivalent circuit in Fig. 11.56
RC1=20e3; // in ohms
```

```
RS=1e3; // in ohms
bta=-0.82/(20+0.82); // Feedback factor
RL1=parallel(RC1,ro1); // in ohms
Ib2_IC1=RL1/(RL1+r_pi2+(1+bta2)*parallel(20e3,0.82e3
    )); // Ib2/IC1
Ib1_IS=parallel(RS,20.82e3)/(r_pi1+parallel(RS,20.82
    e3)); // Ib1/IS
AoL=bta2*Ib2_IC1*bta1*Ib1_IS; // Current gain
    without feedback
T=-bta*AoL;
AF=AoL/(1+T);
disp(T,"T =");
disp(AoL,"AoL =");
disp(AF,"AF =");
```

Scilab code Exa 11.19 Closed loop parameters

```
// Example 11.19: (a) AIF
//                (b) R1F
//                (c) A1F'
//                (d) AVF
clc, clear
btao=50;
r_pi=2e3; // in ohms
// From equivalent circuit without feedback but
    taking loading effect in Fig. 11.58
RS=1e3; // in ohms
Rf=15e3; // in ohms
RE2=10e3; // in ohms
RC1=10e3; // in ohms
RC2=10e3; // in ohms

function[c]=parallel(a,b)
    c=a*b/(a+b);
endfunction
```

```
disp("Part (a)");
RS_dash=parallel(RS,Rf+RE2); // in ohms
gm=btao/r_pi; // in mho
RE2_dash=parallel(RE2,Rf); // in ohms
Rx=r_pi+(1+btao)*RE2_dash; // in ohms
I2_IS=-gm*parallel(RS_dash,r_pi)*RC1/(RC1+Rx); // I2/IS
AI=-btao*I2_IS; // Open loop
If_IS=(1+btao)*I2_IS*RE2/(RE2+Rf); // If/IS
bta=If_IS/AI; // Feedback factor
T=-bta*AI;
AIF=AI/(1+T);
disp(AIF,"AIF =");

disp("Part (b)");
RID=parallel(RS,parallel(Rf+RE2,r_pi));
R1F=RID/(1+T); // in ohms
disp(R1F,"R1F (  ) =");

disp("Part (c)");
Ii_IS=RS/(RS+parallel(Rf+RE2,r_pi)); // Ii'/IS
AI_dash=AI*Ii_IS;
T=-bta*AI_dash;
A1F_dash=AI_dash/(1+T);
disp(A1F_dash,"A1F =");

disp("Part (d)");
AVF=AIF*RC2/RS;
disp(AVF,"AVF =");
```

Scilab code Exa 11.20 Closed loop parameters

```
// Example 11.20: (a) AVF
//                (b) AIF
```

```
//                    (c) RIF
//                    (d) ROF
clc, clear
btao=50;
r_pi=1.1e3; // in ohms
function[c]=parallel(a,b)
    c=a*b/(a+b);
endfunction
// From equivalent circuit of amplifier without feedback in Fig. 11.60
RS=4.7e3; // in ohms
RF=15e3; // in ohms
RE2=0.1e3; // in ohms
RB1=parallel(91e3,10e3); // in ohms
RC1=4.7e3; // in ohms
RC2=4.7e3; // in ohms
RB2=RB1; // in ohms

disp("Part (b)");
RL1=parallel(RS,parallel(RF+RE2,RB1)); // in ohms
I1_IS=RL1/(RL1+r_pi); // I1/IS
IC1_IS=btao*I1_IS; // IC1/IS
Ri2=r_pi+(1+btao)*parallel(RE2,RF); // in ohms
I2_IS=-IC1_IS*parallel(RC1,RB2)/(parallel(RC1,RB2)+Ri2); // in ohms
IC2_IS=btao*I2_IS; // IC2/IS
AID=-IC2_IS/2; // Open loop
IF_IS=IC2_IS*RE2/(RE2+RF); // IF/IS
bta=IF_IS/AID; // Feedback factor
T=-bta*AID;
AIF=AID/(1+T);
disp(AIF,"AIF =");

disp("Part (a)");
AVF=AIF*RC2/RS;
disp(AVF,"AVF =");

disp("Part (c)");
```

```
RID=parallel(parallel(RS,RE2+RF),parallel(RB1,r_pi)); // in ohms
RIF=RID/(1+T); // in ohms
disp(RIF,"RIF (  ) =");

disp("Part (d)");
ROF=RC2*1e-3; // in kilo-ohms
disp(ROF,"ROF ( k   ) =");
```

Scilab code Exa 11.21 `Voltage gain`

```
// Example 11.21: (c) AF, T
//                (d) Voltage gain
clc, clear
ICQ1=0.25e-3; // in amperes
ICQ2=1e-3; // in amperes
ICQ3=0.5e-3; // in amperes
RC1=5e3; // in ohms
RC2=7.5e3; // in ohms
RC3=10e3; // in ohms
R1=0.2e3; // in ohms
R2=0.33e3; // in ohms
RS=0.6e3; // in ohms
RF=20e3; // in ohms
btao=200;
VA=125; // in volts
VT=25e-3; // Voltage equivalent to temperatue at room temperature in volts

function[c]=parallel(a,b)
    c=a*b/(a+b);
endfunction

disp("Part (c)");
gm1=ICQ1/VT; // in mho
```

```
r_pi1=btao/gm1; // in ohms
ro1=VA/ICQ1; // in ohms
gm2=ICQ2/VT; // in mho
r_pi2=btao/gm2; // in ohms
ro2=VA/ICQ2; // in ohms
gm3=ICQ3/VT; // in mho
r_pi3=btao/gm3; // in ohms
ro3=VA/ICQ3; // in ohms
Rin1=r_pi1+(btao+1)*parallel(RF+R2,R1); // in ohms
RL1=parallel(RC1,ro1); // in ohms
RL2=parallel(RC2,ro2); // in ohms
Rin2=r_pi2; // in ohms
Rin3=r_pi3+(btao+1)*parallel(R2,RF+R1); // in ohms
Io_Ib3=btao; // Io/Ib3
Ib3_Ic2=-RL2/(RL2+Rin3); // Ib3/Ic2
Ic2_Ib2=btao; // Ic2/Ib2
Ib2_Ic1=-RL1/(RL1+Rin2); // Ib2/Ic1
Ic1_Ib1=btao; // Ic1/Ib1
Ib1_VS=1/(RS+Rin1); // Ib1/VS in mho
AoL=Io_Ib3*Ib3_Ic2*Ic2_Ib2*Ib2_Ic1*Ic1_Ib1*Ib1_VS;
    // Open loop
bta=-R1*R2/(R1+R2+RF); // Feedback factor
T=-bta*AoL;
AF=AoL/(1+T);
disp(T,"T =");
disp(AF,"AF =");

disp("Part (d)");
Vo_VS=-AF*parallel(RC3,ro3);
disp(Vo_VS,"Voltage gain =");
```

Scilab code Exa 11.22 Feedback in FETs

```
// Example 11.22: AF, RoF
clc, clear
```

```
gm=2e-3; // in mho
rd=20e3; // in ohms
RD=12e3; // in ohms
RG=500e3; // in ohms
Rs=50; // in ohms
RF=5e3; // in ohms
function[c]=parallel(a,b)
    c=a*b/(a+b);
endfunction
Ro=parallel(RD,rd); // in ohms
AV1=-gm*parallel(RD,parallel(rd,RG));
AV2=AV1;
AV3=-gm*parallel(RD,rd);
AV=AV1*AV2*AV3;
RG_dash=parallel(RG,RF); // in ohms
Vi_Vs=RG_dash/(RG_dash+Rs); // Vi/Vs
AoL=AV*Vi_Vs*RF/(RF+Ro); // Vo/Vs (Open loop)
bta=1/RF; // Feedback factor
RM=AoL*Rs; // in ohms
T=-bta*RM; // Return ratio
AF=AoL/(1+T);
RoD=parallel(Ro,RF); // in ohms
RoF=RoD/(1+T); // in ohms
disp(AF,"AF =");
disp(RoF,"RoF (   ) =");
```

Chapter 12

Oscillators

Scilab code Exa 12.1 Phase shift oscillator

```
// Example 12.1: (a) RD
//               (b) Product RC
//               (c) Reasonable value of R and C
clc, clear
fo=8e3; // in hertz
mu=59;
rd=10; // in kilo-ohms

disp("Part (a)");
RD=29*rd/(mu-29); // in kilo-ohms
disp(RD,"RD ( k ) =");

disp("Part (b)");
RC=1/(2*%pi*fo*sqrt(6)); // in seconds
RC=RC*1e6; // in micro-seconds
disp(RC,"Product RC ( s ) =");

disp("Part (c)");
R=50; // in kilo-ohms
C=RC/R; // in nano-farad
C=C*1e3; // in pico-farad
```

```
disp(R,"Reasonable value of R ( k ) =");
disp(C,"Reasonable value of C (pF) =");
```

Scilab code Exa 12.2 Wien Bridge oscillator

```
// Example 12.2: Designing a Wein Bridge Oscillator
clc, clear
fo=2e3; // in hertz
R=10; // in kilo-ohms
C=1/(2*%pi*fo*R*1e3); // in farads
C=C*1e9; // in nano-farads
disp(R,"R1 ( k ) =");
disp(R,"R2 ( k ) =");
disp(2*R,"R3 ( k ) =");
disp(R,"R4 ( k ) =");
disp(C,"C1 (nF) =");
disp(C,"C2 (nF) =");
```

Scilab code Exa 12.3 Hartley oscillator

```
// Example 12.3: Range of capacitance
clc, clear
L1=2e-3; // in henry
L2=1.5e-3; // in henry
fmin=1000e3; // in hertz
fmax=2000e3; // in hertz
Cmin=1/((2*%pi*fmax)^2*(L1+L2)); // in farads
Cmax=1/((2*%pi*fmin)^2*(L1+L2)); // in farads
Cmin=Cmin*1e12; // in pico-farads
Cmax=Cmax*1e12; // in pico-farads
disp(Cmin,"Minimum value of C (pF) =");
disp(Cmax,"Maximum value of C (pF) =");
```

Chapter 13

Power Amplifiers and Voltage Regulators

Scilab code Exa 13.1 Series fed amplifier

```
// Example 13.1: dc input power, ac output power,
   Efficiency
clc, clear
Ib=5e-3; // Base current in amperes
// From Fig. 13.8
RB=1.5e3; // in ohms
RC=16; // in ohms
bta=40;
VCC=18; // in volts
VBE=0.7; // in volts
IBQ=(VCC-VBE)/RB; // in amperes
ICQ=bta*IBQ; // in amperes
Pi_dc=VCC*ICQ; // dc input power in watts
Ic=bta*Ib; // in amperes
Po_ac=Ic^2*RC; // ac output power
eta=Po_ac*100/Pi_dc; // Efficiency in percentage
disp(Pi_dc,"dc input power (W) =");
disp(Po_ac,"ac output power (W) =");
disp(eta,"Efficiency (%) =");
```

Scilab code Exa 13.2 Transformer turn ratio

```
// Example 13.2: Transformer turns ratio
clc, clear
function[c]=parallel(a,b)
    c=a*b/(a+b);
endfunction
RL=parallel(parallel(16,16),parallel(16,16)); // in
   ohms
RL_dash=8e3; // in ohms
TR=sqrt(RL_dash/RL); // Transformer turns ratio
disp(TR,"Transformer turns ratio =");
```

Scilab code Exa 13.3 Class A amplifier

```
// Example 12.3: Efficiency
clc, clear
P_ac=2; // in watts
ICQ=150e-3; // in amperes
VCC=36; // in volts
P_dc=VCC*ICQ; // in watts
eta=P_ac*100/P_dc; // Efficiency in percentage
disp(eta,"Efficiency (%) =");
```

Scilab code Exa 13.4 Class B push pull amplifier

```
// Example 13.4: Maximum input power, Maximum ac
   output power, Maximum conversion efficiency,
   Maximum power dissipated by each transistor
```

```
clc, clear
VCC=15; // in volts
RL=8; // in ohms
P_dc=2*VCC^2/(%pi*RL); // Maximum input power in
    watts
P_ac=VCC^2/(2*RL); // Maximum ac output power in
    watts
eta=P_ac*100/P_dc; // Maximum efficiency in
    percentage
PD=2*VCC^2/(%pi^2*RL); // Maximum power dissipated
    in watts
PD_each=PD/2; // Maximum power dissipated by each
    transistor in watts
disp(P_dc,"Maximum input power (W) =");
disp(P_ac,"Maximum ac output power (W) =");
disp(eta,"Maximum conversion efficiency (%) =");
disp(PD_each,"Maximum power dissipated by each
    transistor (W) =");
```

Scilab code Exa 13.5 Class B output stage

```
// Example 13.5: Supply voltage, Peak current drawn
    from each supply, Total supply power, Power
    conversion efficiency, Maximum power that each
    transistor can dissipate safely
clc, clear
P_ac=20; // Average power delivered in watts
RL=8; // Load in ohms
Vm=sqrt(2*P_ac*RL); // Peak output voltage in volts
VCC=Vm+5; // Supply voltage in volts
Im=Vm/RL; // Peak current drawn from each supply in
    amperes
P_dc=2*Im*VCC/%pi; // Total supply power in watts
eta=P_ac*100/P_dc; // Power conversion efficiency in
    percentage
```

```
PD=2*VCC^2/(%pi^2*RL); // Maximum power dissipated in watts
PD_each=PD/2; // Maximum power dissipated by each transistor in watts
disp(VCC,"Supply voltage (V) =");
disp(Im,"Peak current drawn from each supply (A) =");
disp(P_dc,"Total supply power (W) =");
disp(eta,"Power conversion efficiency (%) =");
disp(PD_each,"Maximum power that each transistor can dissipate safely (W) =");
```

Scilab code Exa 13.6 `Thermal considerations`

```
// Example 13.6: Thermal resistance , Power rating at 70 C , Junction temperature at 100 mW
clc, clear
TAo=25; // in C
PDo=200; // in mili-watts
Tj_max=150; // Maximum junction temperature in C
T=70; // in C
P=100; // in mili-watts
TA=50; // Ambient temperature in C
theta=(Tj_max-TAo)/PDo; // Thermal resistance in C per mili-watts
PR=(Tj_max-T)/theta; // Power rating at 70 C in mili-watts
Tj=TA+theta*P; // Junction temperature at 100 mW in C
disp(theta,"Thermal resistance ( C /mW) =");
disp(PR,"Power rating at 70 C (mW) =");
disp(Tj,"Junction temperature at 100 mW ( C ) =");
```