Solution 1.1

Answering machine
Alarm clock
Automatic door
Automatic lights
ATM
Automobile:
- Engine controller
- Temperature control
- ABS
- Electronic dash
- Navigation system

Automotive tune-up equipment
Baggage scanner
Bar code scanner
NiCad/Lithium Ion battery chargers
Cable/DSL Modems and routers
Calculator
Camcorder
Carbon monoxide detector
Cash register
CD and DVD players
Ceiling fan (remote)
Cellular phones
Coffee maker
Compass
Copy machine
Cordless phone
Depth finder
Digital Camera
Digital watch
Digital voice recorder
Digital scale
Digital thermometer
Electronic dart board
Electric guitar
Electronic door bell
Electronic gas pump
Elevator
Exercise machine
Fax machine
Fish finder
Garage door opener
Solution continued on the next page...

GPS
Hearing aid
Invisible dog fences
Laser pointer
LCD projector
Light dimmer
Keyboard synthesizer
Keyless entry system
Laboratory instruments
Metal detector
Microwave oven
Model airplanes
MP3 player
Musical greeting cards
Musical tuner
Pagers
Personal computer
Personal planner/organizer (PDA)
Radar detector
Broadcast Radio (AM/FM/Shortwave)
Razor
Satellite radio receiver
Security systems
Sewing machine
Smoke detector
Sprinkler system
Stereo system
    Amplifier
    CD/DVD player
    Receiver
    Tape player
Stud sensor
Talking toys
Telephone
Telescope controller
Thermostats
Toy robots
Traffic light controller
TV receiver & remote control
Variable speed appliances
    Blender
    Drill
    Mixer
    Food processor
    Fan

Solution continued on the next page...

Vending machines
Video game controllers
Wireless headphones & speakers
Wireless thermometer
Workstations

Electromechanical Appliances*
- Air conditioning and heating systems
- Clothes washer and dryer
- Dish washer
- Electrical timer
- Iron, vacuum cleaner, toaster
- Oven, refrigerator, stove, etc.

*These appliances are historically based only upon on-off (bang-bang) control. However, most high end versions of these appliances have now added sophisticated electronic control.
ated electronic control.

Solution 1.2

$N = 1327 x 10^{(2020-1970)/6.52} = 61.9\ x\ 10^{9}$ transistors/chip

Solution 1.3

$N = \left(2.233x10^{9}\right)x10^{(2021-2014)/10.1} = 11.0\ x\ 10^{9}$ Transistors/Chip

Solution 1.4

$$B = 19.97\ x\ 10^{0.1997(2021-1960)} = 30.3\ x\ 10^{12} = 30.3 \text{ Tb/chip}$$

Solution 1.5

(a)

$$\frac{B_2}{B_1} = \frac{19.97x10^{0.1977(Y_2-1960)}}{19.97x10^{0.1977(Y_1-1960)}} = 10^{0.1977(Y_2-Y_1)} \quad so \quad 2 = 10^{0.1977(Y_2-Y_1)}$$

$$Y_2 - Y_1 = \frac{\log 2}{0.1977} = 1.52 \; years$$

(b) $$Y_2 - Y_1 = \frac{\log 10}{0.1977} = 5.06 \; years$$

Solution 1.6

$$\frac{N_2}{N_1} = \frac{1327x10^{(Y_2-1970)/6.52}}{1327x10^{(Y_1-1970)/6.52}} = 10^{(Y_2-Y_1)/6.52}$$

$$(a)\ Y_2 - Y_1 = 6.52\log 2 = 1.96\ years$$

$$(b)\ Y_2 - Y_1 = 6.52\log 10 = 6.52\ years$$

Solution 1.7

$$\frac{N_2}{N_1}=\frac{\left(2.233x10^9\right)x10^{\left(Y_2-2014\right)/10.1}}{\left(2.233x10^9\right)x10^{\left(Y_1-2014\right)/10.1}}=10^{\left(Y_2-Y_1\right)/10.1}$$

$(a)\ Y_2-Y_1=10.1\log 2=3.07\ years$

$(b)\ Y_2-Y_1=10.1\log 10=10.1\ years$

Solution 1.8

$$F = 8.00x10^{-0.05806(2020-1970)}\mu m = 10\ nm\ .$$

Although this distance corresponds to the diameter of only a few atoms, ITRS projections are on track to produce feature sizes in this range. See the Intel website for example.

Solution 1.9

$$P = \left(268x10^6 \text{tubes}\right)\left(1.5\text{W/tube}\right) = 402 \text{ MW!} \qquad I = \frac{4.02\ x\ 10^8 W}{220V} = 1.83\ MA!$$

$$V = \left(268x10^6 \text{tubes}\right)\left(80cm^3 / tube\right) = 21.4x10^9 cm^3 = 21400\ m^3$$

Solution 1.10

D, D, A, A, D, A, A, D, A, D, A

Solution 1.11

$$V_{LSB} = \frac{5V}{2^8 bits} = \frac{5V}{256 bits} = 19.53\frac{\text{mV}}{\text{bit}} \quad \text{and} \quad \frac{3.06\text{V}}{19.53\frac{\text{mV}}{\text{bit}}} = 156.7 \text{ bits} \rightarrow 157 \text{ LSB}$$

$$157_{10} = \left(128+16+8+4+1\right)_{10} = 10011101_2$$

Solution 1.12

$$V_{LSB} = \frac{2.5V}{2^{10}\ bits} = \frac{2.5V}{1024\ bits} = 2.441\frac{mV}{bit}$$

$$0101100110_2 = \left(2^8 + 2^6 + 2^5 + 2^2 + 2^1\right)_{10} = 358_{10} \qquad V_O = 358\left(\frac{2.5V}{1024}\right) = 0.874\ V$$

Solution 1.13

$$V_{LSB} = \frac{10V}{2^{12} bits} = \frac{10V}{4096 bits} = 2.441\ mV \qquad \text{V}_{\text{MSB}} = \frac{10V}{2} = 5.000\ V$$

$$100100101001_2 = 2^{11} + 2^8 + 2^5 + 2^3 + 2^0 = 2345_{10} \qquad V_O = 2345\left(2.441 mV\right) = 5.724\ V$$

Solution 1.14

$$V_{LSB} = \frac{10V}{2^{15} bits} = 0.3052 \frac{\text{mV}}{\text{bit}} \quad \text{and} \quad \frac{6.89\text{V}}{10V}\left(2^{15} bits\right) = 22577 \text{ bits}$$

$$22577_{10} = \left(16384 + 4096 + 2048 + 32 + 16 + 1\right)_{10}$$

$$22577_{10} = 101100000110001_2$$

Solution 1.15

(a) A 4 digit readout ranges from 0000 to 2000 and has a resolution of 1 part in 2,000. The number of bits must satisfy $2^B \geq 2{,}000$ where B is the number of bits. Here B = 11 bits.

(b) $2^B \geq 10^6$ yields B = 20 bits.

Solution 1.16

$$V_{LSB} = \frac{5.12V}{2^{14}\ bits} = \frac{5.12V}{16384\ bits} = 0.3125\frac{mV}{bit} \quad \text{and} \quad V_O = \left(10101110111010_2\right)V_{LSB} \pm \frac{V_{LSB}}{2}$$

$$V_O = \left(2^{13} + 2^{11} + 2^9 + 2^8 + 2^7 + 2^5 + 2^4 + 2^3 + 2^1\right)_{10} 0.3125mV \pm 0.1625mV$$

$$V_O = 3.49813 \pm 0.0001625 \quad \text{or} \quad 3.49798\text{V} \le \text{V}_\text{O} \le 3.49829V$$

Solution 1.17

I_B = dc component = 7.50 mA, i_b = signal component = 0.003 cos (1000t) A

Solution 1.18

$$V_{GS} = 2.5 \text{ V}, \quad v_{gs} = 0.5u(t-1) + 0.1 \cos 2000\pi t \text{ Volts}$$

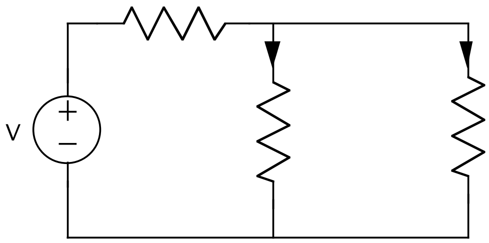
Solution 1.19

$$v_{CE} = [5 + 2 \cos (5000t)] \text{ V}$$

Solution 1.20

$$v_{DS} = [5 + 2 \sin(2500t) + 4 \sin(1000t)] \text{ V}$$

Solution 1.21



V = 1 V, R_1 = 24 kΩ, R_2= 30 kΩ and R_3 = 11 kΩ.

$$V_1 = 1V\frac{24k\Omega}{24k\Omega + (30k\Omega \| 11k\Omega)} = 0.749\ V \qquad V_2 = 1V\frac{30k\Omega \| 11k\Omega}{24k\Omega + (30k\Omega \| 11k\Omega)} = 0.251\ V$$

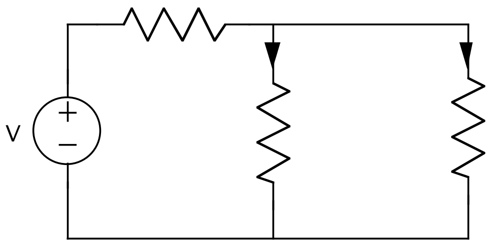
Checking: $V_1 + V_2 = 0.749 + 0.251 = 1.00\ V$ which is correct.

$$I_1 = \frac{1V}{24k\Omega + (30k\Omega \| 11k\Omega)} = 31.2\ \mu A \qquad I_2 = I_1\frac{R_3}{R_2 + R_3} = (31.2\mu A)\frac{11k\Omega}{30k\Omega + 11k\Omega} = 8.37\ \mu A$$

$$I_3 = I_1\frac{R_2}{R_2 + R_3} = (31.2\mu A)\frac{30k\Omega}{30k\Omega + 11k\Omega} = 22.8\ \mu A$$

Checking: $I_2 + I_3 = 31.2\ \mu A$

Solution 1.22



V = 8 V, R_1 = 30 kΩ, R_2= 24 kΩ and R_3 = 15 kΩ.

$$V_1 = 8V\frac{30k\Omega}{30k\Omega + \left(24k\Omega \| 15k\Omega\right)} = 8V\frac{30k\Omega}{30k\Omega + 9.23k\Omega} = 6.12\ V$$

$$V_2 = 8V\frac{24k\Omega \| 15k\Omega}{30k\Omega + \left(24k\Omega \| 15k\Omega\right)} = 1.88\ V \qquad \text{Checking: } 6.12+1.88 = 8.00\ V$$

$$I_2 = I_1\frac{R_3}{R_2 + R_3} = \left(\frac{8V}{30k\Omega + 9.23k\Omega}\right)\frac{15k\Omega}{24k\Omega + 15k\Omega} = 78.4\ \mu A$$

$$I_3 = I_1\frac{R_2}{R_2 + R_3} = \left(\frac{8V}{30k\Omega + 9.23k\Omega}\right)\frac{24k\Omega}{24k\Omega + 15k\Omega} = 125\ \mu A$$

Checking: $I_1 = \dfrac{8V}{30k\Omega + 9.23k\Omega} = 204\ \mu A$ and $I_1 = I_2 + I_3$

Solution 1.23

$$I_2 = 200\mu A\left(\frac{150k\Omega}{150k\Omega + 150k\Omega}\right) = 100\ \mu A \qquad I_3 = 200\mu A\left(\frac{150k\Omega}{150k\Omega + 150k\Omega}\right) = 100\ \mu A$$

$$V_3 = 200\mu A\left(150k\Omega \| 150k\Omega\right)\left(\frac{82k\Omega}{68k\Omega + 82k\Omega}\right) = 8.2V$$

Checking: $I_1 + I_2 = 200\ \mu A$ and $I_2 R_2 = 100\mu A\left(82k\Omega\right) = 8.2\ V$

Solution 1.24

$$I_1 = 4mA\frac{(3.9k\Omega + 5.6k\Omega)}{(3.9k\Omega + 5.6k\Omega) + 2.4k\Omega} = 3.19\ mA \qquad I_2 = 4mA\frac{2.4k\Omega}{9.5k\Omega + 2.4k\Omega} = 0.807\ mA$$

$$V_3 = 4mA(2.4k\Omega \| 9.5k\Omega)\frac{5.6k\Omega}{3.9k\Omega + 5.6k\Omega} = 4.52\ V$$

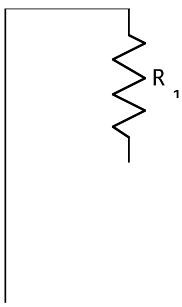
Checking: $I_1 + I_2 = 4.00\ mA$ and $I_2 R_3 = 0.807mA(5.6k\Omega) = 4.52\ V$

Solution 1.25

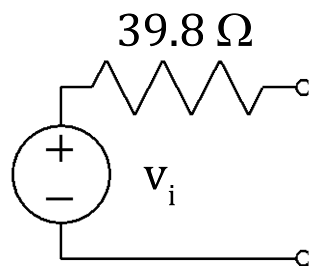
Summing currents at the open circuited output node yields:

$$\frac{v}{10^4} + .025v = 0 \text{ so } v = 0 \text{ and } v_{th} = v_i - v = v_i$$

To find the Thévenin equivalent resistance, we apply a test source to the output with v_i set to zero:



Thévenin equivalent circuit:

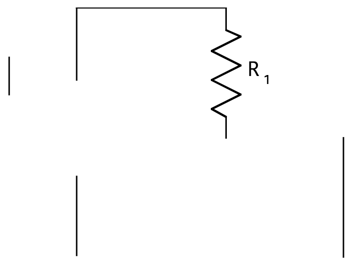


Summing currents at the output node:

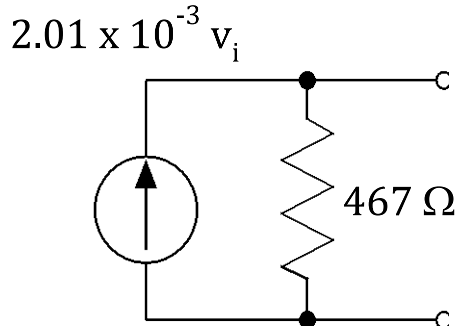
$$i_x = -\frac{v}{R_1} - g_m v = 0 \text{ but } v = -v_x$$

$$i_x = \frac{v_x}{R_1} + g_m v_x = 0 \quad R_{th} = \frac{v_x}{i_x} = \frac{1}{\frac{1}{R_1} + g_m} = \frac{1}{\frac{1}{10k\Omega} + 0.025S} = 39.8\ \Omega$$

Solution 1.26



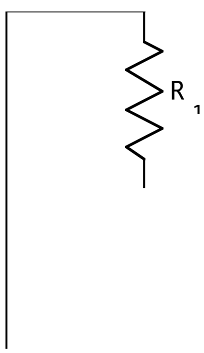
Norton equivalent circuit:



The short circuit current is:

$$i_n = \frac{v}{75\text{k}\Omega} + 0.002v \ \text{ and } \ v = v_i \quad \rightarrow \quad i_n = \frac{v_i}{75\text{k}\Omega} + 0.002v_i = 2.01x10^{-3}v_i$$

To find the Thévenin equivalent resistance, we apply a test source to the output with v_i set to zero:

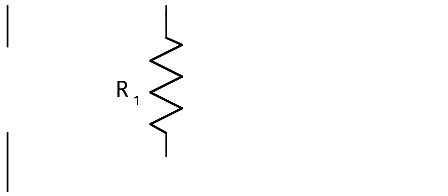


Summing currents at the output node:

$$i_x = -\frac{v}{R_1} - g_m v = 0 \ \text{ but } \ v = -v_x$$

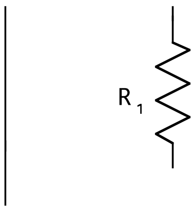
$$i_x = \frac{v_x}{R_1} + g_m v_x = 0 \qquad R_{th} = \frac{v_x}{i_x} = \frac{1}{\frac{1}{R_1} + g_m} = \frac{1}{\frac{1}{75k\Omega} + 0.002S} = 467\ \Omega$$

Solution 1.27

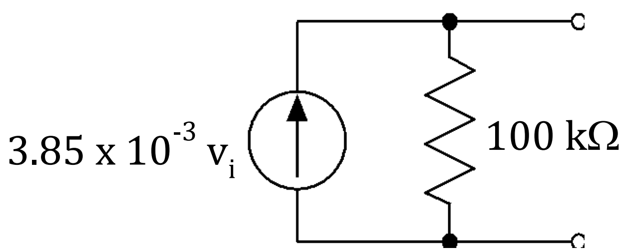


(a)

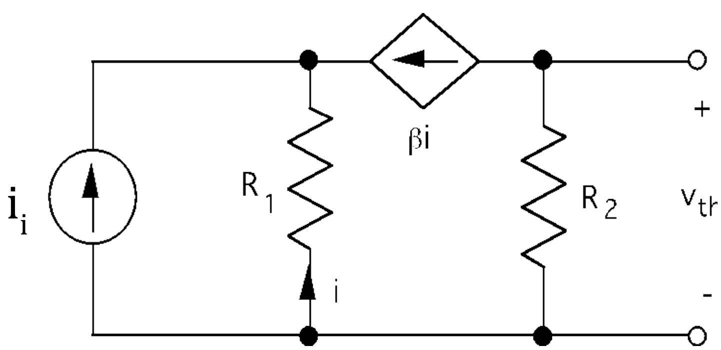
$i_n = -\beta i$ but $i = -\dfrac{v_i}{R_1}$ and $i_n = \dfrac{\beta}{R_1} v_i = \dfrac{150}{39k\Omega} v_i = 3.85\ x\ 10^{-3} v_i$

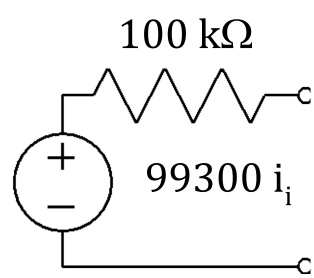


$R_{th} = \dfrac{v_x}{i_x}$; $i_x = \dfrac{v_x}{R_2} + \beta i$ but $i = 0$ since $v_{R_1} = 0.$ $R_{th} = R_2 = 100\ k\Omega.$



Noton equivalent circuit:



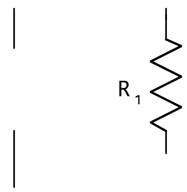


(b)

$v_{th} = v_{oc} = -\beta i R_2$ where $i + \beta i + i_i = 0$ and $v_{th} = R_2\left(\dfrac{\beta}{\beta+1}\right) i_i = 100k\Omega\left(\dfrac{150}{151}\right) i_i = 99300 i_i$

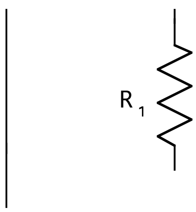
R_{th} is found in part (a).

Solution 1.28



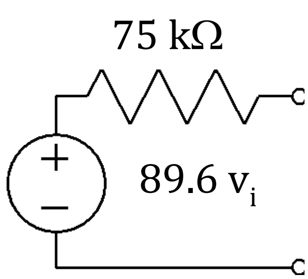
(a)

$v_{th} = v_{oc} = -\beta \; i \; R_2$ but $i = -\dfrac{v_i}{R_1}$ and $v_{th} = \beta \; v_i \; \dfrac{R_2}{R_1} = 120 \; v_i \; \dfrac{56k\Omega}{75k\Omega} = 89.6 \; v_i$

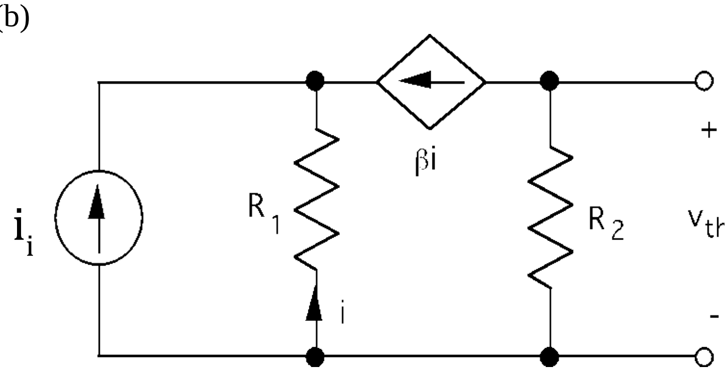


$R_{th} = \dfrac{v_x}{i_x}$; $i_x = \dfrac{v_x}{R_2} + \beta i$ but $i = 0$ since $v_{R_1} = 0.$ $R_{th} = R_2 = 75 \; k\Omega.$

Thévenin equivalent circuit:

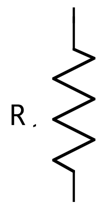


(b)



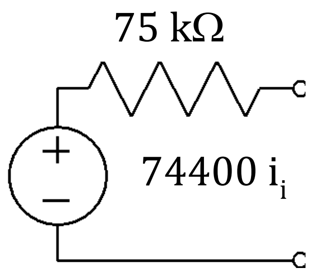
$v_{th} = v_{oc} = -\beta \; i \; R_2$ where $i + \beta i + i_i = 0$ and $v_{th} = R_2 \left(\dfrac{\beta}{\beta + 1} \right) i_i = 75k\Omega \left(\dfrac{120}{121} \right) i_i = 74400 \; i_i$

Solution continued on the next page....

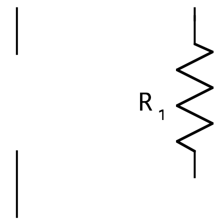


$R_{th} = \frac{v_x}{i_x}$; $i_x = \frac{v_x}{R_2} + \beta i$ but $i + \beta i = 0$ so $i = 0$ and $R_{th} = R_2 = 75\ k\Omega$

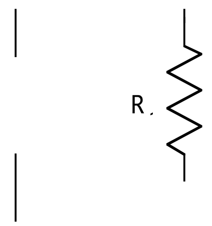
Thévenin equivalent circuit:



Solution 1.29



(a)



(b)

(a) $i_i = \frac{v_i}{R_1} - \beta i = \frac{v_i}{R_1} + \beta \frac{v_i}{R_1} = v_i \frac{\beta+1}{R_1} \qquad R = \frac{v_i}{i_i} = \frac{R_1}{\beta+1} = \frac{100k\Omega}{76} = 1.32\ k\Omega$

(b) Source is i_i in part (b).

$v_i = -iR_1$ and $i_i = -i - \beta i = -(\beta+1)i \qquad R = \frac{v_i}{i_i} = -\frac{-1}{\beta+1} R_1 = \frac{100k\Omega}{76} = 1.32\ k\Omega$

Solution 1.30

The open circuit voltage is $v_{th} = -g_m v\ R_2$ where $v = +i_i R_1$.

$v_{th} = -g_m R_1 R_2 i_i = -(0.0025)\left(2x10^5\right)\left(2x10^6\right)i_i = 1.0\ x\ 10^9 i_i$

For $i_i = 0,\ v = 0,$ and $R_{th} = R_2 = 2\ M\Omega$

Solution 1.31

$(a)\ R_{AB} = 10k\Omega + 10k\Omega \| \left[10k\Omega + \left(10k\Omega \| 10k\Omega \right) \right] = 16\ k\Omega$

$(b)\ R_{CD} = 10k\Omega \| \left[10k\Omega + \left(10k\Omega \| 10k\Omega \right) \right] = 6\ k\Omega$

$(c)\ R_{EF} = 10k\Omega \| 10k\Omega \| \left(10k\Omega + 10k\Omega \right) = 4\ k\Omega$

(d) Terminals B & D are the same as E & F. $R_{BD} = 4\ k\Omega$

Solution 1.32

(a) The open-circuit voltage is $v_{th} = 18V \dfrac{36k\Omega}{82k\Omega + 36k\Omega} = 5.49\ V$

The The′venin equivalent resistance is $R_{th} = 36k\Omega \| 82k\Omega = 25.0\ k\Omega$

(b) The short-circuit current is $i_n = \dfrac{18V}{82k\Omega} = 220\ \mu A$

The The′venin equivalent resistance is $R_{th} = 36k\Omega \| 82k\Omega = 25.0\ k\Omega$

Checking: $i_n R_{th} = 5.49\ V$ which equals v_{th} and is correct.

Solution 1.33

(a) The open-circuit voltage is $v_{th} = -9V + I\ x\ 27k\Omega = -9V + \left(\frac{18V}{68k\Omega + 27k\Omega}\right)27k\Omega = -3.88\ V$

The open-circuit voltage is also $v_{th} = +9V - I\ x\ 68k\Omega = -9V + \left(\frac{18V}{68k\Omega + 27k\Omega}\right)68k\Omega = -3.88\ V$

Using voltage division yields $v_{th} = -9V + 18V\left(\frac{27k\Omega}{68k\Omega + 27k\Omega}\right) = -3.88\ V$

Using voltage division yields $v_{th} = +9V - 18V\left(\frac{68k\Omega}{68k\Omega + 27k\Omega}\right) = -3.88\ V$

The The′venin equivalent resistance is $R_{th} = 27k\Omega \| 68k\Omega = 19.3\ k\Omega$

(b) The short-circuit current is $i_n = \frac{9V}{68k\Omega} - \frac{9V}{27k\Omega} = -201\ \mu A$

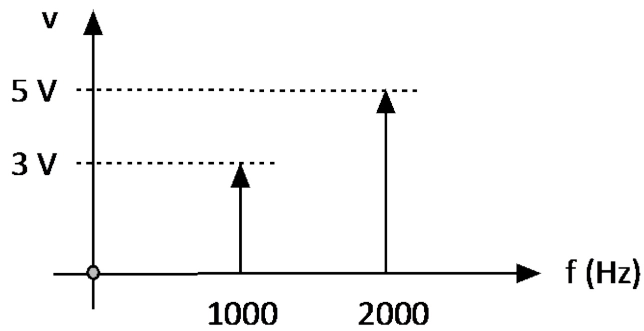
The The′venin equivalent resistance is $R_{th} = 27k\Omega \| 68k\Omega = 19.3\ k\Omega$

Checking: $i_n R_{th} = -3.88\ V$ which equals v_{th} and is correct.

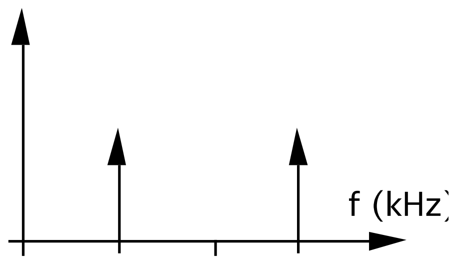
Solution 1.34

(a) If the 36 kΩ resistor was shorted, or the 82 kΩ resistor was open, then the output voltage would be 0. If the 82 kΩ resistor was shorted, the output would be 18 V (unless the 36 kΩ resistor was also shorted. (b) If the 68 kΩ resistor was shorted, or the 27 kΩ resistor was open, then the output voltage would be +9 V. If the 27 kΩ resistor was shorted, or the 68 kΩ resistor was open, the output would be -9 V. Otherwise the voltage would be between –9 and +9 volts.

Solution 1.35

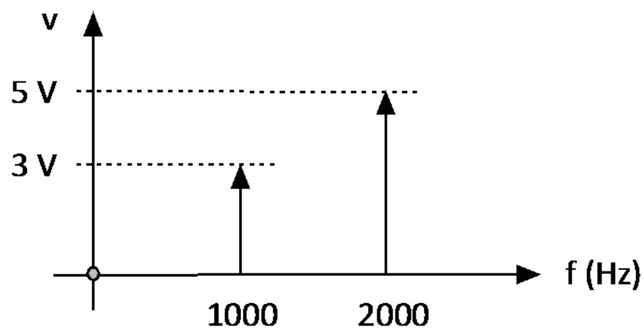


Solution 1.36



$$v = 4\sin(20000\pi t)\sin(2000\pi t) = \frac{4}{2}\left[\cos(20000\pi t + 2000\pi t) + \cos(20000\pi t - 2000\pi t)\right]$$

$$v = 2\cos(22000\pi t) + 2\cos(18000\pi t)$$



Solution 1.37

$$A = \frac{4\angle 56^o}{10^{-4}\angle 0^0} = 4x10^4\angle 56^o \quad |A| = 4x10^4 \quad \angle A = 56^o$$

Solution 1.38

(a) $A = \dfrac{10^{-1}\angle -12^o}{2x10^{-3}\angle 0^o} = 50\angle -12^o$ $|\mathrm{A}| = 50$ $\angle A = \text{-}12^{\mathrm{o}}$

(b) $A = \dfrac{10^{-2}\angle -45^o}{10^{-3}\angle 0^o} = 10\angle -45^o$ $|\mathrm{A}| = 10$ $\angle A = \text{-}45^{\mathrm{o}}$

Solution 1.39

(a) $A_v = -\frac{R_2}{R_1} = -\frac{560k\Omega}{12k\Omega} = -46.7$ (b) $A_v = -\frac{360k\Omega}{18k\Omega} = -20.0$ (c) $A_v = -\frac{62k\Omega}{2k\Omega} = -31.0$

Solution 1.40

$$v_o(t) = -\frac{R_2}{R_1} v_i(t) = -\frac{7500}{910}(0.01 \sin 750\pi t) = (-82.4 \sin 750\pi t) \text{ mV}$$

$$i_i = \frac{v_i}{R_1} = \frac{0.01V}{910\Omega} = 11.0\mu A \quad \text{and} \quad i_i(t) = (11.0 \sin 750\pi t) \ \mu A$$

Solution 1.41

Since the voltage across the op amp input terminals must be zero, $v_- = v_+$ and $v_o = v_i$.
Therefore $A_v = 1$.

Solution 1.42

Since the voltage across the op amp input terminals must be zero, $v_- = v_+ = v_i$. Also, $i_- = 0$.

$$\frac{v_- - v_o}{R_2} + i_- + \frac{v_-}{R_1} = 0 \quad \text{or} \quad \frac{v_i - v_o}{R_2} + \frac{v_i}{R_1} = 0 \quad \text{and} \quad A_v = \frac{v_o}{v_i} = 1 + \frac{R_2}{R_1}$$

Solution 1.43

Writing a nodal equation at the inverting input terminal of the op amp gives

$$\frac{v_1 - v_-}{R_1} + \frac{v_2 - v_-}{R_2} = i_- + \frac{v_- - v_o}{R_3} \quad \text{but} \quad v_- = v_+ = 0 \quad \text{and} \quad i_- = 0$$

$$v_o = -\frac{R_3}{R_1} v_1 - -\frac{R_3}{R_2} v_2 = \left(-0.255 \sin 3770t - 0.250 \sin 10000t \right) \text{ volts}$$

Solution 1.44

$$v_O = -V_{REF}\left(\frac{b_1}{2}+\frac{b_2}{4}+\frac{b_3}{8}\right)$$

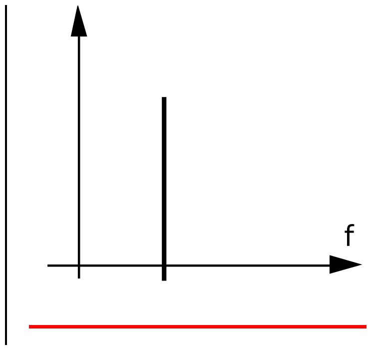
(a) $v_O = -5\left(\frac{0}{2}+\frac{1}{4}+\frac{1}{8}\right) = -1.875V$ (b) $v_O = -5\left(\frac{1}{2}+\frac{0}{4}+\frac{0}{8}\right) = -2.500V$

$b_1b_2b_3$	v_O (V)
000	0
001	-0.625
010	-1.250
011	-1.875
100	-2.500
101	-3.125
110	-3.750
111	-4.375

Solution 1.45

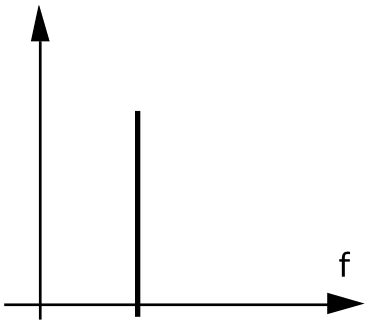
Low-pass amplifier

Solution 1.46



Solution 1.46

High-pass amplifier



Solution 1.48

Refers to Prob. 1.45

$$v_O(t) = 10x5\sin(2000\pi t) + 10x3\cos(8000\pi t) + 0x3\cos(15000\pi t)$$

$$v_O(t) = \left[50\sin(2000\pi t) + 30\cos(8000\pi t)\right] \text{ volts}$$

Solution 1.49

$$v_O(t) = 20x0.5\sin(2500\pi t) + 20x0.75\cos(8000\pi t) + 0x0.6\cos(12000\pi t)$$

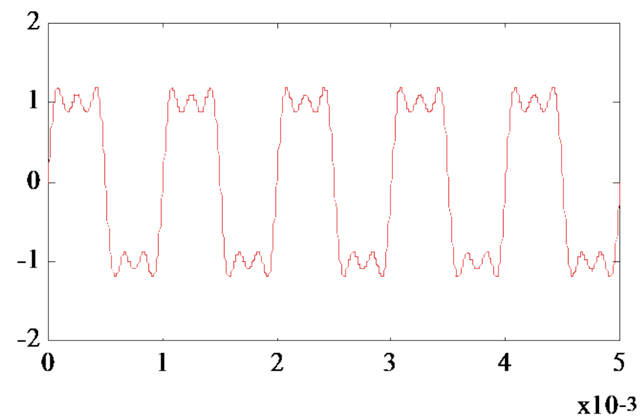
$$v_O(t) = \left[10.0\sin(2500\pi t) + 15.0\cos(8000\pi t)\right] \text{ volts}$$

Solution 1.50

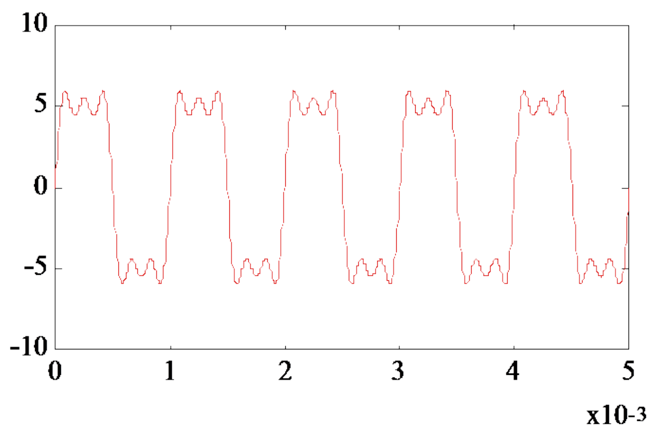
The gain is zero at each frequency: $v_O(t) = 0$.

Solution 1.51

```
t=linspace(0,.005,1000);
w=2*pi*1000;
v=(4/pi)*(sin(w*t)+sin(3*w*t)/3+sin(5*w*t)/5);
v1=5*v;
v2=5*(4/pi)*sin(w*t);
v3=(4/pi)*(5*sin(w*t)+3*sin(3*w*t)/3+sin(5*w*t)/5);
plot(t,v)
plot(t,v1)
plot(t,v2)
plot(t,v3)
```

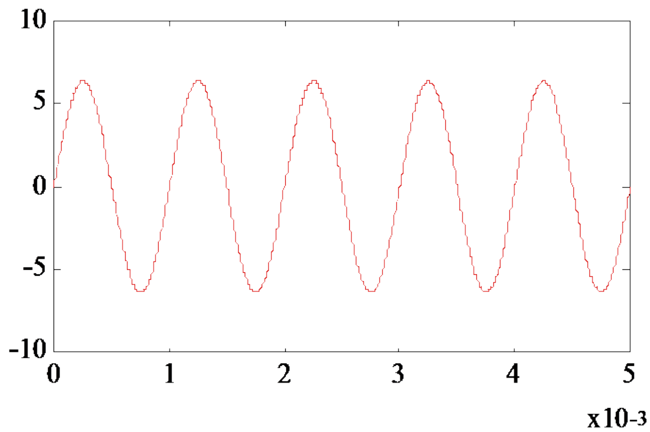


(a)

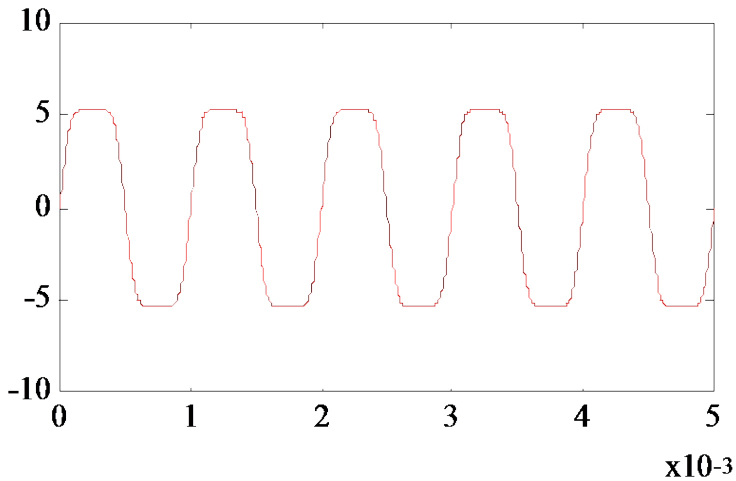


(b)

Solution continued on the next page....



(c)



(d)

Solution 1.52

$(a)\ 4700(1-.01) \le R \le 4700(1+.01)$ or $4650\Omega \le R \le 4750\Omega$

$(b)\ 4700(1-.05) \le R \le 4700(1+.05)$ or $4460\Omega \le R \le 4940\Omega$

$(c)\ 4700(1-.10) \le R \le 4700(1+.10)$ or $4230\Omega \le R \le 5170\Omega$

Solution 1.53

$$10000\mu F\left(1-.5\right)\leq C\leq 10000\mu F\left(1+.2\right)\quad \text{or}\quad 5000\mu F\leq R\leq 12000\mu F$$

Solution 1.54

$$V_{nom} = 1.8V \qquad |\Delta V| \le 0.05V \qquad T \le \frac{0.05}{1.80} = 0.0278 \text{ or } 2.78\ \%$$

Solution 1.55

$8200(1-0.1) \le R \le 8200(1+0.1)$ or $7380\Omega \le R \le 9020\Omega$

Yes, the resistor is within the allowable range of values.

Solution 1.56

(a) $5V(1-.05) \le V \le 5V(1+.05)$ or $4.75\text{V} \le V \le 5.25V$

V = 5.30 V exceeds the maximum range, so it is out of the specification limits.

(b) However, if the meter is reading 1.5% high, then the actual voltage would be

$V_{meter} = 1.015V_{act}$ or $\text{V}_{\text{act}} = \dfrac{5.30}{1.015} = 5.22V$ which is within specifications limits.

Solution 1.57

$$TCR = \frac{\Delta R}{\Delta T} = \frac{6562 - 6066}{100 - 0} = 4.96 \frac{\Omega}{^{o}C}$$

$$\mathrm{R}_{\mathrm{nom}} = R\big|_{0^{o}C} + TCR\ (\Delta \mathrm{T}) = 6066 + 4.96(27) = 6200\Omega$$

Solution 1.58

$At\ 30^oC,\ 7500\Omega(1-0.05) \le R \le 7500\Omega(1+0.05)$ or $7120\ \Omega \le R \le 7880\ \Omega$

Adding the effect of TC for $\Delta T = 45^oC$:

$\mathrm{R_{min}} = 7120\Omega\left(1+45\frac{2200}{10^6}\right) = 7820\ \Omega$ $\quad \mathrm{R_{max}} = 7780\Omega\left[1+45\left(2.2x10^{-3}\right)\right] = 8550\ \Omega$

$7820\ \Omega \le R \le 8550\ \Omega$ with accumulated rounding

$7830\ \Omega \le R \le 8650\ \Omega$ more exact calculation

Solution 1.59

I = 200 μA, R_1 = 150 kΩ, R_2 = 68 kΩ and R_3 = 82 kΩ.

$$I_1 = I\frac{R_2+R_3}{R_1+R_2+R_3} = I\frac{1}{1+\frac{R_1}{R_2+R_3}} \quad \text{and similarly} \quad I_2 = I\frac{1}{1+\frac{R_2+R_3}{R_1}}$$

$$I_1^{\max} = \frac{200(1.02)}{1+\frac{150k\Omega(0.90)}{68k\Omega(1.1)+82k\Omega(1.1)}}\mu A = 112\ \mu A \qquad I_1^{\min} = \frac{200(0.98)}{1+\frac{150k\Omega(1.1)}{68k\Omega(0.90)+82k\Omega(0.90)}}\mu A = 88.2\ \mu A$$

$$I_2^{\max} = \frac{200(1.02)}{1+\frac{68k\Omega(0.90)+82k\Omega(0.90)}{150k\Omega(1.1)}}\mu A = 112\ \mu A \qquad I_2^{\min} = \frac{200(0.98)}{1+\frac{68k\Omega(1.1)+82k\Omega(1.1)}{150k\Omega(0.90)}}\mu A = 88.2\ \mu A$$

$$V_3 = I_2 R_3 = \frac{I}{\frac{1}{R_1}+\frac{1}{R_3}+\frac{R_2}{R_1R_3}}$$

$$V_3^{\max} = \frac{200\mu A(1.02)}{\frac{1}{150k\Omega(1.1)}+\frac{1}{82k\Omega(1.1)}+\frac{68k\Omega(0.9)}{150k\Omega(1.1)(82k\Omega)(1.1)}} 9.60\text{ V}$$

$$V_3^{\min} = \frac{200\mu A(0.98)}{\frac{1}{150k\Omega(0.9)}+\frac{1}{82k\Omega(0.9)}+\frac{68k\Omega(1.1)}{150k\Omega(0.9)(82k\Omega)(0.9)}} = 6.89\text{ V}$$

Solution 1.60

V = 1 V, R_1 = 24 kΩ, R_2 = 30 kΩ and R_3 = 11 kΩ.

Let $R_X = R_2 \| R_3$ then $V_1 = V\dfrac{R_1}{R_1 + R_X} = \dfrac{V_1}{1 + \dfrac{R_X}{R_1}}$

$$R_X^{min} = \frac{30k\Omega(0.9)(11k\Omega)(0.9)}{30k\Omega(0.9) + 11k\Omega(0.9)} = 7.24k\Omega \quad R_X^{max} = \frac{30k\Omega(1.1)(11k\Omega)(1.1)}{30k\Omega(1.1) + 11k\Omega(1.1)} = 8.85k\Omega$$

$$V_1^{max} = \frac{1(1.05)}{1 + \dfrac{7.24k\Omega}{24k\Omega(1.1)}} = 0.824\ V \qquad V_1^{min} = \frac{1(0.95)}{1 + \dfrac{8.85k\Omega}{24k\Omega(0.9)}} = 0.674\ V$$

$$I_1 = \frac{V}{R_1 + R_X} \quad \text{and} \quad I_2 = I_1\frac{R_3}{R_2 + R_3} = \left(\frac{V}{R_1 + R_X}\right)\frac{1}{1 + \dfrac{R_2}{R_3}}$$

$$I_2^{max} = \frac{1(1.05)}{24k\Omega(0.9) + 7.24k\Omega}\,\frac{1}{1 + \dfrac{(30k\Omega)(0.9)}{11k\Omega(1.1)}} = 11.3\ \mu A$$

$$I_2^{min} = \frac{1(0.95)}{24k\Omega(1.1) + 8.85k\Omega}\,\frac{1}{1 + \dfrac{(30k\Omega)(1.1)}{11k\Omega(0.9)}} = 6.22\ \mu A$$

$$I_3 = I_1\frac{R_2}{R_2 + R_3} = \frac{I_1}{1 + \dfrac{R_3}{R_2}}$$

$$I_3^{max} = \frac{1(1.05)}{24k\Omega(0.9) + 7.24k\Omega}\,\frac{1}{1 + \dfrac{(11k\Omega)(0.9)}{30k\Omega(1.1)}} = 28.0\ \mu A$$

$$I_3^{min} = \frac{1(0.95)}{24k\Omega(1.1) + 8.85k\Omega}\,\frac{1}{1 + \dfrac{(11k\Omega)(1.1)}{30k\Omega(0.9)}} = 18.6\ \mu A$$

Solution 1.61

From Prob. 1.24: $R_{th} = \dfrac{1}{g_m + \dfrac{1}{R_1}}$

$$R_{th}^{\max} = \frac{1}{0.002(0.9) + \dfrac{1}{7.5x10^4(1.2)}} = 552\ \Omega \qquad R_{th}^{\min} = \frac{1}{0.002(1.1) + \dfrac{1}{7.5x10^4(0.8)}} = 451\ \Omega$$

Solution 1.62

For one set of 200 cases using the Equations in Prob. 1.59 (mA & kΩ):

$I = 0.200*(0.98 + 0.04*RAND()) \quad R_1 = 150*(0.9 + 0.2*RAND())$

$R_2 = 68*(0.9 + 0.2*RAND()) \quad R_3 = 82*(0.9 + 0.2*RAND())$

	I_1	I_2	V_3
Min	89.9 μA	91.2 μA	7.34 V
Max	110 μA	109 μA	9.23 V
Average	100 μA	99.8 μA	8.23 V

Solution 1.63

For one set of 200 cases using the equations in Prob. 1.60.

$V = 1*(0.95 + 0.1*RAND())$ $R_1 = 24000*(0.9 + 0.2*RAND())$

$R_2 = 30000*(0.9 + 0.2*RAND())$ $R_3 = 11000*(0.9 + 0.2*RAND())$

	V_1	I_2	I_3
Min	0.685 V	6.70 μA	19.7 μA
Max	0.814V	10.1 μA	27.1 μA
Average	0.754 V	8.49 μA	22.9 μA

Solution 1.64

3.29, 0.995, -6.16; 3.295, 0.9952, -6.155

Solution 1.65

(a) (1.763 mA)(20.70 kΩ) = 36.5 V (b) 36 V
(c) (0.1021 μA)(97.80 kΩ) = 9.99 V; 10 V