Semiconductor Example

Consider a Si crystal which is doped with 10^{12} phosphorous (P) atoms/cm^3 and with 10^{13} aluminum (Al) atoms/cm^3. Assume all of the dopants are ionized and that the semiconductor is at room temperature.

Identify the dopants as donors and/or acceptors.

Calculate the equilibrium electron and hole concentrations.

Calculate the Fermi level.

Calculate the resistivity given mobilities of $\mu_n = 1450$ cm^2/Vs *and* $\mu_p = 500$ cm^2/Vs.

Semiconductor Example

Consider a Si crystal with a Fermi level of $(E_F - E_i) = 0.200$ eV. The dimensions are length 5 mm, width 1 mm, and height 1 mm. Assume that the semiconductor is at room temperature.

Is the semiconductor n-type or p-type and why?

Calculate the equilibrium electron and hole concentrations.

What are the doping concentrations?

Calculate the resistivity given mobilities of $\mu_n = 1450\ cm^2/Vs$ *and* $\mu_p = 500\ cm^2/Vs$.

Calculate the resistance.

Junction Example

Consider an abrupt Si junction with only $N_{ap}^{-} = 10^{17}$ cm^{-3} on the p side and only $N_{dn}^{+} = 10^{13}$ cm^{-3} on the n side. Assume that the semiconductor is at room temperature.

Calculate the contact potential.

Calculate the Fermi levels.

Calculate the ratio of x_{no} / x_{po}.

Junction Example

Consider an abrupt Si junction with $N_{ap}^{-} = 10^{16}$ cm^{-3} and $N_{dp}^{+} = 10^{15}$ cm^{-3} on the p side and only $N_{dn}^{+} = 10^{15}$ cm^{-3} on the n side. Assume that the semiconductor is at room temperature.

Calculate the contact potential.

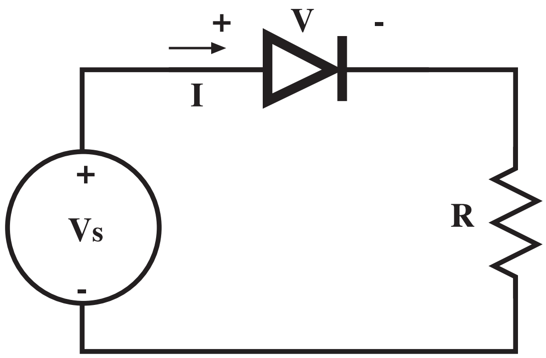
Calculate the depletion width W_0 at equilibrium.

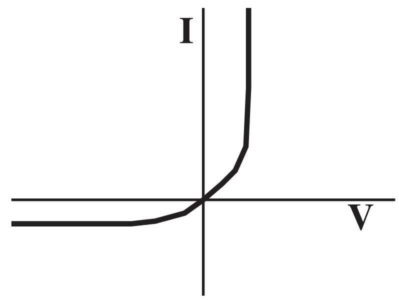
Calculate the equilibrium depletion values x_{no} and x_{po}.

Calculate the depletion width W for a reverse bias of $V = -100$ V.

Diode Biasing Example

Consider the following circuit with a source voltage $V_S = 5.0 \sin(10t)$ V, a load resistor R = 1.00 kΩ, and diode IV characteristics of turn-on voltage $V_{to} = 0.7$ V and reverse saturation current of $I_0 = 0.01$ mA.





Calculate the maximum voltage and current for forward bias, i.e. the diode is on.

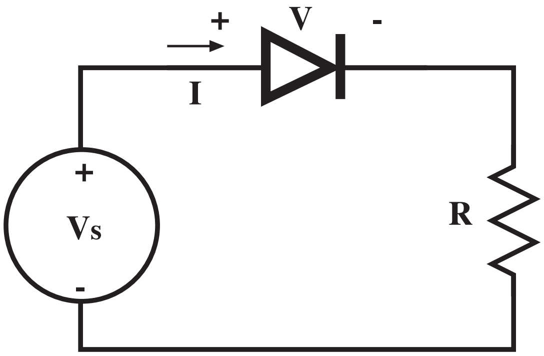
Calculate the voltage across the resistor for this maximum condition.

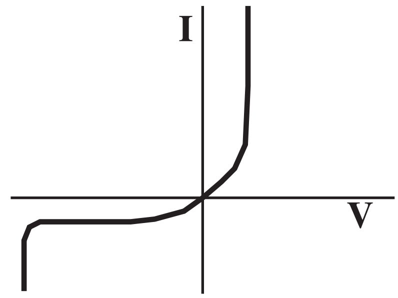
Calculate the minimum voltage and current for reverse bias, i.e. the diode is off.

Calculate the voltage across the resistor for this minimum condition.

Breakdown Diode Biasing Example

Consider the following diode circuit with a constant source voltage V_S, a load resistor R = 1.00 kΩ, and diode IV characteristics of turn-on voltage V_{to} = 0.7 V, reverse saturation current of I_0 = 0.01 mA, and a breakdown voltage V_{br} = 26 V.



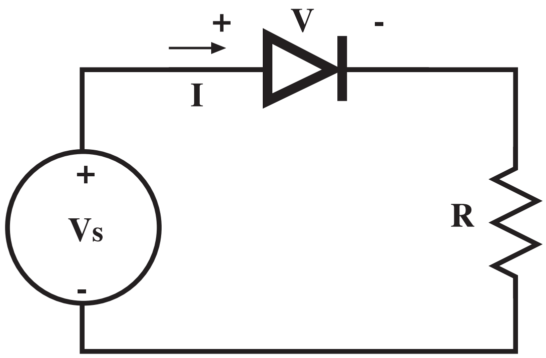


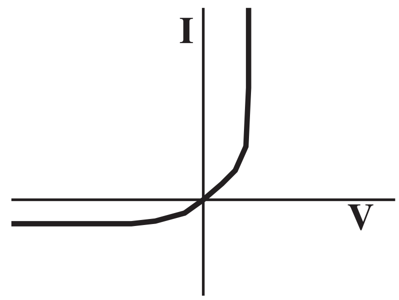
Calculate the operating point if V_S = - 25 V. Is the diode forward biased or reverse biased?

Calculate the operating point if V_S = - 30 V.

Diode Biasing Example

Consider the following circuit with a constant source voltage V_S, an unknown load resistance R, and diode IV characteristics of turn-on voltage V_{to} = 0.70 V and reverse saturation current of I_0 = 0.01 mA.





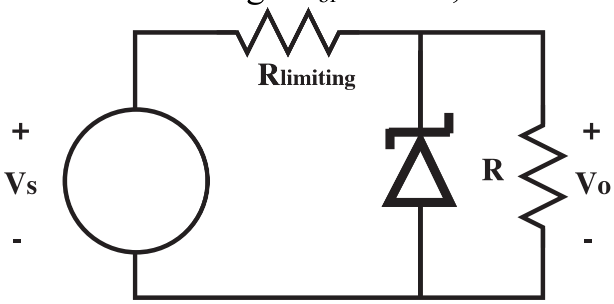
Calculate the diode current for which the voltage is V = - 0.070 V. Use the low-level-injection diode equation and assume room temperature.

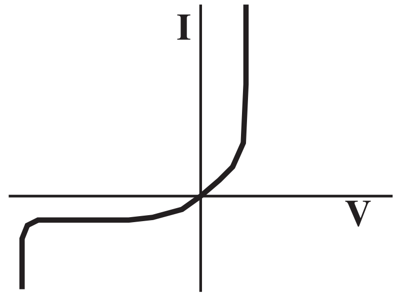
If the source voltage is V_S = +4.0 V, calculate the required resistance for a diode current of I = + 2.0 mA.

If the source voltage is V_S = +4.0 V, calculate the required resistance for a diode current of I = + 4.0 mA.

Diode Limiter Example

Consider the following limiting circuit with a source voltage V_S, resistances $R_{limiting}$ = R = 1.0 kΩ, and diode IV characteristics of turn-on voltage V_{to} = 0.70 V, breakdown voltage V_{br} = 10 V, and reverse saturation current of I_0 = 0.10 mA.



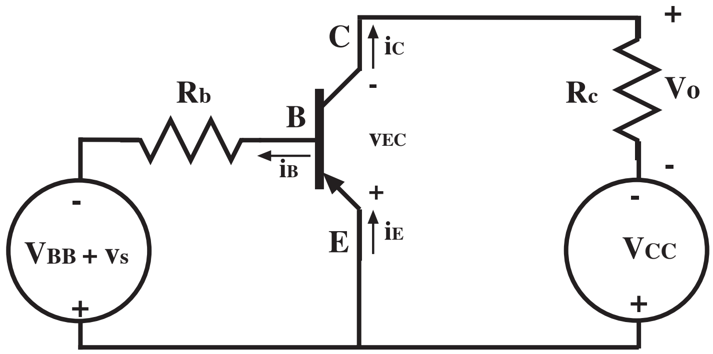


If the source voltage is a square wave that varies between $V_{S,Max}$ = +30.0 V and $V_{S,Min}$ = +10.0 V, calculate the load voltage V_0 for the minimum input level.

If the source voltage is a square wave that varies between $V_{S,Max}$ = +30.0 V and $V_{S,Min}$ = +10.0 V, calculate the load voltage V_0 for the maximum input level.

Common Emitter Circuit Example

Consider a pnp BJT circuit with β = 200, R_b = 10.0 kΩ, V_{BB} = 2.7 V, V_{CC} =16 V, and R_c = 200 Ω. Assume the base-emitter turn-on voltage is 0.7 V. Let v_S = 0.

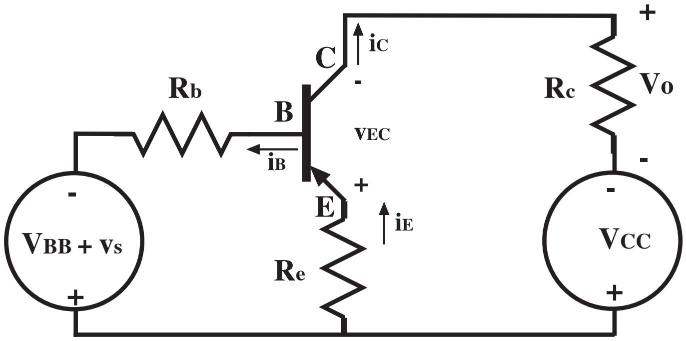


Calculate the operating point i_C and v_{EC}.

Check KCL for the transistor.

Common Emitter Circuit Example

Consider a pnp BJT circuit with $\beta = 200$, $R_b = 10.0\ k\Omega$, $V_{BB} = 2.7\ V$, $V_{CC} = 16\ V$, $R_e = 100\ \Omega$, and $R_c = 100\ \Omega$. Assume the base-emitter turn-on voltage is 0.7 V.



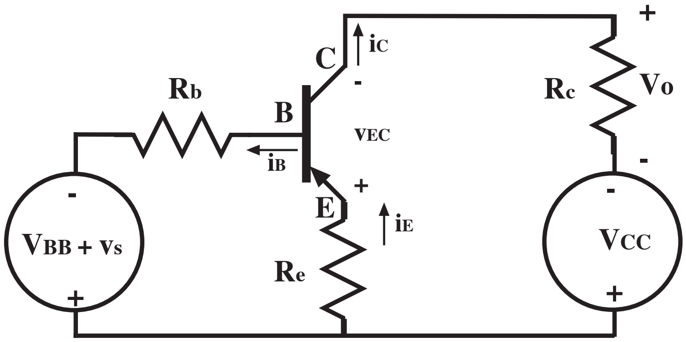
Let $v_S = 0$.

Calculate the operating point i_C and v_{EC}.

Calculate the current i_C if the gain changes to 150.

Common Emitter Circuit Example

Consider a pnp BJT circuit with $\beta = 200$, $R_b = 10.0\ k\Omega$, $V_{BB} = 2.7\ V$, $V_{CC} = 16\ V$, $R_e =$ **500** Ω, and $R_c =$ **500** Ω. Assume the base-emitter turn-on voltage is 0.7 V.



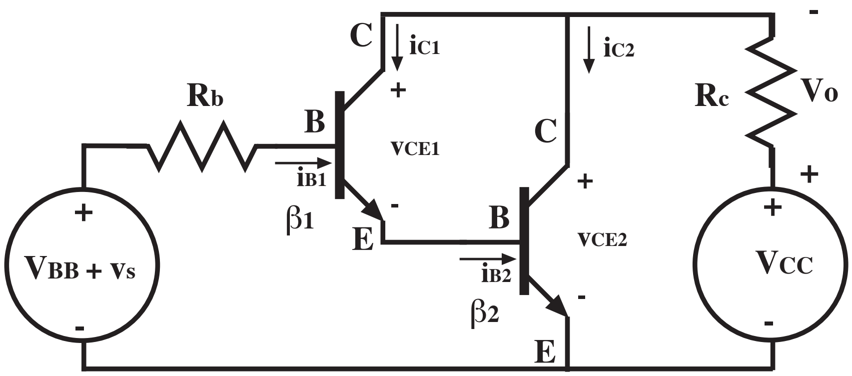
Let $v_S = 0$.

Calculate the operating point i_C and v_{EC}.

Calculate the current i_C if the gain changes to 150.

Darlington Amplifier Circuit Example

Consider an npn BJT circuit with $\beta = 50$, $R_b = 100.0\ k\Omega$, $V_{BB} = 3.4$ V, $V_{CC} = 16$ V, and $R_c = 200\ \Omega$. Assume the base-emitter turn-on voltage is 0.7 V. Let $v_S = 0$.

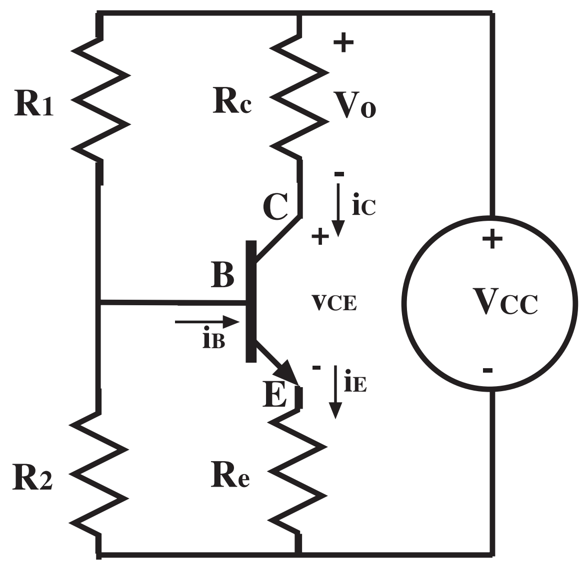


Calculate the currents i_{C1} and i_{C2}.

Calculate the voltages v_{CE1} and v_{CE2}.

Common Emitter Circuit Example

Consider an npn BJT circuit with β = 200, R_1 = 40.0 kΩ, R_2 = 10.0 kΩ, V_{CC} =15 V, R_e = 1.0 kΩ, and R_c = 1.0 kΩ. Assume the base-emitter turn-on voltage is 0.7 V.

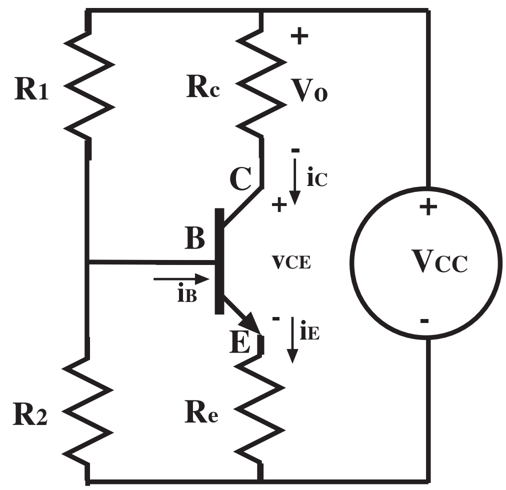


Calculate the Thevenin equivalent with respect to the Base circuit, i.e. V_{BB} and R_b.

Calculate the operating point i_C and v_{CE}.

Common Emitter Circuit Example

Consider an npn BJT circuit with $\beta = 200$, $R_b = 10.0\ k\Omega$, $V_{BB} = 2.7$ V, $V_{CC} = 16$ V, $R_e = 500\ \Omega$, and $R_c = 500\ \Omega$. Assume the base-emitter turn-on voltage is 0.7 V.

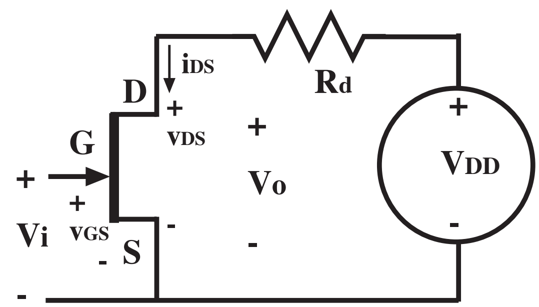


Calculate the value of resistors R_1 and R_2 that will produce the equivalent circuit for $R_b = 10.0\ k\Omega$ and $V_{BB} = 2.7\ V$.

Calculate the operating point i_C and v_{CE}.

Common Source JFET Circuit Example

Consider a n-channel JFET circuit with V_{po} = 5.0 V, I_{DSS} = 1.0 mA, R_d = ?? Ω, $V_{GG} = V_i$, and V_{DD} = 15 V.



Calculate the maximum input voltage V_i for which the JFET operating point has i_{DS} = 0 A. Also, calculate v_{DS}.

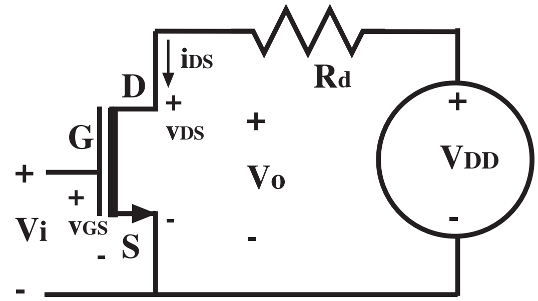
Calculate the input voltage V_i for which the JFET operating point has $i_{DS} = I_{DSS}$ and the JFET is just in saturation. Also, calculate v_{DS}.

Calculate the resistance R_d for which the JFET circuit load line passes through both of these operating points.

Common Source MOSFET Circuit Examples

Consider a n-channel depletion-mode MOSFET circuit with V_{po} = 5.0 V, I_{DSS} = 1.0 mA, and V_{DD} = 15 V.

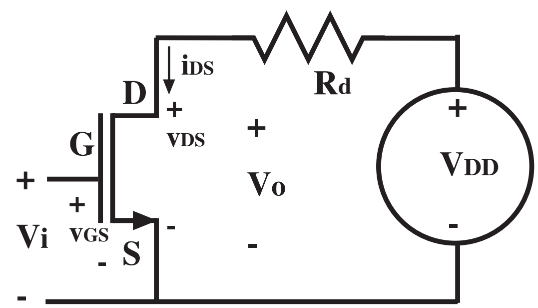
Calculate the input voltage V_i for which the MOSFET circuit load line has i_{DS} = 0 A and i_{DS} = 2 mA for saturation.



Calculate the resistance R_d for which the MOSFET circuit load line passes through operating points (v_{DS} = 15 V, i_{DS} = 0 A) and (v_{DS} = 5 V, i_{DS} = 2 mA).

Consider a n-channel enhancement-mode MOSFET circuit with V_{on} = 2.0 V, K = 0.04 mA/V^2, and V_{DD} = 15 V.

Calculate the input voltage V_i for which the MOSFET circuit load line has i_{DS} = 0 A and i_{DS} = 2 mA for saturation.



Calculate the resistance R_d for which the MOSFET circuit load line passes through operating points (v_{DS} = 15 V, i_{DS} = 0 A) and (v_{DS} = 5 V, i_{DS} = 2 mA).

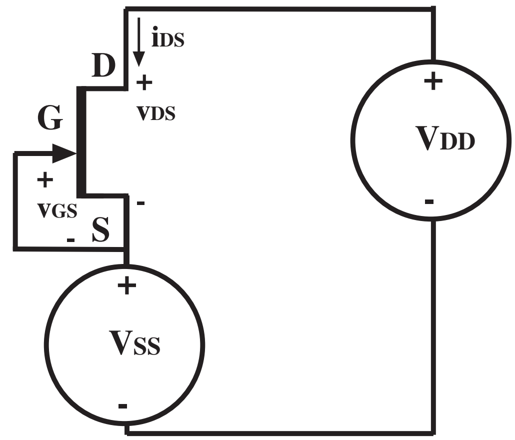
MOSFET Circuit as an Active Load

Consider a n-channel depletion-mode MOSFET circuit with V_{po} = 5.0 V and I_{DSS} = 1.0 mA. Note that

$v_{GS} = 0$ V.

and

$v_{DS} = V_{DD} - V_{SS}$



Calculate the current i_{DS} for which the MOSFET circuit has

$v_{DS} = V_{DD} - V_{SS} = 0.5\ V_{po}$.

Calculate the current i_{DS} for which the MOSFET circuit has

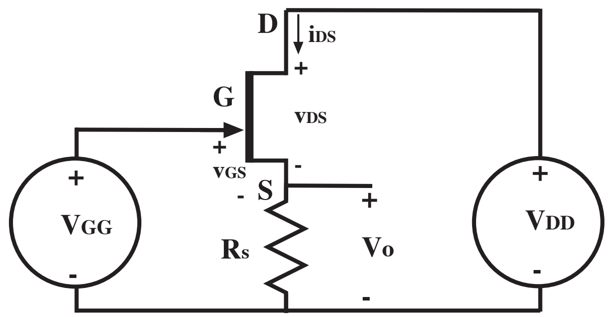
$v_{DS} = V_{DD} - V_{SS} = V_{po}$.

Calculate the current i_{DS} for which the MOSFET circuit has

$v_{DS} = V_{DD} - V_{SS} = 2\ V_{po}$.

Source Follower JFET Circuit Example

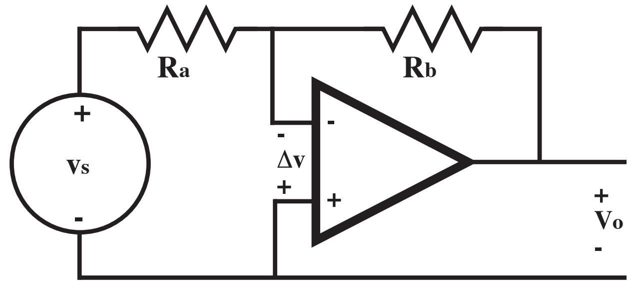
Consider a n-channel JFET circuit with V_{po} = 5.0 V, I_{DSS} = 1.0 mA, R_s = 1000 Ω, V_{GG} = - 2.5 V, and V_{DD} = 15 V.



Calculate the operating point v_{DS} and i_{DS}.

INVERTING OPAMP WITH FINITE GAIN

Consider an inverting OpAmp circuit with an OpAmp gain of A, V_S =+5 V, R_a = 500 Ω, and R_b = 1,000 Ω. Besides the OpAmp gain A, the OpAmp is ideal.



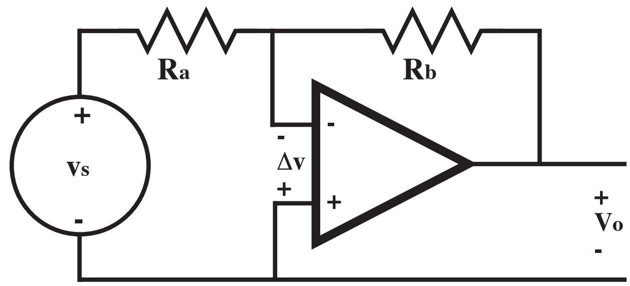
Calculate the output voltage V_0, if A goes to infinity.

Calculate the output voltage V_0, if A equals 10,000.

Calculate the output voltage V_0, if A equals 100,000.

INVERTING OPAMP EXAMPLE

Consider an inverting OpAmp circuit with R_a = 1,000 Ω, R_b = 3,000 Ω, and V_S =+5.0 V, Assume that the OpAmp is ideal.

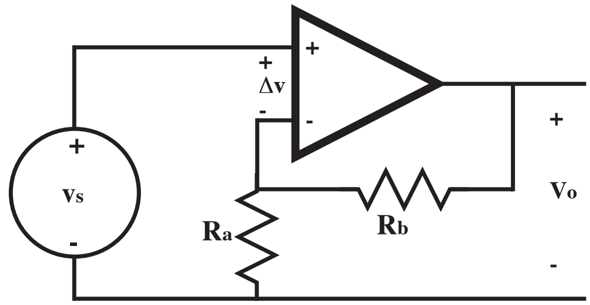


Calculate the currents through the R_a resistor and through the R_b resistor.

Calculate the current generated by the OpAmp if a load resistor of R_L = 1,000 Ω is attached.

NON-INVERTING OPAMP EXAMPLE

Consider a non-inverting OpAmp circuit with $R_a + R_b = R_{Total} = 1.0\ k\Omega$ with $R_a = wR_{Total}$ and $R_b = (1 – w)R_{Total}$. Let V_S =+10.0 mV. Assume that the OpAmp is ideal.

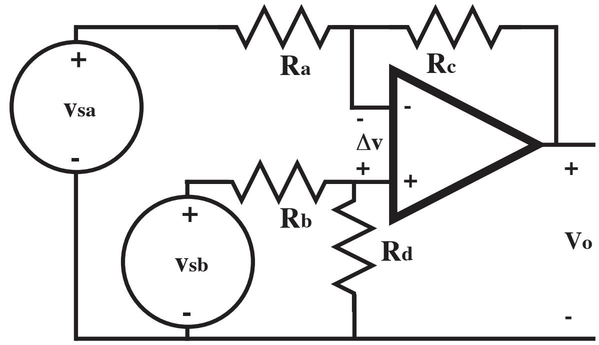


For a gain of 2, calculate the fraction w and the resistor values for R_a and R_b.

Calculate the power dissipated in R_a and R_b.

SUBTRACTOR OPAMP EXAMPLE

Consider a subtractor OpAmp circuit with R_a = (x)1,000 Ω, R_c = (1 - x)1,000 Ω, R_b = (y)100 Ω, and R_d = (1 - y)100 Ω where 0<x<1 and 0<y<1. Assume that the OpAmp is ideal.



Calculate the values x and y for which the magnitude of the component gain for input V_{Sa} is 3 and the magnitude of the component gain for input V_{Sb} is also 3.

Calculate the output voltage V_0, if V_{Sa} = 2V and V_{Sb} = 4 V.

OPAMP DESIGN EXAMPLE

Design an OpAmp circuit with a minimum number of ideal OpAmps that has the following characteristics:

Has an overall signal gain of - 5 and

Draws no current from the input source.

Implementation #1

Implementation #2

SEMICONDUCTOR ABSORPTION EXAMPLE

Consider a crystal semiconductor InP. It has an energy gap of $E_G = 1.35$ eV.

Electron Charge	$q = 1.602 \times 10^{-19}$ C
Speed of Light (Vacuum)	$c = 2.998 \times 10^{10}$ cm/s
Planck's Constant	$h = 4.136 \times 10^{-15}$ eV-sec $= 6.626 \times 10^{-34}$ J-sec

Calculate the optical wavelength and frequency associated with a bandgap transition.

In what part of the optical spectrum is this threshold value?

For a 1.0 mW wave at this threshold wavelength, how many photons are present?

SEMICONDUCTOR ABSORPTION EXAMPLE

A laser beam of irradiance 1.0 W/m^2 is incident upon a silicon (Si) sample. The absorption coefficient α_L at the laser wavelength is 1000 cm^{-1}.

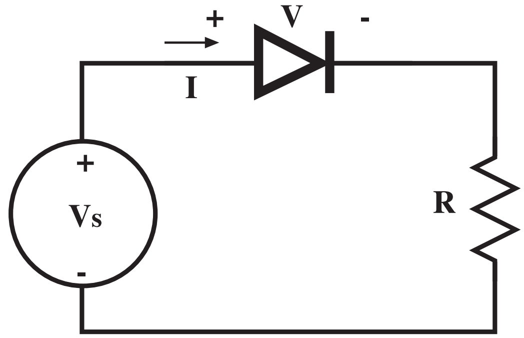
Calculate the thickness in microns (μm) for which the transmitted irradiance is reduced to one half of the initial value, i.e. 0.50 W/m^2. Neglect reflections.

Calculate the thickness in microns (μm) for which the transmitted irradiance is reduced to 0.10 W/m^2. Neglect reflections.

Calculate the thickness in microns (μm) for which the transmitted irradiance is reduced to 0.010 W/m^2. Neglect reflections.

APD EXAMPLE

A Si avalanche photodiode is reverse-biased for source voltage $V_S = -80$ V. The reverse saturation current is 0.010 mA and the $\lambda = 900$ nm. Assume $|V| >> kT/q$. The resistance is R = 20.0 kΩ.



If the optical power is 0.10 mW, calculate the needed quantum efficiency (including the avalanche gain) to produce a diode current of - 1.0 mA.

For the diode current of - 1.0 mA, calculate the diode voltage.