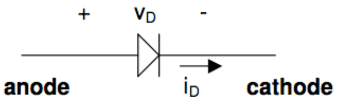
References

ENG125/243 Txtbk →	Electrical Engineering – Fourth Ed. By Allan R. Hambley
Other reference →	Alexander, Fundamentals of Electric Circuits, 3rd Edition. McGraw Hill, 2007.
Calculator used →	Casio fx – 9860G AU
Calculator book → –	Mathematics with a graphics calculator - Casio fx 9860G Auby Barry Kissane & Marian Kemp

quiescent = being at rest; quiet; still; inactive or motionless: a quiescent mind.



Diode Equation

ENG262 Lect notes 1 – pg4

When $V_D > 0$ then :

equations (3) …. and (4) on diodes.

$$i_D = I_S\left(e^{\frac{v_D}{nV_T}} - 1\right) \qquad v_D = nV_T\,\ell n\left(\frac{i_D}{I_S} + 1\right)$$

$$\cong I_S\, e^{\frac{v_D}{nV_T}} \qquad \cong nV_T\,\ell n\left(\frac{i_D}{I_S}\right)$$

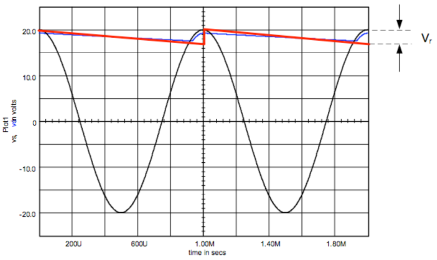
where I_S is called the **saturation current** (typical values: 10^{-8} A to 10^{-16} A)

V_T is called the **thermal voltage**, which, at room temperature is about 25mV.

n is called the **emission coefficient**, with values in the range $1 \leq n \leq 2$.

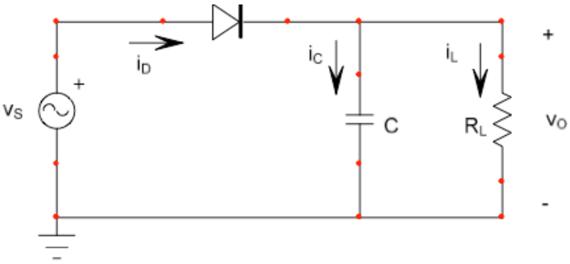
Ripple Voltage – ENG262 Lect2 - pg2

$$V_r = \frac{V_S T}{C R_L}$$



Where :

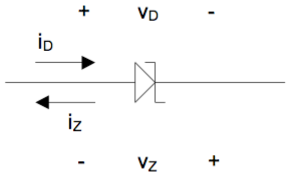
$$T = \frac{1}{f}$$



Example

For $R_L = 200\Omega$, $T = 0.02$ seconds (i.e. $f = 50$Hz), and if $V_R < 0.1V_S$, then we require $C \geq 1$mF.

Zener Diode : ENG262 Lect 3



- Generally used as voltage regulators.
- Do KCL above the Diode.
- Zeners work in the breakdown region.
- When in this region the calculations are done with the +ve and -ve reversed as shown in the diagram above.

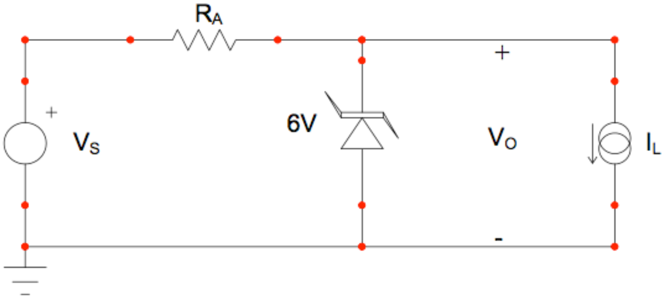
Overview of how Zeners work.

The Zener wants to keep the voltage the same at the pointy end of the zener schematic.

1. If the voltage gets too low then it stops current flowing down it and thus more current will flow off to the load.
2 If the voltage gets too high then it reaches the breakdown region and effectively becomes a short circuit and all the current will flow down it instead of to the load.

Note: The graph is in the negative but the standard way of understanding it is to invert it so -ve becomes +ve and vice versa.

Diagram from eng348 study guide 3 question 7.



Design Rule of thumb for Zener Diodes : ENG262 Lect 3 page 8

$$I_{Z.max} = 10 \times I_{Z.min}$$

Transistors : ENG262 Lect 5

$$i_C = \beta i_\beta$$

Forward Active region : ENG262 Lect 5 page 1

When $V_{BE} > 0.7$v and $V_{CE} > V_{CE.sat}$

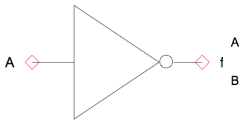
Saturation Region :

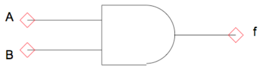
When $V_{BE} > 0.7$v and $V_{CE} < V_{CE.sat}$ then $V_{CE} = V_{CE.sat}$ and V_{CE} is no longer controlled by i_{BE}.

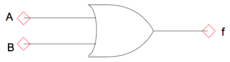
Cut off Region :

If $V_{BE} < 0.7$v then the whole transistor turns off and it becomes an open circuit.

Not : **And :** * **Or :** +



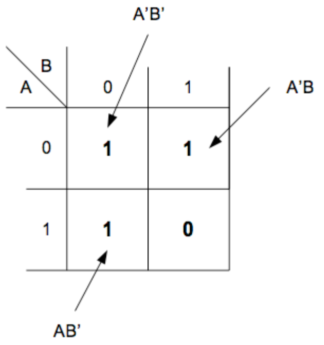




De Morgans Theorem :

(AB)' = A' + B' NOT (P AND Q) = (NOT P) OR (NOT Q)
(A + B)' = A' B' NOT (P OR Q) = (NOT P) AND (NOT Q)

Karnaugh Maps (Grey code) : ENG262 lect8 pg3



A \ B	0	1
0	**1**	**1**
1	**1**	**0**

What is : ENG262 lect 12 page 7

Common Base?
Common Emmiter?
Common Follower?

,

Selecting an output point for a transistor amplifier : ENG262 lect12 p9

$$I_{CQ} = \frac{V_{CC}}{2(R_C + R_E)}$$

(14)

Summary of the small-signal solution technique : ENG262 lect13 p12

1. Solve for the dc operating point(s) of the transistor(s). For dc analysis, it is usually valid to use the simplified transistor model with VBE = VBE,on.
2. Compute the hybrid-π model parameters for each transistor: $gm = ICQ / VT$
$r\pi = \beta / gm$ 3. Draw the ac schematic diagram, where
- dc voltage sources and capacitors are replaced by short-circuits;
- dc current sources and inductors are replaced by open-circuits.
4. Replace each transistor by its hybrid-π model.
5. Solve the set of linear circuit equations. Usually the quantity of interest is a transfer function - output / input.
6. If required, combine the dc and ac results.

Design Process of a transistor Amplifier : ENG262 Lect14 p1

Do this exmaple

.

$$\text{Radians} = \frac{\pi}{180^o} \times \text{Degrees}$$

Transistor Amplifier Design : ENG262 Lect 14 p2

Approximate gain for a single stage common emitter Amp.

$$A_v = \frac{V_O}{V_S} \simeq -\frac{R_C}{R_E} \quad (1)$$

where A_V = Amplification factor.

Design Rule of Thumb : ENG262 lect14 p4

$$\frac{R_{BB}}{\beta} = \frac{R_E}{10} \quad (9)$$

A note on notation : ENG262 lesson13 page4

Rather than using the delta (Δ) convention to denote time-varying quantities, it is standard practice to represent time-varying currents and voltages with lower case letters that have lower case subscripts, so that

$\Delta V_{BE} \rightarrow v_{be}(t)$ or simply v_{be}

$\Delta I_C \rightarrow i_c(t)$ or i_c etc.

Small signal transconductance of the transistor : ENG262 lect13 p7

$$g_m = \frac{I_{CQ}}{V_T}$$

where usually $V_T = 0.025$

(13)

Small-signal input resistance : ENG262 Lect 13 p8

$$r_\pi = \frac{\beta}{g_m}$$

(17)

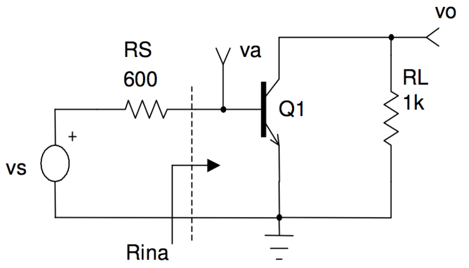
Therefore

$v_a = r_\pi \times i_\beta$ See example below

ENG262 Study Guide 14 : Q6

In the ac schematic diagram shown below, the transistor has been biased for a quiescent collector current of 1mA, and has a current gain of β = 100. Find

(i) the voltage gain v_o/v_a;
(ii) the input resistance R_{ina};
(iii) the voltage gain v_a/v_s;
(iv) the overall voltage gain $A_v = v_o/v_s$.



ANS:

(i) From the quiescent collector current:

$$g_m = \frac{I_{CQ}}{V_T} = \frac{1}{0.025} = 40\ mA/V$$

$$r_\pi = \frac{\beta}{g_m} = \frac{100}{40} = 2.5\ k\Omega$$

Small-signal circuit:

From the small-signal circuit:

$$v_o = 1 \times (-i_c) = 1 \times (-100\, i_b) = -100\, i_b$$

$$v_a = r_\pi i_b = 2.5\, i_b$$

$$\therefore \frac{v_o}{v_a} = \frac{-100}{2.5} = -40$$

(ii) $R_{ina} = \frac{v_a}{i_b} = r_\pi = 2.5\ k\Omega$

(iii) The circuit to the right of the dotted line can not be replaced by the equivalent resistance R_{ina}. Hence we can find v_a in terms of v_s by using the resistor divider rule:

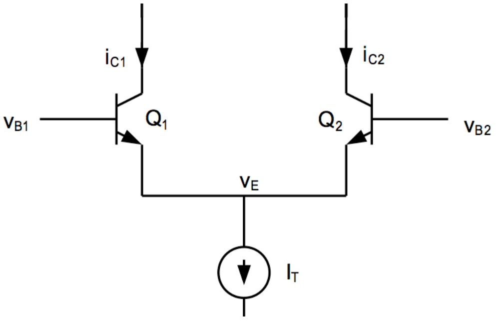
$$v_a = \frac{2.5}{2.5 + 0.6} v_s = 0.806\, v_s$$

(iv) $A_v = \frac{v_o}{v_a} \times \frac{v_a}{v_s} = -40 \times 0.806 = -32.2$

Difference Signals : ENG262 Lect 19 Page 1

Amplifies the difference between 2 signals.

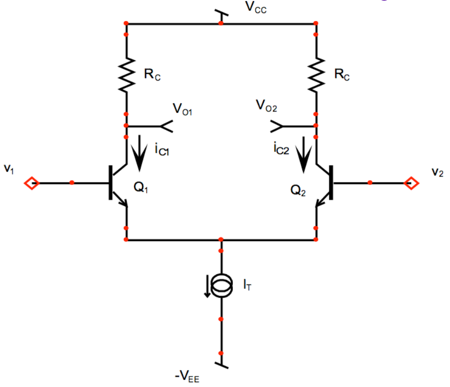
$v_o = A_v(v_a - v_b)$ Where A_v is the amplification factor.



$$i_{C1} = I_T \frac{1}{1 + e^{-v_D/V_T}}$$

where $v_D \equiv v_{B1} - v_{B2}$ is the ***differential input voltage***.

Differential Pairs : ENG262 Lect 20 Page 2



$$i_{c1} = \frac{g_m}{2} v_{id}$$

$$i_{c2} = -\frac{g_m}{2} v_{id}$$

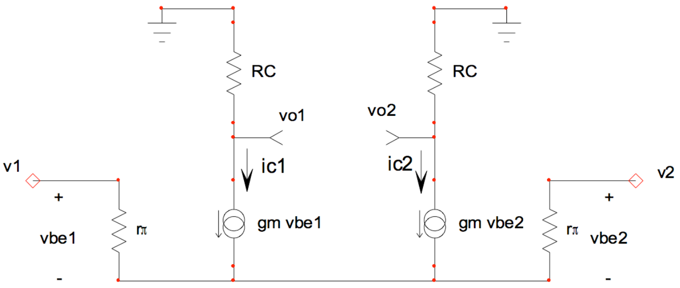
$$\text{where } v_{id} = v_1 - v_2$$

Differential Gain : ENG262 Lect20 page 3

Amplification factor = A$_v$

$$A_{v1} = \frac{v_{01}}{v_{id}} = -\frac{g_m R_C}{2}$$

And for the



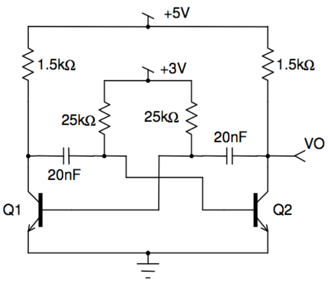
full differential gain we use

$$A_{v1} = \frac{v_{od}}{v_{id}} = -g_m R_C \quad \text{where} \quad v_{id} = v_1 - v_2$$

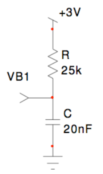
Multivibrator Actions : ENG262 SG10 Q3 & practise Exam 2009 Q6

When the Voltage on the Collector drops by 4.8v to 0.2 the base voltage also does simultaneously. See example below.

3. An astable multivibrator is shown in the figure below. The model parameters for each transistor are $V_{BE,on} = 0.7V$ and $V_{CE,sat} = 0.2V$. Just prior to time $t = 0$, Q_1 is ON and saturated while Q_2 is OFF. At time $t = 0$ the circuit changes state, with Q_1 immediately turning OFF and Q_2 immediately saturating.
   (a) What is the value for the voltage at the base of Q_1 immediately after $t = 0$.
   (b) How long does it take before the circuit returns to the state (Q_1 saturated, Q_2 OFF)?



3. ANS:
   (a) Just prior to switching: $v_O(0^-) = 5V$ and $v_{B1}(0^-) = 0.7V$. Just after switching, v_O drops to 0.2V: $v_O(0+) = 0.2V$. v_{B1} drops by the same amount to $v_{B1}(0+) = 0.7 - (5 - 0.2) = -4.1V$.
   (b) The circuit for charging the volatge at the base of Q$_1$ is:



For $t > 0$, the voltage v_{B1} is given by:

$$v_{B1} = A e^{-t/RC} + B$$

$$v_{B1}\left(0^+\right) = -4.1 = A + B$$

$$v_{B1}(\infty) = 3 = B$$

$$\therefore \quad A = -4.1 - 3 = -7.1$$

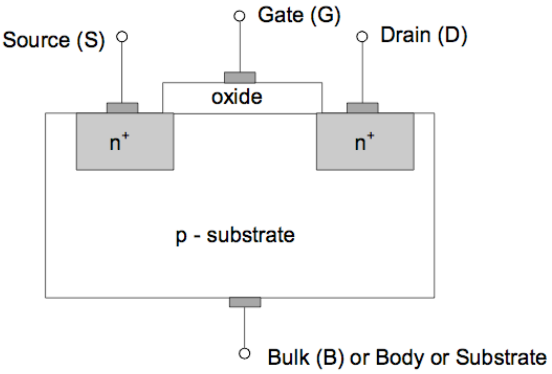
$$\therefore \quad v_{B1} = -7.1 e^{-t/RC} + 3$$

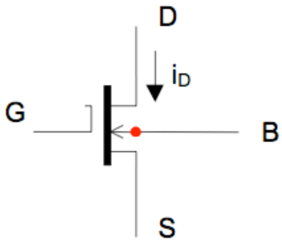
The time taken for v_{B1} to rise to 0.7V is given by T where:

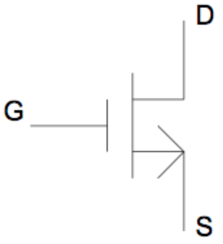
$$0.7 = -7.1 e^{-T/RC} + 3$$

$$\therefore \quad T = 25000 \times 20 \times 10^{-9} \times \ln\left(\frac{7.1}{2.3}\right) = 564 \ \mu s$$

Mosfets : ENG262 – Lect24







Where :

$k = \mu_n C_{ox}$;

μ_n is the ***electron mobility*** in the channel; 3

$C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}}$ is the ***oxide capacitance per unit area***, where ε_{ox} is the ***permittivity*** of the oxide and t_{ox} is the ***oxide thickness***;

W is the ***width*** of the channel;

L is the ***length*** of the channel (the distance between source and drain).

regions of operation : ENG262 lect24 pg 6

1. *Cut off region :*

$V_{GS} < V_t$

where V_t = The voltage cut off region

2. *Triode region :*

$V_{GS} > V_t$

$V_{DS} < V_{GS} - Vt$

Transistor acts like a voltage controlled resistor.

$$i_D \cong k\left(\frac{W}{L}\right)\left(v_{GS} - V_t\right) v_{DS}$$

$$or \quad v_{DS} \cong R_n i_D$$

$$where \quad R_n = \frac{1}{k\left(\frac{W}{L}\right)\left[v_{GS} - V_t\right]}$$

R_n = Resistance of Mosfet

3. *Saturation region :*

In the saturation region the transistor acts like a voltage controlled current source.

$$i_D = \frac{1}{2} \times k \times \left(\frac{W}{L}\right) \times \left[v_{GS} - V_t\right]^2$$

At the point where triode and saturation models meet

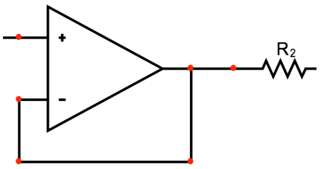
$$i_D = \frac{1}{2} \times k \times \left(\frac{W}{L}\right) \times \left[v_{GS} - V_t\right]^2$$

$$and \quad v_{DS} = v_{GS} - V_t$$

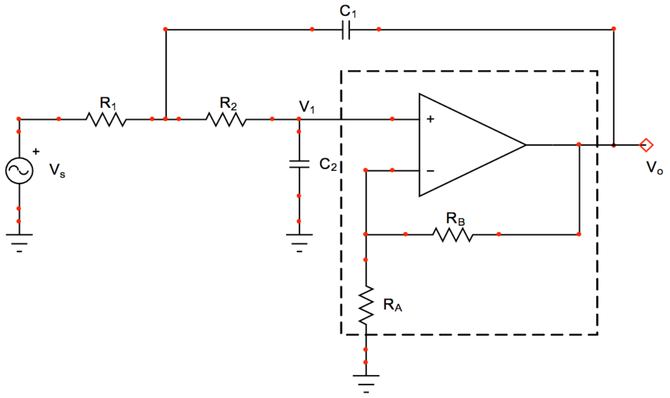
Hence

$$i_D = \frac{1}{2} \times k \times \left(\frac{W}{L}\right) \times v_{DS}^2$$

Voltage following OpAmp : ENG262 lect18 pg1



Sallen Key Filter : ENG262 lect18 pg 2



Gain

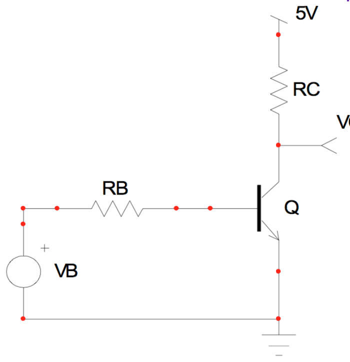
$$A = \frac{R_B}{R_A} \qquad \textbf{(2)}$$

Set A to whatever gain you want. In the example it was 1.586

Transfer Function for Sallen Key filter :

$$H(\omega) = \frac{A \times \dfrac{1}{R_1 R_2 C_1 C_2}}{-\omega^2 + j\omega\left(\dfrac{1}{R_1 C_1} + \dfrac{1}{R_2 C_1} + \dfrac{1-A}{R_2 C_2}\right) + \dfrac{1}{R_1 R_2 C_1 C_2}}$$

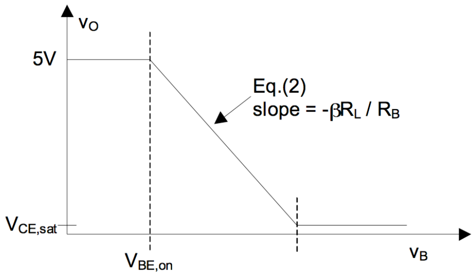
Transistor inverter : ENG262 lect6 page 3



As VB goes up VO will go down until it reaches 0.2v. This is the saturation region for Q (also known as V_{CE}) .

This is also saying that as i_B gets bigger that VO gets smaller.

This creates the curve :



The voltage gain of the circuit is :

$$\frac{dv_0}{dv_B} = -\frac{\beta R_C}{R_B}$$

LIST
Lesson 13 – Small signal transistor models.
Lesson 19
Lesson 20
Reprint rule sheets. 243,125,262

Lesson 16
Lesson 17