2015/2016 SEMESTER 1 EXAMINATION

Diploma in Aerospace Electronics (DASE)
Diploma in Energy Systems Management (DESM)
Diploma in Computer Engineering (DCPE)
Diploma in Electrical & Electronic Engineering (DEEE)
Common Engineering Programme (DCEP)
Diploma in Engineering with Business (DEB)
1st Year and 2nd Year FT

PRINCIPLES OF ELECTRICAL & ELECTRONIC ENGINEERING II

Time Allowed: 2 Hours

Instructions to Candidates

1. The examination rules set out on the last page of the answer booklet are to be complied with.

2. This paper consists of **TWO** sections:
   Section A - 10 Multiple Choice Questions, 2 marks each.
   Section B - 8 Short Questions, 10 marks each.

3. **ALL** questions are **COMPULSORY**.

4. **All questions are to be answered in the answer booklet**.

5. **Start** each question in Section B on a **new page**.

6. Fill in the Question Numbers, in the order that they were answered, in the boxes found on the front cover of the answer booklet under the column "Questions Answered".

7. This paper contains **10** pages, inclusive of formulae sheets.

SECTION A

MULTIPLE CHOICE QUESTIONS (20 marks)

1. Please **tick** your answers in the **MCQ box** on the inside of the front cover of the answer booklet.
2. No marks will be deducted for incorrect answers.

A1. A 40 mH inductor is connected in series with a capacitor C_1. They are then connected across a 15 V ac generator operating at a frequency of 5 kHz. If the total impedance is $Z = j377\ \Omega$, the value of C_1 is:

(a) 5 µF (b) 84.4 nF (c) 288.9 mF (d) 36.2 nF

A2. The phasor diagram in Figure A2 shows two phasors $\mathbf{V_A}$ and $\mathbf{V_B}$:

Which one of the following statements is false?

(a) $\mathbf{V_A}$ leads $\mathbf{V_B}$ by 30°
(b) $\mathbf{V_A}$ lags $\mathbf{V_B}$ by 30°
(c) $\mathbf{V_B}$ leads $\mathbf{V_A}$ by 30°
(d) $\mathbf{V_B}$ lags $\mathbf{V_A}$ by 330°

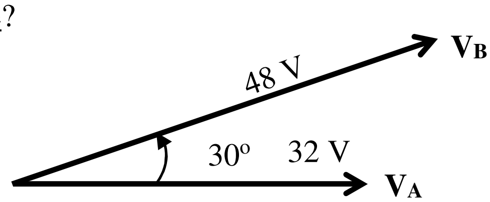

Figure A2

A3. A series RLC circuit has the following resistance and reactances:

$R = 25\ k\Omega$, $X_L = 40\ k\Omega$, $X_C = 20\ k\Omega$

What is the impedance $\mathbf{Z}$ of this circuit in rectangular form?

(a) $\mathbf{Z} = (25 - j60)\ k\Omega$ (b) $\mathbf{Z} = (-25 + j60)\ k\Omega$
(c) $\mathbf{Z} = (25 + j20)\ k\Omega$ (d) $\mathbf{Z} = (25 - j20)\ k\Omega$

A4. An ac circuit consumed 3 kW of true power (P). If an apparent power (S) of 5 kVA is measured, what is the reactive power (Q) of the circuit?

(a) 5.83 kW (b) 4 kW (c) 4 kVAR (d) 2 kVA

A5. For the circuit shown in Figure A5, calculate the peak voltage across resistor R?

(a) 10.44 V
(b) 13 V
(c) 12.8 V
(d) 7.76 V

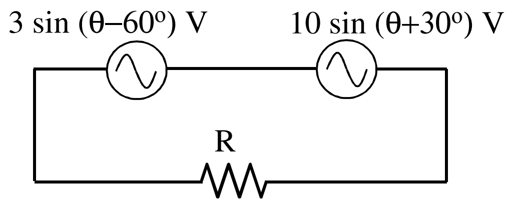

Figure A5

A6. In Figure A6, the value of $\bar{I}_2$ is:

(a) (3 + j3) A
(b) (3 – j3) A
(c) (-3 – j3) A
(d) (-3 + j3) A

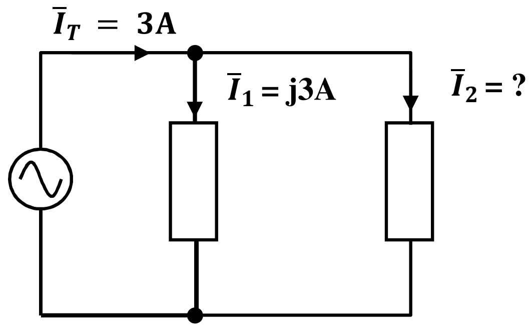

Figure A6

A7. Which one of the following statements describes the purpose of the transistor shown in Figure A7?

(a) To amplify the voltage across the relay coil
(b) To protect the relay coil from damage
(c) To function as an electronic switch
(d) To provide a buffer for the input signal

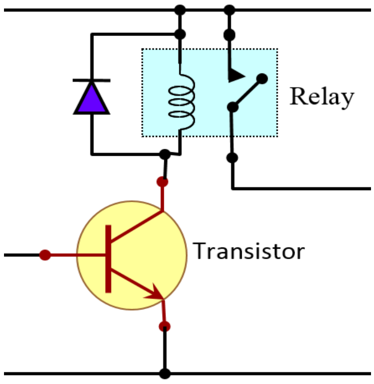

Figure A7

A8. Which one of the following devices is best suited to detect falling rain drops?

(a) Moisture sensor (b) Light dependent resistor (LDR)
(c) Photodiode (d) Thermistor

A9. Which one of the following does not require the use of an op amp?

(a) Voltage follower (b) Multi-channel scaling amplifier
(c) Averaging amplifier (d) Sinewave rectifier

A10. Which one of the following op amp configurations in Figure A10 will satisfy the equation $\mathbf{V_{out} = -V_{in}}$?

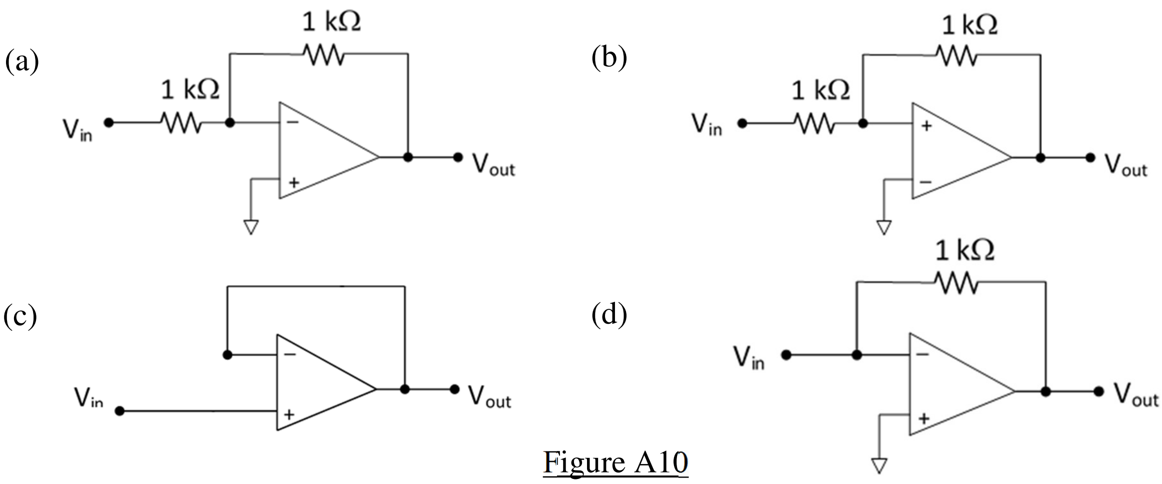

Figure A10

SECTION B

SHORT QUESTIONS (80 marks)

B1. Sketch the output voltage waveform across the resistor R_2 in Figure B1, indicating clearly the maximum and minimum levels of V_O. Include working to show how you obtain the maximum and minimum values of V_O. (10 marks)

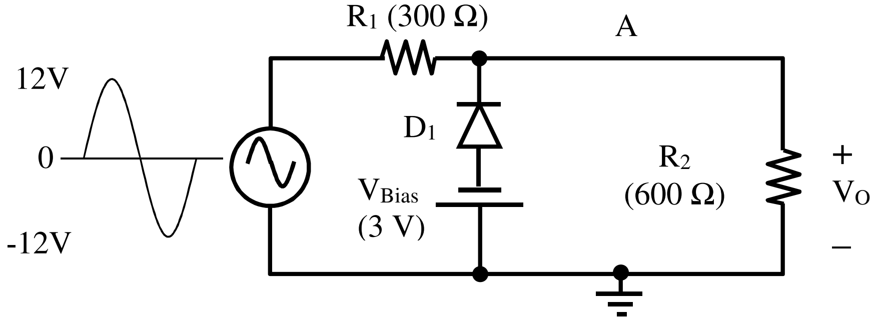

Figure B1

B2. In Figure B2, the thermistor, R_{TH}, has a resistance of 64 kΩ at 20°C and 28 kΩ at 100°C. At 100°C, the transistor reaches its saturation with $V_{CE}(sat) = 0.2$ V and LED is turned on. At 20°C, the transistor is cut-off and LED is turned off.
Given that: V_{LED} is 1.9 V when forward-biased, $\beta = 120$ and $V_{BE} = 0.7$ V. Determine:

(a) The minimum voltage of V_a for saturation to occur; (5 marks)

(b) The minimum value of R_1 for saturation to occur; (3 marks)

(c) Show also that, with the calculated value of R_1, whether the transistor is cut off or conducting at 20°C. (2 marks)

Use:

$$V_a = \frac{R_1}{R_{TH}+R_1} \times V_{CC}$$

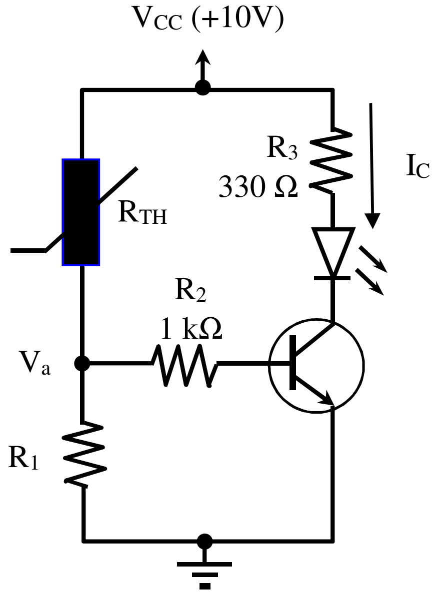

Figure B2

B3. (a) Redraw Figure B3, replacing Device A with the symbol of an LED and correctly biased. (4 marks)

(b) Describe the operation of the circuit. Your description should include the following:

(i) How the LED and photodiode are biased (reverse/forward); (2 marks)

(ii) The effect on the micro-ammeter reading when the light between the LED and photodiode is unblocked and blocked, and the reason for it. (4 marks)

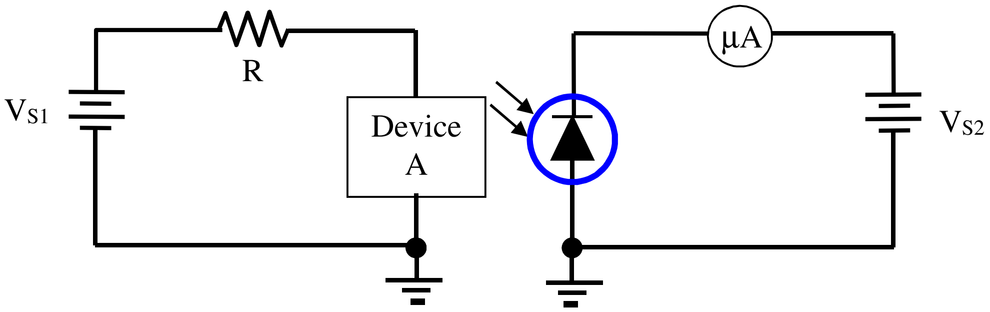

Figure B3

B4. Two 2 kHz sinusoidal ac voltage sources are connected in series as shown in Figure B4. The expressions for the two sources are respectively:

$v_{S1}(t) = 40 \sin(\omega t + 45^o)$ V

$v_{S2}(t) = 25 \sin(\omega t + 30^o)$ V

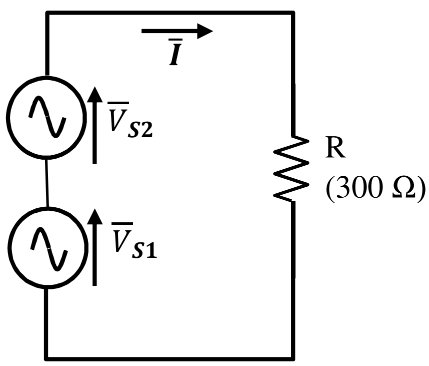

Figure B4

(a) Express $\bar{V}_{S1}$ and $\bar{V}_{S2}$ as phasors in polar form, with the voltage magnitudes expressed in their rms values. (2 marks)

(b) Draw the phasor diagram for $\bar{V}_{S1}$ and $\bar{V}_{S2}$. Indicate their magnitudes and phase angles in your diagram. (3 marks)

(c) Calculate the total rms source voltage in polar form. (3 marks)

(d) Write down the time-domain sinusoidal expression for the circuit current. (2 marks)

B5. (a) For the circuit in Figure B5, find the total impedance ($\bar{Z}_T$), circuit current ($\bar{I}$), and the voltages across the resistor ($\bar{V}_R$), inductor ($\bar{V}_L$) and capacitor ($\bar{V}_C$). Express all answers in polar form. (6 marks)

(b) Sketch the phasor diagram of $\bar{I}$, $\bar{V}_L$, $\bar{V}_C$ and $\bar{V}_R$ obtained in part (a). (4 marks)

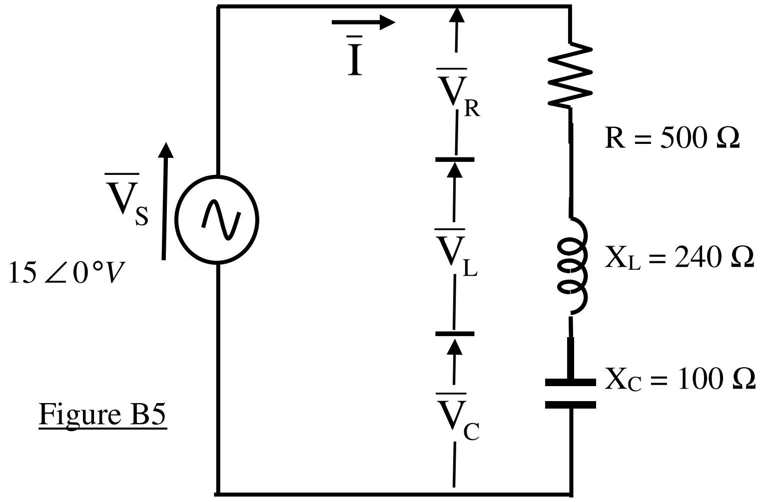

Figure B5

B6. The supply voltage, $\bar{V}_S$, is to be used as the reference phasor in analysing the parallel RLC circuit shown in Figure B6.

(a) Calculate the total impedance, $\bar{Z}_T$. (4 marks)

(b) What is the power factor of the circuit? Is it leading or lagging? (2 marks)

(c) Calculate the circuit current, $\bar{I}$, in polar form. (2 marks)

(d) Calculate the real power **P** delivered. (2 marks)

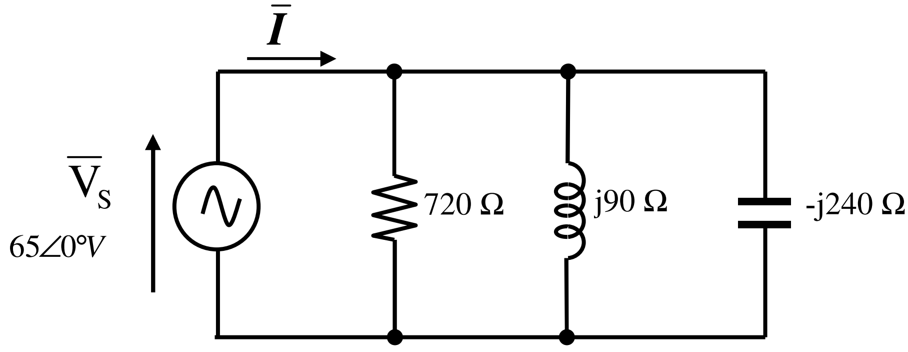

Figure B6

B7. Figure B7 shows the configuration of an op amp circuit which has three input terminals V_{in1}, V_{in2} and V_{in3}; and an output terminal V_{out1}. Resistors available for design are of the following values: 1 kΩ, 2 kΩ, 3 kΩ, 4 kΩ, and 10 kΩ.

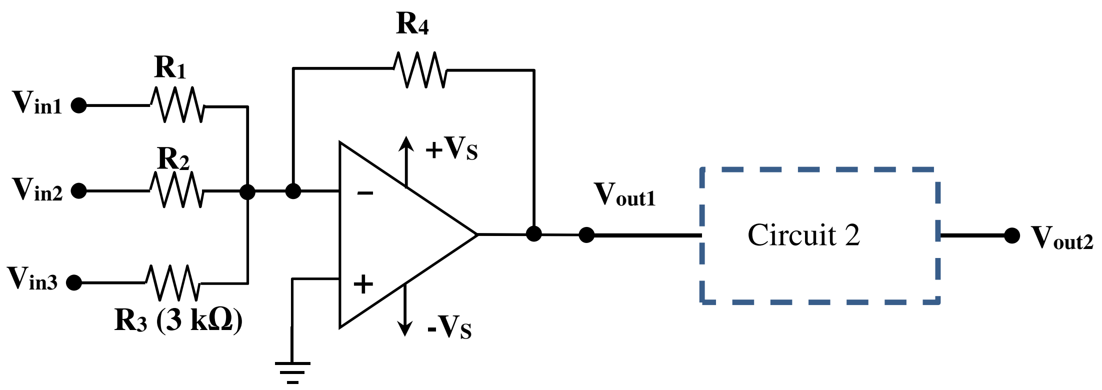

Figure B7

(a) Design a multichannel scaling circuit using the configuration of Figure B7 by selecting the appropriate resistors for R_1, R_2, and R_4 so that it satisfies the equation:

$$V_{out1} = -\left\{\frac{1}{4}V_{in1} + \frac{1}{2}V_{in2} + \frac{1}{3}V_{in3}\right\}$$

.

Redraw your circuit and label the resistance values. (6 marks)

(b) If V_{in1} = 3 V, V_{in2} = -4 V, and V_{in3} = 1.5 V, determine V_{out1} (indicate sign).

(2 marks)

(c) Design and draw a circuit (Circuit 2) such that the entire circuit in Figure B7 can produce an output voltage V_{out2} given by:

$$V_{out2} = -\{\, V_{out1}\}$$

Label all resistance values of this circuit. (2 marks)

B8. (a) State 4 characteristics of an ideal operation amplifier. (4 marks)

(b) For the amplifier in Figure B8, resistors $R_1 = 10\ k\Omega$ and $R_2 = 15\ k\Omega$, supply voltages $+V_S = +12$ V and $-V_S = -12$ V. The sinusoidal input signal $V_{in} = 4V_p$. Assume that the saturation voltages of the op amp are: $+V_{sat} = 10$ V and $-V_{sat} = -9.5$ V.

(i) What is the value of V_{out} when V_{in} is more positive than V_{UTP}? (1 mark)

(ii) What is the value of V_{out} when V_{in} is more negative than V_{LTP}? (1 mark)

(iii) Calculate both V_{UTP} and V_{LTP}. (2 marks)

(iv) State whether this circuit incorporates: (1) an open loop, (2) a negative feedback loop, or (3) a positive feedback loop configuration. (2 marks)

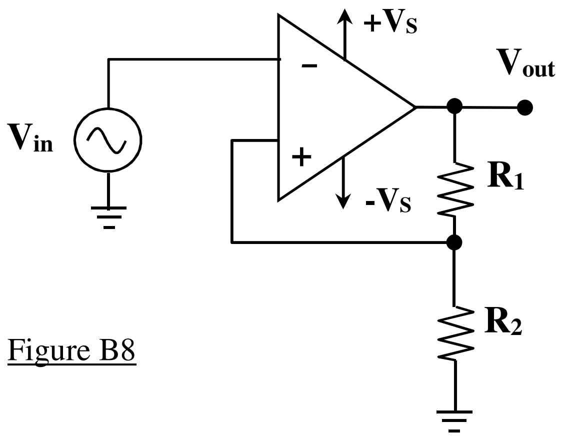

Figure B8

- End of Paper -

Formulae List

Number of electrons in a shell (band) = $2N^2$

6.25×10^{18} electrons ➔ 1C of negative charge

Ohm's Law for ac:

$$\overline{V} = \overline{I}\,\overline{Z} \qquad \overline{I} = \frac{\overline{V}}{\overline{Z}} = \overline{V}\,\overline{Y} \qquad \overline{Z} = \frac{\overline{V}}{\overline{I}}$$

Capacitors:

Capacitive reactance, $X_C = \dfrac{1}{2\pi f C}$ in ohms

Inductors:

Inductive reactance, $X_L = 2\pi f L$ in ohms

AC Voltages and Currents:

$I_{rms} = I_p / \sqrt{2} = 0.7071\ I_p$	$I_{p\text{-}p} = 2I_p$	$I_{av} = 2I_p / \pi = 0.637 I_p$
$V_{rms} = V_p / \sqrt{2} = 0.7071\ V_p$	$V_{p\text{-}p} = 2V_p$	$V_{av} = 2V_p / \pi = 0.637 V_p$

AC Impedance/Admittance:

Series circuit,

$$\overline{Z}_R = R \qquad \overline{Z}_C = -jX_C = -j\frac{1}{\omega C} = \frac{1}{\omega C}\angle -90^o \qquad \overline{Z}_L = jX_L = j\omega L = \omega L \angle 90^o \qquad \omega = 2\pi f$$

$$\overline{Z} = \overline{Z}_1 + \overline{Z}_2 + \overline{Z}_3 + \ldots\ldots\ldots \qquad \phi = \angle\overline{Z} = \angle\overline{I} = \tan^{-1}\frac{X_{tot}}{R_{tot}}$$

Parallel circuit,

$$\overline{Y}_R = G \qquad \overline{Y}_C = jB_C = j\omega C = \omega C \angle 90^o \qquad \overline{Y}_L = -jB_L = -j\frac{1}{\omega L} = \frac{1}{\omega L}\angle -90^o \qquad \omega = 2\pi f$$

$$\overline{Y} = \overline{Y}_1 + \overline{Y}_2 + \overline{Y}_3 + \ldots\ldots\ldots \qquad \phi = \angle\overline{Y} = \angle\overline{V}_S = \tan^{-1}\frac{B_{tot}}{G_{tot}}$$

AC Power:

$$S = V_S I = I^2 Z \qquad P = V_S I \cos\phi \qquad Q = V_S I \sin\phi \qquad \cos\phi = \frac{P}{S}$$

Diodes:

Forward voltage drop is 0.7 V for silicon diode and 0.3 V for germanium diode

Zener dynamic resistance $Z_Z = \dfrac{\Delta V_Z}{\Delta I_Z}$

Half-Wave Rectifier:

$V_{p(out)} = V_{p(\sec)} - 0.7\,V$ $\quad V_{AVG} = \dfrac{V_{p(out)}}{\pi}$ $\quad PIV = V_{p(\sec)}$

Centre-Tapped Full-Wave Rectifier:

$V_{p(out)} = \dfrac{V_{p(\sec)}}{2} - 0.7\,V$ $\quad V_{AVG} = \dfrac{2V_{p(out)}}{\pi}$ $\quad PIV = 2V_{p(out)} + 0.7\,V$

Bridge Full-Wave Rectifier:

$V_{p(out)} = V_{p(\sec)} - 1.4\,V$ $\quad V_{AVG} = \dfrac{2V_{P(out)}}{\pi}$ $\quad PIV = V_{p(out)} + 0.7\,V$

Ripple Factor:

$r = \dfrac{V_{r(rms)}}{V_{DC}}$ where $V_{r(rms)} = \dfrac{V_{r(p-p)}}{2\sqrt{3}}$

Line Regulation = $\left(\dfrac{\Delta V_{OUT}}{\Delta V_{IN}}\right)100\,\%$ **Load Regulation =** $\left(\dfrac{V_{NL} - V_{FL}}{V_{FL}}\right)100\,\%$

Transistors:

$I_E = I_C + I_B$ $\quad \beta_{DC} = \dfrac{I_C}{I_B}$ $\quad \alpha_{DC} = \dfrac{I_C}{I_E}$ $\quad \beta_{DC} = \dfrac{\alpha_{DC}}{1-\alpha_{DC}}$

$V_{BE} = 0.7V$ $\quad V_{BB} = V_{BE} + I_B R_B$ $\quad V_{CE} = V_{CB} + V_{BE}$

Operational Amplifiers

Voltage Gain of Inverting Amplifier: $-\dfrac{R_f}{R_i}$

Voltage Gain of Non-inverting Amplifier: $1 + \dfrac{R_f}{R_i}$

Output voltage of summing amplifier:

$V_O = -\left(\dfrac{R_f}{R_1}V_1 + \dfrac{R_f}{R_2}V_2 + \dfrac{R_f}{R_3}V_3 + \ldots\ldots\ldots + \dfrac{R_f}{R_n}V_n\right)$ for “n” inputs

Threshold Voltages for comparator with positive feedback:

Upper Trigger Point (UTP) = $\dfrac{R_2}{R_1 + R_2}(+V_{O[max]})$

Lower Trigger Point (LTP) = $\dfrac{R_2}{R_1 + R_2}(-V_{O[max]})$