Design Engineering – DE1.3 Electronics

Solutions to Problem Sheet 4 (Topics 9 to 11)

1.

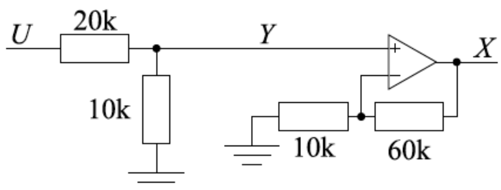
Circuit (a) is an inverting amplifier with gain $\frac{X}{U} = -\frac{10}{1} = -10$. Circuit (b) is a non-inverting amplifier with gain $\frac{Y}{U} = 1 + \frac{10}{1} = +11$. Another way to see this is to notice that, since the opamp inputs draw no current, the potential divider means that the -ve opamp input is at $\frac{Y}{11}$ and, since the negative feedback ensures the opamp terminals are at the same voltage, $U = \frac{Y}{11}$.

2.

(a) Negative, (b) Positive, (c) Negative, (d) Positive. In simple circuits like these, you can just see which terminal the output feeds back to.

3.

The best way to think of this circuit is as a potential divider with gain $\frac{Y}{U} = \frac{1}{3}$ followed by a non-inverting opamp circuit with gain $\frac{X}{Y} = 1 + \frac{60}{10} = 7$. The combined gain is then $\frac{X}{U} = \frac{1}{3} \times 7 = \frac{7}{3}$.



4.

(a) You can either recognise this a a standard inverting summing amplifier with gain $X = -\left(\frac{40}{20}U_1 + \frac{40}{10}U_2\right) = -2U_1 - 4U_2$ or else apply KCL at the +ve input terminal with the assumption that negative feedback will ensure that this terminal is at the same voltage as the –ve terminal i.e. 0 V. This gives: $\frac{0-U_1}{20} + \frac{0-U_2}{10} + \frac{0-X}{40} = 0$ from which $X = -2U_1 - 4U_2$.

(b) The network connected to the +ve terminal is a weighted averaging circuit so $V_+ = \frac{1}{3}U_1 + \frac{2}{3}U_2$. The opamp circuit itself is a non-inverting amplifier with a gain of $1 + \frac{50}{10} = 6$. So, $Y = 6 \times \left(\frac{1}{3}U_1 + \frac{2}{3}U_2\right) = 2U_1 + 4U_2$.

(c) [Superposition method] Following the method of part (b) above, if $U_3 = 0$, we have $Z = 5 \times \left(\frac{1}{5}U_1 + \frac{4}{5}U_2\right) = U_1 + 4U_2$. If, on the other hand, $U_1 = U_2 = 0$, then $V_+ = 0$ and so we have an inverting amplifier with a gain of $-\frac{40}{10} = -4$. Hence $Z = -4U_3$.

Combining these gives $Z = U_1 + 4U_2 - 4U_3$.

[Nodal analysis method] The top two resistors are a weighted average circuit so $V_+ = \frac{1}{5}U_1 + \frac{4}{5}U_2$. Now, assuming that $V_- = V_+$, we do KCL at V_- to give $\frac{\frac{1}{5}U_1 + \frac{4}{5}U_2 - U_3}{10} + \frac{\frac{1}{5}U_1 + \frac{4}{5}U_2 - Z}{40} = 0$ from which $U_1 + 4U_2 - 4U_3 - Z = 0$ giving $Z = U_1 + 4U_2 - 4U_3$.

5.

We can use superposition. If $U_2 = 0$,then $V_+ = 0$ and we have an inverting amplifier with a gain $\frac{X}{U_1} = -\frac{60}{R_1}$. The question tells us that this must equal -3 so we must have $R_1 = 20$. Now, if $U_1 = 0$, the circuit consists of a potential divider with a gain of $\frac{60}{R_2+60}$ followed by a non-inverting amplifier with a gain of $1 + \frac{60}{R_1} = 4$. The combined gain must equal 2 (from the question) so the potential divider must have a gain of $\frac{1}{2}$ which means $R_2 = 60\,\text{k}\Omega$.