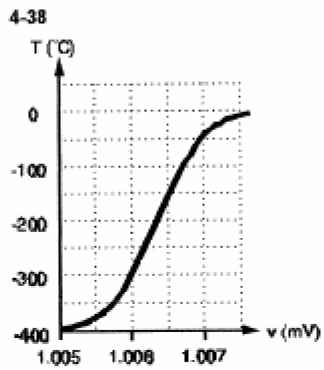
Homework Solutions 9

(4-32) Design a signal conditioning circuit for the temperature transducer whose characteristics are shown in Figure P4-38. The conditioning circuit must convert the transducer output for temperatures between -300 C and -100 C to a range of 0 to 5. The voltage gain for all stages must be less than 1000.



At -300 °C the transducer output is 1.006 mV and the desired output is 0 V. At -100 °C the transducer output is 1.00667 mV and the desired output is +5 V.

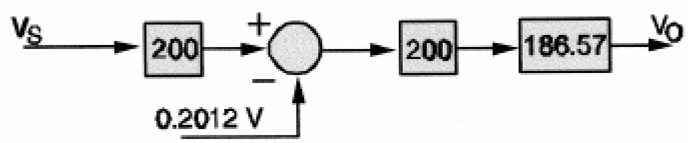
$$K = \frac{\text{output-range}}{\text{input-range}} = \frac{5-(0)}{(1.00667-1.006)\cdot 10^{-3}} = 7.1463*10^{\wedge}6$$

$K = (200)\cdot(200)\cdot(186.57)$ <—Use three stages to keep stage gains below 1000.

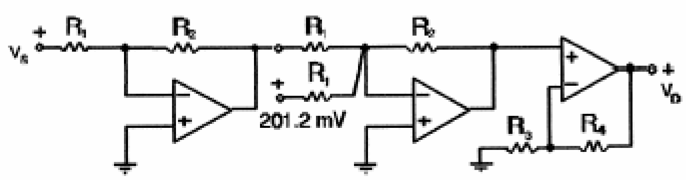
Remove bias term after one K = 200 stage

$$\text{bias} = 200\cdot 1.006\cdot 10^{-3} = 0.2012$$

block diagram



circuit realization



$$\frac{R_2}{R_1} = 200$$

$$\frac{R_4}{R_3} + 1 =$$

Input-output relationship: $v_O(v_s) := 186.57\cdot(-200)\cdot\left[(-200)\cdot v_s + 0.2012\right]$

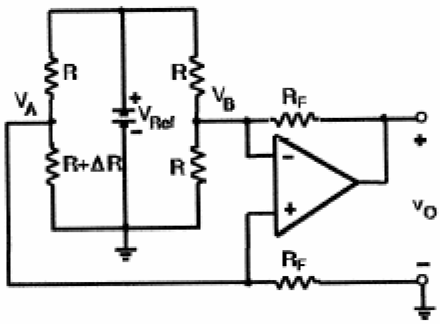
Checking $v_O\left(1.006\cdot 10^{-3}\right) = 0$ $\quad v_O\left(1.00667\cdot 10^{-3}\right) = 5$

In these types of problems you must design your own circuit, so there can be many variations in answers. Remember that you must remove the "bias constant" after the first stage always when designing the transducer. It is also suggestible that all the gains (K1*K2*K3 = K) of the three stages be relatively close to each other because it will help reduce noise with in the circuit. This is the reason they choose (200) (200) (186.57) because when multiplied you get a gain from all three stages to be 7.1463 * 10^6. For more information on how to solve this problem and ones like it check out pages 189-190.

(4-55) WHEATSTONE BRIDGE AMPLIFIER
SEE TEXT FOR PROBLEM STATEMENT

(a) Verify that this expression is correct and the express K in terms of circuit paramenters.
(b) For Vref = 15V, R = 100Ω and ΔR/R in the range of +/-0.04%, select the value Rf so that the output voltage Vo falls in the range +/-3V.

4-55 (a) Writing node-voltage equations



Node A: $\left(\frac{1}{R} + \frac{1}{R+\Delta R} + \frac{1}{R_F}\right) \cdot v_A - \frac{v_{Ref}}{R} = 0$

Node B: $\left(\frac{2}{R} + \frac{1}{R_F}\right) \cdot v_B - \frac{v_O}{R_F} - \frac{V_{Ref}}{R} = 0$

For an ideal OP AMP $v_A = v_B$, solving for v_O

$$v_O = \left(\frac{\Delta R \cdot R_F}{2 \cdot R \cdot R_F + R_F \cdot \Delta R + R^2 + R \cdot \Delta R}\right) \cdot \frac{R_F}{R} \cdot V_{Ref}$$

For $\Delta R/R \ll 1$ this reduces to

$$v_O = \left[\left(2 + \frac{R}{R_F}\right)^{-1} \cdot \frac{R_F}{R}\right] \cdot \frac{\Delta R}{R} \cdot V_{Ref} = K \cdot \frac{\Delta R}{R} \cdot V_{Ref}$$

(b) For $v_O = \pm 3$ V when $\Delta R/R = \pm 0.0004$ and $V_{CC} = 15$ V requires

$$\left[\frac{R_F}{R} \cdot \left(2 + \frac{R}{R_F}\right)^{-1}\right] \cdot 4 \cdot 10^{-4} \cdot 15 = 3$$

This requires $\frac{R_F}{R} = 1000.5$ Since R = 100 Ω we have $R_F = 100.05 \cdot 10^3$

This major trick of this problem is to understand that Vb = Va which is a property of how Operational Amplifiers function because if in = ip = 0, then Va must be Vb for this problem. Once you know that,find your nodal equations and set Va to Vb and solve for Vo. Also remember that K will be expressed in terms of circuit parameters.

(5-8) An exponential waveform is 5V at t = 5ms and 2V at t = 6ms. Find the amplitude and time constant.

5-8 $V_A \cdot \exp\left(\frac{-0.005}{T_C}\right) = 4$ $\quad V_A \cdot \exp\left(\frac{-0.006}{T_C}\right) = 2$ $\quad \frac{\exp\left(\frac{-0.005}{T_C}\right)}{\exp\left(\frac{-0.006}{T_C}\right)} = 2$ $\quad \exp\left(\frac{0.006}{T_C}\right) = 2 \cdot \exp\left(\frac{0.005}{T_C}\right)$

$\frac{0.006}{T_C} = \ln(2) + \frac{0.005}{T_C}$ $\quad T_C := \frac{1}{1000 \cdot \ln(2)}$ $\quad T_C = 1.4427 \times 10^{-3}$ $\quad V_A := 4 \cdot \exp\left(\frac{0.005}{T_C}\right)$ $\quad V_A = 128$

Checking solution $\quad 128 \cdot \exp\left(\frac{-0.005}{1.4427 \cdot 10^{-3}}\right) = 4$ $\quad 128 \cdot \exp\left(\frac{-0.006}{1.4427 \cdot 10^{-3}}\right) = 2$ $\quad$ Checks

(5-14) A sinusoid has frequency of 5MHz, a value of -10V at t = 0, and reaches its first positive peak at t = 125ns. Find the amplitude, phase angle , and Fourier coefficients.

5-14 The waveform is of the form $v(t) = V_A \cdot \cos\left[2 \cdot \pi \cdot 5 \cdot 10^6 \cdot \left(t - 125 \cdot 10^{-9}\right)\right]$ $\quad v(0) = -10$

$V_A \cdot \cos\left[2 \cdot \pi \cdot 5 \cdot 10^6 \cdot \left(0 - 125 \cdot 10^{-9}\right)\right] = -10$ $\quad V_A := \frac{-10}{\cos\left[2 \cdot \pi \cdot 5 \cdot 10^6 \cdot \left(0 - 125 \cdot 10^{-9}\right)\right]}$ $\quad V_A = 14.142$

$T_0 := \frac{1}{5 \cdot 10^6}$ $\quad T_S := 125 \cdot 10^{-9}$ $\quad \phi := -2 \cdot \pi \cdot \frac{T_S}{T_0}$ $\quad a := V_A \cdot \cos(\phi)$ $\quad b := -V_A \cdot \sin(\phi)$

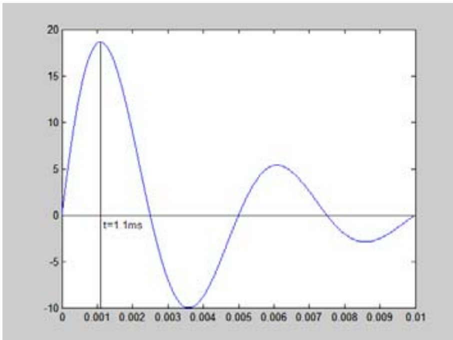
$\phi = -3.927$ $\quad \phi \cdot \frac{180}{\pi} = -225$ $\quad a = -10$ $\quad b = -10$

$v(t) := a \cdot \cos\left(2 \cdot \pi \cdot 5 \cdot 10^6 \cdot t\right) + b \cdot \sin\left(2 \cdot \pi \cdot 5 \cdot 10^6 \cdot t\right)$ $\quad t := 0, \frac{T_0}{20} .. T_0$

$v(0) = -10$ $\quad v\left(125 \cdot 10^{-9}\right) = 14.142$

(5-29)

The curve shown below is from the equation $v(t) = V_a\left[e^{-\alpha t}\sin(\beta t)\right]u(t)$.



The book gives the period of the sine wave to be 5ms, the value of the first peak to be at 18V at 1.3ms, and the value of the first minimum to be at -10V. The u(t) means that the value of this function at times less than t=0 is 0V.

1)The value of beta can be determined from the period of the sine wave.

$$\beta = 2\pi / T = 400\pi$$

2)You can tell by looking at the graph that the peak occurs before the halfway point between the zero crossings. The book gives that the peak occurs at 1.3ms and the halfway point between the first two zero crossings is at 1.25ms, so the book is in error.

3)The first minimum occurs at half of the period of the sine wave after the first maximum.

4)If you solve this system of equations based on the book's value of t=1.3ms

$$18 = V_a\left[e^{-\alpha * .0013}\sin\left(400\pi * .0013\right)\right]$$

$$-10 = V_a\left[e^{-\alpha * .0038}\sin\left(400\pi * .0038\right)\right]$$

then you will get a negative value for alpha which causes an exponentially growing instead of decaying waveform.

5)The correct way to do this is to find

$$\frac{dv(t)}{dt} = V_a e^{-\alpha t}\left[\beta\cos(\beta t) - \alpha\sin(\beta t)\right]$$

6)Set this derivative to 0 and solve for t to get the location of the maxima and minima

$t = \frac{1}{\beta}\left[\tan^{-1}\left(\frac{\beta}{\alpha}\right) + N\pi\right]$, N=0 at the first maximum and N=1 at the first minimum.

7)Now substitute these values of t into step 4 instead of using t=.0013 and t=.0038 and you'll have two equations with the two unknowns Va and alpha since beta is known.

$$18 = V_a\left[e^{-\frac{\alpha}{\beta}\tan^{-1}\left(\frac{\beta}{\alpha}\right)}\sin\left(\tan^{-1}\left(\frac{\beta}{\alpha}\right)\right)\right]$$

$$-10 = V_a\left[e^{-*\frac{\alpha}{\beta}\left[\tan^{-1}\left(\frac{\beta}{\alpha}\right)+\pi\right]}\sin\left(\tan^{-1}\left(\frac{\beta}{\alpha}\right)+\pi\right)\right]$$

8)Solve this and you should arrive at this solution

Va=24.92, alpha=248.66, beta=400*pi

(5-39)

$V(t) = 100 - 200\cos(2000\pi t) - 75\sin(40000\pi t) + 35\cos(80000\pi t)$

Take out multiples of two pi out of each sinusoidal term

Therefore,

2*π*(1000)
40*π*(1000)
80*π*(1000)

$f_o = 1000$Hz; $T_o = 10^{-3}$; $V_{avg} = 0.1$;

First component amplitude = 200; $f_{max} = 40000$;