EE323 **MIDTERM** October 23, 2001
1:30pm – 3:00pm

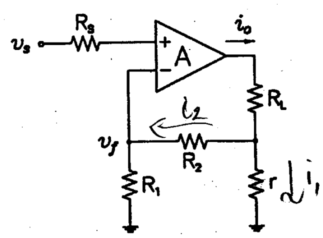
Open books, open notes. Answer all questions.
Use the other site of the paper if you require more space.
Total mark: 50

Name: Solution

Stud. # :

1. **Question 1 (15 marks)**

In the non-inverting voltage-to-current converter shown, the basic op-amp has infinite input resistance and zero output resistance. For input v_s and output i_o, find an expression for the feedback factor $\beta = v_f/i_o$. For an open loop gain $A = 10^3$ mA/V, what must β be for a closed-loop gain of 10 mA/V? For this β, find values of R_1, R_2, and r to make $i_o/v_s = 10$ mA/V, (while allowing the voltage across R_L to be as large as possible for a given power supply, yet using no resistor smaller than 150Ω). What is the value of i_o when v_s=1V?



$$i_2 = i_o \frac{r}{r+R_1+R_2}$$

$$v_f = i_2 R_1 = \frac{rR_1}{r+R_1+R_2} i_o$$

$$\therefore \boxed{\beta = \frac{v_f}{i_o} = \frac{rR_1}{r+R_1+R_2}}$$

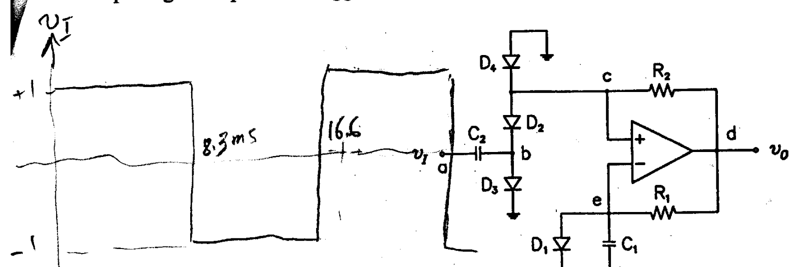
$A_{OL} = 10^3$ mA/V, $A_{CL} = 10$ mA/V $\Big\}$ $A_{CL} = \frac{A_{OL}}{1+A_{OL}\beta}$ or $\beta \cong \frac{1}{A_{CL}} = \frac{1}{10 \text{ mA/V}} = 100\ \frac{V}{A}$ (99 to be exact)

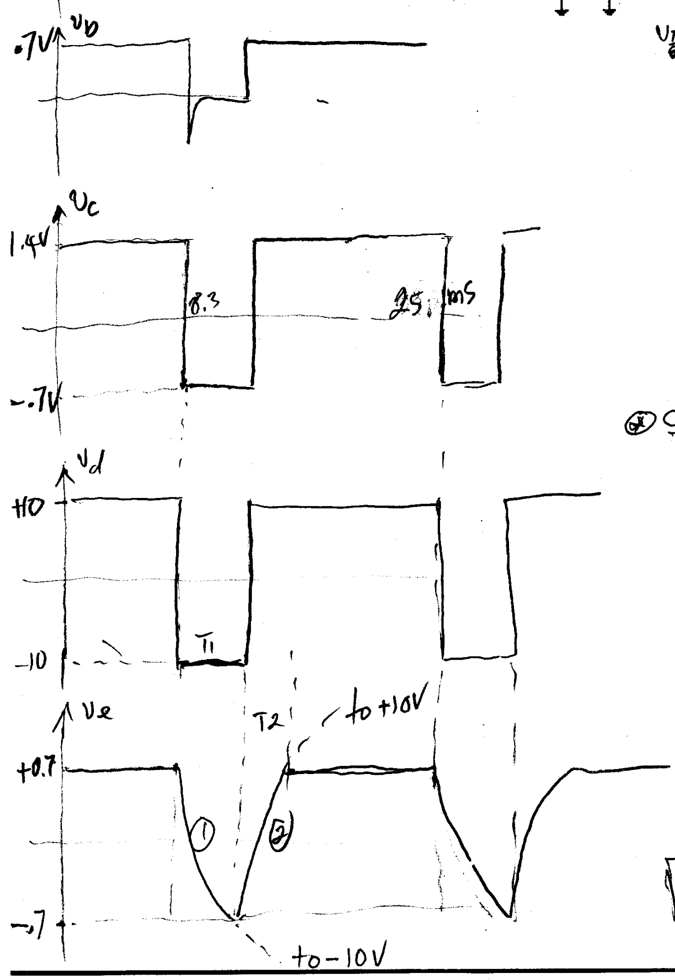
Choose $r = 150\Omega$, $R_2 = 150\Omega$ $\Rightarrow$ $100 = \frac{150R_1}{300+R_1}$ or $50R_1 = 30000$, $R_1 = 600\ \Omega$

$i_o = A_{CL} v_s = \left(10 \frac{mA}{V}\right)(1V) = 10$ mA

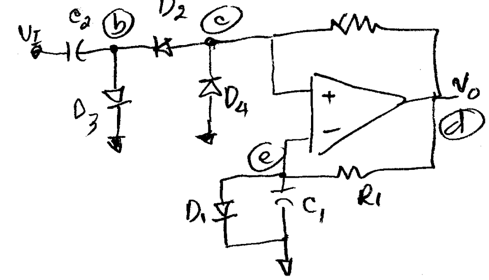
2. Question 2 (20 marks)

Consider the circuit shown, using diodes which conduct at $V_D = 0.7V$, and an amplifier saturating at ±10V, with R1 = R2 = 10 K and C1 = 10C2 = 0.01 μF. Find the output pulse width and frequency, if v_I is a 60 Hz square wave of 2Vpp amplitude. Sketch the waveforms at nodes a through e. What is the smallest input signal required to trigger the circuit? How long does it take for this circuit to be ready for a new input?





Redraw :



$L_+ = 10V$, $L_- = -10V$

$V_D = 0.7V$

Curve ①: Cap. discharges to L_-

$$V_e = L_- - (L_- - V_D)\, e^{-\frac{t}{C_1R_1}}$$

$$V_e(T) = -V_D$$

$$\Rightarrow -V_D = L_- - (L_- - V_D)\, e^{-\frac{T}{C_1R_1}}$$

$$e^{-\frac{T_1}{C_1R_1}} = \frac{L_- + V_D}{L_- - V_D}$$

or
$$\boxed{T_1 = -C_1R_1 \ln\left(\frac{L_- + V_D}{L_- - V_D}\right)}$$

$$T_1 = -(0.01\mu F)(10k)\ln\left(\frac{-10+0.7}{-10-0.7}\right)$$

$$\boxed{T_1 = 14\,\mu s}$$

(*) Curve (2) : Cap. charges to L_+

Same $T_1 = T_2$ since discharges from +0.7V to −0.7V
and charges from −0.7V to +0.7V

$\therefore$ $T_2 = 14\,\mu s$ (recovering period)

The circuit is ready for the next trigger signal (negative edge) at $8.3ms + 28\mu s = 8.33ms$ (the next negative edge for 60Hz input is at 25ms

(*) The output has a period of $25ms - 8.3ms = 16.7ms$

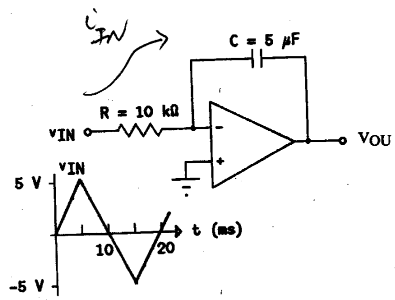
$f = \frac{1}{T} = \frac{1}{16.7ms} = 60Hz$

(note that duty cycle is not 50% as v_{IN})

(*) The smallest input signal requires is $1.4V_{pp}$.

3. Question 3 (15 marks)

A 5V peak triangular voltage with a period of 20ms, depicted on the axis shown below, is applied to an ideal op-amp integrator. Sketch V_{OUT} as a function of time. The capacitor has zero initial charge.



$i_{IN} = \frac{v_{IN}}{R}$

$v_C = v_O$

$i_{IN} = C\frac{dv_C}{dt} = -\frac{v_{IN}}{R}$

$\frac{dv_C}{dt} = \frac{-1}{CR} v_{IN}$

$v_O = v_C = -\frac{1}{CR}\int_0^t v_{in}\,dt$

① $0 < t < 5ms$, $v_{IN} = \alpha t$ where $\alpha = \frac{1V}{ms}$ and t is in ms

$RC = (10K)(5\mu F) = 50\,ms$

$\Rightarrow v_o = -\frac{1}{RC}\int_0^t \alpha t\,dt = -\frac{\alpha t^2}{2RC} = -\frac{1V/ms}{2(50ms)}t^2 = -\frac{t^2}{100\,ms^2/V}$

$t = 0$, $v_o = 0$

$t = 5ms$, $v_o = -\frac{(5ms)^2}{100\frac{ms^2}{V}} = -0.25mV$ } parabola

② $5 < t < 10ms \Rightarrow v_{IN}$ positive (but returning to zero), v_o will continue increasing negatively but its slope will become more shallow as time progress $t = 10ms \Rightarrow v_o = -0.5V$

③ Over the next 10 ms, during which time v_{IN} become negative, v_o will begin to increase from the negative peak, reaching zero at $t = 20\,ms$.