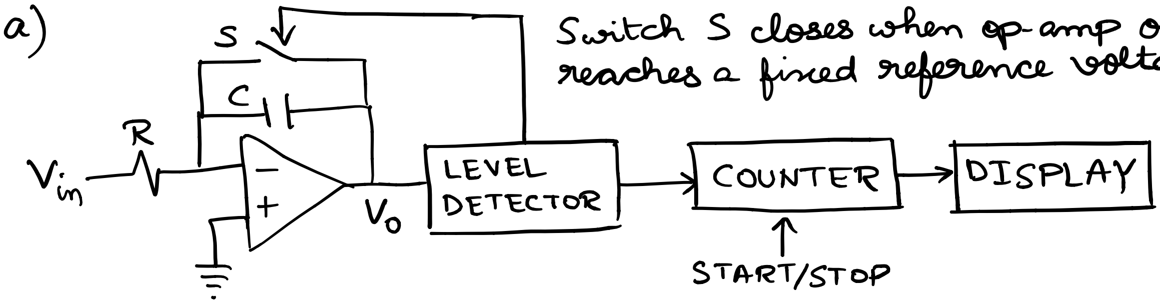
SOLUTIONS

ELL 301 MINOR TEST 1 DURATION = 1 HR MARKS = 20

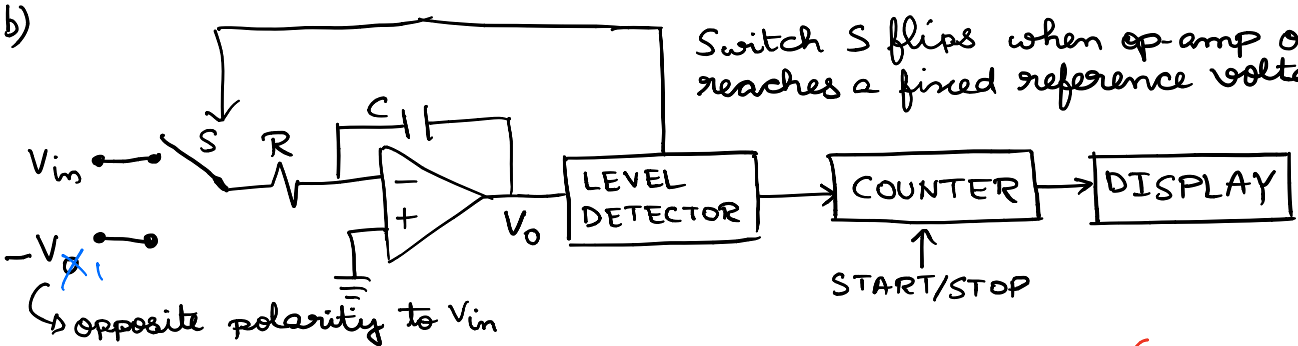
1. Describe how these integrator-based ADC circuits work. Draw V_o vs time when V_{in} is constant. 6 marks

a)



Switch S closes when op-amp output reaches a fixed reference voltage.

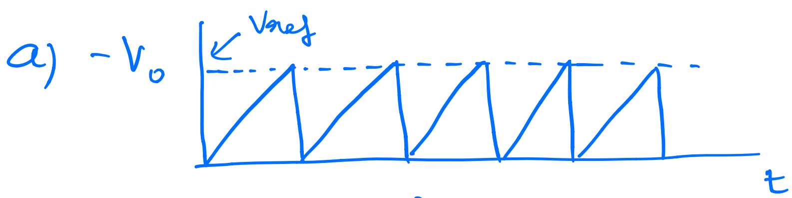
b)



Switch S flips when op-amp output reaches a fixed reference voltage.

3

4



Capacitor charges. When it reaches a certain level, S closes and capacitor discharges.

V_o increments the counter in a fixed time duration. Counter output is displayed.

3

b) Working is same as above, except that the capacitor discharges to opposite polarity '$-V_1$'.

In a dual slope integrator ADC, the capacitor charges for a fixed time after which S flips and capacitor discharges to zero. The time it takes to discharge to zero is counted.

2. Consider the dynamics $\ddot{x} + \dot{x} + x = u$. What is the steady-state response of x if a) $u = A\sin\omega t$, b) $u = A^2\sin^2\omega t$, c) $u = B\sin\omega t\,\sin(\omega t+\phi)$, where A, B, and ϕ are constants.

<u>6 marks</u>

a) $\ddot{x} + \dot{x} + x = u$

$\Rightarrow s^2 X(s) + sX(s) + X(s) = U(s)$, assuming $x(0)=0$, $\dot{x}(0)=0$

$$\Rightarrow X(s) = \frac{1}{\underbrace{s^2+s+1}_{\text{poles are in LHP}}}\cdot U(s)$$

If $u = A\sin\omega t$, then at steady-state,

$x(t) = AA'\sin(\omega t+\theta)$, where

$$A' = \left|\frac{1}{s^2+s+1}\right|\Bigg|_{\text{at } s=j\omega}, \quad \theta = \tan^{-1}\frac{\omega}{1-\omega^2}$$

(2)

This follows directly from the property of a linear system subject to sinusoidal input.

b) $u = A^2\sin^2\omega t = \frac{A^2}{2}(1-\cos\omega t)$

Response to $\frac{A^2}{2}$ is $\mathcal{L}^{-1}\left\{\frac{1}{s^2+s+1}\cdot\frac{1}{s}\cdot\frac{A^2}{2}\right\}$, whose final value from Final Value Theorem is $\frac{A^2}{2}$

Response to $\frac{A^2}{2}\cos\omega t$ is $\frac{A^2}{2}\cdot A'\cos(\omega t+\theta)$, where A' and θ are as above.

$$\therefore \text{ steady-state is } \underbrace{\frac{A^2}{2} - \frac{A^2}{2}\cdot A'\cos(\omega t+\theta)}_{(2)}$$

c) $u = B \sin\omega t \sin(\omega t + \phi)$

$= B(\cos\phi - \cos(2\omega t + \phi))$

Response to $B\cos\phi$ is $\mathcal{L}^{-1}\left\{\frac{1}{s^2+s+1} \cdot \frac{1}{s} \cdot B\cos\phi\right\}$,

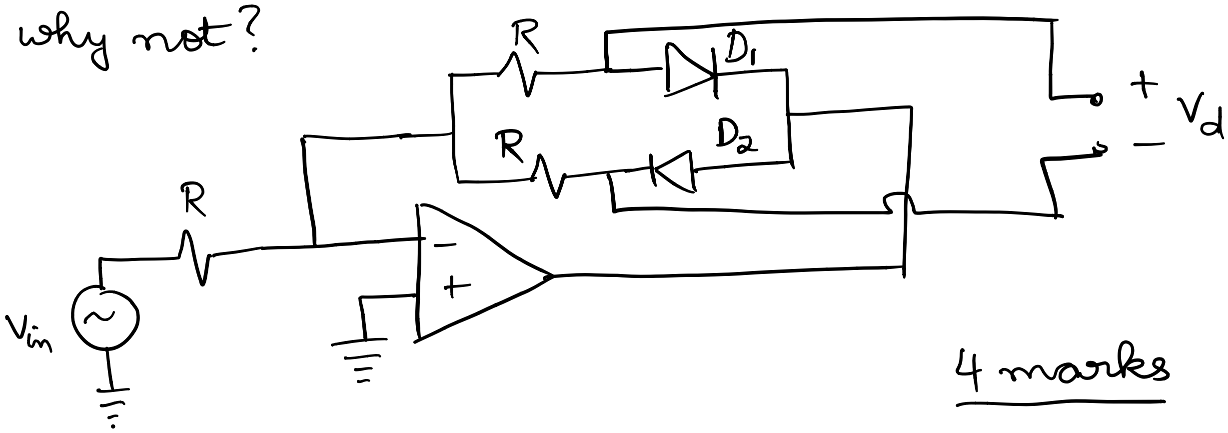
whose final value is $B\cos\phi$.

Response to $B\cos(2\omega t + \phi)$ is $B \cdot B' \cos(2\omega t + \phi + \phi')$,

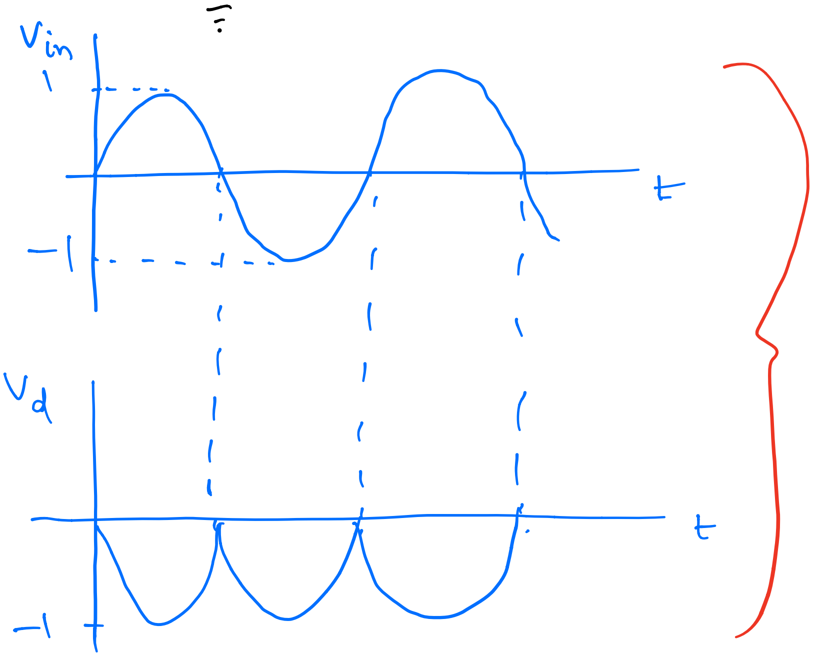
where $B' = \left| \frac{1}{s^2+s+1} \right|_{s=j2\omega}$, $\phi' = \tan^{-1}\left(\frac{2\omega}{1-4\omega^2}\right)$.

$\therefore$ steady-state is $\underbrace{B\cos\phi - BB'\cos(2\omega t + \phi + \phi')}_{(2)}$.

3. If $V_{in} = \sin\omega t$, sketch V_d vs time. Diodes are ideal. Can both diodes be ON or OFF simultaneously? Why or why not?



4 marks



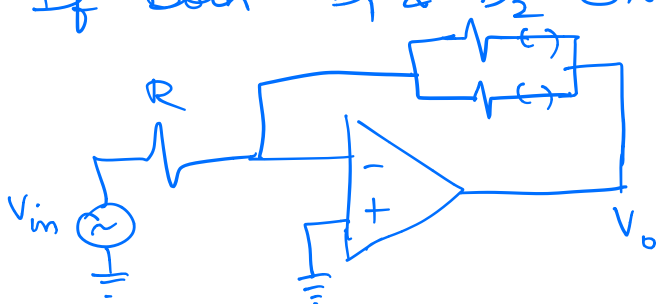
2

$D_1 \rightarrow$ ON OFF ON . . .

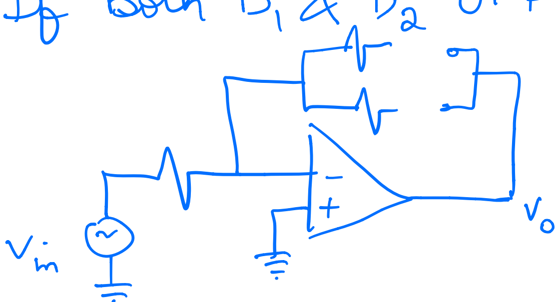
$D_2 \rightarrow$ OFF ON OFF . . .

2

If both D_1 & D_2 ON simultaneously, it would imply that potential drop across them is same. A contradiction.

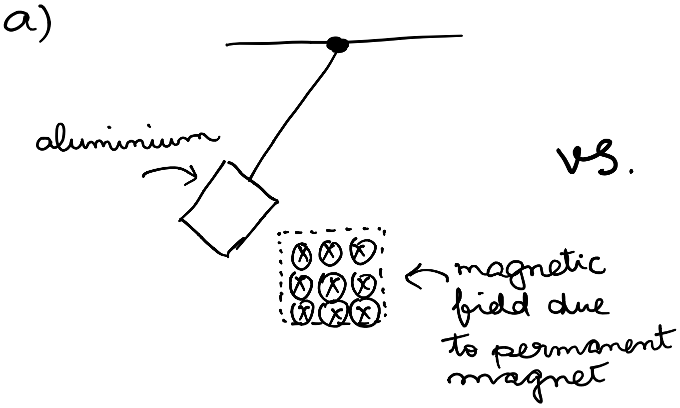


If both D_1 & D_2 OFF simultaneously, it would imply again the same thing. Also a contradiction.



4. Discuss the role of eddy currents in each of the following scenarios. <u>4 marks</u>

a)

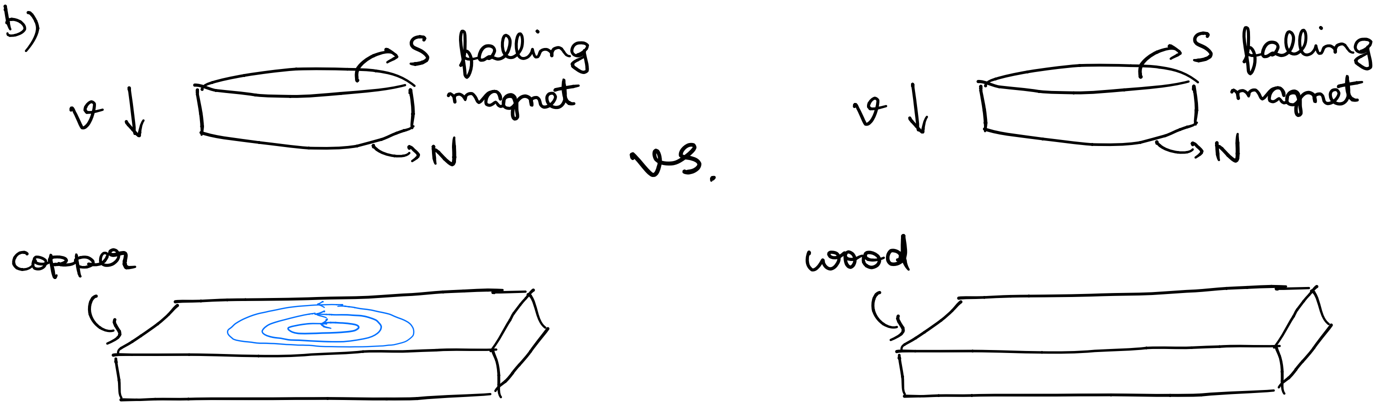


Eddy currents will be induced in both cases. These will be such that the aluminium object will be damped. → 1

The one with the slits will be damped less as eddy current paths are smaller. → 1

Note that depending on the zone of the aluminium object entering or exiting the magnetic field, the directions of eddy current will be different.

b)



Eddy currents will be generated which will repel the falling magnet. → 1

Especially, for copper plate the magnet may land "softly". → 1