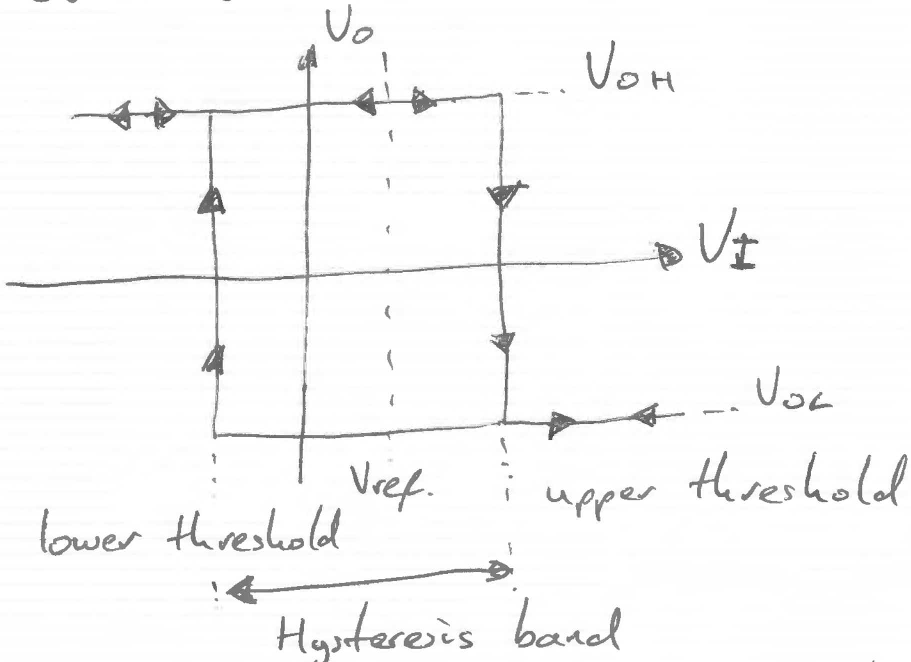
Q1

a) Hysteresis improves a comparator circuit's immunity to noise by placing a deadband around the switching boundary.

b) Schmitt trigger hysteresis characteristic



Inverting Schmitt trigger $V_I > V^+_H$ V_O goes low (V_{OL})

$V_I < V^+_L$ V_O goes high (V_{OH}).

Need to find value of V_I that causes V_O to change state

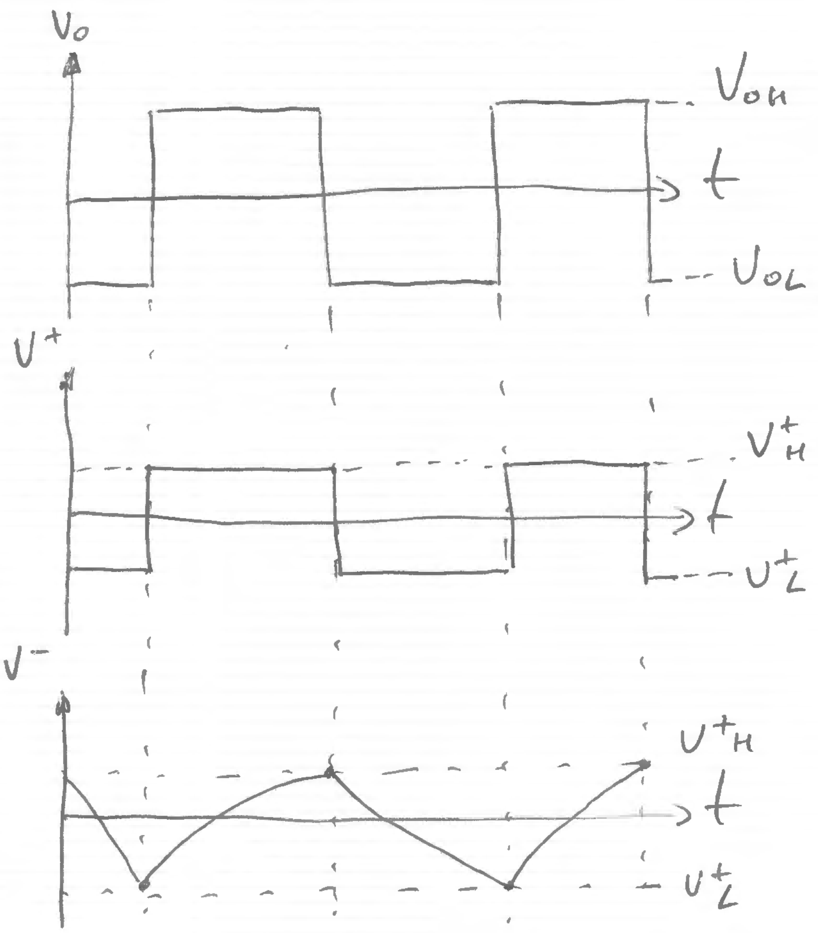
$$V^+ = V_{ref} - (V_{ref} - V_O)\frac{R_1}{R_1+R_2}$$

If $V_O = V_{OH}$ then $V^+_H = V_{ref} - (V_{ref} - V_{OH})\frac{R_1}{R_1+R_2}$ – upper threshold

If $V_O = V_{OL}$ then $V^+_L = V_{ref} - (V_{ref} - V_{OL})\frac{R_1}{R_1+R_2}$ – lower threshold

Hysteresis $= V^+_H - V^+_L = (V_{OH} - V_{OL})\frac{R_1}{R_1+R_2}$

Q1 c).



d) When $V_o = V_{OH}$, $V_C(t) = V^-(t) = (V_{OH} - V^+_L)(1 - e^{-\frac{t}{\tau}}) + V^+_L$.

since $V_{OH} = -V_{OL}$, $V^+_H = -V^+_L = \frac{R_1}{R_1+R_2} V_{OH}$

One complete half-period is the time taken for V^- to travel from V^+_L to V^+_H. So,

$$\frac{R_1}{R_1+R_2} V_{OH} = \left(V_{OH} + \frac{R_1}{R_1+R_2} V_{OH}\right)(1 - e^{-\frac{t}{\tau}}) - V_{OH}\frac{R_1}{R_1+R_2}.$$

Simplifying and solving for t gives

$$t = \tau \ln\left(\frac{2R_1+R_2}{R_2}\right)$$

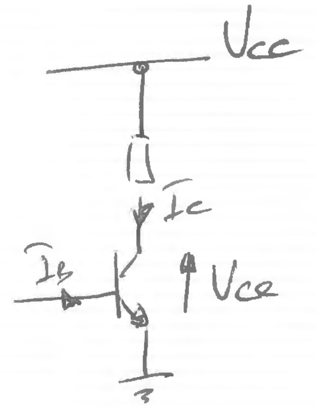
so the whole oscillation period is.

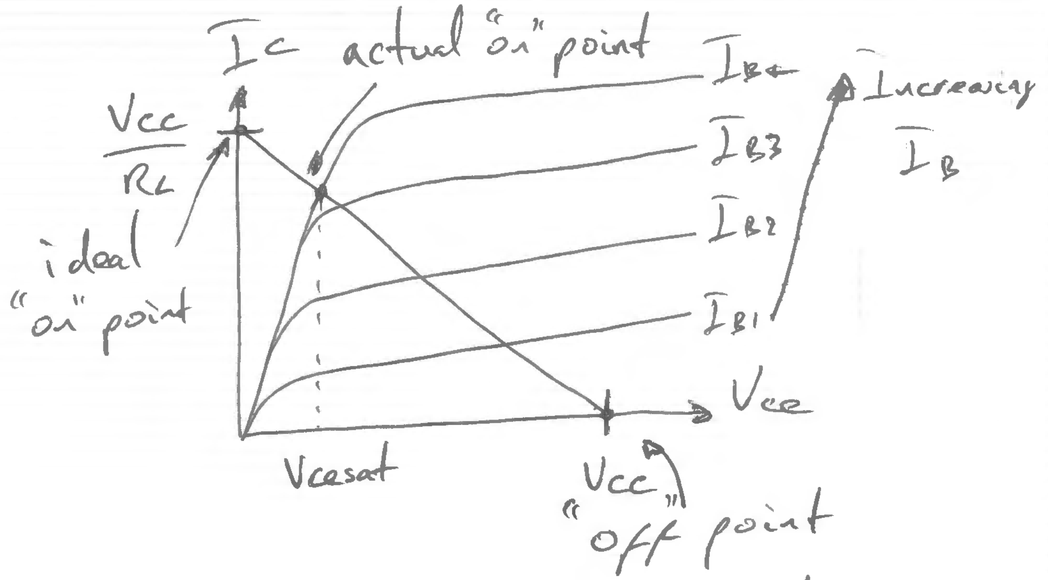
$$T_{osc} = 2t = 2\tau \ln\left(\frac{2R_1+R_2}{R_2}\right) = 2RC \ln\left(\frac{2R_1+R_2}{R_2}\right).$$

e). $RC = \dfrac{T_{osc}}{2\ln\left(\frac{2R_1+R_2}{R_2}\right)} = 1.28 \times 10^{-4}\,s.$

Q2

a)





b) Overdriving is necessary to compensate for the difficulty associated with specifying a suitable value for h_{FE} which varies with temperature, collector current and device-to-device.

Advantage – improves turn-on time

Disadvantage – degrades turn-off time due to reverse recovery of transistor.

c) Assuming $V_{cesat} \simeq 0V$, $I_c \simeq \frac{V_{cc}}{R_L} = \frac{300}{15} = 20A.$

$$I_{BS} = \frac{I_c}{h_{FE}} = \frac{20}{50} = 0.4A.$$

$$I_B = M \cdot I_{BS} = 6 \times 0.4 = 2.4A$$

$$R_b = \frac{V_{ION} - V_{be\,on}}{I_B} = \frac{9-1}{2.4} = 3.33\Omega$$

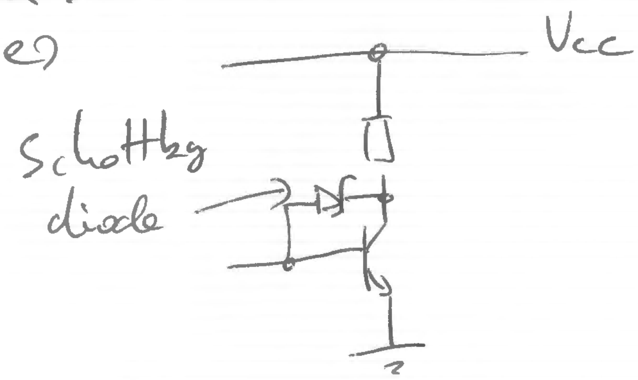
d) If $I_B = 2.4A$ then $Q_s = I_B \times t_s = 2.4 \times 450 \times 10^{-9} = 1.08 \times 10^{-6}C$

$Q_s = C_b \Delta V$ $\quad \Delta V = (V_{ION} - V_{be\,on}) - (V_{Ioff} - V_{be\,off}) = 8 - (-3) = 11.$

$$C_b = \frac{Q_s}{\Delta V} = \frac{1.08 \times 10^{-6}}{11} = 98nF \ (100nF)$$

Q3

e)



Q3

a) Barkhausen criterion.

Self-sustained oscillations occurs when the loop gain $= 1$ and phase difference $\angle = 0^\circ$

There are two ways to achieve this.

loop gain $= 1$ phase $= 0^\circ$

loop gain $= -1$ phase $= 180^\circ$.

b) Transfer function.

$$Z_1 = R + \frac{1}{sC} = \frac{sCR+1}{sC}$$

$$Z_2 = \frac{1}{\frac{1}{R} + sC} = \frac{R}{1+sCR}$$

$$\frac{V_2}{V_1} = \frac{Z_2}{Z_1+Z_2} = \frac{sCR}{s^2C^2R^2+3sCR+1}$$

c) $$\frac{V_2}{V_1} = \frac{j\omega CR}{1-\omega^2C^2R^2+3j\omega CR}$$

purely real when $1-\omega^2C^2R^2 = 0$.

$$\omega_{osc} = \frac{1}{CR} \qquad f_{osc} = \frac{1}{2\pi CR}$$

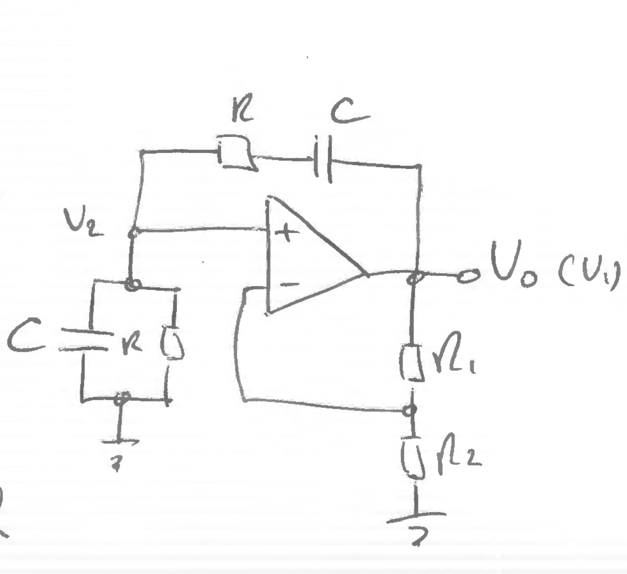
at f_{osc} $\left|\frac{V_2}{V_1}\right| = \frac{1}{3}$

d)

$$\frac{V_o}{V_2} = 1 + \frac{R_1}{R_2} = 3.$$

$$\therefore \frac{R_1}{R_2} = 2.$$

$R_1 = 1k\Omega,\ R_2 = 2k\Omega$



$$f_{osc} = \frac{1}{2\pi CR}$$

$$R = \frac{1}{2\pi f_{osc} C}$$

$C = 10nF$

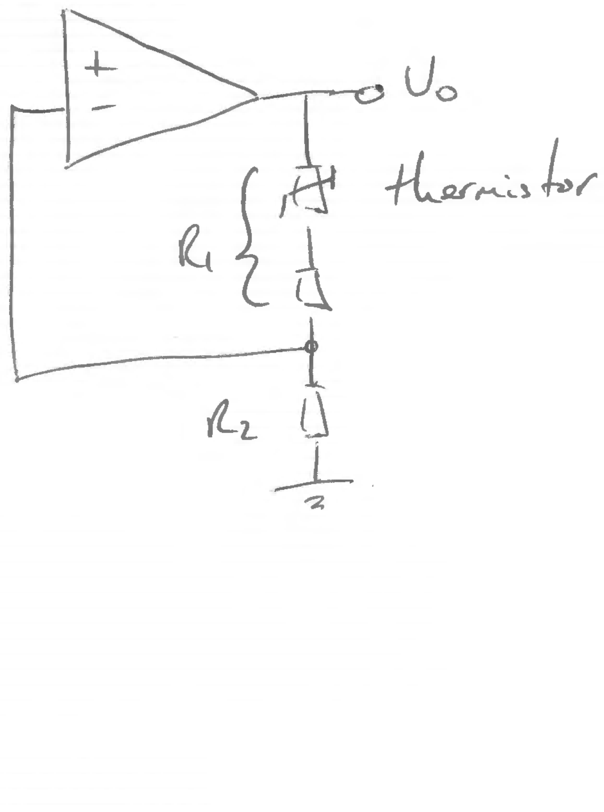
$R = 15,915\ \cancel{k}\Omega$

Q3 e7. Non-linear gain is required to ensure sustained oscillation are achieved as the circuit component values vary due to temperature and ageing.

As V_o increase the loop gain needs to decrease to maintain stability

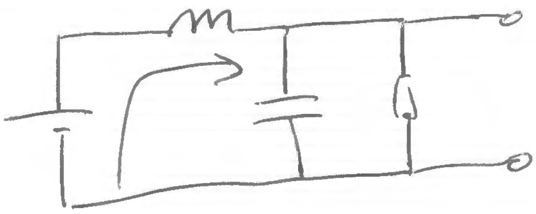
$$\frac{V_o}{V_2} = 1 + \frac{R_1}{R_2}$$

the above expression will decrease if R_1 decrease so R_1 would need to be the thermistor



4.

a) T_1 on, D off

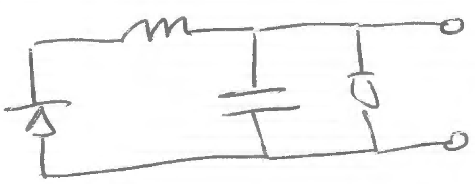


when T_1 is on energy is stored in the inductor

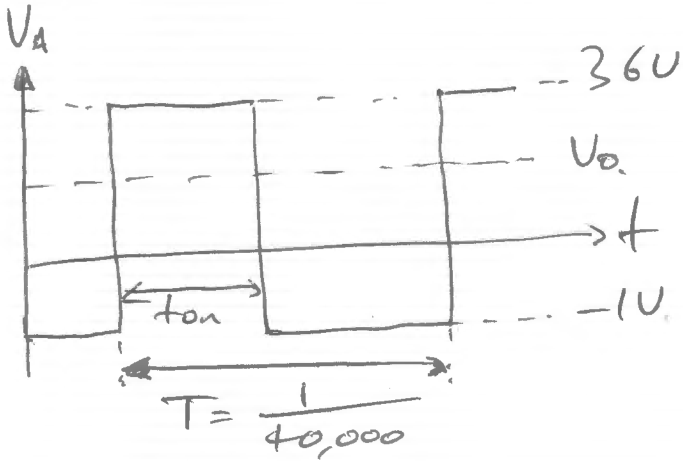
when T_1 is off energy is transferred for the inductor to the capacitor.

The inductor is the main energy storage element and the capacitor controlls the ripple voltage

T_1 off, D on



b)



$$V_o = \frac{1}{T}\int_0^T U_A(t)\,dt = \frac{1}{T}\left[U_{dc}t_{on} - (T - t_{on})\right]$$

$$t_{on} = \frac{T(V_o + 1)}{U_{dc} + 1} = \frac{6}{37}T = 4.05 \times 10^{-6}\,s$$

c) Resistor R_b is used to control the minimum value of inductor current to ensure current continuously flows in the inductor

$$I_{o\,min} = \frac{V_o}{R_b} = \frac{5}{330} = 0.015\,A.$$

Need to ensure $I_{omin} - \frac{\Delta I}{2} > 0$

$V_{dc} - V_o = L \frac{\Delta I}{t_{on}}$ $\quad \therefore \frac{\Delta I}{2} = (V_{dc} - V_o) \frac{t_{on}}{2L}$

$L > \frac{(V_{dc} - V_o) t_{on}}{2 I_{omin}}$

$> 4.18 mH.$

d) Value of C to limit $V_r < 50mV$.

$Q = \int (I_L - I_o) dt. = \frac{1}{2} \frac{T}{2} \frac{\Delta I}{2} = \frac{T \Delta I}{8.}$

$Q = C \Delta V.$

ensure that $\Delta V < V_r$.

$\Delta V = \frac{Q}{C}$ so $\frac{Q}{C} < V_r$.

or $C > \frac{Q}{V_r} > \frac{T \Delta I}{8 V_r}$.

Assume $I_{omin} = \frac{\Delta I}{2}$.

$C > \frac{T I_{omin}}{4 V_r}$

$> 1.87 \mu F.$

e) Synchronous buck converter deadtime

Dead time is required to be inserted into the MOSFET control signals to ensure that both MOSFETs do not conduct simultaneously. Should both MOSFETs conduct at the same time large pulsating currents would flow and in all likelihood they would become damage