Question 1 [20 marks]

Calculate the fan-out of the DTL gate shown in Fig. 1, assuming $V_{CC} = 5$ V, $R_1 = 2$ kΩ, $R_2 = 2$ kΩ, $R_3 = 1$ kΩ, $R_4 = 1$ kΩ, $V_{D(ON)} = V_{BE(sat)} = 0.7$ V, $V_{CE(sat)} = 0.2$ V, $\beta_F = 20$, and $\beta_R = 0.2$.

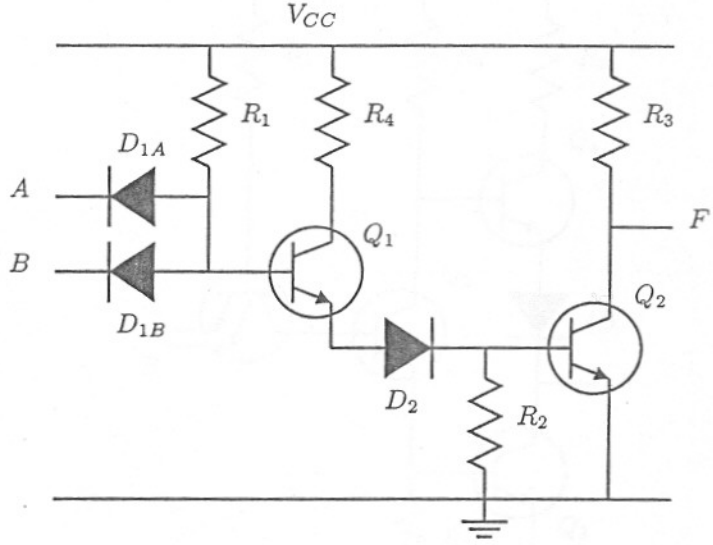

Figure 1

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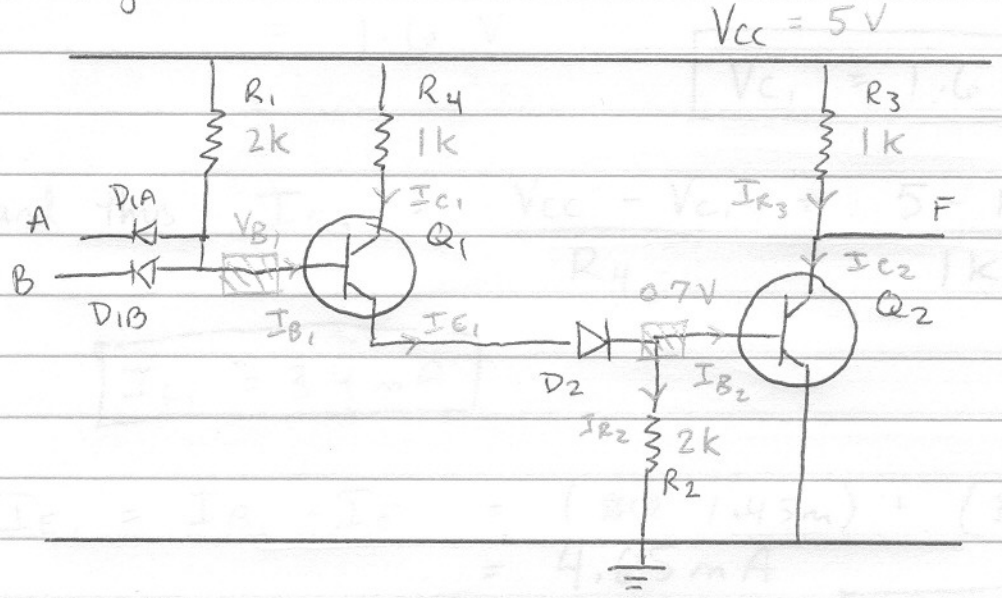
DTL gate fan-out.



$V_{D(on)} = V_{BE(sat)} = 0.7\,V$ $\quad V_{CE(sat)} = 0.2\,V$

$\beta_F = 20$

$$V_{B_1} = V_{BE(sat)_2} + V_{D_2} + V_{BE(sat)_1}$$
$$= 3(0.7) = 2.1\,V$$

$$\boxed{V_{B_1} = 2.1\,V}$$

$$I_{B_1} = \frac{V_{CC} - V_{B_1}}{R_1} = \frac{5 - 2.1}{2k} = 1.45\,mA$$

$$\boxed{I_{B_1} = 1.45\,mA}$$

Now, assuming Q_1 not saturated

$$I_{C_1} = \beta_F I_{B_1} = (20)(1.45m) = 29\,mA$$

$$\boxed{I_{C_1} = 29\,mA}$$

Check:

$$V_{B_1} = V_{CC} - R_4 I_{C_1} = 5 - (1k)(29\,mA)$$
$$\neq -24\,V$$

Therefore Q_1 IS saturated

So, $V_{C_1} = V_{BE(sat)_2} + V_D + V_{CE(sat)_1}$

$= 0.7 + 0.7 + 0.2$

$= 1.6\ V$

$\boxed{V_{C_1} = 1.6\ V}$

and thus $I_{C_1} = \frac{V_{CC} - V_{C_1}}{R_4} = \frac{5 - 1.6}{1k} = 3.4\ mA$

$\boxed{I_{C_1} = 3.4\ mA}$

$I_{E_1} = I_{B_1} + I_{C_1} = (1.45m) + (3.4m)$

$= 4.85\ mA$

$\boxed{I_{E_1} = 4.85\ mA}$

$I_{B_2} = I_{E_1} - I_{R_2}$

$I_{R_2} = \frac{V_{BE(sat)_2} - 0}{R_2} = \frac{0.7}{2k} = 0.35\ mA$

$I_{B_2} = 4.85m - 0.35m = 4.5\ mA$

$\boxed{I_{B_2} = 4.5\ mA}$

$I_{C_2(max)} = \beta_F I_{B_2} = (20)(4.5m)$

$= 90\ mA$

$\boxed{I_{C_2(max)} = 90\ mA}$

$I_{R_3} = \frac{V_{CC} - V_{CE(sat)_2}}{R_3} = \frac{5 - 0.2}{1} = 4.8\ mA$

$\boxed{I_{R_3} = 4.8\ mA}$

$I_{LOAD} = \frac{V_{CC} - V_{CE(sat)_2} - V_D}{R_1} = \frac{5 - 0.9}{2k} = 2.05\ mA$

$\boxed{I_{LOAD} = 2.05\ mA}$

$$I_{C_2(max)} = N \cdot I_{LOAD} + I_{R_3}$$

$$90\,m = N \cdot (2.05m) + (4.8m)$$

$$N = \frac{90m - 4.8m}{2.05m} = 41.56$$

$$\boxed{N = 41}$$

Q completed in 14:48