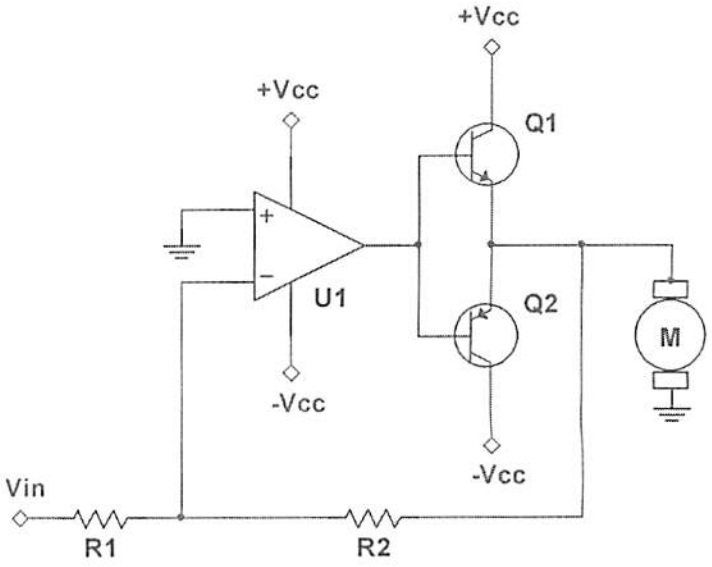
## ECE 363 (F19) QUIZ 2 NAME: Solutions

## 1 problem for 20 pts

## Push-Pull Current Booster

Design a voltage amplifier to drive a 5V DC motor with a max power consumption of 1W. The design constraints are the following:

- Use an LF356 op amp.
- Q1 is either a 2N4401 or TIP31.
  NOTE: The pnp versions are the 2N4403 and TIP32.
- 12, 18, 24, and 30 °C/W heat sinks are available
- $V_{CC}$ is either 4.5, 6, 9, or 12V
- Input impedance $Z_{IN} \geq 20$ kohm
- All resistors are 5% standard values.




(a) Perform a "quick" analysis to choose $V_{CC}$. Show all calculations!

(b) Perform a "quick" analysis and datasheets to show why Q1 should be the TIP31 rather than the 2N4401. If Q1 needs a heat sink, choose one of the available values (assume $\theta_{CS} = 0.5$°C/W and $T_A = 25$°C).

(c) Show that the op amp can provide the required output voltage and current **under worst-case transistor conditions**.

(d) Suppose the input signal is 0.2V. Choose R1 and R2 so that the motor voltage is close to -5V. Show all work! NOTE: $Z_{IN}$ = R1 for an inverting amplifier.

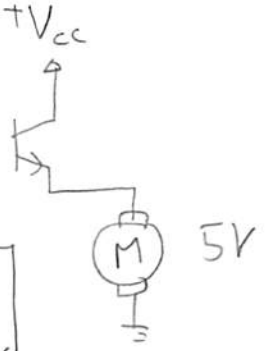
(a) DC motor → max $I_L = \frac{1W}{5V} = 0.2A$

Want: $V_{cc} > 5 + V_{CE,sat} + 2 = 7V$

+5

Assume 0 (↑ $V_{CE,sat}$) Head room (↑ 2)

⇒ Choose $V_{cc} = 9V$




(b) Max $I_L = 0.2A$ ×2 → want > 0.4A rating

$P \sim \frac{.2A}{101}(0.7) + 0.99(0.2A)(9-5) = 0.793W$ ×2 → want 1.587W rating or more

Max $V_{CE} = 9 - (-5) = 14V$ ×2 → 28V rating or more

(extra sheet for work)

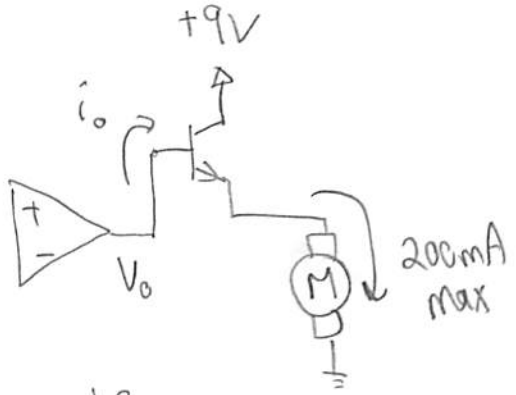
+6

| | Max $I_c$ | $P_{rating}$ (no HS) | $P_{rating}$ (w/HS) | $V_{CE}$ | |
|---|---|---|---|---|---|
| 2N4401 | .6A ✓ | .625W X | 1.5W X | 40V ✓ | Choose TIP31 |
| TIP31A | 1A ✓ | 2W ✓ | 40W ✓ | 40V ✓ | No HS needed. |

↑ > 1.587W rating

(c)

$\text{Max } V_o = 5 + V_{BE,max}$




$$\frac{\text{Typ } V_{BE}}{\text{Max } V_{BE}} = \frac{0.7V}{?} = \frac{1.2V}{1.8V}$$

@ .2A @ 3A

$$\Rightarrow \text{Max } V_{BE} = \frac{1.8}{1.2} \times .7 = 1.05V$$

$\rightarrow$ Max $V_o = 5 + 1.05 = \underline{6.05V}$

$$\frac{\text{Typ } \beta}{\text{Min } \beta} = \frac{65}{25} = \frac{150}{?} \Rightarrow \text{min}\beta = \frac{25}{65} \times 150 = 57.7$$

@ 1A

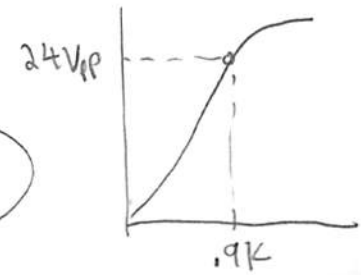
$$\Rightarrow \text{Max } i_o = \frac{200\,mA}{57.7} = \underline{3.47mA}$$

op amp head room = $9 - 6.05 = \underline{2.95V}$ @ 3.47mA

+6

$V_{cc} = 15V \rightarrow 15 - 2.95 = \underline{12.05V} = 13.4mA$ ✓ (.9K)

TES!




(d) $\frac{V_{OUT}}{V_{IN}} = -\frac{R_2}{R_1} = \frac{-5V}{0.2} = 25$

$R_1 = 22K$

$R_2 = 560K$

Gain = $\frac{560K}{22K} = 25.46$ (1.8% error)

+3