EE 414 INTRODUCTION TO ANALOG INTEGRATED CIRCUITS

Take Home Exam 2
Due: 23:55 on April 07, 2019
(ODTÜClass)

Reference Circuits

Q1. Figure 1 shows the low voltage band-gap reference circuit. W/L ratios of M_1, M_2 and M_3 transistors are same, emitter area ratio between Q_1 and Q_2 is 1:8. Also, assume $r_o = \infty$ and $A=\infty$. Ignore base current of BJT`s.

a) Derive the output voltage expression.

b) According to expression in part (a), determine the ratios of R_3/R_1 and R_2/R_1 to provide 0.5V temperature independent output voltage. (Take V_{DD}=1 V, V_{BE1}=0.7 V, V_t= 25 mV and M factor is 23.5, $M=(R_2/R_1)\ln(n)$.)

c) Explain intuitively (with hand calculation if possible) how the PTAT-reference circuit in the BGR can be stable. Consider two feedback loops formed by the op-amp given that one is positive feedback and the other negative. Is R_1 critical in your argument?

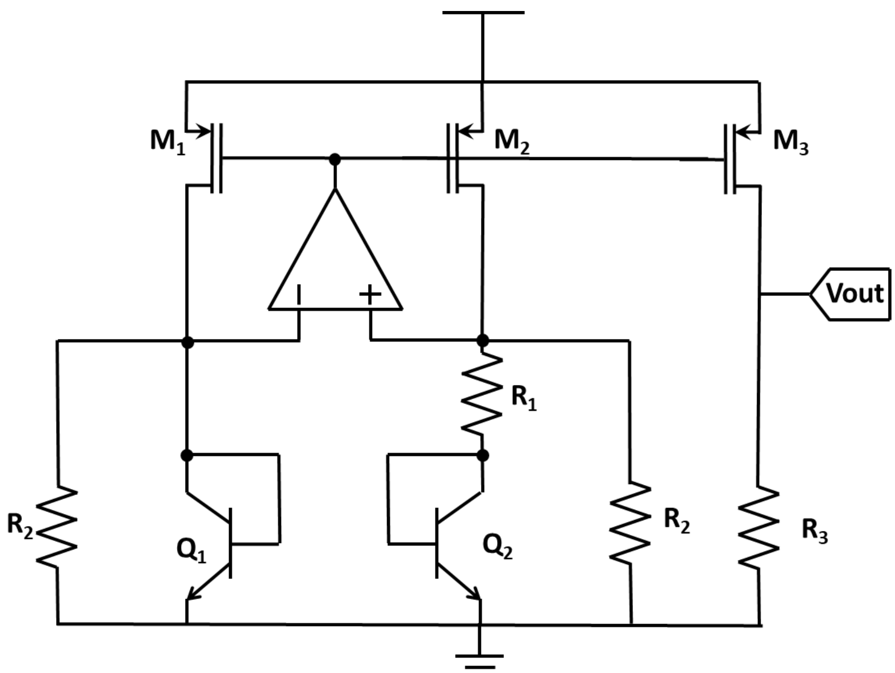

Figure 1. Low voltage band-gap reference circuit.

Q2. Figure 2 shows a band-gap reference circuit (BGR). Emitter area ratio between Q_1 and Q_2 is n:1. Answer the following questions.

a) Ignore base currents of the of BJT`s and derive a closed-form expression for V_{out}. Find the ratio between R_1 and R_2 to get temperature independent BGR at 300K (Take dV_{BE}/d_T = -1.5 mV/K at 300K).

b) Now, don`t ignore base currents of Q_1 and Q_2 transistors and find expression for R_3 resistor for eliminate the error due to base currents.

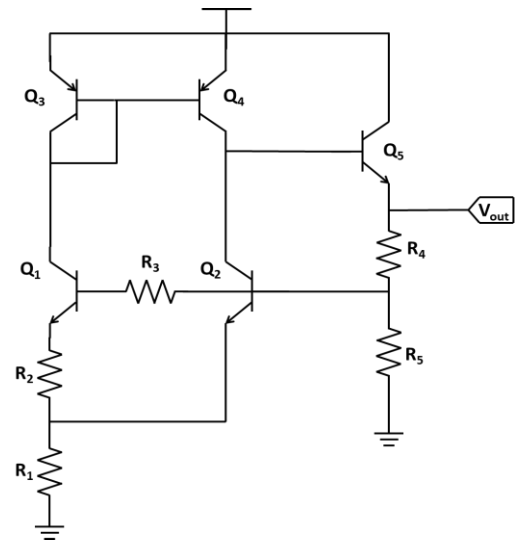

Figure 2. Band-gap reference circuit