(20%) 1. (a) In Fig.1a, a Widlar current source consists of one resistor and two identical MOSFETs M_1 and M_2. Assume that $K = \frac{\mu_n C_{ox}}{2}\left(\frac{W}{L}\right)_{M1,M2}$, please derive I_O as a function of I_{REF}, K, and R. (10%)

(b) A Widlar current source which consists of one resistor and two identical BJTs(Q_1, Q_2) is shown in Fig.1b. Let I_{REF} = 1mA, R = 10kΩ, and the thermal voltage V_T = 25mV, please calculate the output current I_O by iterative approach. Your answer should be expressed in μA and accurate to one decimal place. (10%)

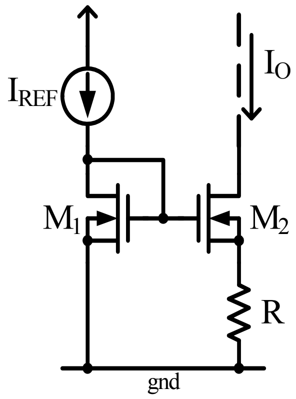

Fig.1a

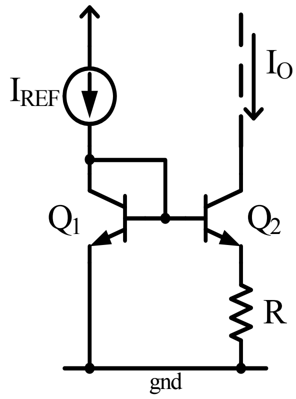

Fig.1b

(15%) 2. (a) Fig.2a shows the output stage of the 741 without the protection circuitry. Assume that Q_{13A} delivers a current of 180μA to the network, and R_{10} = 40kΩ. If we neglect the base currents of Q_{14} and Q_{20}, and assume V_{BE18} is approximately 0.6V at first. Please find the bias currents I_{C18}, I_{C19}, and I_{C14}, where V_T = 25mV, β_{Q18}=200, $I_S=3\cdot10^{-14}$A for Q_{14} and Q_{20}, and $I_S=10^{-14}$ A for other BJTs. (10%)

(b) If we use two diode-connected BJTs Q_1 and Q_2 to establish the voltage between the bases of the output BJTs Q_{14} and Q_{20}, as shown in Fig.2b, find the I_{C14}. (5%)

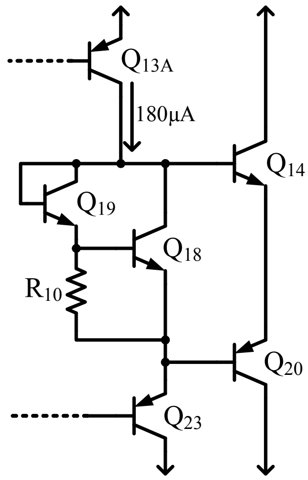

Fig.2a

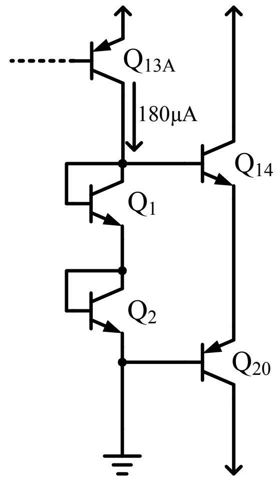

Fig.2b

(15%) 3. Draw a basic circuit of a 3-bit DAC utilizing an R-2R ladder network, and describe its operation.

(15%) 4. Briefly explain (a) full-power bandwidth (b) Stagger-tuned amplifier (c) Barkhausen criterion

(20%) 5. (a) Explain why the circuit shown in Fig.5 acts as a resistor. How does the stray capacitance affect this circuit? (10%)

(b) Sketch two kinds of stray-insensitive switched-capacitor integrators (both inverting and non-inverting) (10%)

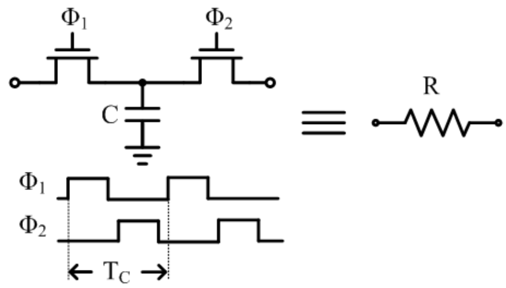

Fig.5

(15%) 6. Consider a 2nd-order Butterworth low-pass filter with ε = 0.5. Assume that its passband edge is ω_p, and its stopband edge $\omega_s = 10\cdot\omega_p$. (Butterworth transmission function= $\frac{1}{\sqrt{1+\varepsilon^2(\frac{\omega}{\omega_p})^{2N}}}$)

(a) Find the maximum allowed variation in passband transmission A_{max} and the minimun required stopband attenuation A_{min}. Your answers should be expressed in dB. (10%)

(b) Derive the normalized polynomial T(s). (5%)