

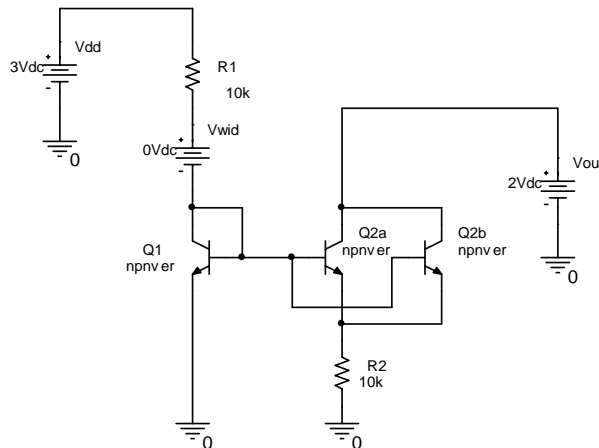
Lab4 – Current and voltage references

Lab assignment:

Design a bootstrap current reference based on the NPN Widlar cell. The output current of the reference should be $50\mu\text{A}$, compensated against supply voltage variations. Use the PTAT output current to implement a bandgap voltage reference whose temperature coefficient is zero at room temperature. Design the circuit for the given specifications. For simplicity, consider all resistors temperature independent.

1. The Widlar PTAT current reference with NPN transistors

The test schematic:

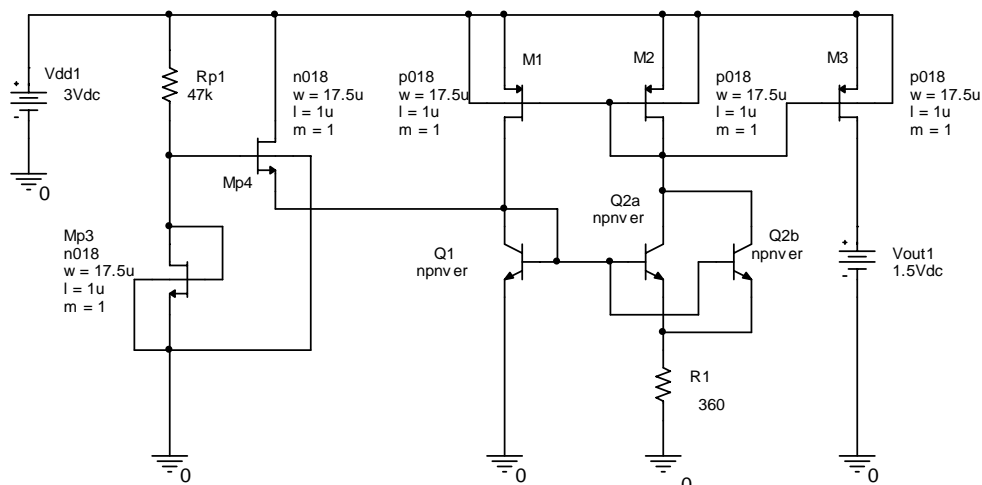


Proposed exercises:

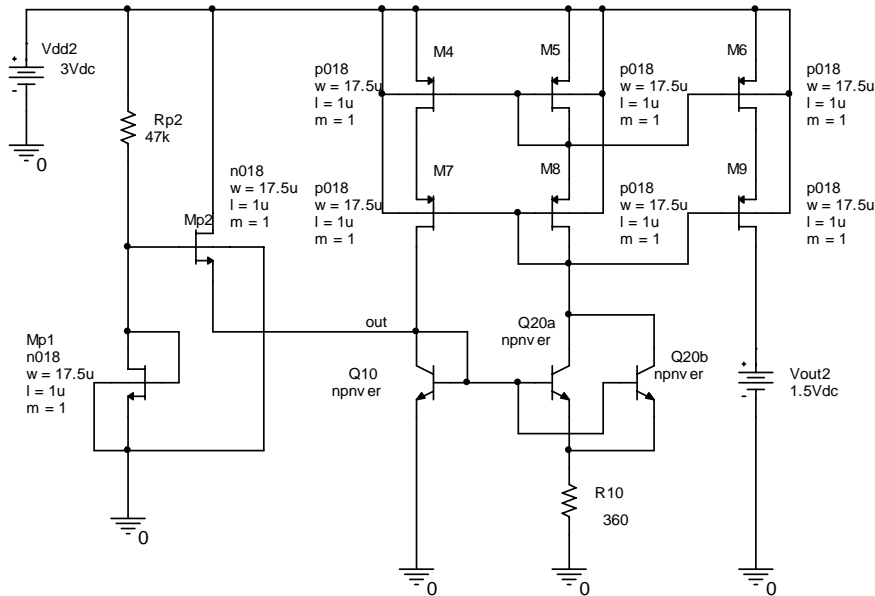
1. Size the resistors in order to set the output current to $I_{\text{out}}=50\mu\text{A}$ at $T=300\text{K}$.
2. Simulate and adjust component operating points.
3. Determine the sensitivity of the output ($I(V_{\text{wid}})$) and input ($I(V_{\text{out}})$) currents with the supply voltage V_{dd} . (for sensitivity analysis setup check the appendix to this document).
4. Plot the variation of the output current with temperature. Is it PTAT?

2. The Widlar bootstrap current reference

The test schematics (simple and cascode mirrors):



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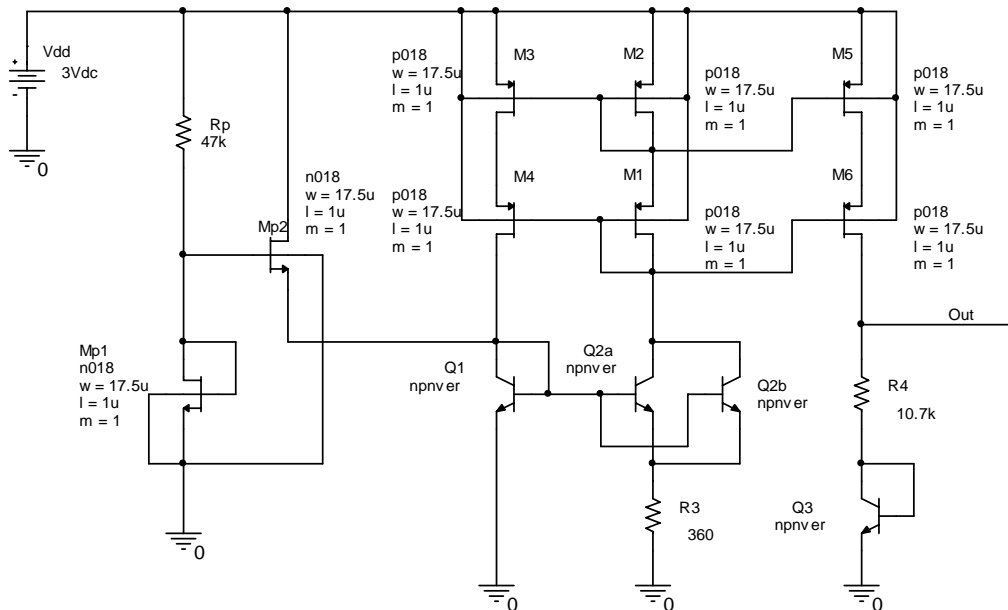


Proposed exercises:

5. Size the MOS transistors in the circuit for $I_D=50\mu\text{A}$ and $V_{od}=250\text{mV}$.
6. Simulate the OP of the devices and adjust the schematic in order to meet the specifications.
7. Determine the sensitivity of the output current with the supply voltage V_{DD} . Compare the sensitivities of bootstrap and Widlar references. Find a method to decrease sensitivity and repeat simulations (Hint: replace the simple PMOS mirror with the cascode version)

3. The Song bandgap reference

The test schematic:



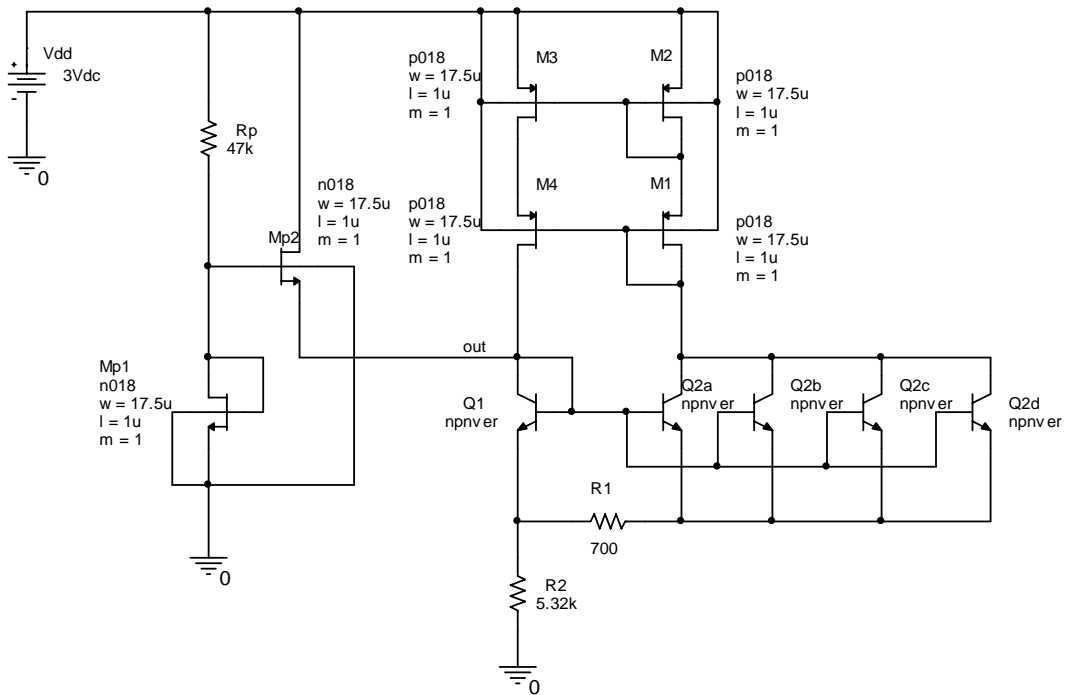
Proposed exercises:

8. Determine the expression of the output voltage.
9. Size the resistor R_4 on the output branch of the reference according to the equations from the previous exercise. The temperature coefficient will be canceled at 300K.

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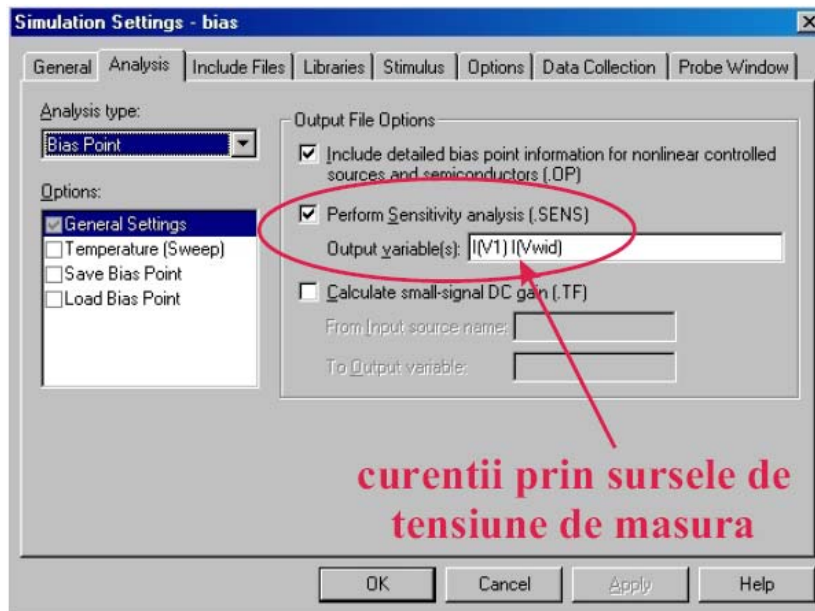
10. Simulate the operating points of the components and adjust the schematic in order to meet specifications (the PTAT current should be $50\mu\text{A}$).
11. Plot the variation of the output voltage against temperature. Change the temperature in the range $(-40^{\circ}; +100^{\circ})$ and adjust the circuit in order to obtain $\text{TC}=0$ at 300K . Determine the temperature coefficient of the reference.
12. Plot the variation of the output voltage against changes of the supply voltage V_{DD} . Measure the sensitivity for a $\pm 10\%$ swing around the nominal 3V .

HOMEWORK: design the Brokaw bandgap voltage reference in the schematic below. The nominal current through the circuit branches will be $50\mu\text{A}$, while the bipolar transistor area ratio should be chosen $N=4$.



Analiza de senzitivitate

- Analiza de senzitivitate ține de **bias point**
- Spice știe să măsoare un curent **numai printr-o sursă de tensiune**. Drept urmare, pentru a calcula senzitivitatea unui curent pe ramura de circuit străbătută de curent se inserează un VDC de valoare 0 pentru măsură.



Rezultatul analizei de senzitivitate – din Output File

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DC SENSITIVITIES OF OUTPUT I(V_V1)

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ELEMENT NAME	ELEMENT VALUE	ELEMENT SENSITIVITY (AMPS/UNIT)	NORMALIZED SENSITIVITY (AMPS/PERCENT)
R_R1	4.778E+04	6.121E-10	2.925E-07
R_R2	3.600E+02	5.672E-08	2.042E-07
V_V1	2.000E+00	-2.989E-07	-5.979E-09
V_Vwid	0.000E+00	1.223E-05	0.000E+00
V_VCC	3.000E+00	-1.223E-05	-3.668E-07
Q_Q1			
RB	0.000E+00	0.000E+00	0.000E+00
RC	5.000E+01	-1.457E-11	-7.283E-12
RE	0.000E+00	0.000E+00	0.000E+00
BF	1.500E+02	-1.289E-09	-1.933E-09
ISE	3.500E-15	3.705E+06	1.297E-10
BR	2.000E+00	-1.148E-21	-2.296E-23
ISC	1.000E-15	7.211E-07	7.211E-24
IS	3.108E-15	9.285E+09	2.886E-07

În exemplul din figură senzitivitatea curentului $I(V_V1)$ cu V_{CC} este de $-12.2\mu A/V$

Variația tensiunii cu temperatura

Se rulează o analiză .DC în funcție de temperatură. După terminarea simulării afișați în mod obișnuit curentul sau tensiunea de interes.

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