LDO for a DPLL Chip

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Pursuing the Unknown

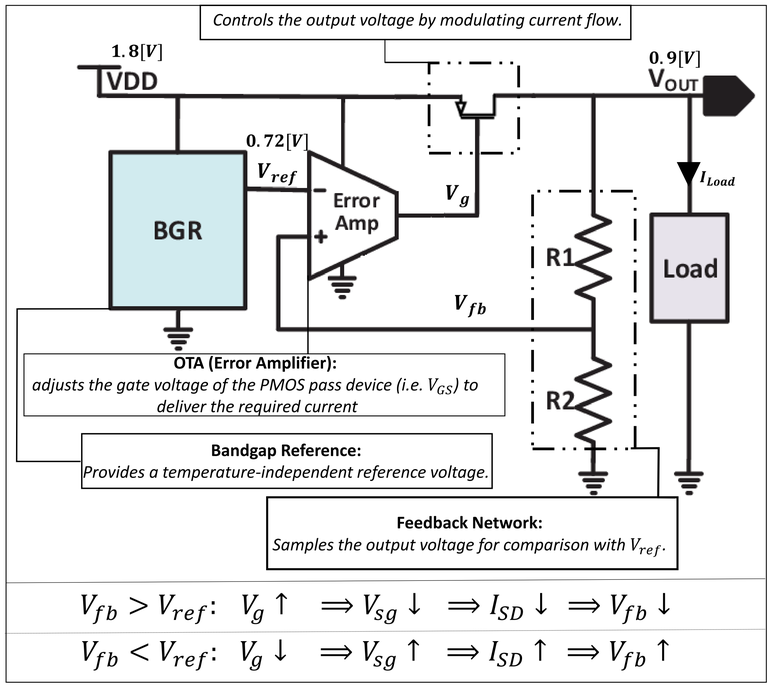
DPLL 2024/25

Motivation & Objective

To ensure low phase noise and precise timing, the DPLL needs a stable, low-noise supply. Our LDO is designed to provide a consistent output voltage across supply and temperature variations, tailored specifically for DPLL requirements.

Operating Principle

Internal architecture of the LDO:



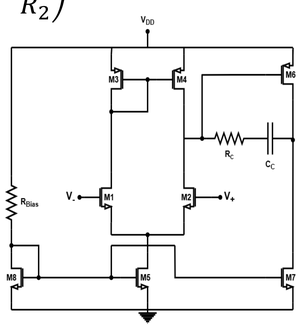
The regulated output voltage is given by:

$$V_{out} = V_{ref}\left(1 + \frac{R_1}{R_2}\right)$$

Miller OTA as an Error Amplifier:

In BGR, forces $V_A = V_B$ to generate a temperature-independent current.

In LDO, used as a current regulator that stabilizes V_{out}. High gain ($\sim 80dB$) improves accuracy and regulation.



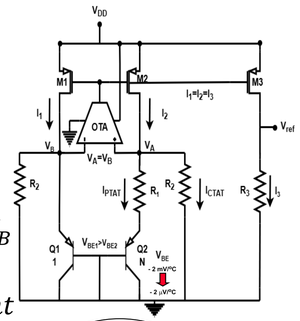
The Bandgap Reference

The bandgap reference generates a precise, temperature-independent voltage.

$$V_A = \frac{kT}{q} ln\left(\frac{I}{N \times I_s}\right) + IR_1 = \overbrace{\frac{kT}{q} ln\left(\frac{I}{I_s}\right)}^{V_{BE1} = V_{CTAT}} = V_B$$

$$I = \frac{V_{BE1} - V_{BE2}}{R_1} = \frac{kT}{qR_1}\ln(N) \rightarrow PTAT\ current$$

$$V_{ref} = R_3(I_{PTAT} + I_{CTAT}) = R_3\left(\frac{\ln(N)V_T}{R_1} + \frac{V_A}{R_2}\right) \rightarrow \frac{\partial V_{ref}}{\partial T} = 0$$



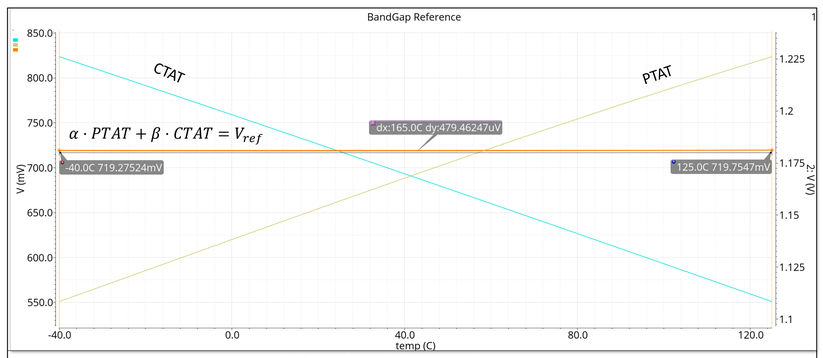


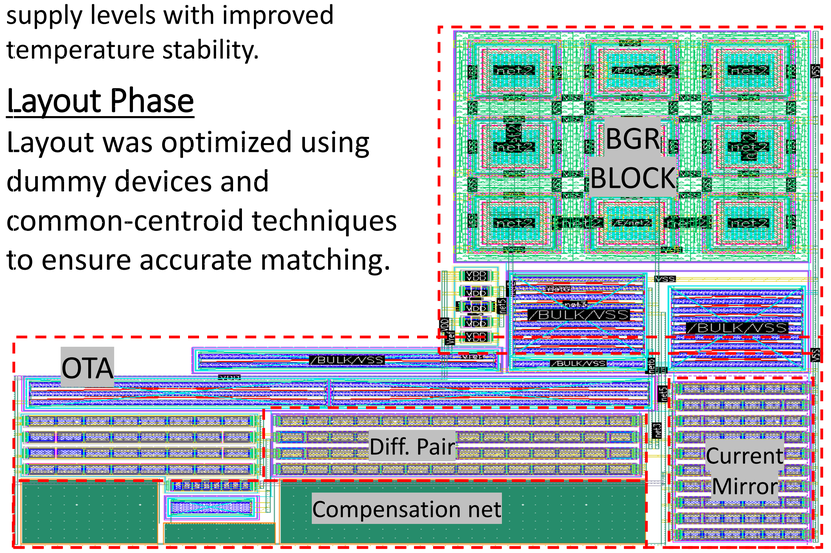
figure 1: Operating principle of the Bandgap reference
PTAT – **Proportional** to temperature coefficient ; CTAT – **Complementary** to temperature coefficient

Implementation

The LDO, designed in TSMC 28nm with a two-stage OTA and modified bandgap (0.72V), reliably regulates 0.9V across varying loads and supply levels with improved temperature stability.

Layout Phase

Layout was optimized using dummy devices and common-centroid techniques to ensure accurate matching.



Results

The following table summarizes three critical performance metrics of the LDO:

Metric	Definition	Requirement	Achieved
Temperature Coefficient	$\frac{dV_{out}}{dT}$ (ppm/°C) Stability against temperature variation	< 60	5.8 (↑10.3×)
Line Regulation	$\frac{\Delta V_{out}}{\Delta V_{DD}}$ (V/V) Stability against supply variation	< 0.01	0.001 (↑10×)
Load Regulation	$\frac{\Delta V_{out}}{\Delta I_{load}}$ (mV/mA) Stability against load current variation	< 0.1	0.0044 (↑22.7×)

Table 1: Summary of the three critical performance metrics of the LDO.

Our LDO maintains excellent voltage output stability against variations in load current, supply voltage, and temperature:

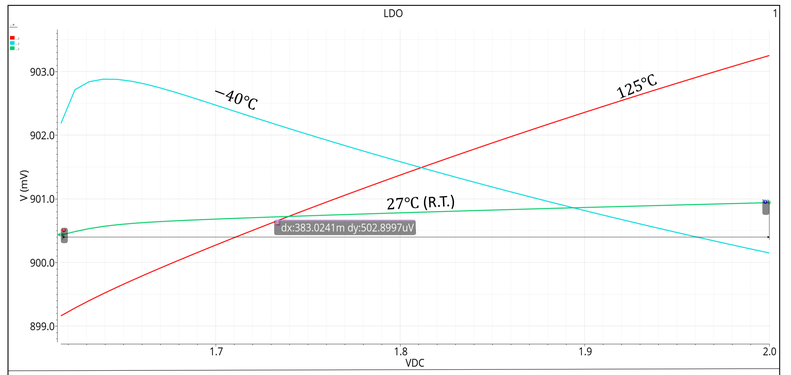


figure 2: V_{out} against Supply Voltage for different temperatures

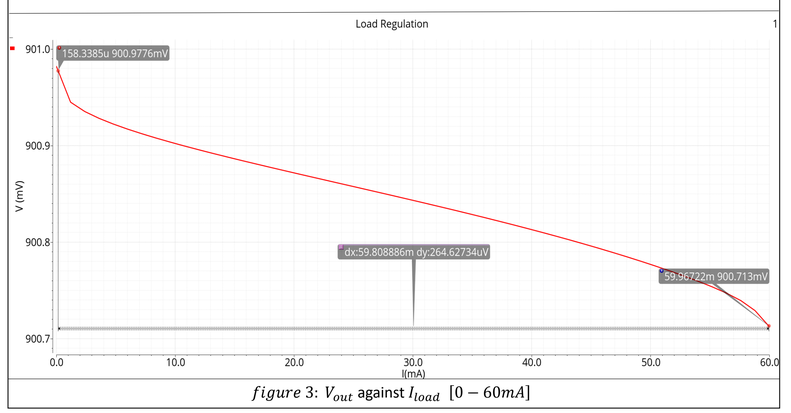


figure 3: V_{out} against I_{load} $[0 - 60mA]$