LOW DROP OUT VOLTAGE REGULATOR CIRCUIT

Required Specs for LDO:

Technology	180nm
Vout	1.8V
Supply Voltage	2V – 3.3V
I_{load}	0.5 – 10mA
Vref (Vinput)	1.2V
$I_{(feedback)}$	20µA
Iop (Operating Current)	250 µA
Phase Margin	≥ 60º
UGB	≥ 5MHz

LDO Voltage Regulator: Theory

A **Low Dropout Voltage Regulator (LDO)** is a linear voltage regulator that provides a stable, regulated output voltage while operating with a small voltage difference (dropout voltage) between the input and output. It is widely used in power management systems for its simplicity, low noise, and efficient regulation under low headroom conditions.

Key Features

1. **Dropout Voltage (V_{DO}):**
   The minimum voltage difference between input (Vin) and output (Vout) required for the regulator to maintain proper regulation. Typically in the range of tens to hundreds of millivolts.
2. **Regulated Output Voltage (Vout):**
   LDO maintains a constant Vout regardless of variations in Vin, load current (Iload), or temperature.

Operating Principle

1. **Error Amplifier:**
   Compares the output voltage (Vout) to a stable reference voltage (Vref) generated by a Bandgap Reference. It amplifies the error signal to control the pass transistor.
2. **Pass Transistor:**
   Acts as a variable resistor (PMOS or NMOS) to regulate the current flow from Vin to Vout, maintaining a stable output voltage.
3. **Feedback Network:**
   A resistive voltage divider provides feedback from Vout to the error amplifier for closed-loop regulation.

Advantages

1. Low noise, making it suitable for analog and RF circuits.
2. Simple design compared to switching regulators.
3. High power supply rejection ratio (PSRR), reducing noise from the input supply.
4. Compact, with fewer components.

Applications

1. **Power Management in ICs:** Supplies power to analog and digital blocks requiring low noise and stable voltage.

2. **Portable Electronics:** Used in battery-operated devices for efficient regulation under low headroom conditions.
3. **RF Systems:** Ensures clean and stable power supply for sensitive RF circuits.
4. **Precision Analog Systems:** Drives operational amplifiers, ADCs, and DACs with stable and noise-free voltage.

Using Balanced Amplifier in LDO Regulator:

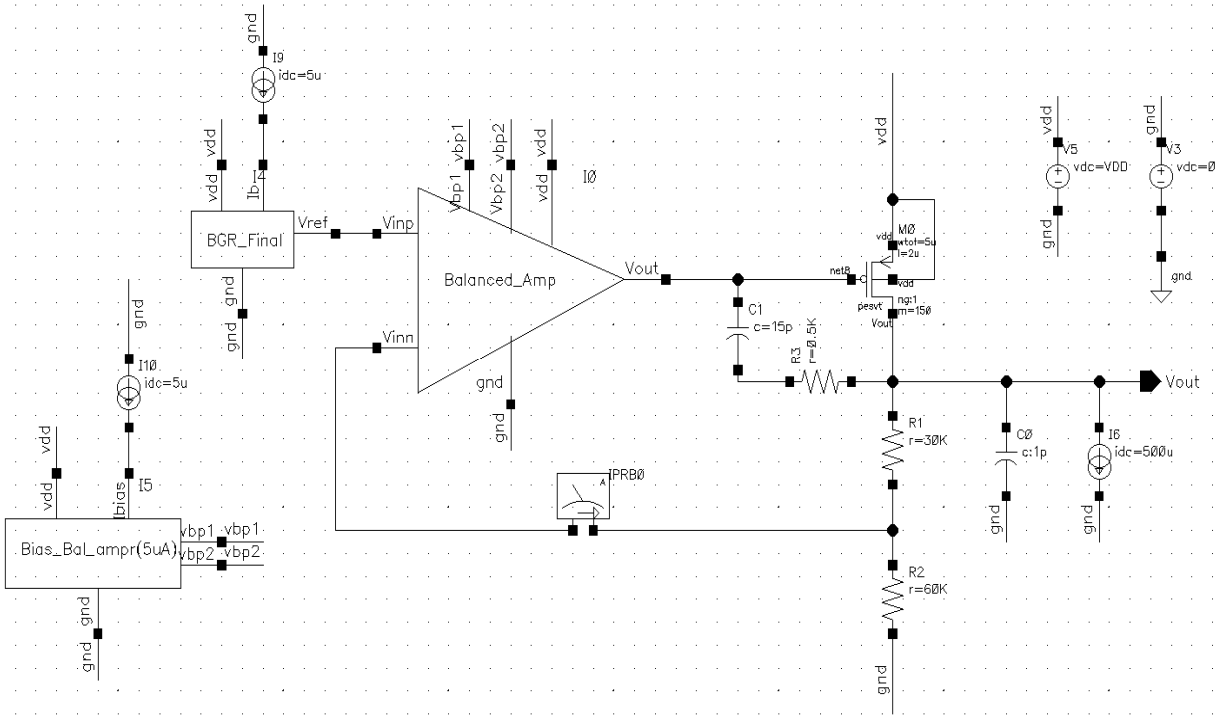
Role of Balanced Amplifier in LDO:

- **Error Amplification:**
  The balanced amplifier in an LDO acts as an **error amplifier** that compares the regulated output voltage (Vout) with a reference voltage (Vref) generated by a bandgap circuit. It amplifies the error signal and adjusts the gate voltage of the pass transistor (usually a PMOS or NMOS device) to maintain the desired output voltage.
- **Improved Power Supply Rejection Ratio (PSRR):**
  The balanced amplifier ensures the rejection of common-mode noise from the power supply, which is critical for achieving high PSRR in LDO circuits.
- **High Gain for Regulation:**
  To achieve accurate regulation and minimize output voltage deviations due to load or supply changes, the balanced amplifier provides high differential gain.
- **Transient Response and Stability:**
  The balanced amplifier plays a key role in shaping the loop gain and phase response of the LDO. Proper design ensures fast transient response and stability across varying load conditions.
- **Load Regulation:**
  By amplifying the difference between Vout and Vref, the balanced amplifier enables precise control over the output voltage, even under dynamic load conditions.

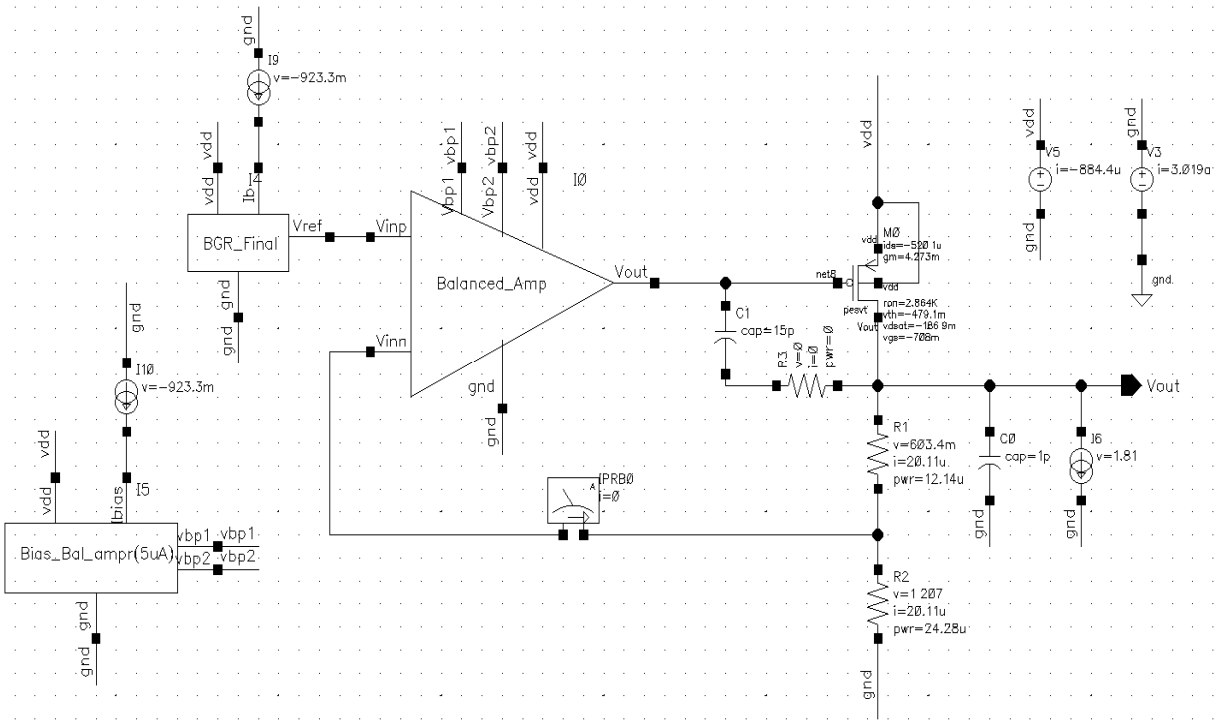
Why Balanced Amplifiers Are Ideal for LDO Circuits:

- **High linearity** for accurate error detection.
- **High PSRR** to suppress noise from the input supply.
- **High CMRR** to handle input and output variations effectively.
- **Precision and stability** ensure consistent voltage regulation across load and temperature variations.

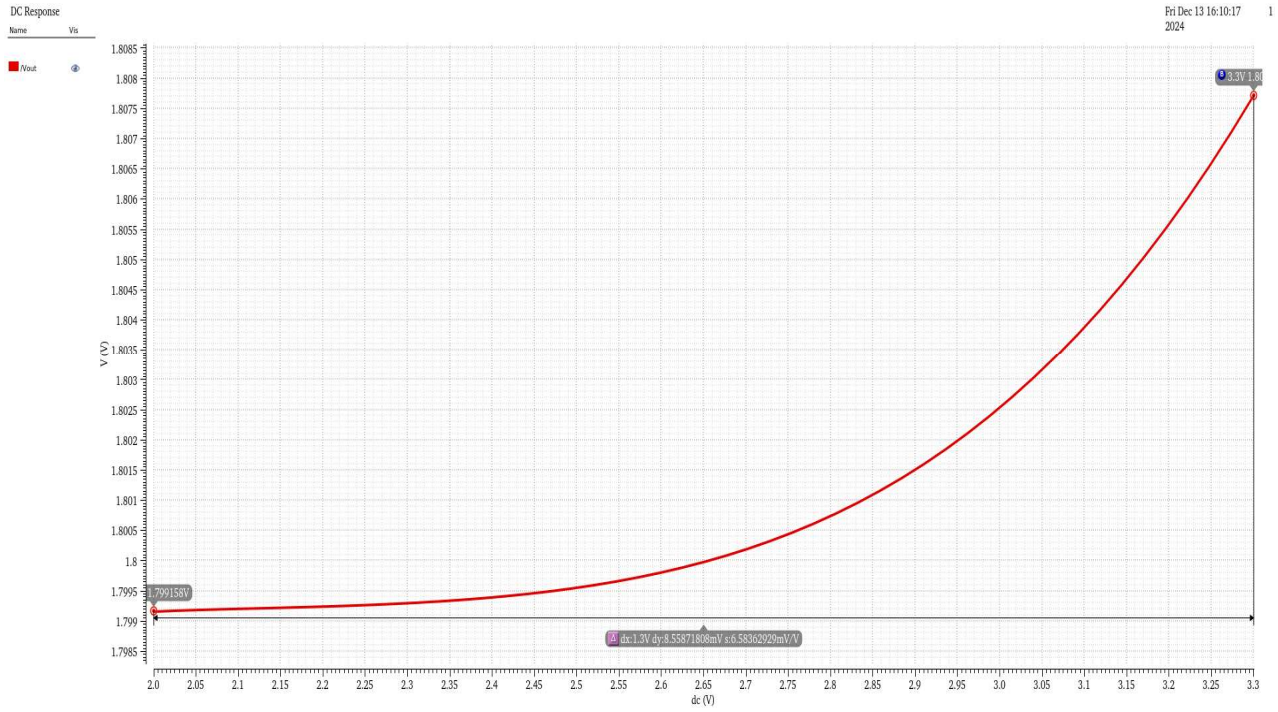
LDO Regulator Schematic:



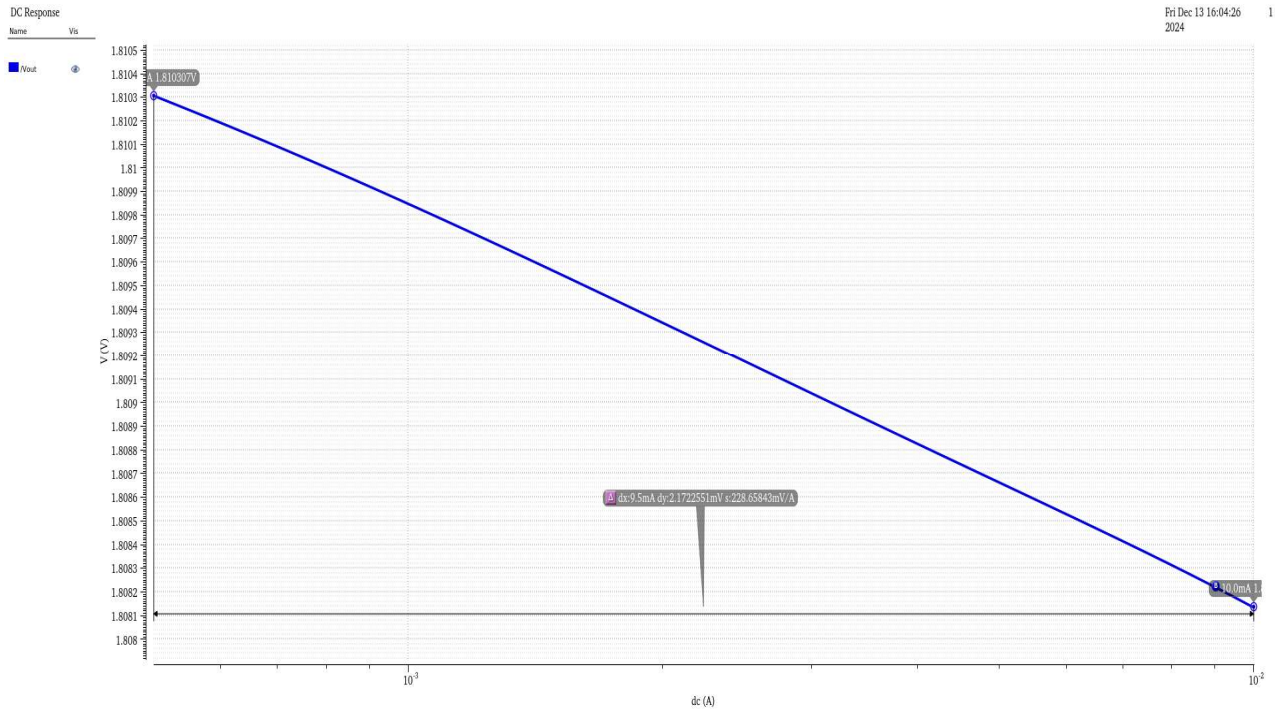
Schematic with DC op point:



Simulation (LDO Line Regulation):



LDO Load Regulation:



Stability Summary:

Required v/s Achieved Specs for the LDO Regulator:

	Required	Achieved
Vout	1.8V	1.807V
Vout Range (Vdd variation)	-	8.55 mV
Vout Range (Load variation)	-	2.17 mV
Phase Margin	$\geq 60^{o}$	63.85^{o}
UGB	$\geq$ 5MHz	5.735 MHz