BAND-GAP REFERENCE BIAS CIRCUIT

BGR Bias Circuit: Theory

A **Bandgap Reference (BGR) circuit** generates a stable, temperature-independent reference voltage, typically close to 1.2V for silicon, making it an essential building block in analog and mixed-signal IC design. This stability is crucial for biasing other circuit components like operational amplifiers, ADCs, and voltage regulators.

Operating Principle

The BGR circuit combines two temperature-dependent voltages with opposite temperature coefficients:

1. **Base-Emitter Voltage (V_{BE}):**
   A PN junction voltage with a **negative temperature coefficient (TC)** of approximately -2 mV/°C.
2. **Thermal Voltage (V_T):**
   A proportional-to-absolute-temperature (PTAT) voltage with a **positive temperature coefficient**.

$$V_T = kT/q$$

By summing a scaled PTAT voltage ($m*V_T$) and V_{BE}, the resulting voltage cancels the temperature dependence:

$$V_{ref} = V_{BE} + m*V_T$$

Key Components

1. **Bipolar Junction Transistors (BJTs):** Generate V_{BE} and V_T.
2. **Resistors:** Scale the PTAT voltage and set bias currents.
3. **Operational Amplifier (Optional):** Ensures proper biasing and improves stability.

Features of a Bandgap Reference

- **Temperature Independence:** Achieves a low temperature coefficient, typically in the range of a few ppm/°C.
- **Supply Independence:** High power supply rejection ratio (PSRR) ensures stability against supply variations.
- **Process Scalability:** The design is robust to process variations, making it suitable for various CMOS and bipolar processes.

Applications

1. Biasing circuits in analog ICs (e.g., operational amplifiers, comparators).
2. Reference voltage generation for ADCs, DACs, and voltage regulators (LDOs).

3. Power management systems for stable operation across temperature and supply variations.

Advantages

- Highly stable voltage output.
- Temperature independence over a wide range.
- Minimal sensitivity to supply noise and process variations.

Using Balanced Amplifier in BGR:

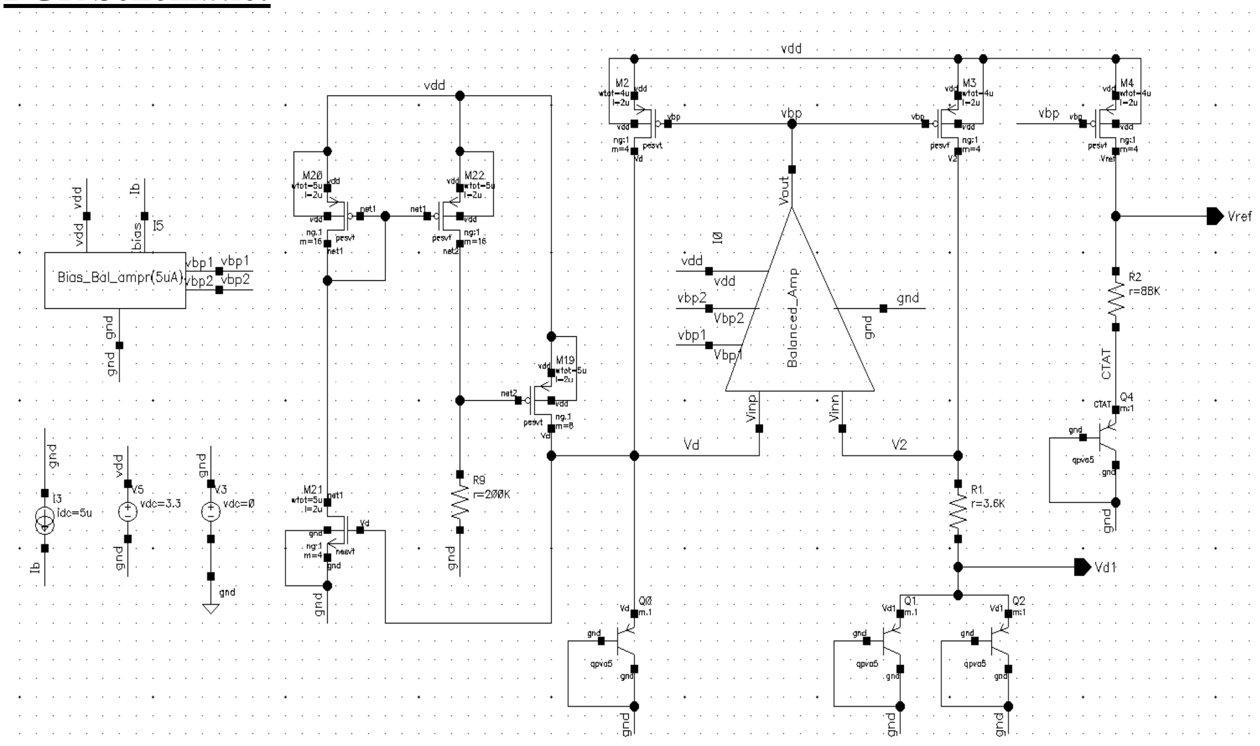
Role of Balanced Amplifier in BGR:

- **Error Amplification:**
  In a BGR circuit, the balanced amplifier is often used to amplify the difference between two voltage signals, which are typically derived from the temperature-dependent base-emitter voltages (VBEV_{BE}VBE) of two bipolar junction transistors (BJTs) or parasitic diodes. The goal is to maintain a precise relationship between these voltages for temperature compensation.
- **Improved Common-Mode Rejection:**
  Since BGR circuits are susceptible to noise and variations in supply voltage (e.g., power supply ripple), the balanced amplifier rejects common-mode disturbances, ensuring stable operation.
- **High Gain for Accuracy:**
  The balanced amplifier provides high differential gain, which ensures accurate control of the feedback loop, maintaining the desired reference voltage with minimal offset and drift.
- **Layout Symmetry for Precision:**
  Symmetrically designed balanced amplifiers minimize mismatches in current mirrors or resistors, leading to better temperature stability and reduced offset voltage in the BGR circuit.

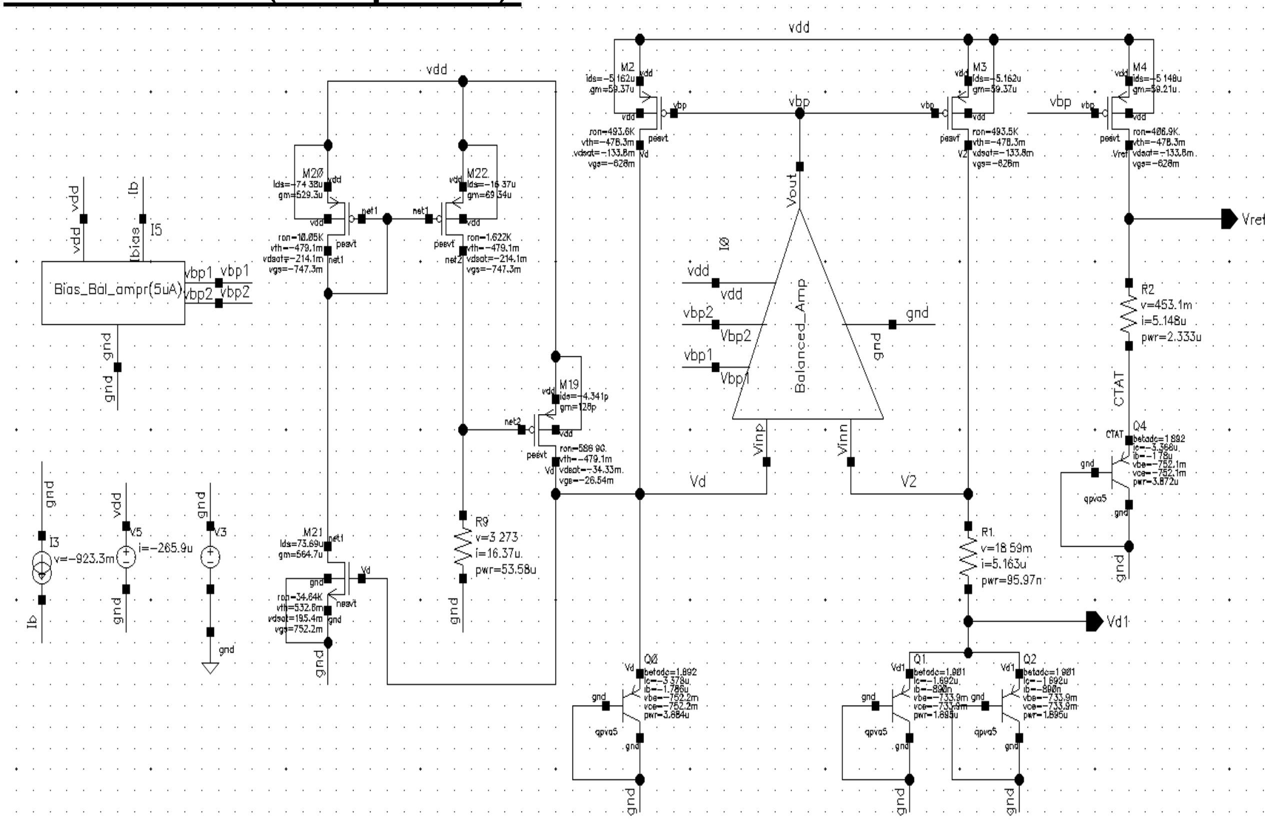
Why Balanced Amplifiers Are Ideal for BGR:

- High **common-mode rejection ratio (CMRR)** for rejecting supply noise.
- Precise matching ensures temperature stability of the reference voltage.
- Low distortion ensures a linear relationship between circuit components.

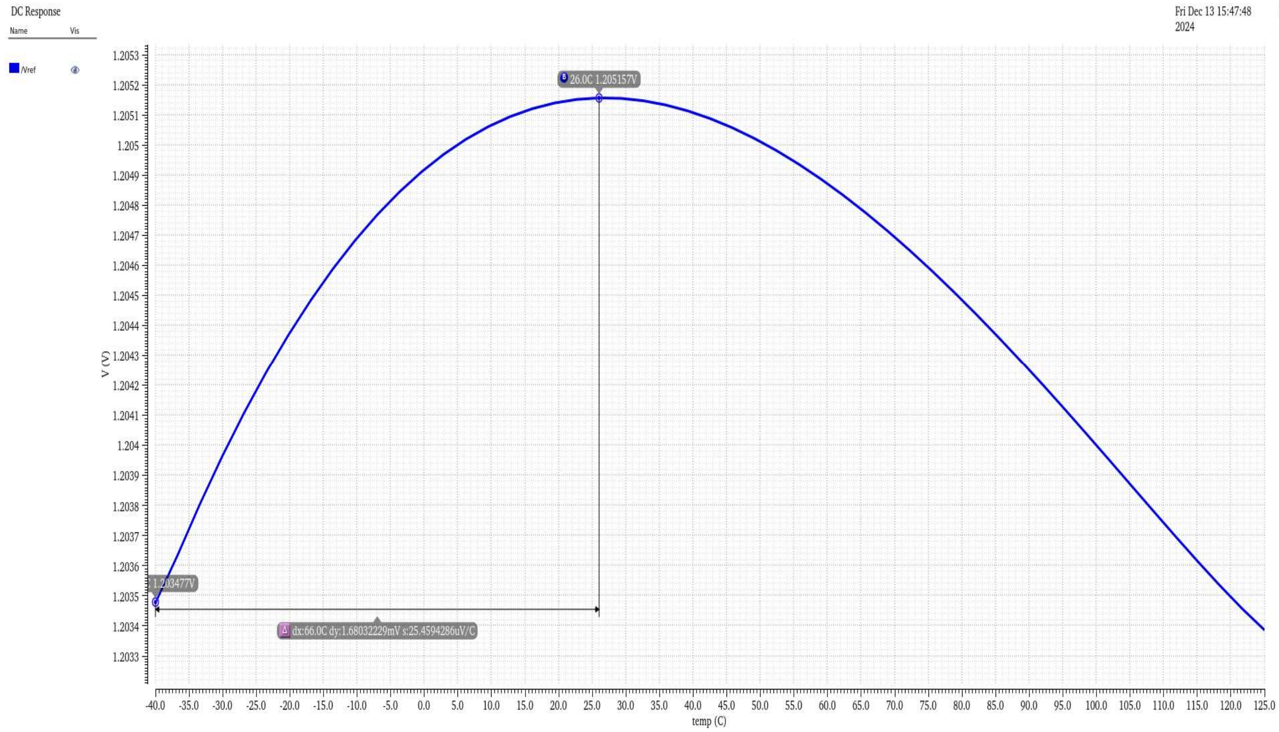
BGR Schematic:



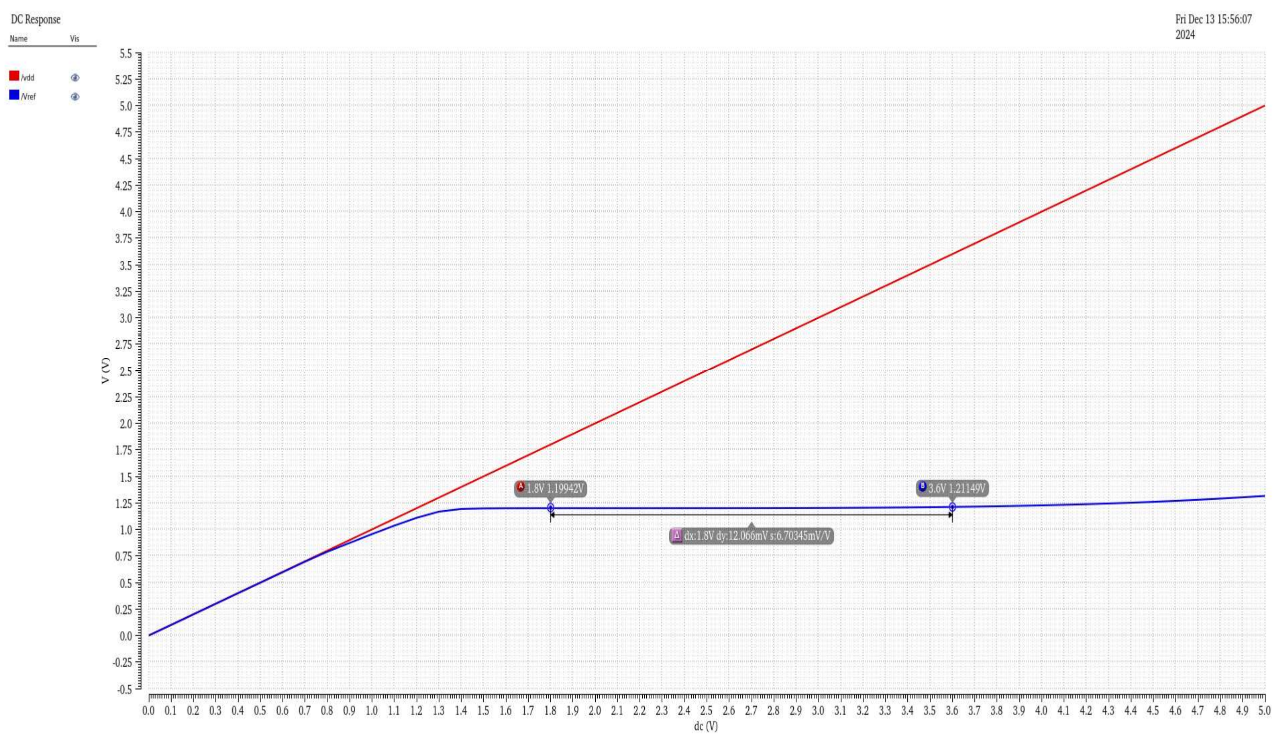
BGR Schematic (DC Op. Point):



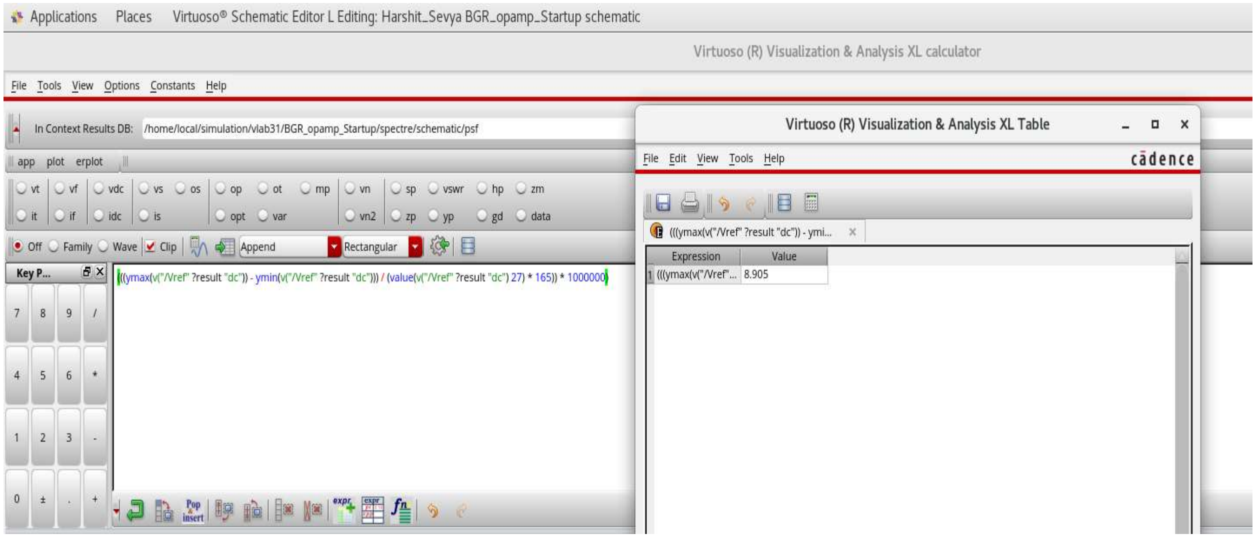
Simulation (Temp. Variation):



Supply Voltage Variation:



Tempco. Calculation:



Observations:

Vref	1.2V
Range of Vref (Temp Variation)	1.68 mV
Range of Vref (Supply Variation)	12 mV
Tempco	8.905 ppm/ºC