Design of a Current Mirror–Based Bandgap Voltage Reference

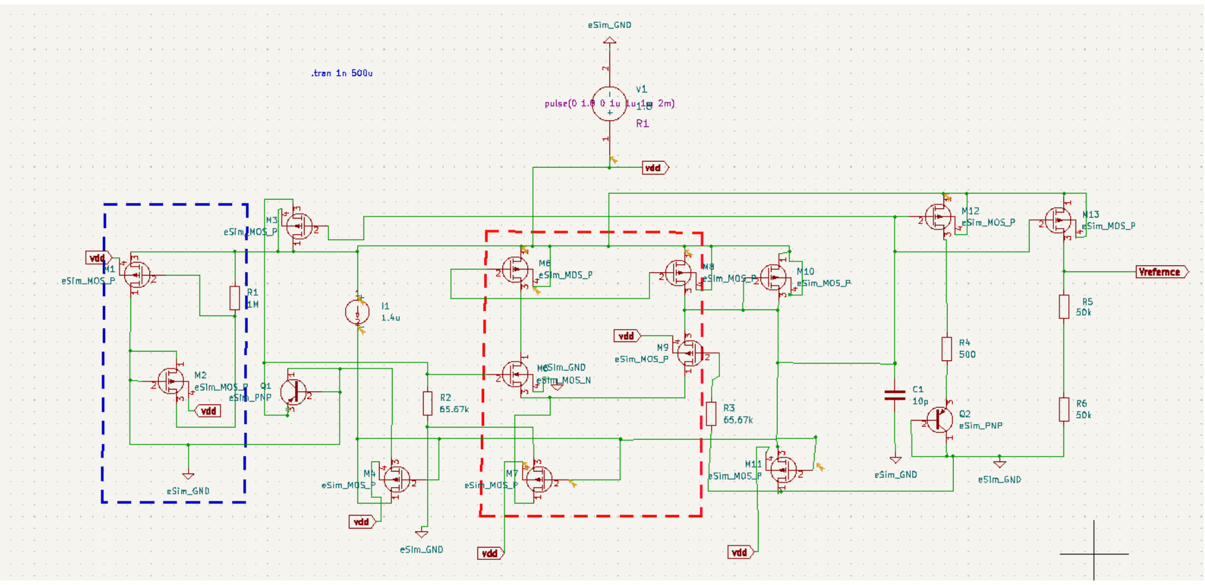
Abstract :

A current mirror–based Bandgap Voltage Reference (BGR) is designed using 90 nm CMOS technology, a two stage current mirror is used to ensure uniform current flow and improved bias stability. The circuit operates using a current-mode approach with a supply voltage of 1.8 V, the circuit generates voltage of 1.75 V while consuming 1.4 μA from dc current source.

Introduction :

1. Biasing and Start-Up Operation

At power-up, the start-up network ensures that the circuit does not remain in the zero-current stable state. This blue block (shown in the schematic) injects a small bias current into the core, forcing the bandgap loop to turn ON and reach its correct operating point. Once steady state is achieved, the start-up circuit becomes inactive and does not disturb normal operation.



2. PTAT Current Generation

The core of the circuit uses two bipolar junction transistors (implemented using parasitic BJTs **QP1 and QP2**).

- Due to the difference in emitter areas (or effective current density), a **ΔV_BE** is generated between QP1 and QP2.
- This **ΔV_BE** is proportional to absolute temperature (PTAT).
- The PTAT voltage is dropped across resistor **R2 (and R3)**, producing a **PTAT current**:

As the current increases linearly , with temperature also increases linearly.

3. CTAT Current Generation

In parallel, the base–emitter voltage **V_BE** of the bipolar transistor exhibits **CTAT behavior** (it decreases with temperature).

- This CTAT voltage is converted into a current through resistor **R3**.
- The resulting current decreases with temperature and acts as the **CTAT current component**.

4. Current Summation and Bandgap Formation

The PMOS mirror network (**shown with the red block)** mirrors and combines the PTAT and CTAT currents.

- Proper sizing of resistors **R2 and R3** ensures that:

  IPTAT+ICTAT≈temperature independent

- This summed current is therefore **almost constant over temperature**, forming the bandgap reference current.

This is why the circuit is called a **current-based BGR**, unlike voltage-mode bandgaps.

5. Current Mirroring and Scaling

The PMOS current mirrors replicate the temperature-independent reference current to different branches without disturbing the core loop.

- This allows the reference current to be reused for biasing other analog blocks.
- Device matching ensures accuracy and stability.

6. Reference Voltage Generation (Vref)

The stable reference current is converted into a voltage using the resistor divider **R5–R6**.

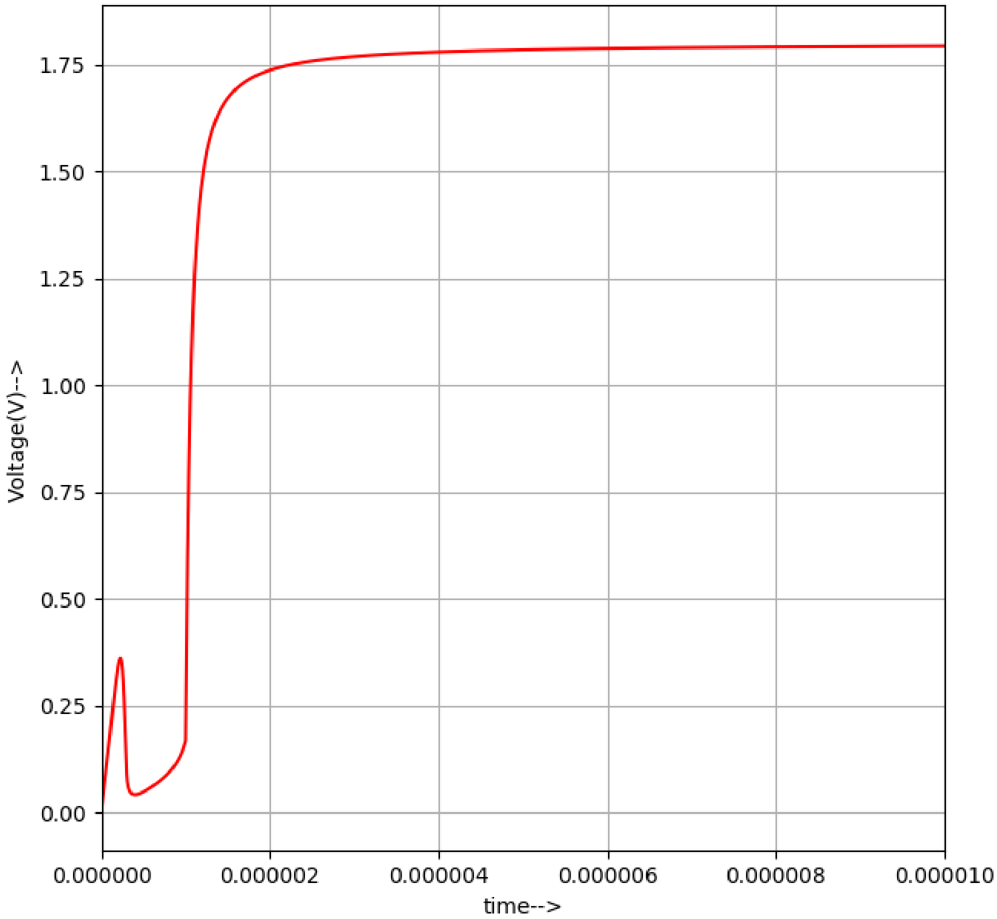
- Capacitor **C1** provides loop stability and suppresses noise.
- Transistor hookup at the output ensures buffering and load isolation.

The resulting **Vref remains nearly constant** across temperature, supply variations, and process changes.

7. Supply and Temperature Independence

- **Supply independence** is achieved by cascoded PMOS mirrors that reduce channel-length modulation.
- **Temperature independence** results from precise cancellation of PTAT and CTAT components.
- The feedback loop forces a unique operating point, ensuring stability.

4. Waveforms and Output Analysis



The transient simulation results confirm the correct start-up and stable operation of the proposed current-based bandgap reference circuit. When the supply voltage is applied, the output initially starts from zero and gradually rises to its steady-state value without any overshoot or oscillations. This behavior verifies the effectiveness of the start-up circuit in driving the system out of the zero-current state.

After the initial transient period, both the reference current and the reference voltage settle to constant values, indicating proper loop stability and biasing. The smooth settling response demonstrates that the PTAT and CTAT current components are correctly generated and balanced. The absence of glitches and ripples in the steady-state region confirms reliable operation of the bandgap core.

Overall, the transient response validates that the circuit achieves fast settling, stable bias generation, and robust operation, making it suitable for low-power analog and mixed-signal applications.