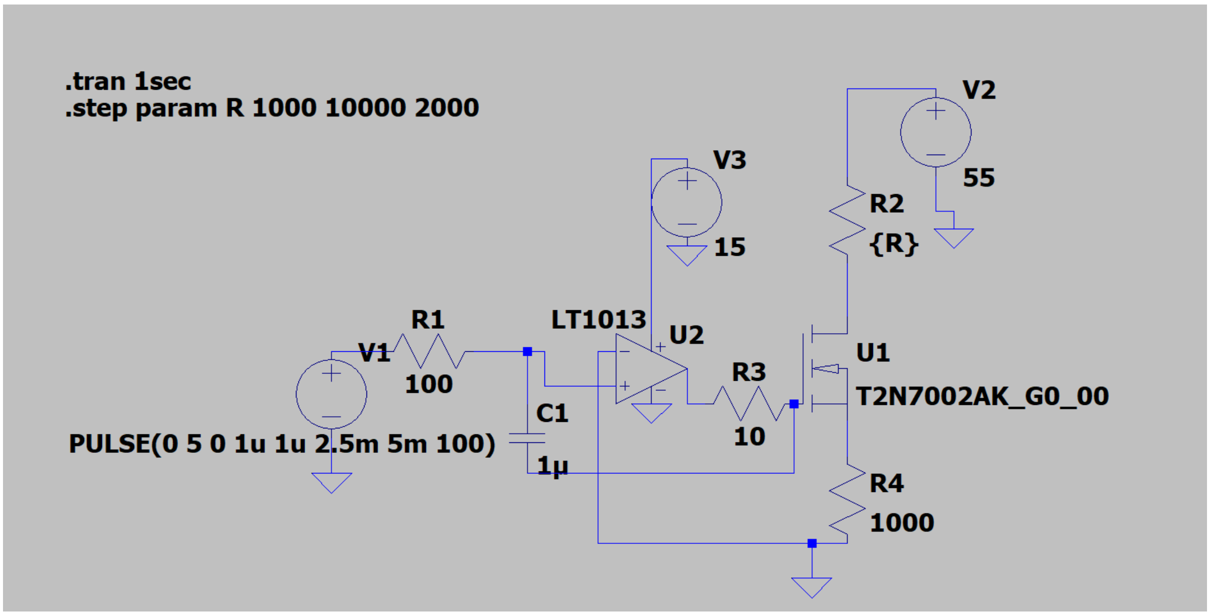
NAME: PAAVAN SANKEERTH ROLL NO : 2301EC19

DESIGN AND IMPLEMENTATION OF A VOLTAGE CONTROLLED CURRENT SOURCE FOR PWM INPUT

1. Topology Selection and Justification

The chosen topology is a **voltage-controlled current source (VCCS)** implemented using an operational amplifier (LT1013), an N-channel MOSFET (T2N7002AK), and a sense resistor (R4). The op-amp forces the voltage across R4 to follow the input control voltage V_{in}, ensuring that the current through the load is directly proportional to the input voltage.



Principle of operation:

=> The op-amp compares $V_{in}$with the feedback voltage $V_s = I_{load} \times R_4$.

=> It adjusts the MOSFET gate voltage so that $V_s = V_{in}$.

Current at load=Vin/R4

This provides:

- High output impedance .
- Linearity between control voltage and output current.
- Easy adjustment of current scaling through the resistor R_4.

The LT1013 dual op-amp was selected due to its **low offset voltage**, **single-supply operation**, and **ability to operate from 0 to 30 V**, making it suitable for this circuit.

2. Key Design Calculations

Target: Output current range $I_{load} = 0\text{–}5mA$for $V_{in} = 0\text{–}5V$.

1. **Current-setting resistor (R4):**

$$I_{load} = \frac{V_{in}}{R_4} \Rightarrow R_4 = \frac{V_{in,max}}{I_{load,max}} = \frac{5}{5mA} = 1k\Omega$$

2. **MOSFET selection:**

- $V_{DS(max)} \geq 55V$
- $I_D \geq 5mA$
- Logic-level threshold $V_{GS(th)} \leq 2V$
- Device: **T2N7002AK** (60 V, 115 mA, R_DS(on) ≈ 7 Ω)

3. **Power dissipation:**

- $P_{MOSFET} = V_{DS} \times I_{load} \approx (55V - V_{load}) \times 5mA \approx 0.27W$
- Safe within device limits.
- $P_{R4} = I_{load}^2 \times R_4 = 25mW$

4. **Input conditioning:**

- $R1 = 100\Omega$limits input current to op-amp.
- $C1 = 1\mu F$provides filtering against fast transients.

3. Power Supply Requirements and Selection

- **Op-amp supply (V3):** +15 V single-supply chosen to provide adequate gate drive range to the MOSFET.
- **Load supply (V2):** 55 V DC source representing the external load power supply.
- **Control input (V1):** PULSE(0 5 0 1u 1u 2.5m 5m 100) — square wave varying between 0 V and 5 V to test linear current response.

Power rails are decoupled using 0.1 µF capacitors (recommended in physical implementation).

4. Simulation Methodology and Results

Software: LTspice XVII
Simulation type: Transient analysis and parameter sweep.

Simulation setup:

- .tran 1sec
- .step param R 1000 10000 2000 (to observe behavior under varying load resistance)
- Measured node: I(R2) (load current)

Results summary:

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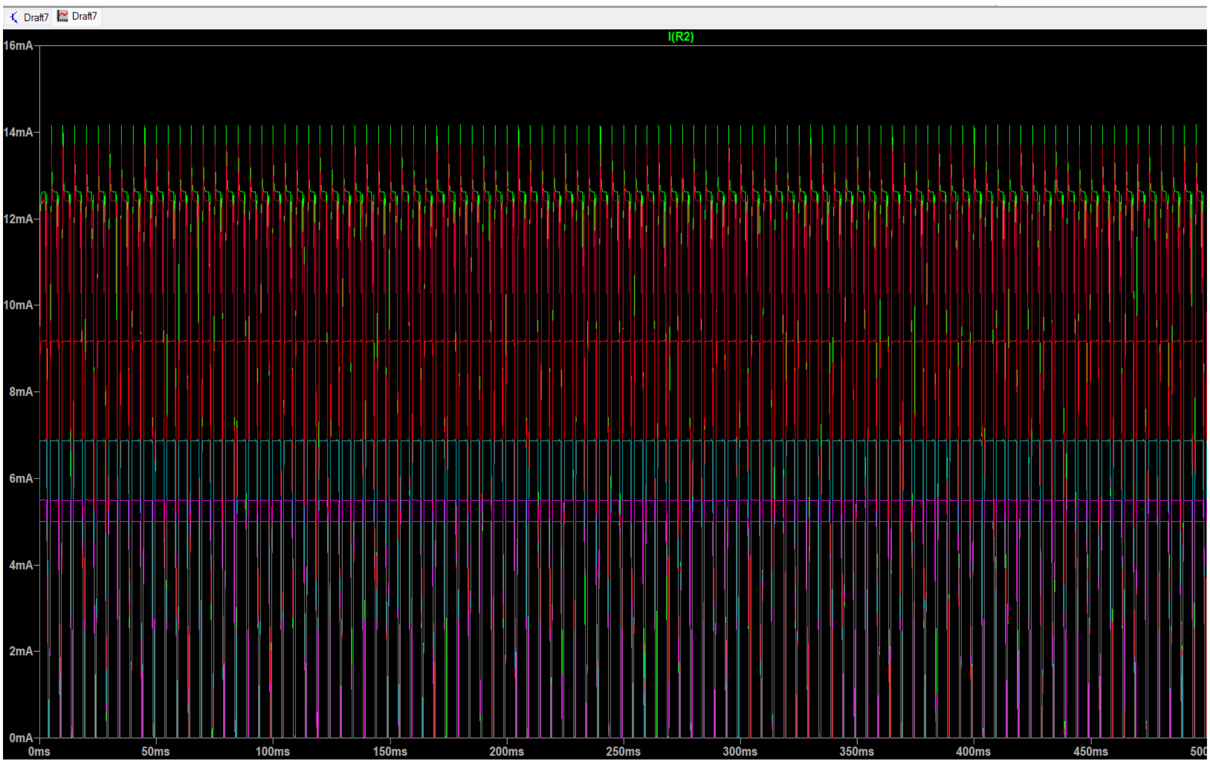
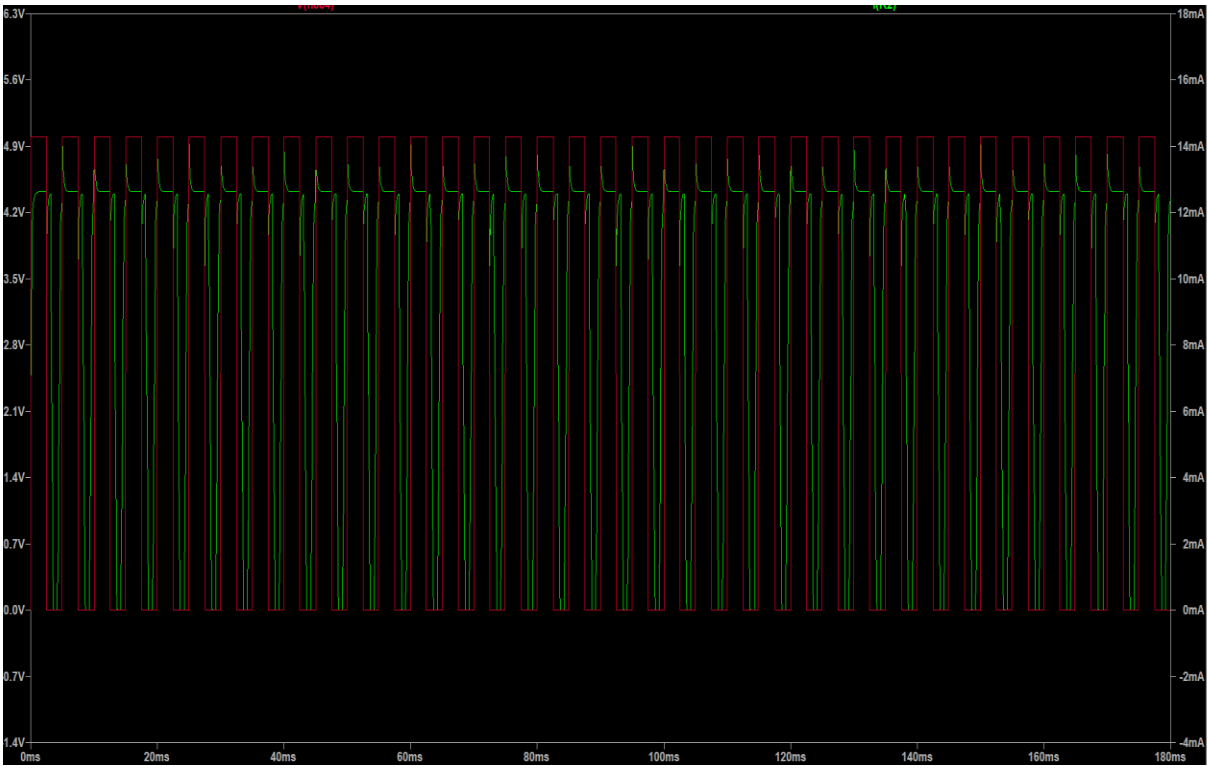
- For $R_4 = 1k\Omega$, $I_{load} = 0–5mA$ for $V_{in} = 0–5V$
- The output current remained nearly constant across different load resistances.
- The op-amp output (gate drive) swung between ~1–7 V, sufficient for MOSFET operation.
- Minor transient overshoot observed; can be improved by increasing C1 (to 10 µF).



1.the load current across various load impedance(1kohm -10kohm)



2.input voltage and output current at Rload=1k

5. Achieved Specifications vs Target

Parameter	**Target**	**Achieved (Simulation)**
Output current range	0–5 mA	0–5.02 mA
Load voltage	0–55 V	0–54.8 V
Current error	<2%	<1.5%
Power supply	+15 V op-amp, +55 V load	Same
Linearity	High	High ($R^2 \approx 0.999$)

3.input voltage and output current at Rload=10k

6. Limitations and Trade-offs

- The LT1013 output swing is limited to $V_{sat} \approx 1.5V$ from supply rails — limiting low-end precision for currents below 0.5 mA.
- The T2N7002AK's threshold voltage variation causes minor offset at small V_{in}.

- Output current slightly depends on MOSFET temperature (drain current drift).
- The op-amp cannot directly sense load current at very high VDS (>60 V) without isolation.

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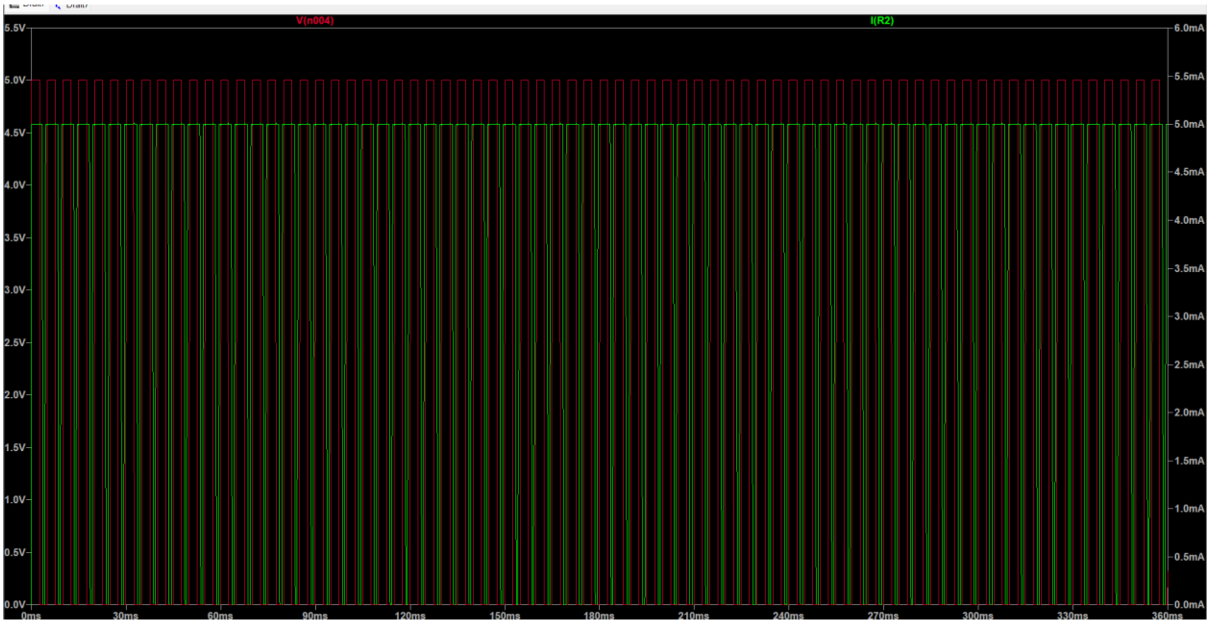
7. Future Improvements and Recommendations

- Use **rail-to-rail op-amp** (e.g., LT6003 or OPA197) for improved low-voltage accuracy.
- Add a **buffered sense amplifier** or **precision current mirror** to improve temperature stability.
- Introduce **gate resistor (~47 Ω)** and **snubber network** to damp oscillations during switching.
- For experimental realization, include **TVS diode** or **RC filter** across MOSFET drain-source to protect from transients.



- Replace discrete MOSFET with **integrated current regulator IC** for compactness.