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Lab Report: Weighted Summer Circuit Using Op-Amp (TL084/LM324)

Course: EICN2241 – Electronics Lab
Faculty of Engineering, Cairo University
SBME Department – Academic Year 2024/2025
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Introduction

Objective

- Construct and simulate a weighted summer circuit using an operational amplifier (TL084/LM324).
- Derive the transfer function and compare theoretical vs. practical results.

Key Properties

1. Fixed Gain Configuration
   - Identical resistors ($R_1 = R_2 = R_3 = 100\ k\Omega$) ensure equal weighting:
   - $V_0 = -\left((R_3/R_1)V_1 + (R_3/R_2)V_2 \right) = -(V_1 + V_2)$
2. Infinite Loop Gain ($A \to \infty$)
   - Ideal op-amp assumption enables:
     - Virtual short circuit: $V- \approx V+$ (both inputs at equal potential)
     - Virtual ground: $V- \approx 0$ when $V+$ is grounded
3. Negative Feedback
   - Forces the op-amp to operate linearly
   - Stabilizes gain despite open-loop variations

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Methodology

Simulation Procedure (MATLAB/Simulink)

1. **Launch Simulink Environment**
   - Open MATLAB → Type simulink → Select Simscape Electrical library
2. **Build the Circuit**
   - **Place TL084/LM324 op-amp from Simscape library**
   - **Add three 100kΩ resistors (R_1, R_2, R_3):**
     - Connect R_1 between V_1 and inverting input
     - Connect R_2 between V_2 and inverting input
     - Connect R_3 between output and inverting input (feedback)
   - **Set DC voltage sources:**
     Configure ±12V power supplies
3. **Measurement Setup**
   - **Voltmeter Block:**
     - Place "Voltage Sensor" at op-amp output
   - **PS-Simulink Converter:**
     - Convert physical electrical signals to Simulink-compatible data
     - Enable real-time voltage monitoring on the oscilloscope
   - **Simulink Scope:**
     - **Displays time-domain waveform of V_0**
4. **Run Simulation**
   - **Set solver to ode15s (for electrical systems)**
   - **Simulation time: 0.1 sec (sufficient for DC analysis)**
   - **Click Run**

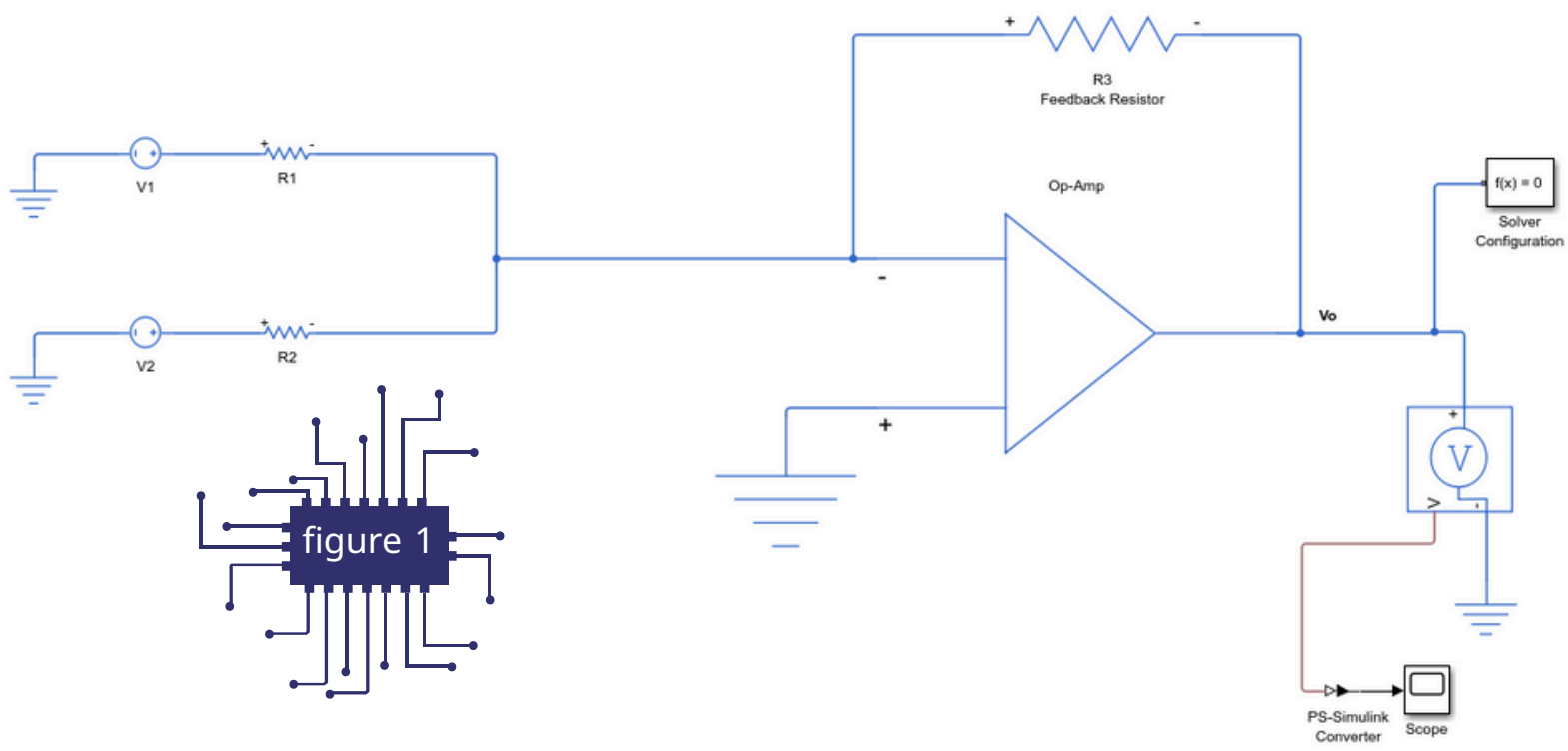
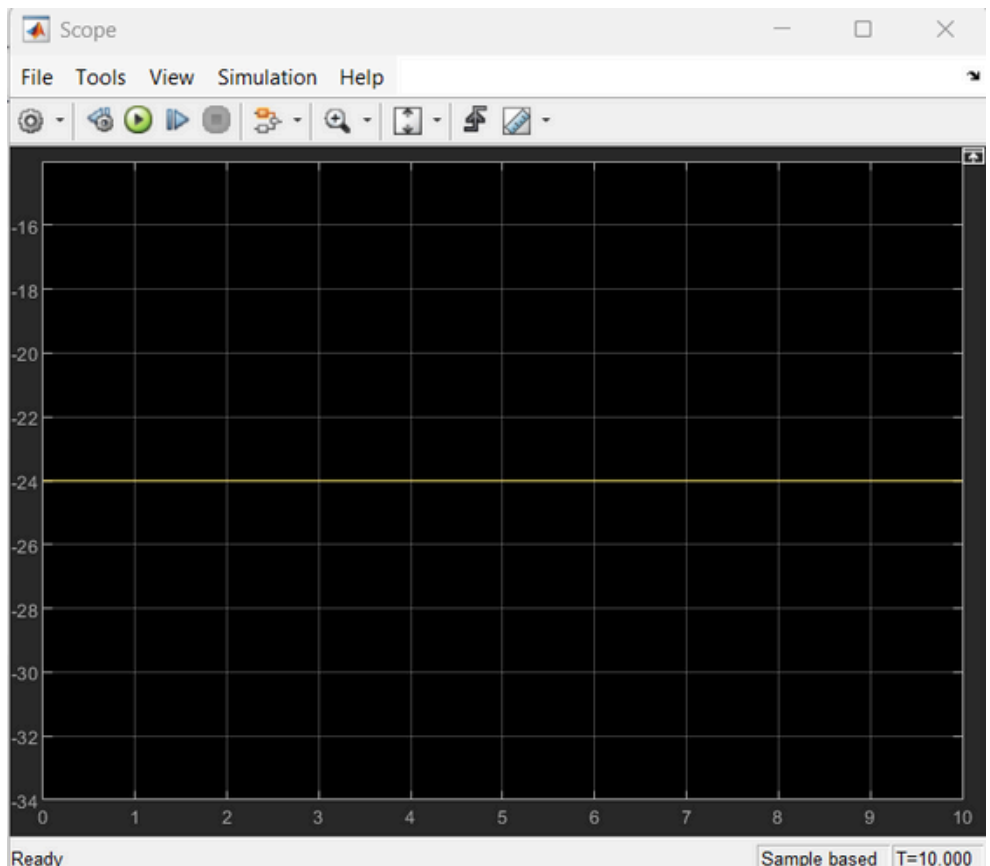


figure 1



output voltage

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Results & Analysis

V_1 (V)	V_2 (V)	Theoretical V_0 (V)	Simulated V_0 (V)	Error (μV)
12	12	−24.0	−24.0	0.0
2.5	3.5	−6.0	−6.0	0.0
−1.2	0.7	0.5	0.5	0.0
4.8	−3.2	−1.6	−1.6	0.0
0.0	0.0	0.0	0.0	0.0

Explanation

- **Ideal Op-Amp Model:**
  Simulink's Simscape uses infinite gain and zero offset by default matlab
- **Perfect Components:**
  - No resistor tolerance (exact 100kΩ)
  - Ideal voltage sources (no internal resistance)

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Hardware Implementation

Components Required:

Component	Value/Model	Purpose
Op-Amp IC	TL084 or LM324	Amplification
Resistors (R_1, R_2, R_3)	100 kΩ each	Input/Feedback
Breadboard	–	Circuit Assembly
DC Power Supply	±12V	Op-Amp Biasing
Digital Multimeter	–	Voltage Measurement
Jumper Wires	–	Connections

Circuit Wiring Steps:

- Insert the Op-Amp into the breadboard (ensure correct pinout).
- Connect Power Rails:
  - +12V to V+ (Pin 7 for TL084).
  - −12V to V− (Pin 4 for TL084).
- Wire the Feedback Resistor (R_3 = 100 kΩ) between output (Pin 6) and inverting input (Pin 2).
- Connect Input Resistors (R_1, R_2 = 100 kΩ) from V_1, V_2 to Pin 2.
- Ground the Non-Inverting Input (Pin 3).
- Measure Output (V_0) using a multimeter between Pin 6 and GND.

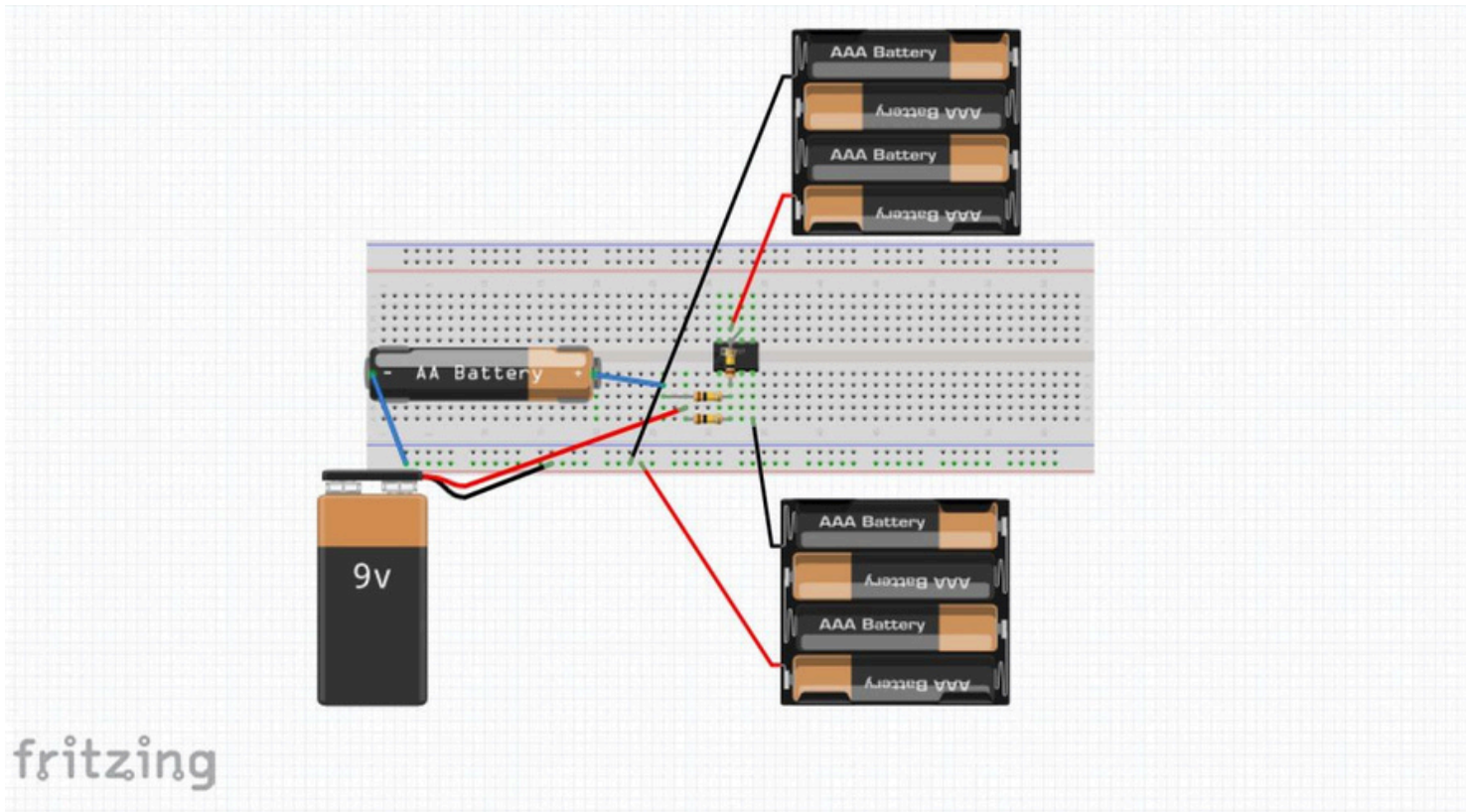

figure 2

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Testing Procedure:

Apply 5 different DC input combinations (e.g., V_1=1V, V_2=0.5V).
Record theoretical (calculated) vs. measured (practical) output.

V_1 (V)	V_2 (V)	Theoretical V_0 (V)	Measured V_0 (V)	Error (µV)

Error Sources:

1. Resistor Tolerance (5% tolerance in 100 kΩ resistors).
2. Measurement Errors (multimeter accuracy)
3. Amplifier imperfections

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Discussion

Key Observations:

- The circuit behaves as expected, following $V_0 = -(V_1 + V_2)$.
- Simulation closely matches theory, but hardware has minor deviations due to real-world factors.

Challenges & Solutions:

Conclusion

- Successfully simulated and built a weighted summer circuit.
- Verified $V_0 = -(V_1 + V_2)$ with slight practical deviations.
- Learned the impact of real-world factors (resistor tolerances, measurement errors).

Applications:

- Audio Mixers (combining multiple signals).
- Sensor Signal Conditioning (summing multiple sensor outputs).

Datasheet References

- TL084 Datasheet
- LM324 Datasheet