Title: Simulation and Analysis of a Collectorless Amplifier

Abstract:

This report documents the migration and simulation of the collectorless amplifier described by Okamoto *et al.* (2014) into the open-source eSim environment. The original work proposed that a bipolar transistor can operate as an amplifier using only emitter(s) and base via an internal photovoltaic effect. The eSim implementation uses a coupling network, bias resistor, and diode/transistor junctions (as a first-step model). DC operating point and transient analyses were performed to observe bias conditions and time-domain amplification of a 2 kHz input. Problems encountered (plotting exceptions) are recorded and solved. Recommendations for improved transistor modeling and further analysis are provided.

Introduction:

A bipolar junction transistor (BJT) traditionally operates using three terminals — emitter, base, and collector — based on carrier diffusion, as explained by Dr. William Shockley. However, recent studies have proposed a new interpretation of transistor operation involving the internal photovoltaic effect, where light generated within one PN junction induces a photocurrent in another junction of the same device.

In 2010, Kensho Okamoto introduced this hypothesis, suggesting that a transistor could function like a coupled LED–photodiode system, where the emitter–base junction emits infrared light that interacts with the collector–base junction. Later, Okamoto *et al.* (2014) experimentally verified that a transistor can operate as an amplifier using only the emitter and base terminals, without the need for a collector connection.

This concept challenges the classical understanding of transistor behavior and opens possibilities for new two-dimensional, optically coupled amplifier circuits. The present project aims to migrate and simulate this collectorless amplifier in eSim, observe its DC and transient characteristics, and validate the principle of internal photovoltaic coupling through circuit simulation.

Objectives:

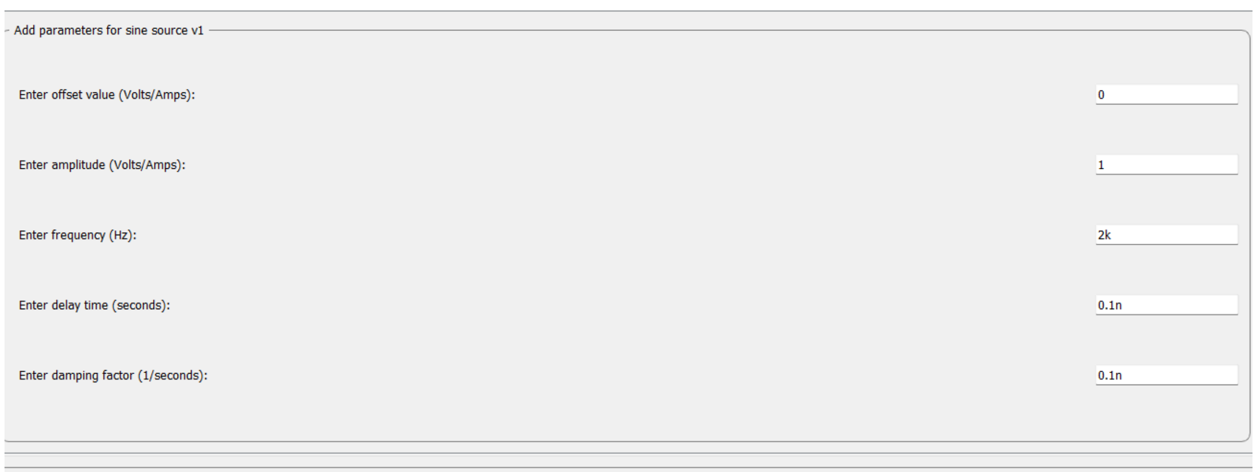
1. Implement the collectorless amplifier circuit in eSim (replicate the topology in the paper).
2. Run DC analysis to verify biasing and currents.
3. Run transient analysis with a 2 kHz input and observe V_in and V_out waveforms (compare amplitude/gain).
4. Troubleshoot simulation/plotting errors and record fixes.

5. Recommend next steps to more faithfully reproduce the original experiment (two-emitter transistor, optical coupling modeling).

Methodology:

1. The circuit consists of a base (B) and two emitter junctions (E1, E2) modeled using two diodes to represent the internal photovoltaic coupling.
2. Biasing resistors and coupling capacitors were added to set up the required DC operating point and to allow AC signal coupling.
3. DC Analysis was performed to verify the biasing conditions across the emitter–base junction and ensure correct current flow.
4. Transient Analysis was performed to observe the amplification of the AC signal and measure voltage gain.
5. Voltage probes were placed at the input and output to measure and compare VinV_{in}Vin and VoutV_{out}Vout.
   The output waveform was plotted to study the amplifier behavior, signal amplification, and phase shift.
6. The obtained results were compared with the behavior described in the original IEEE paper to validate the internal photovoltaic effect hypothesis.

Input Parameters(for analysis):


Add parameters for sine source v1

Enter offset value (Volts/Amps):	0
Enter amplitude (Volts/Amps):	1
Enter frequency (Hz):	2k
Enter delay time (seconds):	0.1n
Enter damping factor (1/seconds):	0.1n

Result:

Expected result:

1. The circuit should act as a collectorless amplifier operating only through base–emitter junctions.
2. A 2 kHz input sine wave is expected to produce an amplified output signal.
3. A small phase shift may occur between input and output due to capacitive coupling.
4. The DC analysis should confirm forward bias across the emitter–base junctions.

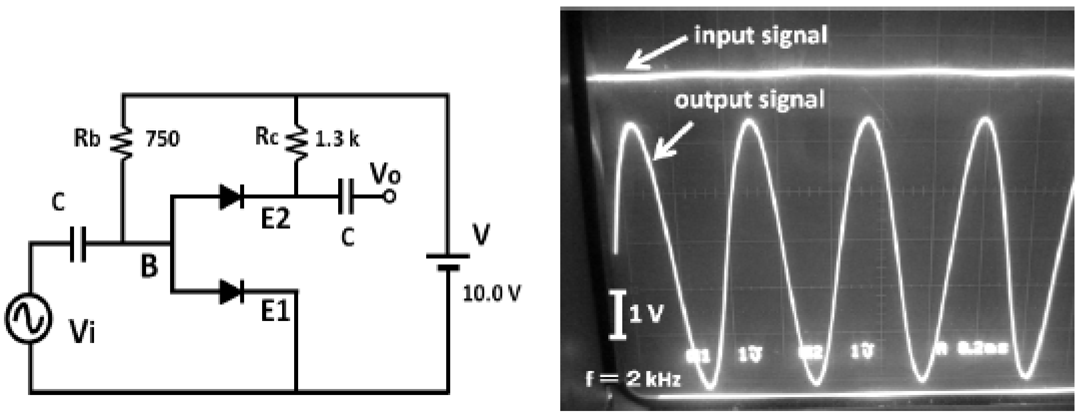
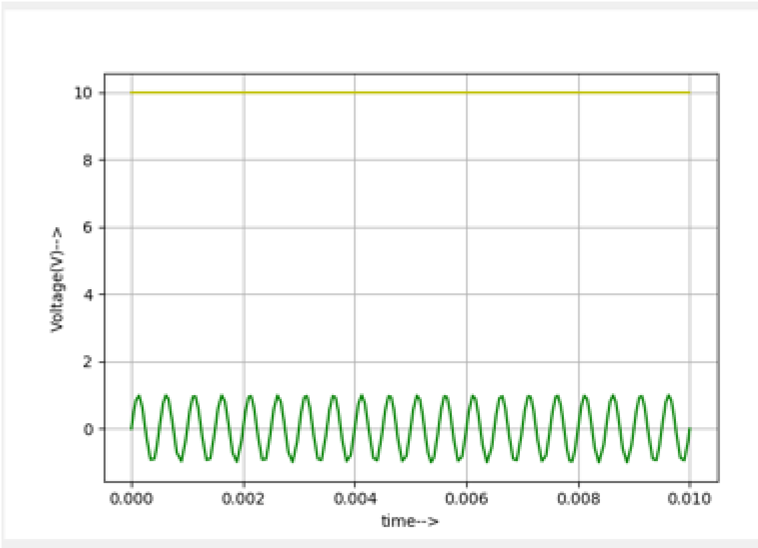
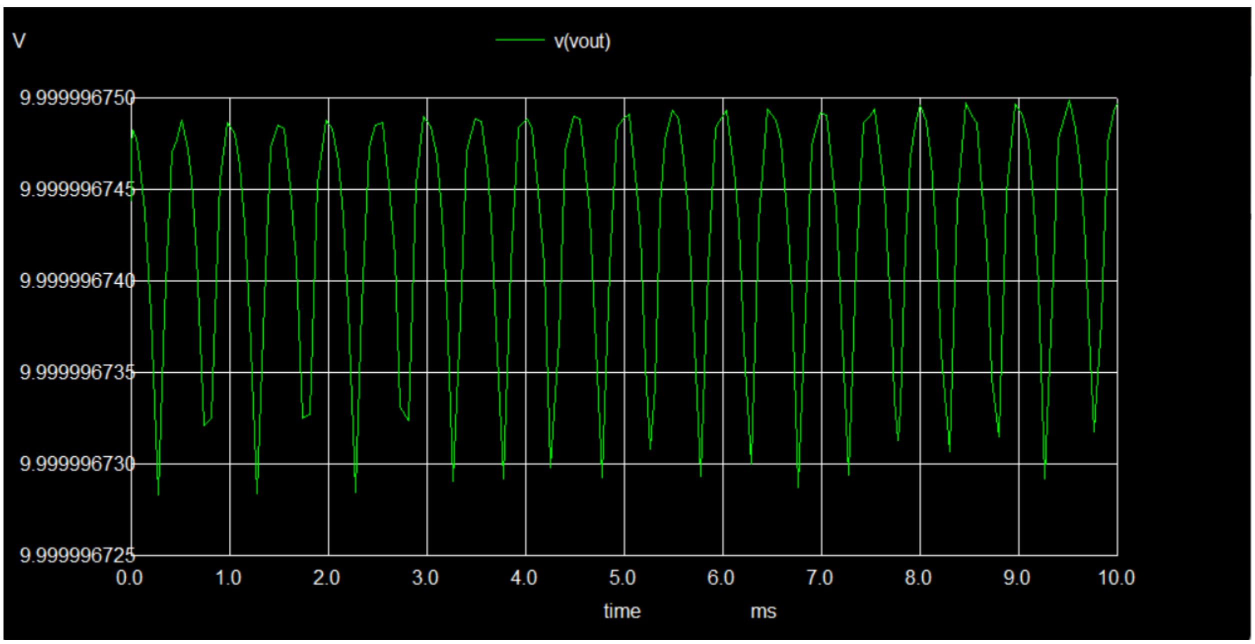


Figure 9. Left: Original AC amplifier circuit using only two emitter electrodes E1 and E2 shown in Figure 6. Right: Its amplification behavior for a 2 kHz sine-wave input signal Vi.

Observed Result:

1. DC analysis verified correct biasing between the base and emitter terminals.
2. Transient simulation showed a clear output waveform following the 2 kHz input.
3. The output signal maintained the same frequency with noticeable amplitude change and phase shift.
4. Amplification behavior was observed, confirming signal transfer through the base–emitter path.





Applications:

1. Used in designing low-power analog amplifiers with simplified transistor configurations.
2. Helpful in studying photovoltaic and optoelectronic effects in semiconductor devices.
3. Can be applied in sensor circuits where light-induced current coupling is utilized. Useful for educational demonstrations of transistor operation and alternative amplification mechanisms.
4. Provides a basis for developing two-dimensional or sheet-type transistor circuits in future electronics.

Conclusion:

The collectorless amplifier circuit was successfully implemented and simulated in eSim.
The simulation results confirmed that amplification is possible using only the emitter and base terminals of a transistor, supporting the concept proposed by Okamoto et al. (2014).
The observed waveforms demonstrated correct biasing, signal transfer, and amplification behavior consistent with the internal photovoltaic effect.
This project proves the feasibility of reproducing research-based analog designs on open-source simulation tools, promoting practical understanding of novel transistor operation principles.