Title of the circuit : Design and Simulation of Dual JFET Operational Amplifier (LM353)

Theory/Description :

The LM353 is a **dual JFET-input operational amplifier** designed using a multi-stage analog integrated circuit architecture to achieve **high input impedance, low input bias current, high open-loop gain, and stable frequency response**. Each amplifier section of the LM353 consists of a **JFET differential input stage, intermediate voltage amplification stages, internal frequency compensation, and a class-AB output buffer**, enabling precision analog signal processing.

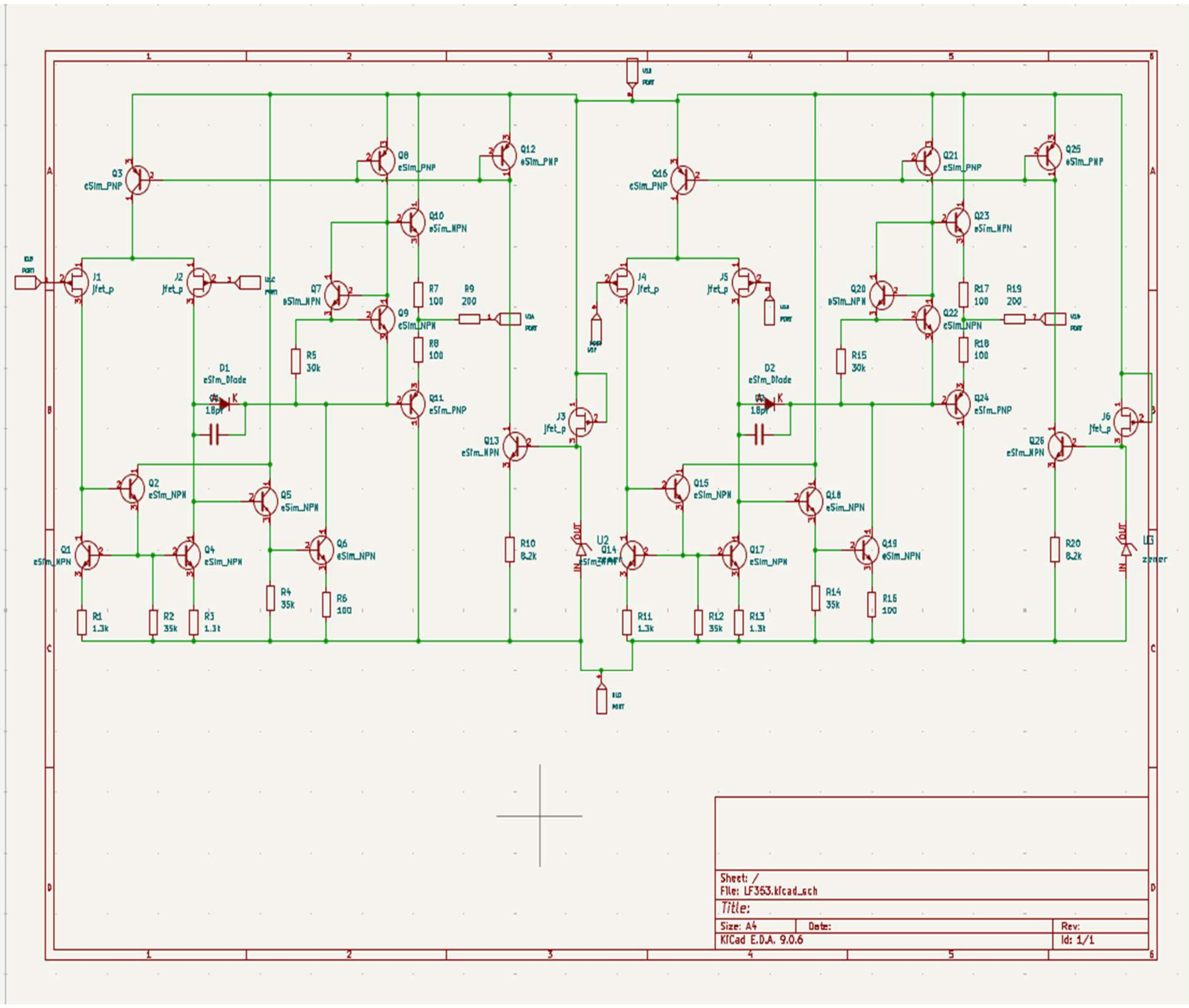
The **input stage** employs a matched **JFET differential pair** that receives the inverting and non-inverting input signals. The use of JFETs at the input provides extremely **high input impedance and low input bias current**, minimizing source loading and reducing input-referred noise. Biasing transistors and resistors establish a stable tail current for the differential pair, improving common-mode rejection and ensuring symmetrical operation under differential excitation.

The differential output from the JFET input stage is converted to a single-ended signal using **active load current mirrors**, which significantly increase the effective gain of the stage while maintaining low power consumption. This signal is then amplified by the **voltage amplification stage (VAS)**, which provides the dominant contribution to the overall open-loop gain of the operational amplifier. Proper biasing and level shifting are achieved using diode-connected transistors and reference networks to ensure correct operating points across all internal stages.

Internal frequency compensation is implemented using an on-chip compensation capacitor connected around the gain stage, introducing a dominant pole that guarantees closed-loop stability for a wide range of feedback configurations. This allows the LM353 to operate reliably in unity-gain and higher-gain applications without external compensation components.

The **output stage** is realized using a **class-AB push–pull emitter follower configuration**, providing low output impedance and the ability to drive resistive loads efficiently. Bias stabilization resistors and diode networks minimize crossover distortion while maintaining thermal stability. The output stage allows symmetrical voltage swing with respect to the supply rails and ensures adequate current drive capability.

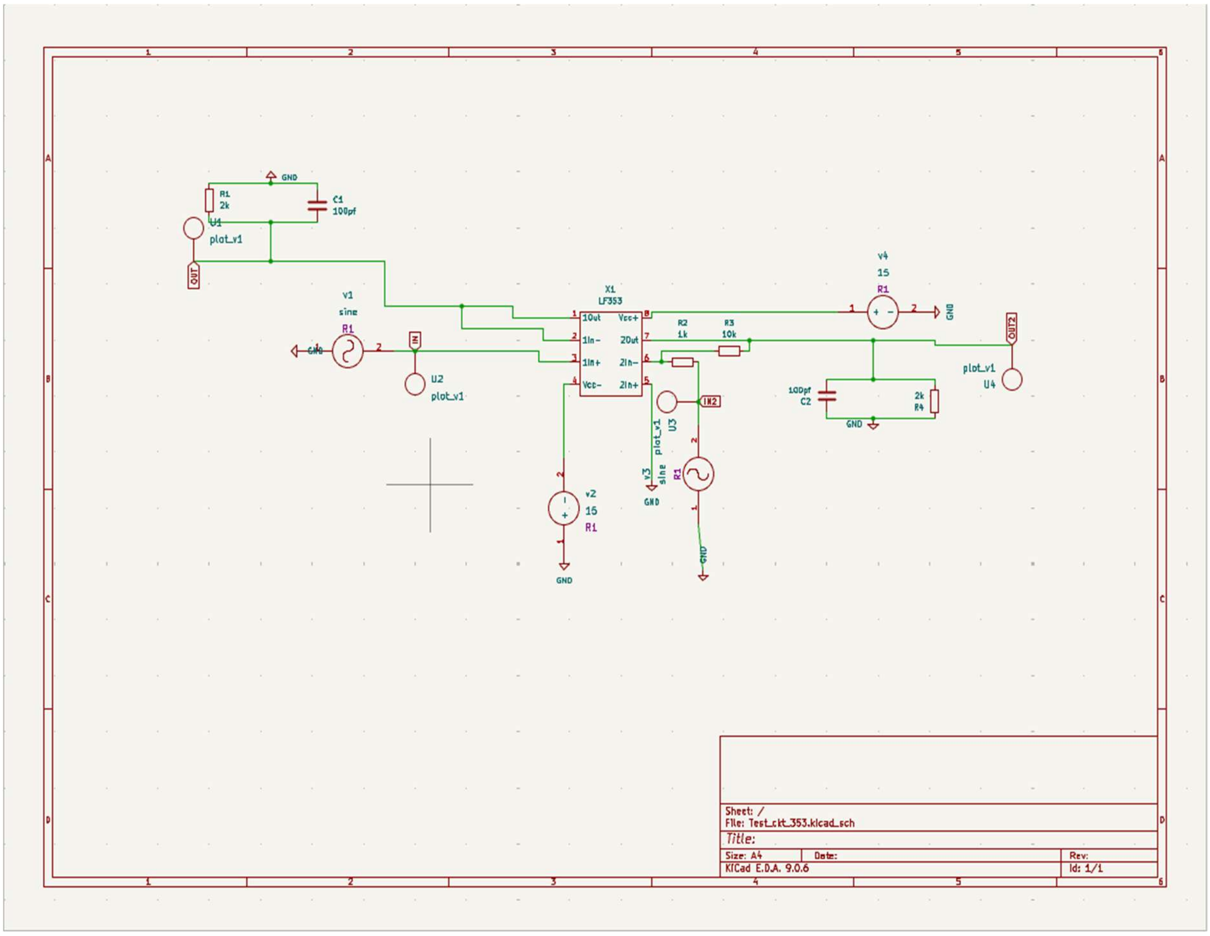
The complete design is simulated using the **eSim/NGSpice simulation environment**. **DC analysis** is used to verify correct transistor biasing, **AC analysis** is performed to obtain the open-loop and closed-loop gain and bandwidth characteristics, and **transient analysis** is used to evaluate the dynamic response of the amplifier. The simulation results validate the functionality and performance of the LM353 dual JFET operational amplifier and demonstrate its suitability for precision analog applications.



The test circuit is designed to evaluate the functional performance of the **LM353 dual JFET operational amplifier** under closed-loop conditions. The operational amplifier is powered using a dual supply, and the input signal is applied through a controlled AC source. A resistive feedback network is used to configure the amplifier in a stable closed-loop gain configuration.

The circuit enables verification of the amplifier's **voltage gain, frequency response, and output swing**. Coupling and bypass capacitors are included to suppress noise and ensure stable operation. The output is monitored to analyze gain accuracy and signal integrity.

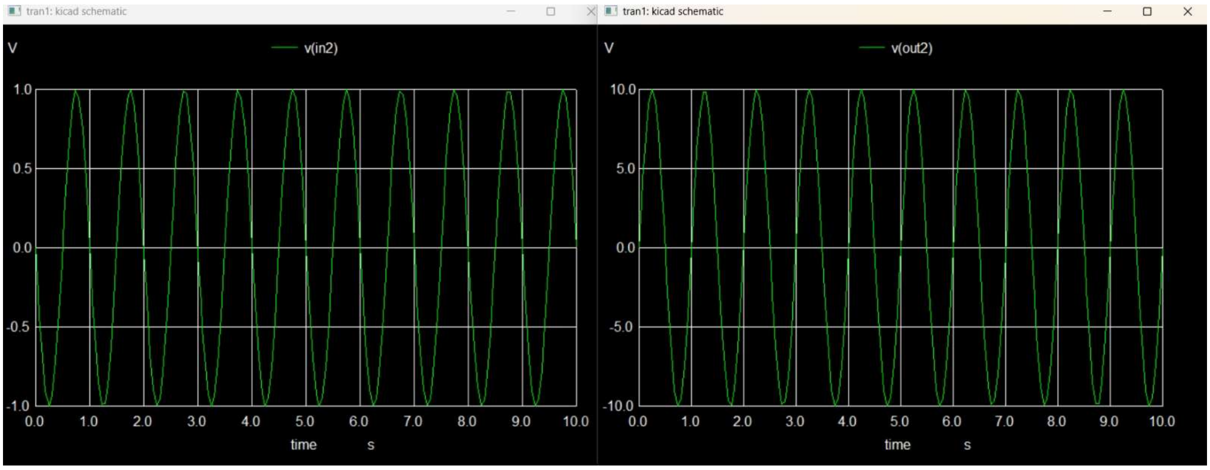
The test circuit is simulated using the **eSim/NGSpice environment**, where **AC analysis** is performed to determine bandwidth and gain, and **transient analysis** is used to observe time-domain response, validating the proper operation of the LM353 operational amplifier.



Output Analysis:

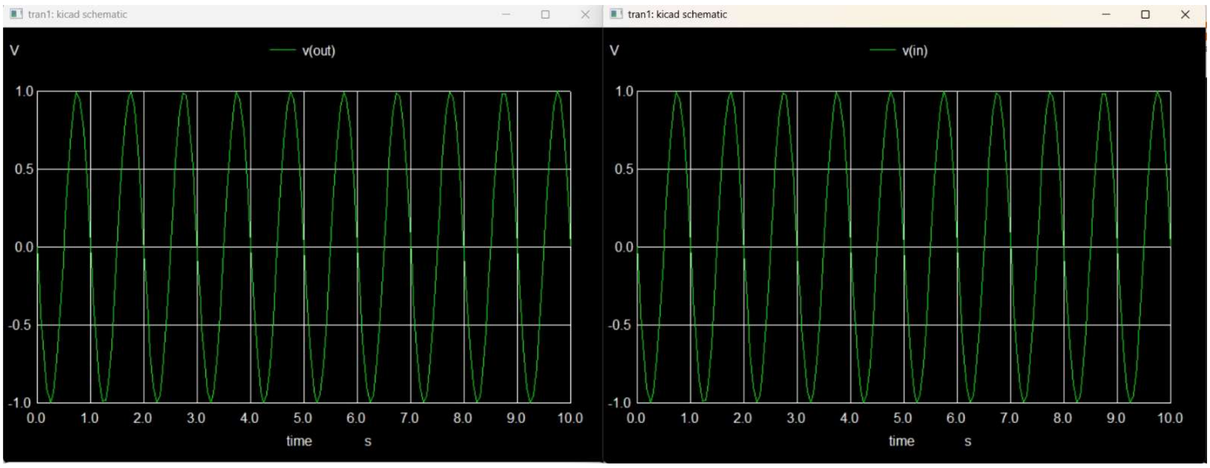
Voltage Follower Mode

In the voltage follower configuration, the output waveform closely follows the input waveform in both amplitude and phase. The simulated input signal has a peak amplitude of approximately ±1 V, and the corresponding output waveform exhibits the same peak value without any noticeable distortion or phase shift. This confirms that the LM353 provides unity gain (Av ≈ 1) with stable operation. The absence of waveform clipping or oscillations indicates proper biasing and sufficient bandwidth for the applied signal frequency.



Amplifier (Gain) Mode

When configured with an external resistive feedback network to provide gain, the output waveform shows a **proportional increase in amplitude** compared to the input signal. For an input amplitude of approximately **±1 V**, the output reaches nearly **±10 V**, indicating a closed-loop voltage gain of approximately **10**. The output waveform maintains the same frequency and shape as the input signal, demonstrating **linear amplification** and minimal distortion.



Source/Reference(s) :

[1] **Texas Instruments**, *LM353 Dual JFET-Input Operational Amplifier Datasheet*, Texas Instruments Incorporated, USA.

[2] **Fairchild Semiconductor**, *LM353 / LF353 Dual JFET Input Operational Amplifier Datasheet*, Fairchild Semiconductor Corporation.

[3] P. R. Gray, P. J. Hurst, S. H. Lewis, and R. G. Meyer, *Analysis and Design of Analog Integrated Circuits*, 5th Edition, Wiley, 2009.