

BOOST AMPLIFIER OUTPUT SWING WITH SIMPLE MODIFICATION

By R. Mark Stitt and Rod Burt (602) 746-7445

In many applications it is desirable for the output of an amplifier to swing close to its power supply rails. Most amplifiers only guarantee an output swing of $\pm 10V$ to $\pm 12V$ when operating on standard $\pm 15V$ power supplies. With the addition of four resistors and a pair of garden-variety transistors, the INA105 or INA106 difference amplifiers can be modified to provide nearly a full $\pm 15V$ output swing on $\pm 15V$ supplies.

Figure 1 shows the modified circuit for the INA105. The combined INA105 quiescent current and output current flowing from its power-supply pins drives external transistors Q_1 and Q_2 through base-emitter connected resistors R_3 and R_4 . Q_1 and Q_2 are arranged as common-emitter amplifiers in a gain of approximately $1.7V/V$ ($1 + 750\Omega/1k\Omega$) so that the INA105's output only needs to swing about $\pm 9V$ for a $\pm 15V$ swing at the buffer output. Figure 4 shows the boosted INA105 driving a $1k\Omega$ load to within a fraction of a volt of its $\pm 15V$ power supplies. Figure 4 is a multiple exposure scope photo showing the composite amplifier output and the power-supply voltages.

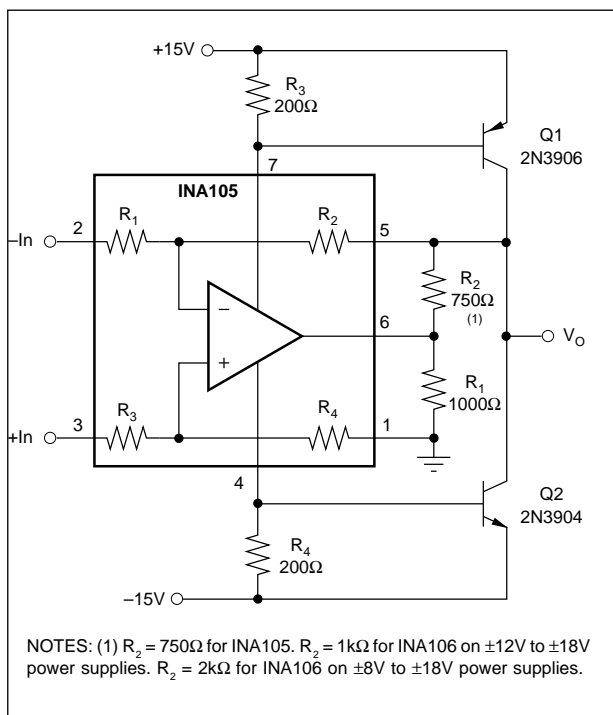


FIGURE 1. External Transistors Q_1 and Q_2 Add Output Boost so the Difference Amplifier Can Drive Loads Close to Its Power-Supply Rails.

Even though there is gain in the feedback of the INA105, the circuit is stable as shown by the small-signal response of the amplifier as seen in the scope photo, Figure 5. Since a unity-gain difference amplifier operates in a noise gain of two, gain can be added in its feedback loop without causing instability with the following restrictions: 1) the added gain is less than $2V/V$, 2) the op amp in the difference amplifier is unity gain stable, and 3) the phase shift added by the gain buffer is low at the unity gain frequency of the op amp. All stability requirements are met when using the INA105.

To understand the details of the composite amplifier, consider the block diagram, Figure 2. Resistors R_1 and R_2 set the gain of the buffer amplifier A_2 . The buffer amplifier is a current-feedback op amp formed from the output transistors in the INA105 and the external transistors, Q_1 and Q_2 . The current feedback amplifier gives wide bandwidth and low phase shift. Figure 3 shows one of two complementary current-feedback amplifiers formed from the NPN output transistor in the INA105 and the external PNP transistor, Q_1 . This current-feedback amplifier section is active for positive swings of the composite amplifier output. A complementary current-feedback amplifier, using external transistor Q_2 , is active for negative output swings of the composite amp.

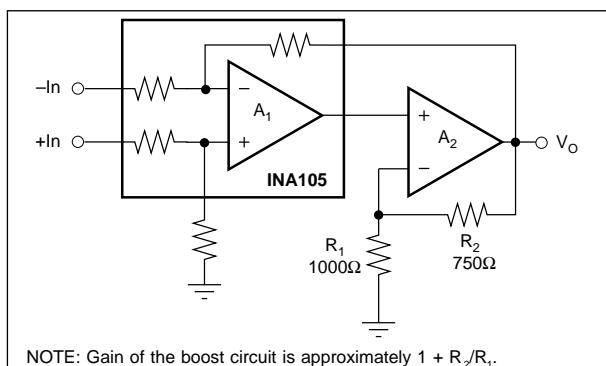


FIGURE 2. Block Diagram Showing Boost Circuit Feedback Arrangement.

Because the maximum gain in the feedback of an INA105 is limited to $2V/V$, the boosted circuit works best with power supplies of $\pm 12V$ or more. The INA105 doesn't have enough output swing on lower supplies to drive a gain-of-2 buffer to the power supply rails. For boosted output swing on lower supplies, consider the INA106 gain-of-10 difference amplifier. Although the op amp in the INA106 is not unity gain stable, the INA106 is stable with added gain in its feedback of up to $3V/V$. This allows full output boost on lower voltage supplies. Scope photograph Figure 6 shows the boosted

INA106 driving a 1kΩ load to within a fraction of a volt on ±8V supplies. Figure 6 is a multiple exposure scope photo showing the composite amplifier output and the power-supply voltages. Scope photograph Figure 7, shows the small signal response of the INA106 with a gain-of-3 feedback buffer.

A word of caution: To obtain the boosted output swing, output protection circuitry was eliminated. There is no current limit in the output buffer. A short circuit at the output may destroy the external output transistors. Still, this simple modification is an effective means to obtain wide output swing.

So long as the stated stability requirements are observed, this technique can be applied to other op amp circuits.

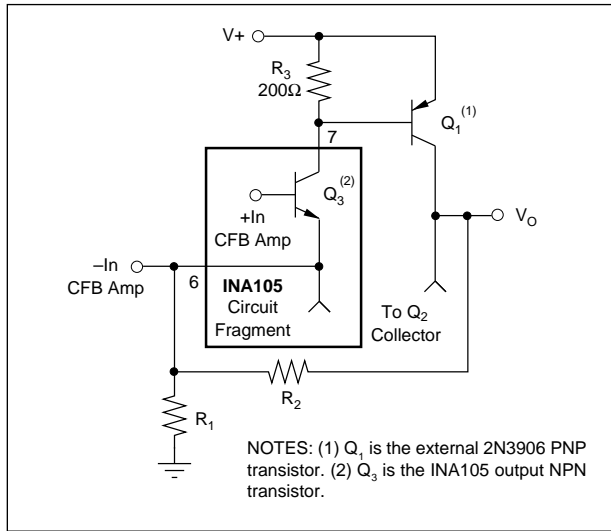


FIGURE 3. Circuit Detail Showing One-Half of the Symmetrical Current-Feedback Amplifier Output Stage, A₂ in Figure 2.

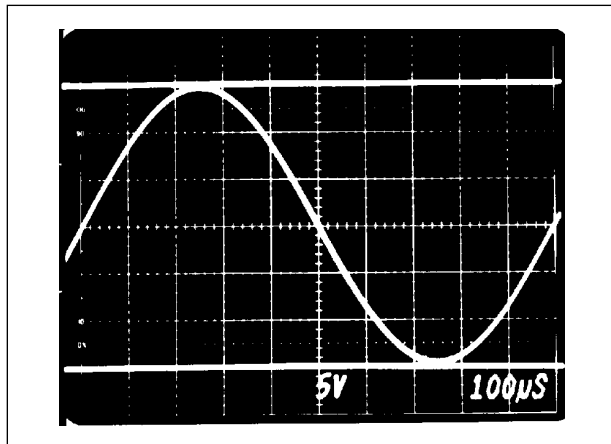


FIGURE 4. Triple Exposure Showing ±15V Power Supplies and Composite Amplifier Output Driving 1kΩ Load.

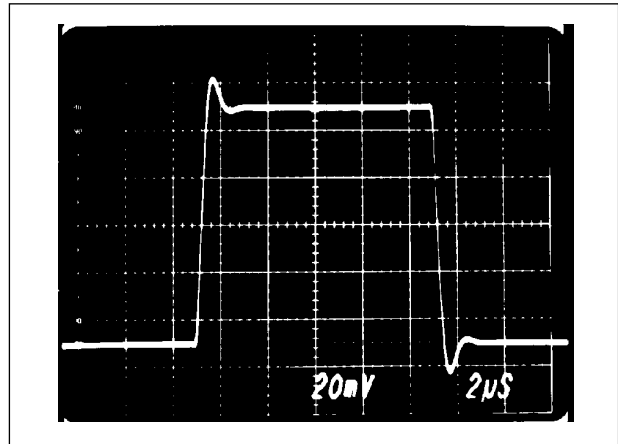


FIGURE 5. Small-Signal Response of Composite Amplifier Using INA105 and Buffer Amplifier with 750Ω, 1kΩ Feedback Resistors.

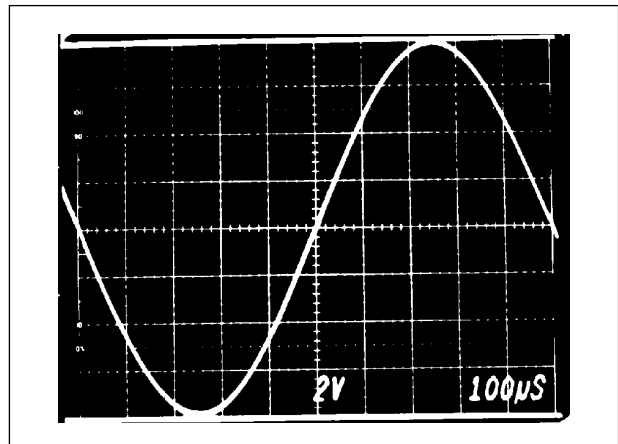


FIGURE 6. Triple Exposure Showing ±8V Power Supplies and Composite Amplifier Output Driving 1kΩ Load.

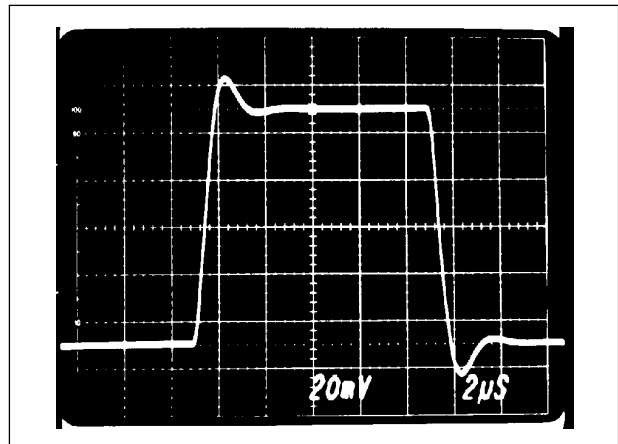


FIGURE 7. Small-Signal Response of Composite Amplifier Using INA106 and Buffer Amplifier with 3kΩ, 1kΩ Feedback Resistors.

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