

# Designing High-Precision, High Output Current Circuits for ATE Applications Using a Composite Amplifier Loop

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## Introduction to Requirements for ATE

Automatic Test Equipment (ATE) frequently requires amplifiers with high-precision and high-output current in order to drive the Device Under Test (DUT). The high drive current is needed for two reasons:

- Driving parallel loads to multiple DUTs
- Driving large capacitive loads

High precision reduces offset errors and helps with signal integrity at the DUT. It is challenging to find a single amplifier that meets both precision and high output current requirements. This application note discusses a composite amplifier loop that uses a precision-amplifier and a high-output current buffer to achieve key system requirements.

## Application of Composite Loop

It is well understood that using a standalone buffer to meet the high drive currents with large capacitive load requirements might result in offset, noise, and harmonic performance deterioration due to the thermal feedback. A solution to this problem is to combine two amplifier components, a voltage feedback amplifier (VFB) and a buffer to achieve desired system performance. This configuration is referred to as a composite loop, where two or more operational amplifiers are cascaded together with a negative-feedback loop around the entire network. Decoupling the high power current drive stage from the precision amplifier gives high precision performance by eliminating the thermal effects on the input offset of the composite loop. Figure 1 is an example of a composite loop circuit.

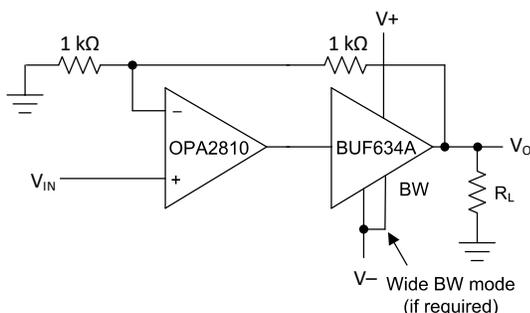


Figure 1. Composite Loop Using the OPA2810 and BUF634A

One of the major advantages of the composite loop is the thermal isolation the buffer provides the VFB amplifier. The power dissipation resulting from the high current drive is isolated to the buffer, hence preserving the precision performance of the VFB. The offset, drift, noise, and harmonic distortion depends on the VFB amplifier selected. Also when connected inside the feedback loop, the offset voltage of the buffer and other errors are corrected by the open-loop gain and feedback of the VFB amplifier.

A simple way to explain this is with the circuit diagram Figure 2. In the circuit, the VFB amplifier has an open-loop gain of 'a', the feedback factor of 'β', and 'ε' is the error introduced due to the offset from the buffer. The equation for the output voltage,  $V_{OUT}$  is expressed in Figure 2.

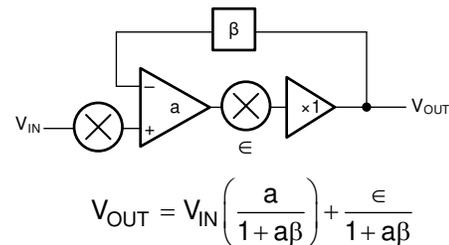


Figure 2. Circuit Diagram

As noted in the equation, the error 'ε' is reduced by the open loop gain of the amplifier since it divided down by  $(1 + a\beta)$ . This holds true for the other errors like offset drift and noise introduced by the buffer.

An added advantage of the composite loop is the low output impedance. The output impedance of the circuit is reduced so the output resistance of the entire circuit is close to zero. The buffer has output impedance that is almost flat across frequency range. This characteristic helps with stabilizing driving high capacitive loads without running into stability issues.

## Product Recommendations for the Composite Loop

This section provides some amplifiers that can be used in the composite loop configuration. Combining the OPA2810, a Dual Channel FET Input VFB amplifier with superior noise and low distortion with the BUF634A, a high-voltage, high-speed 210 MHz, 250 mA buffer to form a composite loop can provide the following advantages:

- Driving large capacitive loads
- Achieving high precision and signal integrity at the DUT
- Signal reproduction at the DUT given the high slew rate (3750 V/ $\mu$ s) capability of the BUF634A

System reliability and fault tolerant behavior is ideal for test equipment. The internal, output current limiting, and thermal shutdown circuit in the BUF634A protects the circuit from irreversible damage in the event of a short-circuit and when the junction temperature exceeds 180°C. For additional specification details and application information, refer to the [OPA2810](#) and [BUF634A](#) data sheet.

Table 1 shows the selection of unity-gain, open-loop buffers from Texas Instruments.

**Table 1. Device Comparison Table Showing the Unity Gain Buffers and Performance**

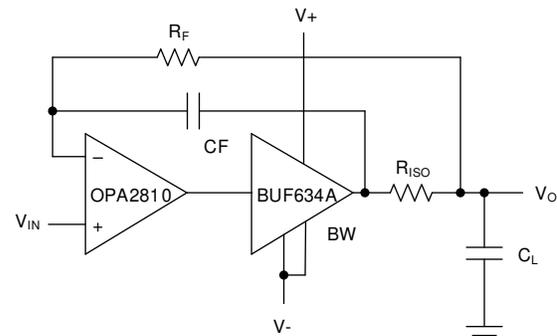
DEVICE	V <sub>SE</sub> (V)	I <sub>O</sub> /CHAN NEL (mA)	BW (MHz)	SLEW RATE (V/ $\mu$ s)	VOLTAGE NOISE (nV/ $\sqrt$ Hz)	AMPLIFIER DESCRIPTION
<a href="#">BUF634A</a>	$\pm$ 18	1.5–8.5	25–210	3750	3.4	Unity-gain, open-loop buffer
<a href="#">BUF602</a>	$\pm$ 6	2.5	1000	8000	4.8	Unity-gain, closed-loop buffer
<a href="#">LMH6321</a>	$\pm$ 18	11	110	1800	2.8	Unity-gain, open-loop buffer with adjustable current limit

### Application Considerations for the BUF634A

Consider the following when designing composite loops with the BUF634A:

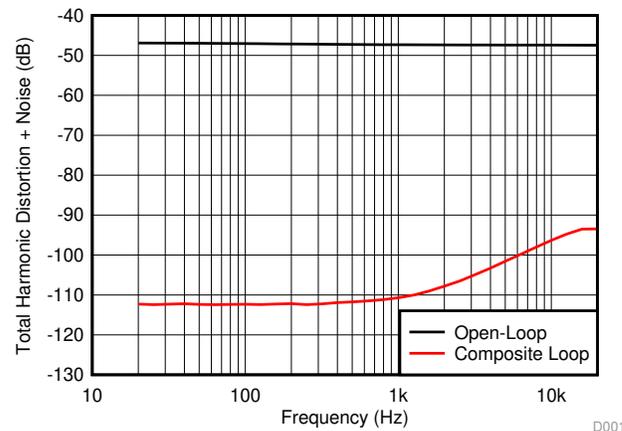
- It is recommended to place an isolation resistor on the output of the buffer to provide adequate phase margin and stability when driving multiple DUT inputs with high capacitive load. This is illustrated in [Figure 3](#).
- The bandwidth of the buffer must be higher compared to the bandwidth of the amplifier to ensure meeting the system bandwidth requirements and stability. For composite amplifier stability, the phase shift introduced by the BUF634A must remain small throughout the loop gain of the circuit.

Additional details on the design procedure to maintain loop stability is available in the [BUF634A data sheet](#).



**Figure 3. Resistive Isolation from Heavy Capacitive Loads in Composite Loops**

The plot in [Figure 4](#) shows the harmonic distortion versus frequency for the stand-alone buffer as well as the composite loop with the BUF634A is in the feedback loop of the OPA2810. As seen, the distortion performance of the composite loop is better compared to the stand-alone buffer.



**Figure 4. Harmonic Distortion Performance of Standalone Buffer and Buffer in a Composite Loop With OPA2810**

In summary, buffers like the BUF634A can be connected inside the feedback loop of most operational amplifiers to increase output current and load drive capability while enabling high precision performance. These advantages coupled with the high-voltage, wide-bandwidth capability of the BUF634A makes it ideal for ATE applications in memory and semiconductor testing, battery testers, virtual ground drivers for dynamic load, and low-distortion end stages for both audio and video signal generators.

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