AN-46

Using the PAD04 To Drive Ink Jet Printer Heads

Synopsis: A discussion of details of driving an ink jet printer head with the PAD04 amplifier presented. Some simple circuits are offered and practical results are detailed.

One important application for linear power amplifiers (op amps) is in the area of driving high voltage ink jet printer heads. Linear amplifiers are ideal when the ink jet element must be driven with pulses of various shapes and amplitudes depending on the ink selected for each printing project. An ink jet printer's computer generates the proper frequency, shape and duty cycle of the required pulse to the input of the PAD04

In this application note some simple circuits will be presented and results shown for possible applications. Many variations are possible and the circuits presented are just a few of many possibilities but illustrate the capability of the PAD04. Pulses are shown which represent the maximum slew rates for the PAD04 as well as maximum pulse currents and internal power dissipation with the load capacitances listed in the text or circuits.

The PAD04 may be very advantageous due to its small footprint (30mm square) and high pulse current output capability (10A). Although the PAD04 is rated to dissipated 30W, the PAD04-1 without the integral heat sink and fan may be able to dissipate more power on a suitably rated custom heat sink, with or without a fan to facilitate cooling of the amplifier. The circuits shown may be implemented on the EVAL04 evaluation kit prior to building the final production circuit board. The results shown were documented using the EVAL04 evaluation kit.

In Figure 1 below a 150V pulse is generated and applied the print head ceramic element shown as a capacitor with a value of 50nF. The PAD04 is capable of driving this load continuously at 20kHz. The peak load current is 5A. The heat sink temperature reaches 85ºC, the maximum rated temperature. The resulting o'scope photo is shown in Figure 2 below. Channel 1(the lower trace) is the resulting current in the load. Channel 2 (the upper trace) is the output voltage. Expanded views are shown in Figures 3 and 4 below. As you may suspect, for any given load capacitance as the frequency increases so also does the amplifier's internal power dissipation. As the pulse rise and fall times get faster so also does the peak load current increase.

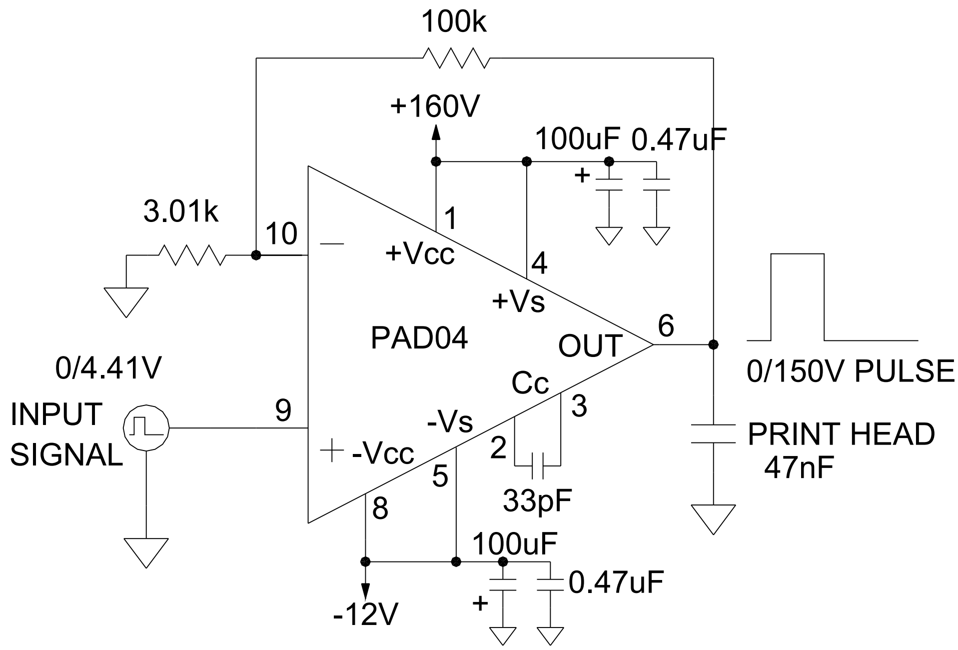

Figure 1
INK JET PRINT HEAD DRIVER CIRCUIT

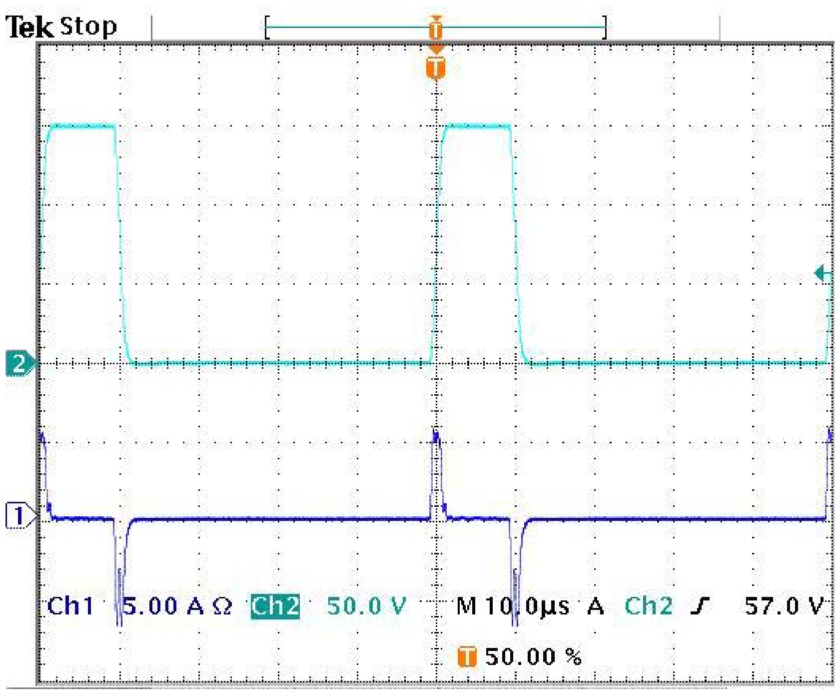

Figure 2
OUTPUT PULSE WITH LOAD CURRENT

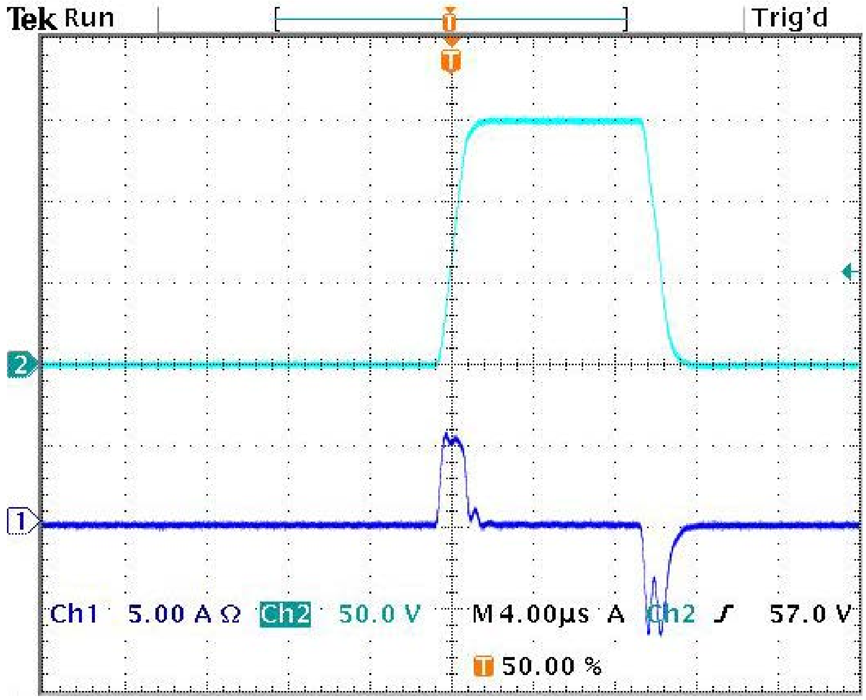

Figure 3
EXPANDED OUTPUT AND CURRENT VIEW TRIGGERED ON
POSITIVE GOING PULSE EDGE

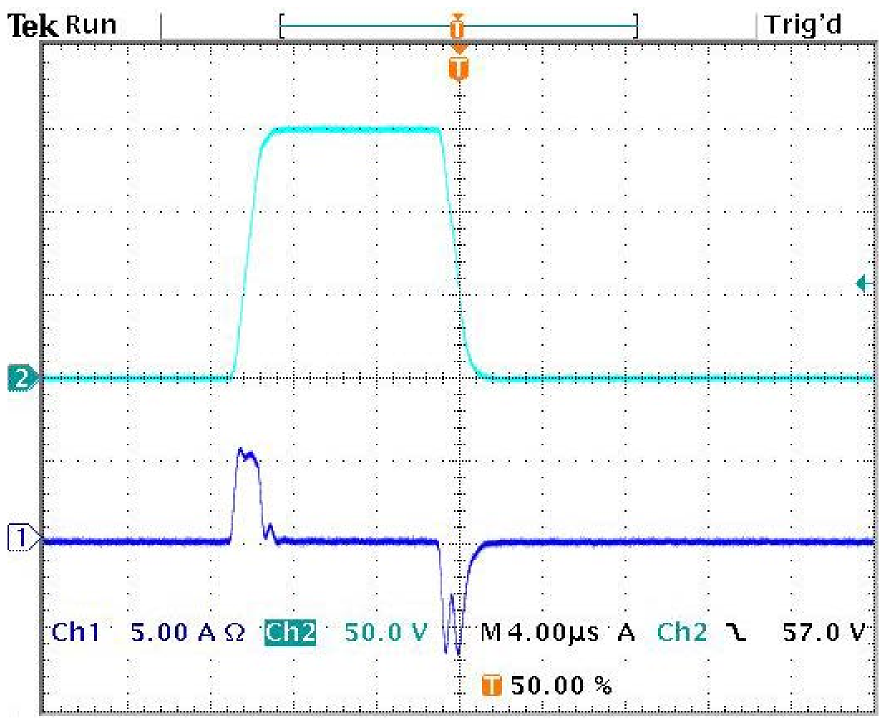

Figure 4
EXPANDED OUTPUT AND CURRENT VIEW TRIGGERED ON
NEGATIVE GOING PULSE EDGE

The circuit in Figure 1 works well as was shown in the o'scope photos above. Although the current in the load capacitance may be 5A peak the average power supply current is only 0.2A due to the fact that the 5A is only present while the amplifier's output is slewing from 0 to 150V with the given load capacitance. And indeed the power supplies in this application do show a monitored current of 0.2A. With proper bypassing the power supplies need not be capable of providing the whole 5A. The o'scope photos show the peak current from the power supplies to be only about 1A. Smaller capacity power supplies can usually supply larger peak current for very short intervals with small duty cycles. In Figure 5 below the current from the +160V power supply is shown (Ch1) in sync with the output signal. The current in the -12V power is similar since the load capacitance must be discharge after every charge cycle as shown in Figure 6 below.

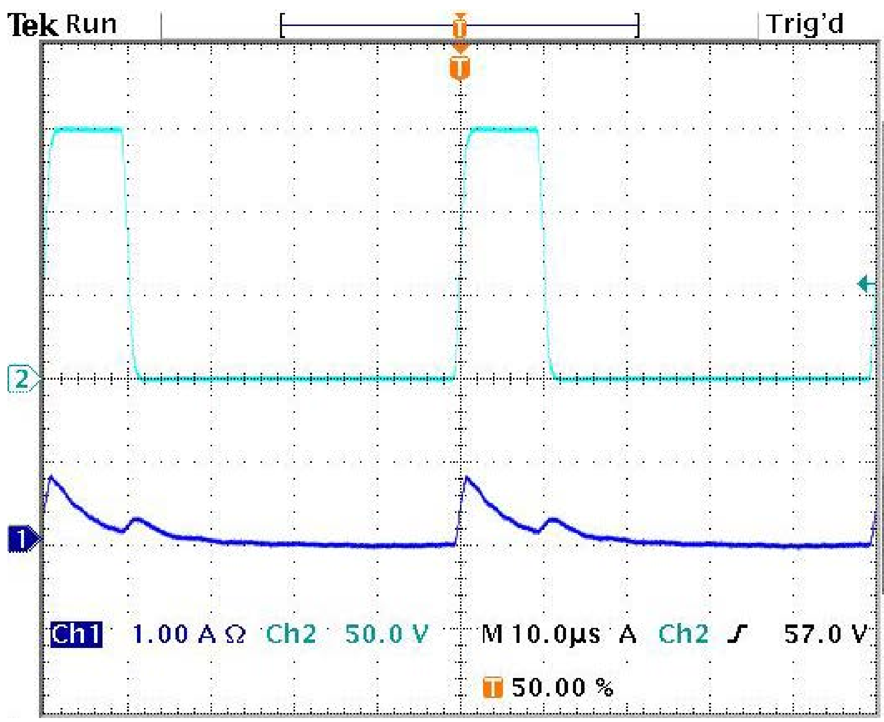

Figure 5
CURRENT FROM +160V POWER SUPPLY (CH1)

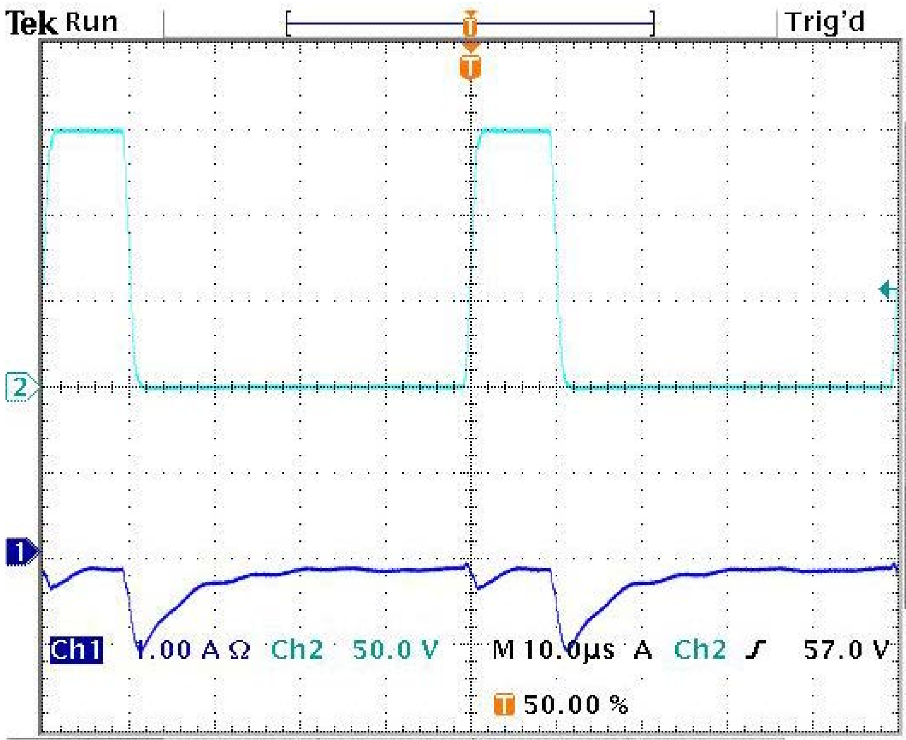

Figure 6
CURRENT FROM -12V POWER SUPPLY (CH1)

This can all work fine for an application circuit that only requires one amplifier but an ink jet printer application circuit may require 6 or 8 amplifiers and the amplifier pulses are likely not in sync. A close analysis of the required average current from the power supplies may show a substantial current requirement of several amps. The circuit in Figure 1 above may require two power supplies capable of 5A or more depending on how many amplifiers are needed and costs are always a concern.

In Figure 7 below another similar circuit is shown that only requires one high-current power supply, thus reducing costs. The -Vs high current power supply has been replaced by a connection to ground. The -12V power supply in this circuit need only provide about 40mA to satisfy the current requirements of the small signal portions of the PAD04 (multiplied by however many amplifiers are needed in the application circuit). Notice, however, that the input signal is slightly different. The resulting output waveforms are shown in Figure 8. It is difficult to decern any difference between Figure 2 and Figure 8.

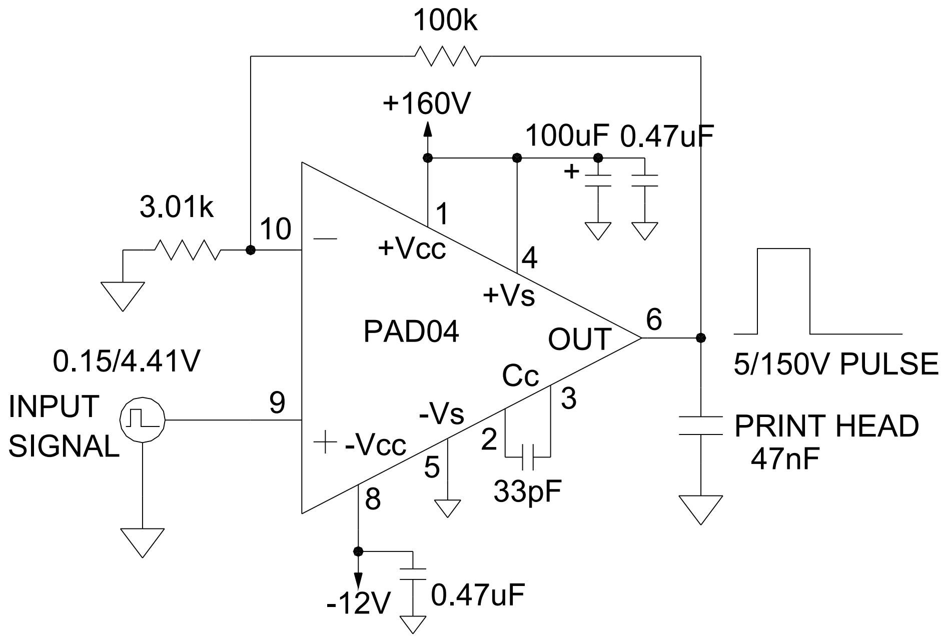

Figure 7
SINGLE HIGH-CURRENT POWER SUPPLY CIRCUIT

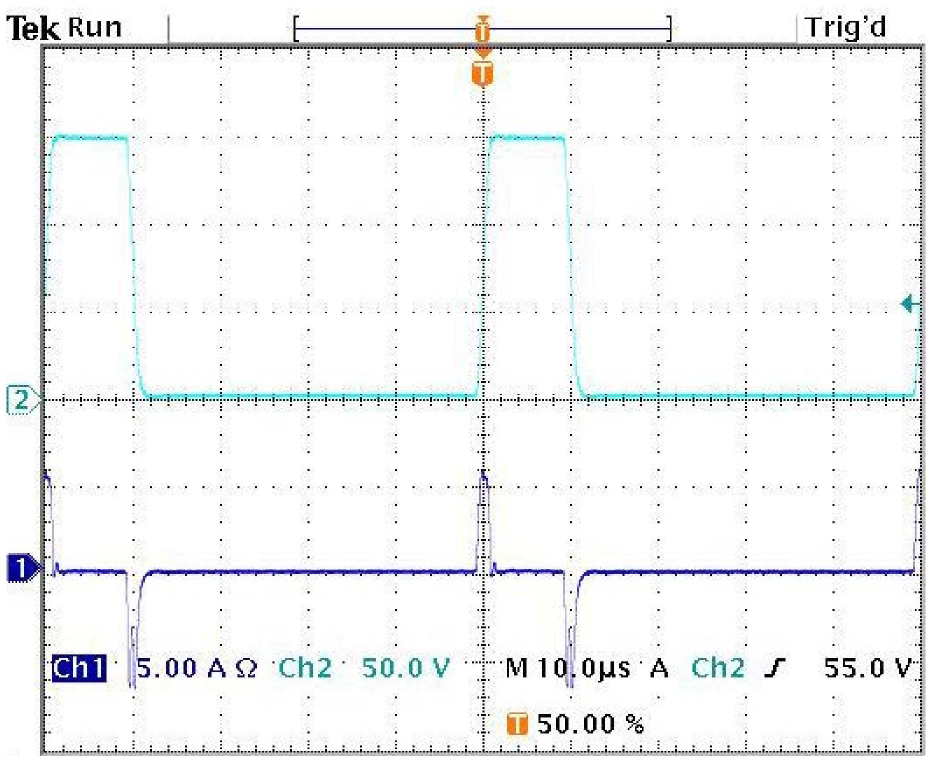

Figure 8
OUTPUT PULSE AND LOAD CURRENT WITH SINGLE HIGH CURRENT POWER SUPPLY

If the input signal low value were zero as in the circuit of Figure 1, two negative effects would result. The first is that the output would be unable to reach zero in a linear fashion. There will always be some difference between the output voltage and the supply voltage rails. It's important to keep the amplifier operating in a linear mode for best fidelity of the output waveform. The second effect is that as the output voltage comes close to zero the internal biasing of the output MOSFET tied to -Vs will be driven so that its drain-source voltage will approach zero (ground) and the parasitic capacitance of the MOSFET will increase greatly similar to what occurs when driving a MOSFET as a switching device. It becomes difficult to turn the MOSFET off quickly due to the large increase in capacitance. The result for the op amp is that as the small signal stage of the PAD04 tries to slew positive with a fast rise time the N channel MOSFET tied to +Vs can start to turn on before the P channel MOSFET tied to -Vs can turn off. This results in a large current flowing between the two output MOSFETs. The resulting current and subsequent power dissipation will likely destroy the amplifier. When the input is biased slightly positive so that the output never goes below (in this case) 5V this effect is greatly reduced or eliminated. In general, if the output is driven to (near) zero with DC or a waveform without a high slew rate, like a sine wave, the effect is not an issue as there is time for amplifier's biasing to adjust properly as it moves from a near zero output to a positive output voltage.

When developing a pulse pattern to drive the PAD04 a parameter to consider is the rise time of the input pulse. The rise time should be chosen so as to not greatly exceed the expected rise time of the amplifier's output. For example, in the circuits shown, if the output of the PAD04 is expected to have a rise time of 1uS for 150V then the rise time of the input signal should not rise to 4.41V in less than 800nS. Exceeding this limit may force the amplifier to try to slew faster than it is capable and force the input to be greatly overdriven. An overdrive of about 20% will help maintain a linear output pulse. The output will most closely track the input signal and provide the most linear output when the input signal is tailored to the capability of the PAD04. Overdriving the input can cause certain devices in the PAD04's internal circuit to saturate or otherwise be limited in response and this will require some time to recover once the input signal stops changing. This effect can change from batch to batch. Limiting the input rise as suggested can provide the most consistent performance over time.

The output full scale and power supply voltage should be also be chosen carefully. A power supply voltage higher than needed will cause excess power dissipation in the PAD04. A power supply voltage too low compared to the output voltage needed will also cause non-linearities in the output signal. It is suggested that the power supply voltage be selected as 10V greater than the required output voltage for best linearity and small signal bandwidth.

In Figure 9 below the capacitance has been doubled to 100nF. The frequency has been cut in half so that the total power dissipation remains the same at 30W. The output current doubles to 10A peak (the maximum rated peak current in the PAD04) due to the doubling of the load capacitance. The output voltage waveform has developed some overshoot due to the higher load capacitance. In Figure 10 the compensation capacitor has been increased to 47pF. The rise time has decreased but the overshoot is reduced or eliminated. Because the overshoot has decreased and the rise time reduced somewhat the output current waveform has also changed somewhat.

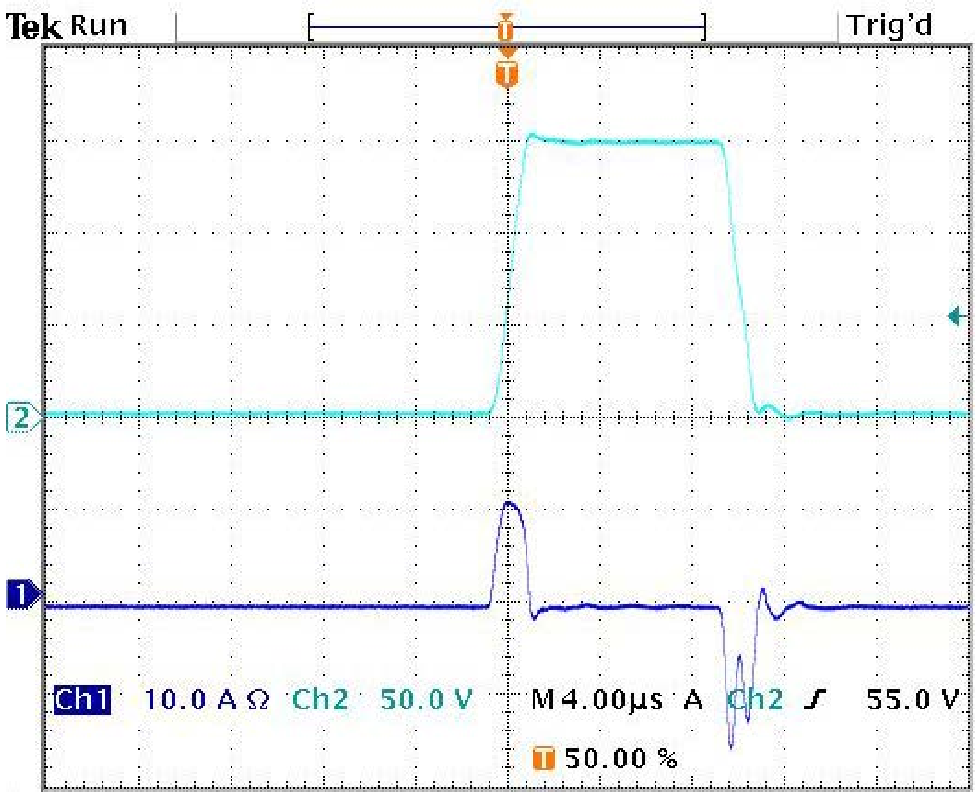

Figure 9
OUTPUT PULSE WITH 100nF LOAD CAPACITANCE AND Cc=33pF

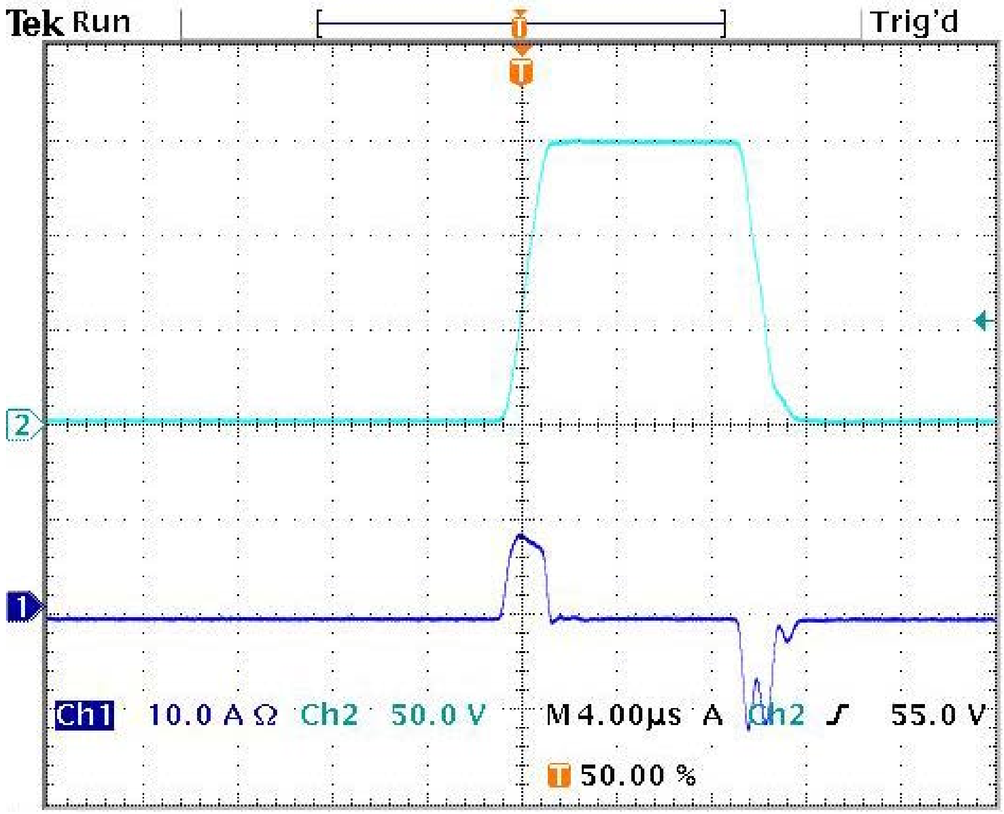

Figure 10
OUTPUT PULSE WITH 100nF LOAD CAPACITANCE AND Cc=47pF

Also note that the EVAL04 is a good evaluation test bed since it provides adequate power supply bypassing, short trace lengths and a short, low inductance output line due to its short and wide trace to the load capacitance. Longer and higher inductance output lines will likely cause ringing in the output voltage waveform. This should be a consideration in the final application circuit for the cable connection to the ink jet printer head. It is important, and in fact critical, that the pin 7 be grounded as well as the heat sink. The heat sink is grounded by a connection to the mounting screws of the amplifier. A connection under pin 7 connects the aluminum base of the circuit board to the pin. It is very important that pin 7 be connected to the ground plane by a very short and wide trace to prevent ringing in the output waveform. Bypassing of the power supplies is also important as well. The bypass circuit should comprise both a high value of electrolytic capacitor in parallel with a ceramic capacitor of the values shown in the circuit diagrams. The lengths of the connections from the capacitors to the power supply pins should be very short. Connecting the load with co-ax cable also help to reduce any ringing in the output wave form. In the data sheet of the EVAL04 you can see the layout of the board for a reference of good practices.