Application Report
SNOA869A–April 2012–Revised May 2013

AN-2235 Circuit Board Design for LMH6517/21/22 and Other High-Speed IF/RF Feedback Amplifiers

ABSTRACT

High-bandwidth, high-performance amplifiers require care in board layout techniques in order to ensure optimum performance. This paper will address the key components of PCB design for high-performance amplifiers, including the new LMH6521 and LMH6522 DVGAs.

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1 General Description

When designing a printed circuit board (PCB) there are a few key considerations. High-speed amplifiers require good power supply bypassing, low parasitic capacitance on the input and output pins, and good termination of the signal paths.

Providing power to a high-speed amplifier is difficult because the amplifier will draw both DC as well as AC power. The DC power is usually the easiest. The LMH6522, for example, contains four amplifiers and requires only 370 mA of current at a nominal 5 V. The LMH6522 has a bandwidth of 1.4GHz. This means that the power supplies must be low impedance not only at DC, but also at 1.4GHz. This condition requires some special care. When selecting power supply bypass capacitors, the capacitors should offer a low impedance up to the amplifier 3dB bandwidth. That means that they should have a low series resistance and low parasitic inductance. The power supply bypass capacitors should be located within 4 mm of the amplifier supply pins, and any vias used to connect the capacitors to the power supply or ground planes should be designed for low inductance. Using multiple vias can help reduce via inductance.

An example of supply bypass capacitor layout is shown in Figure 1. There are a few things to note in the figure. One is that there are two capacitors used in parallel. For a given capacitor, using devices in parallel reduces the equivalent series resistance (ESR) as well as the parasitic inductance. This can offer a significantly higher series resonant frequency (SRF) than could be achieved by one capacitor. Another common technique with parallel capacitors is to use different value capacitors in order to stagger the resonant frequency of the capacitors over a larger frequency range. It is common practice to use values a decade apart, such as 0.1 µF and 0.01 µF.

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While they are fairly new to the market, at least one company is now offering capacitors with reversed aspect ratios. The conductive contacts are placed on the long edge of the capacitor to provide lower parasitic resistance and inductance. The author has not yet tested this new capacitor configuration, but the datasheet specifications look very good.

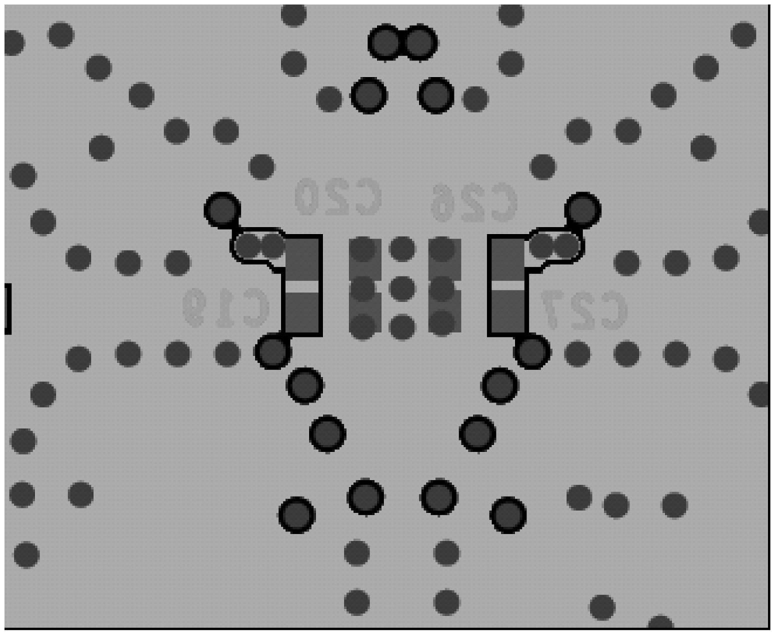

Figure 1. Supply Bypass Capacitors - Double Vias Used for Lower Inductance

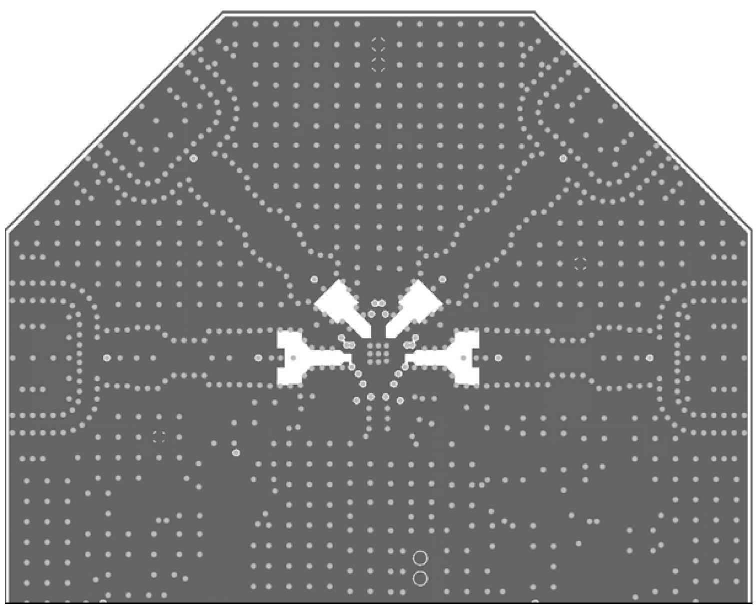

Figure 2. Illustration of Metal Removed From Beneath Amplifier Input and Output Pins

While capacitance to ground is desirable for power supply pins, the output pins of high-speed amplifiers are very sensitive to capacitive loading. With high-impedance amplifiers output capacitance will cause a dramatic loss of bandwidth. With low-impedance feedback amplifiers, capacitive loading will cause a loss of phase margin and can cause gain peaking or instability. One way to reduce capacitive loading on the amplifier output pins is to remove portions of any metal layers beneath the pins. This is shown in Figure 2 .

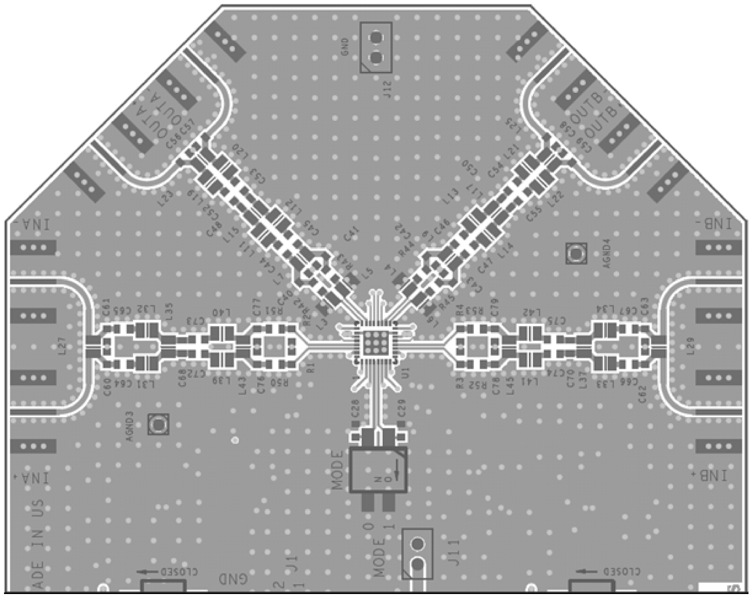

Figure 3. Filter Design

One very important, but often overlooked, consideration for board layout is proper loading and termination of the signal path. This is especially important when only a small amount of the amplifier bandwidth is being used. For instance, the example shown in Figure 3 is designed for a 100 MHz-wide filter centered at 250 MHz. The differential filters provide fifth order selectivity and are designed for 100 Ω differential impedance. While the filters are impedance matched at 250 MHz, the LMH6521 amplifier has a bandwidth of 1.2 GHz. The filters will present reactive load conditions outside of the filter pass-band. At higher frequencies the filter reactance, as well as any transmission line impedance transformation, should be considered. For instance, if a filter is designed to present a short circuit at very high frequencies, a one quarter wavelength of transmission line can transform this into an open circuit at the amplifier input. At 1GHz approximately 4cm of trace on an FR4 substrate equals one quarter wavelength.

With low-impedance output amplifiers like the LMH6517/21/22 the output pins normally require resistors to match the impedance of following stages. Just as with power supply bypass capacitors, it is important to keep the termination resistors close to the DVGA output pins.

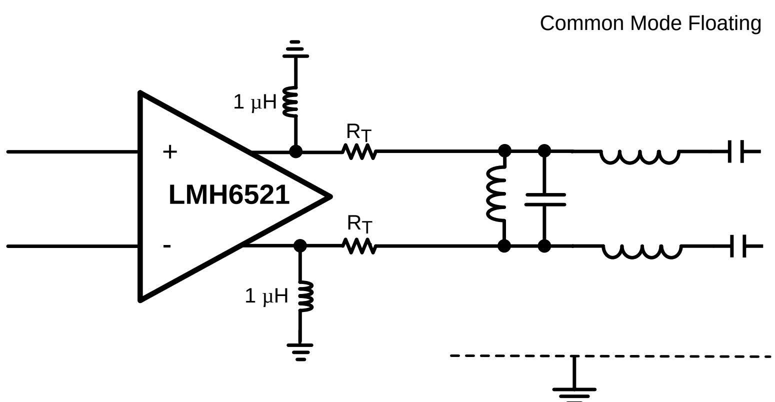

Figure 4. Amplifier With No Common Mode Load

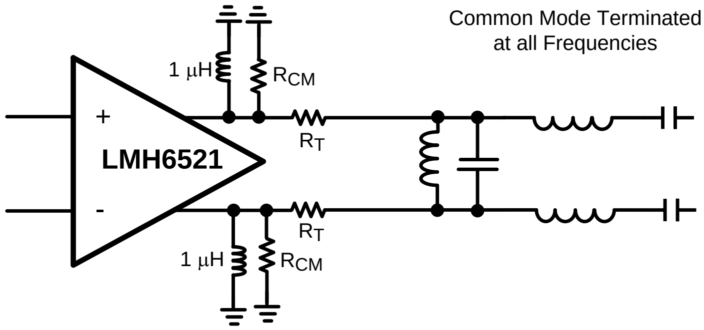

Figure 5. Amplifier With Common Mode Load

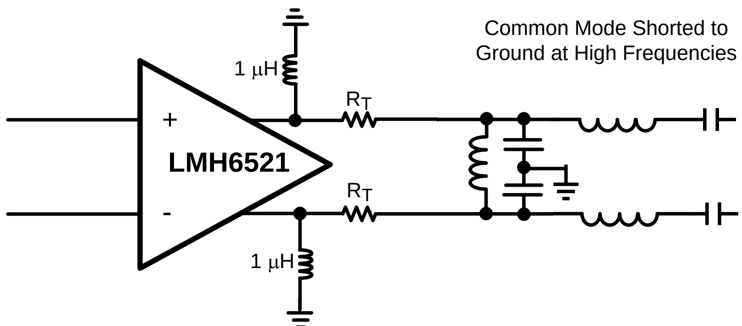

Figure 6. Amplifier With High-Frequency Common Mode Load

Differential signal paths are chosen due to their immunity to many forms of noise. This is because most distant noise sources will couple into a differential signal path as common-mode noise rather than differential noise. In theory, common-mode noise on a differential signal path is of little concern since many elements in the signal path will "reject" the common-mode noise. This is correct in many cases. However, care must still be taken to keep the signal free from excessive noise. One reason is that at very high frequencies many active elements do not have very good common-mode rejection (CMRR). Baluns are one circuit element that have poor CMRR at very high frequencies. Many amplifiers also have trouble suppressing common-mode noise at very high frequencies. Many high-speed analog-to-digital converters (ADC) do not even specify CMRR at all.

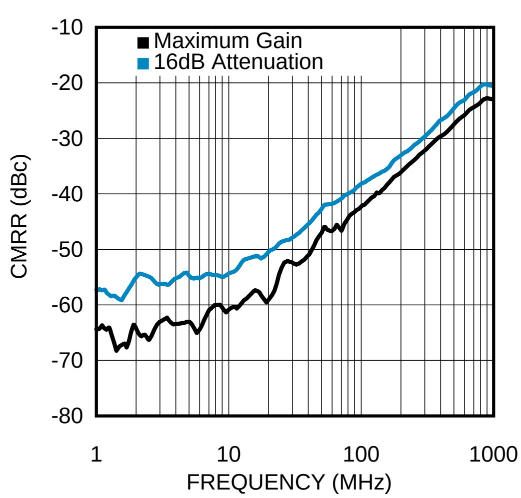

Figure 7. CMRR of the LMH6522 DVGA

As shown in Figure 7 the LMH6522 DVGA has excellent CMRR at modest frequencies, but as frequencies increase, the CMRR gets worse. Fortunately, the board layout can help here as well. As shown in the design of the filter. Creative use of the filter elements and the termination resistors can help reduce common mode noise with very small changes in component configurations. Using capacitors to ground or providing resistive termination to ground directs the common-mode energy to ground instead of conducting it to the next circuit element.

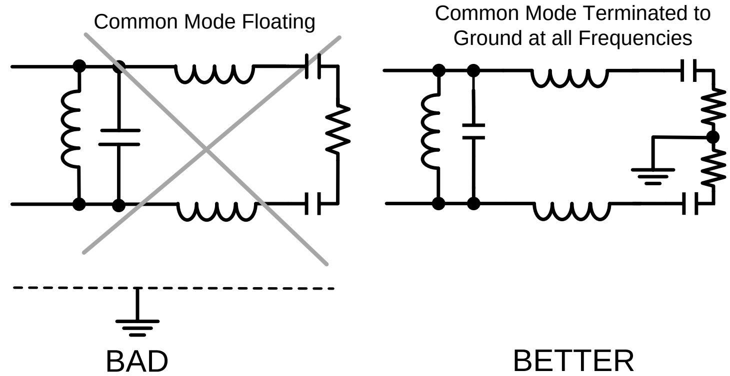

Figure 8. Filters With and Without Common Mode Termination

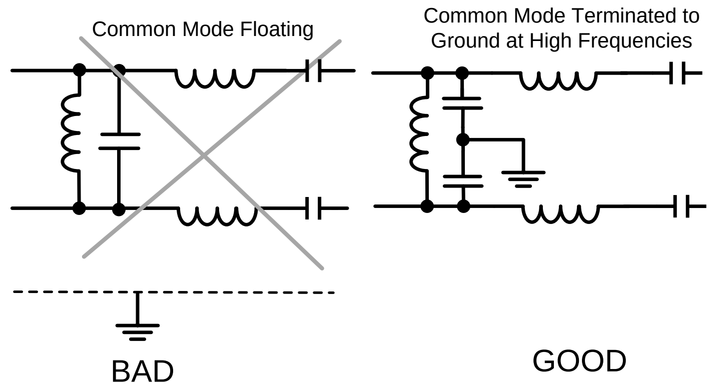

Figure 9. Filters With and Without Common Mode High-Frequency Bypassing

2 Conclusion

High-performance circuit elements require support from a carefully planned printed circuit-board layout. By following the following key guidelines, high-speed, high-performance circuits will perform to their highest potential.

- Place bypass capacitors close to supply pins
- Locate termination resistors close to output pins
- Remove metal from beneath input and output pins
- Terminate transmission lines
- Keep filters close to the amplifier
- Provide both differential and common mode termination

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