

# TRF3765 Output Terminations, Rev. 0.1

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## ABSTRACT

The TRF3765, an integrated wideband VCO and synthesizer, is an excellent choice for use as a local oscillator (LO) source for common signal chains containing modulators, demodulators, and mixers. With the availability of four differential outputs, or eight single-ended outputs, the TRF3765 can meet the demands of future generation wireless base station systems using MIMO or active antenna architectures that employ multiple transmit and receive paths. To accommodate such a versatile demand, the TRF3765 outputs are left open-collector, allowing for maximum flexibility for interfacing the TRF3765 to other components. The possible output terminations for the TRF3765 vary widely with performance tradeoffs to be considered for each. This application report discusses some typical terminations and the benefits and drawbacks of each.

## Contents

1	Broadband Resistive Termination .....	1
2	LC Output Termination .....	3
3	Low-Pass Filtering Output Termination .....	4
4	Conclusion .....	5
5	References .....	5

## List of Figures

1	Broadband Resistive Termination .....	2
2	Output Power for Broadband Resistive Termination .....	2
3	TRF3705 I/Q Modulator Noise Floor vs LO Drive .....	3
4	LC Termination .....	3
5	LO Harmonics vs LO_OUT Frequency .....	4
6	Output Termination including Low-Pass Filtering at 1840 MHz.....	5
7	Output Termination Including Low-Pass Filtering at 700 MHz .....	5

## List of Tables

1	Pullup Resistor and BUFOUT_BIAS Setting for No Output Saturation .....	2
2	Shunt Inductor Values vs Frequency .....	3

## 1 Broadband Resistive Termination

The simplest termination for the open-collector output (see [Figure 1](#)) consists of a shunt resistance followed by a series capacitance. The shunt, or pullup, resistor to VCC provides a bias current path for the differential output amplifier, whereas the series capacitance provides a dc block to the load. Note that although single-ended TRF3765 outputs are possible, the circuit itself is differential. Therefore, maintaining a balanced circuit requires identically terminating each of the two differential outputs. The obvious advantage of this termination is its broadband response.

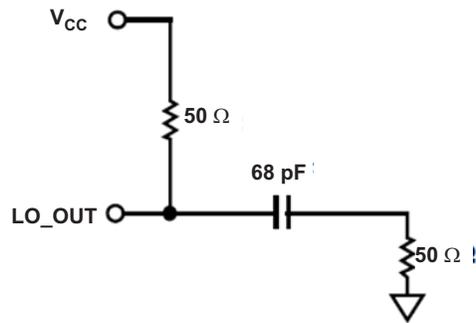
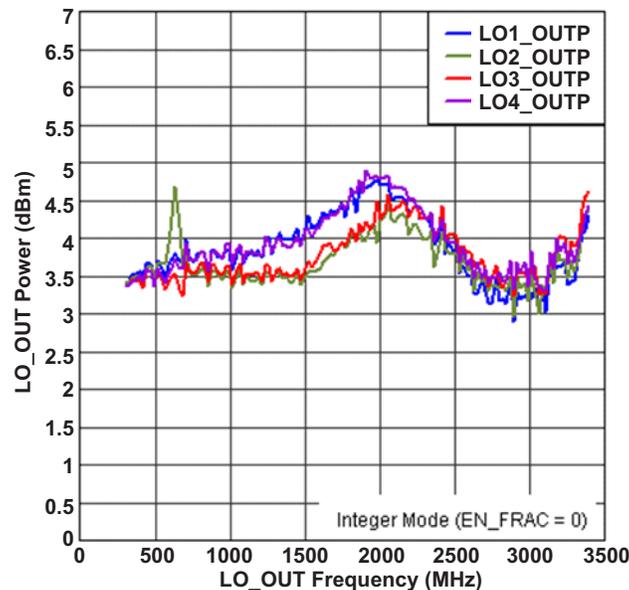

**Figure 1. Broadband Resistive Termination**

Figure 2 shows typical output power from 400 MHz to 3400 MHz for a 100- $\Omega$  pullup resistor and a 47-pF series capacitor driving a 50- $\Omega$  load impedance. Increasing the output resistor achieves higher output power. In so doing, however, the output amplifier operates with less headroom as the IR voltage drop across the pullup resistor increases and thus lowers the voltage on the collector of the output transistor. The same occurs if the bias current of the amplifier increases, which is the case as temperature increases. Therefore, in determining what pullup resistor value to use, consider the minimum VCC level and the highest temperature case.


**Figure 2. Output Power for Broadband Resistive Termination**

Characterization has determined that the output collector voltage must be maintained at a level above 2.4 V. If the collector voltage falls below this bias level, it saturates the output, resulting in reduced output power and degraded harmonics. Table 1 shows a few recommended combinations of terminating resistor values and BUFOUT\_BIAS settings, REG5 B[19..18], that maintain the necessary collector bias voltage to avoid output saturation over a temperature range of  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$  at a VCC of 3.3 V.

**Table 1. Pullup Resistor and BUFOUT\_BIAS Setting for No Output Saturation**

Pullup Resistor ( $\Omega$ )	BUFOUT_BIAS REG5, B[19..18]
50	[11]
75	[11]
100	[10]

## 2 LC Output Termination

Some applications require that the clock source provides a higher output power. For instance, in the case of driving the LO port of an I/Q modulator, the noise floor performance can depend on the LO drive level as Figure 3 illustrates. In this case, a resistive termination may not be the best choice; a reactive termination may be better. In theory, the maximum output power that the device can deliver is achieved when the load presented is the complex conjugate of the output impedance of the device. Although this is simply stated, it is often difficult and impractical to implement. A simpler approach that achieves the goal of higher output power is to replace the pullup resistor with an inductor, which effectively acts as an RF choke. The circuit shown in Figure 4 provides a maximum single-ended output power of +6.9 dbm at 2000 MHz.

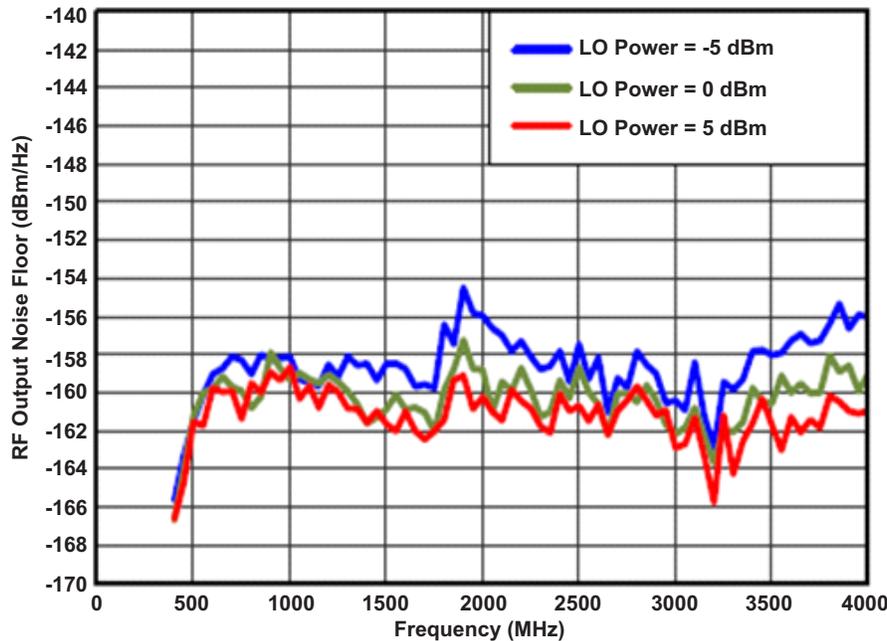


Figure 3. TRF3705 I/Q Modulator Noise Floor vs LO Drive

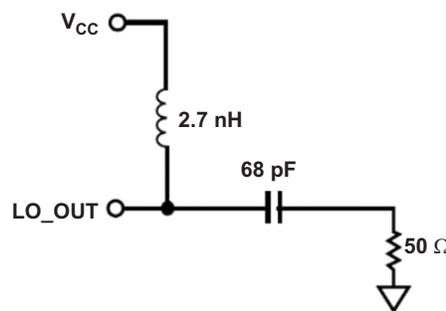


Figure 4. LC Termination

Table 2 lists inductor values and the corresponding output power achieved versus the output power with a 100-Ω pullup resistor for several frequencies of operation.

Table 2. Shunt Inductor Values vs Frequency

Frequency (MHz)	Power Out With 100-Ω Pullup (dBm)	Pullup Inductance (nH)	Power Out With Pullup Inductance (dbm)
900	2.9	30	6.5
1100	3	18	6.6

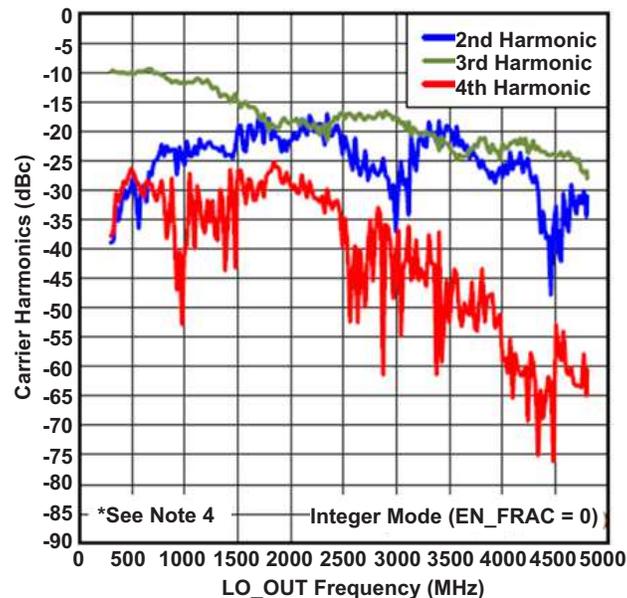
**Table 2. Shunt Inductor Values vs Frequency (continued)**

Frequency (MHz)	Power Out With 100-Ω Pullup (dBm)	Pullup Inductance (nH)	Power Out With Pullup Inductance (dbm)
1300	3	9	7.1
1500	5.5	6.2	7.0
1700	3.1	3.3	7.1
1900	3.6	2.7	6.9
2100	4.4	2.7	6.1

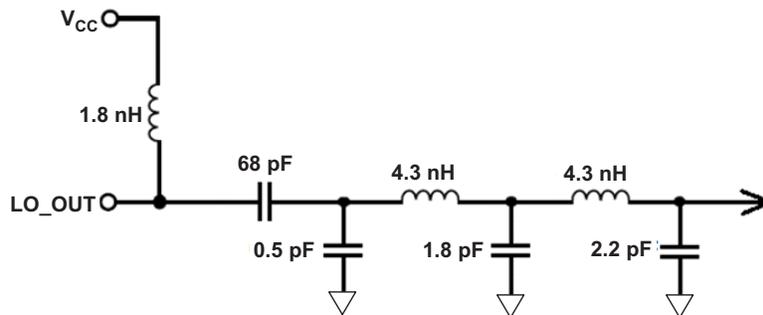
One benefit of using a pullup inductor instead of a pullup resistor is that this alleviates the headroom issue. The dc bias for the output amplifier is provided through the inductor with no IR voltage drop; therefore, the output collector dc voltage remains at VCC regardless of how bias current changes with temperature. This potentially results in less output power variation over extreme conditions of temperature, VCC, and bias current. Although the previously described terminations achieve a higher output power, they do little to filter the harmonics of the signal. Implementing a filter at the output achieves this.

### 3 Low-Pass Filtering Output Termination

The previously described terminations provide little or no filtering for harmonics. Figure 5 shows the typical second-, third-, and fourth-harmonic levels measured with the broadband resistive termination. Depending on the application, this may be of no concern. However, for some applications, such as driving a polyphase bridge circuit for an LO port of a complex transmit modulator (I/Q), LO harmonics can impact modulator performance. In particular, the unwanted sideband suppression of an I/Q modulator depends on second- and third-harmonic amplitude and phase. This is the subject of the application report entitled *LO Harmonic Effects on I/Q Balance and Sideband Suppression in Complex I/Q Modulators* (SLWA059). As cited in this report, most high-performance, digital-to-analog converters (DAC) such as the DAC348x family from Texas Instruments offer quadrature modulation correction (QMC) functionality, thus enabling the performance degradation (that is, sideband suppression) caused by impairments on the LO signal to be compensated by applying phase and amplitude offsets on the baseband signals. Nonetheless, if possible, minimizing such LO impairments is always desirable.

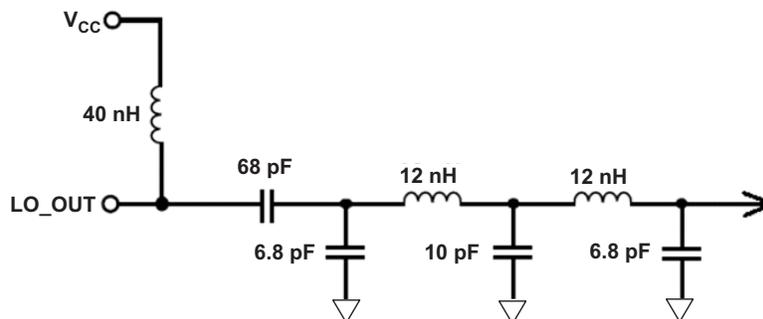

**Figure 5. LO Harmonics vs LO\_OUT Frequency**

One such way to minimize the LO impairments is to minimize the LO harmonics using filtering. As reported in [SLWA059](#), if the second and third harmonics are kept below a level of  $-30$  dBc and  $-60$  dBc, respectively, this minimizes the impact that these harmonics have to the sideband suppression performance of an I/Q modulator. Implementing a fifth-order, low-pass filter at the output of the termination can achieve such performance. With the circuit shown in [Figure 6](#), a second-harmonic level of  $-38$  dBc and a third-harmonic level of  $-88$  dBc were measured at 1840 MHz.



**Figure 6. Output Termination including Low-Pass Filtering at 1840 MHz**

Application report [SLAA519](#) entitled *LO Harmonic Effects on TRF3705 Sideband Suppression* discusses a similar circuit for operation at 700 MHz.



**Figure 7. Output Termination including Low-Pass Filtering at 700 MHz**

#### 4 Conclusion

The open-collector output of the TRF3765 offers flexibility to the user. This application report provides the typical component values for several output topologies. A real output provides broadband operation at a lower output power than is achievable, whereas a reactive output allows for higher output powers. Finally, low-pass filtering of harmonics at the output is desirable in some applications such as driving a polyphase bridge circuit. This report provides two such filters.

#### 5 References

1. *LO Harmonic Effects on I/Q Balance and Sideband Suppression in Complex I/Q Modulators* application report ([SLWA059](#))
2. *LO Harmonic Effects on TRF3705 Sideband Suppression* application report ([SLAA519](#))

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