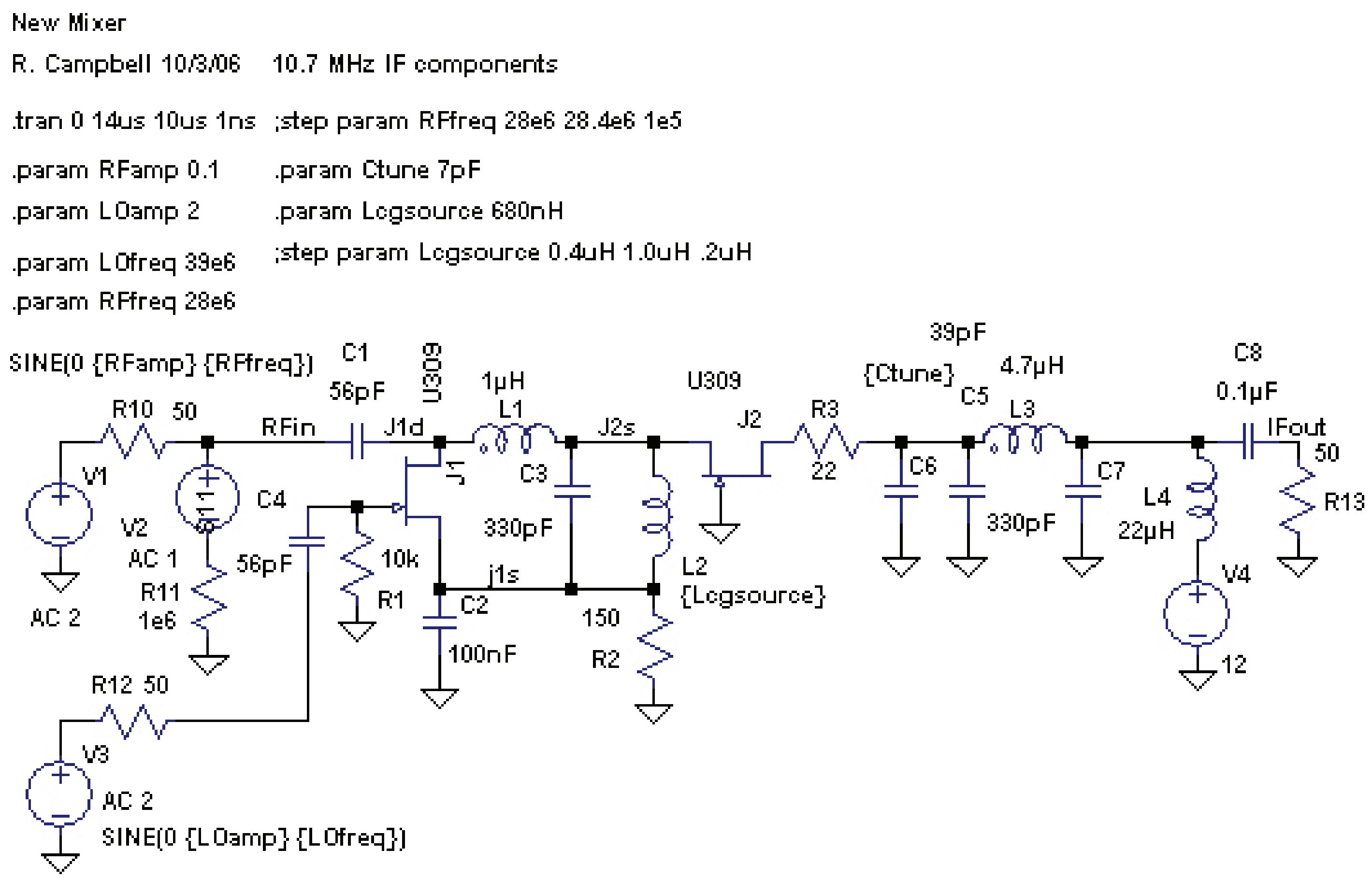
New Mixer Design Notes
Rick Campbell 26 April 07



This mixer is based on a passive FET resistive frequency converter cell described by first described in the literature by Steven Maas [ ] and explored by Wes Hayward and others [ ]. One difficulty with a DFET passive mixer is obtaining negative gate bias. This has been achieved using gate conduction as in the TriQuint 5M31 [Campbell, Criss], a LO frequency driven negative voltage converter as in the Phillips CMY-12 [Roke Manor Research], and pinch-off generators [Campbell, Hayward]. A different method of obtaining negative gate bias is used here. The mixer source and drain float above ground on a bypass capacitor C2. The source voltage of the following common gate IF amplifier is DC coupled to the mixer source and drain using inductors L1 and L2. This results in a mixer biased approximately halfway between 0 volts and Vp for J1. Other mixer and IF amplifier design details have been previously covered in the literature, but will be reviewed here as an application note.

The passive FET mixer cell

C1, C2, C3, C4, J1, L1, L2, R1 and R2 are the basic mixer cell, connected as shown above. This mixer cell may be tested without the IF amplifier by connecting a variable positive voltage source through an inductor with high impedance at the IF to point J2s and taking the IF signal off through a 100 nF capacitor.

J1 operates as a passive switch. The LO drives the gate back and forth between hard pinch-off and a bit of gate conduction. As the gate voltage varies, the source-drain resistance smoothly varies between a few ohms and a very high resistance. There is no non-linearity associated with the frequency conversion, and the gate does not present a non-linear load to the LO below the gate-conduction threshold.

Conversion loss decreases gracefully and monotonically from a few tens of millivolts of LO drive up to a few volts, unlike a diode ring mixer. Conversion loss with 4 volts peak-peak swing on the gate is about 7 dB. Note that the mixer cell may be driven either from the IF side or the LO side for upconverter or downconverter applications.

Component Values

C1, L1 are relatively non-critical, and C2 is a broadband bypass capacitor. As a first pass selecting C1 and L1, they should be about 50 ohms at the geometric mean of the RF and IF. This provides a 1 dB bandiwdth of at least an octave, as long as the RF and IF are separated by more than an octave. High side LO injection may be used to keep the LO out of the IF stages when the RF is less than 4 times the IF, as shown in the following LTSpice examples.

C2 provides a low impedance at the RF across the input of the IF amplifier. C2 is resonant with L2 at the IF. L1, C2 and L2 form a relatively broadband matching network between the nominal impedance of the mixer FET and the input of the IF amplifier FET. Assuming 50 ohms for the mixer fet Z and 70 ohms looking to the IF amplifer FET source and selecting L3 for XL near 50 ohms allows an easy Smith Chart optimization of the three element network.

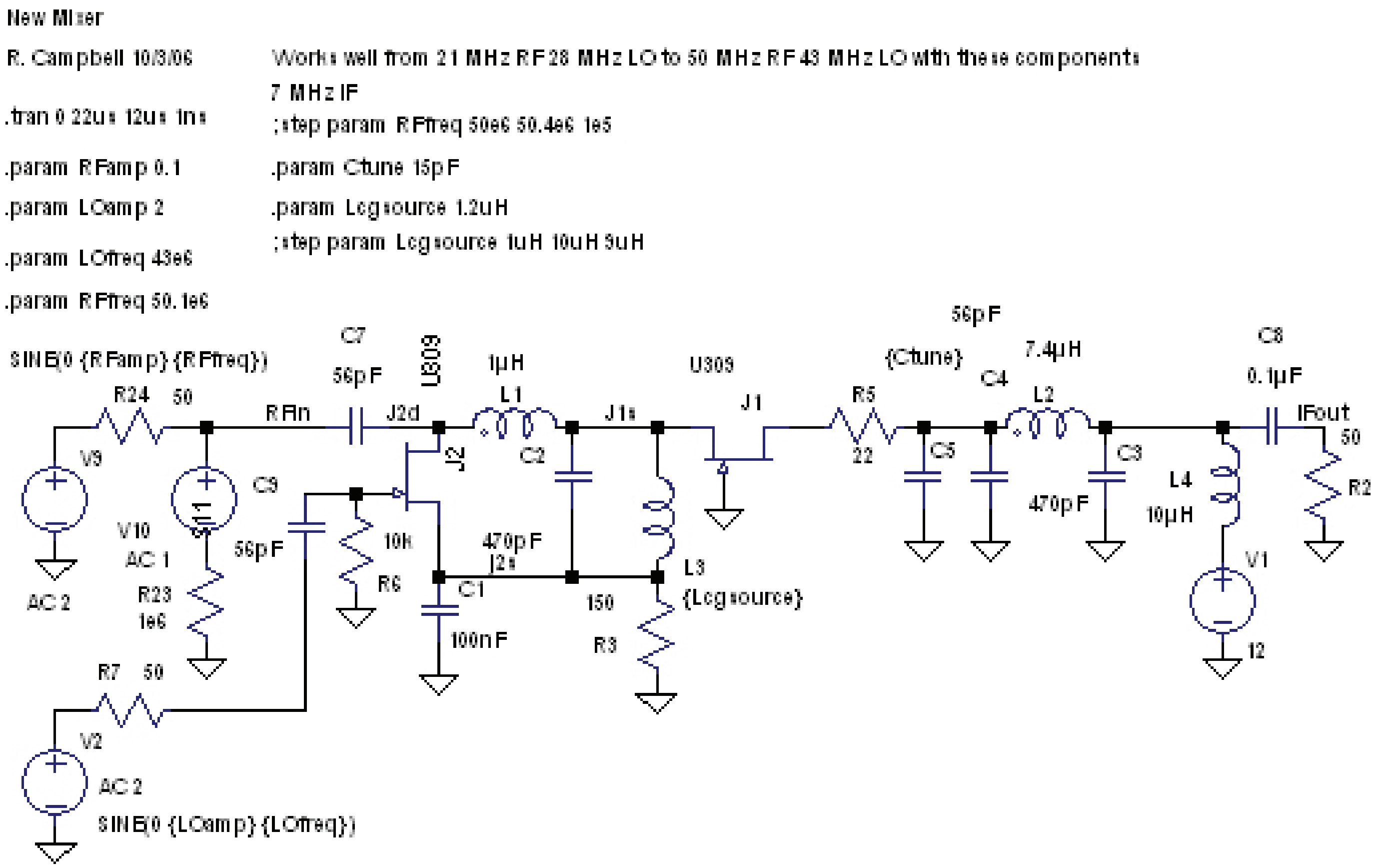
J2 and its associated components form a common gate amplifier. The amplifier bias, gain and operating impedances are selected for a good noise figure and intermod match to the mixer. With 10 mA drain current in J2 and the output network selected to present 500 ohms at the J2 drain the mixer-amplifier combination will have a gain of about 6 dB, a noise figure under 10 dB, and input intercept of approximately +16 dBm. The output network composed of C5, C6, C7 and L3 are designed as a narrow-tuned amplifier for an application involving a fixed frequency IF. For examples of a common-gate amplifier with a bandpass output network, see the common gate amplifiers in chapter 9 ofExperimental Methods in RF design. In the example circuits, L4 is an RF choke, but it may be incorporated into the ouput resonant circuit for additional filtering if desired. C5, C6, C7, L3 and L4 may be studied using the Smith Chart.

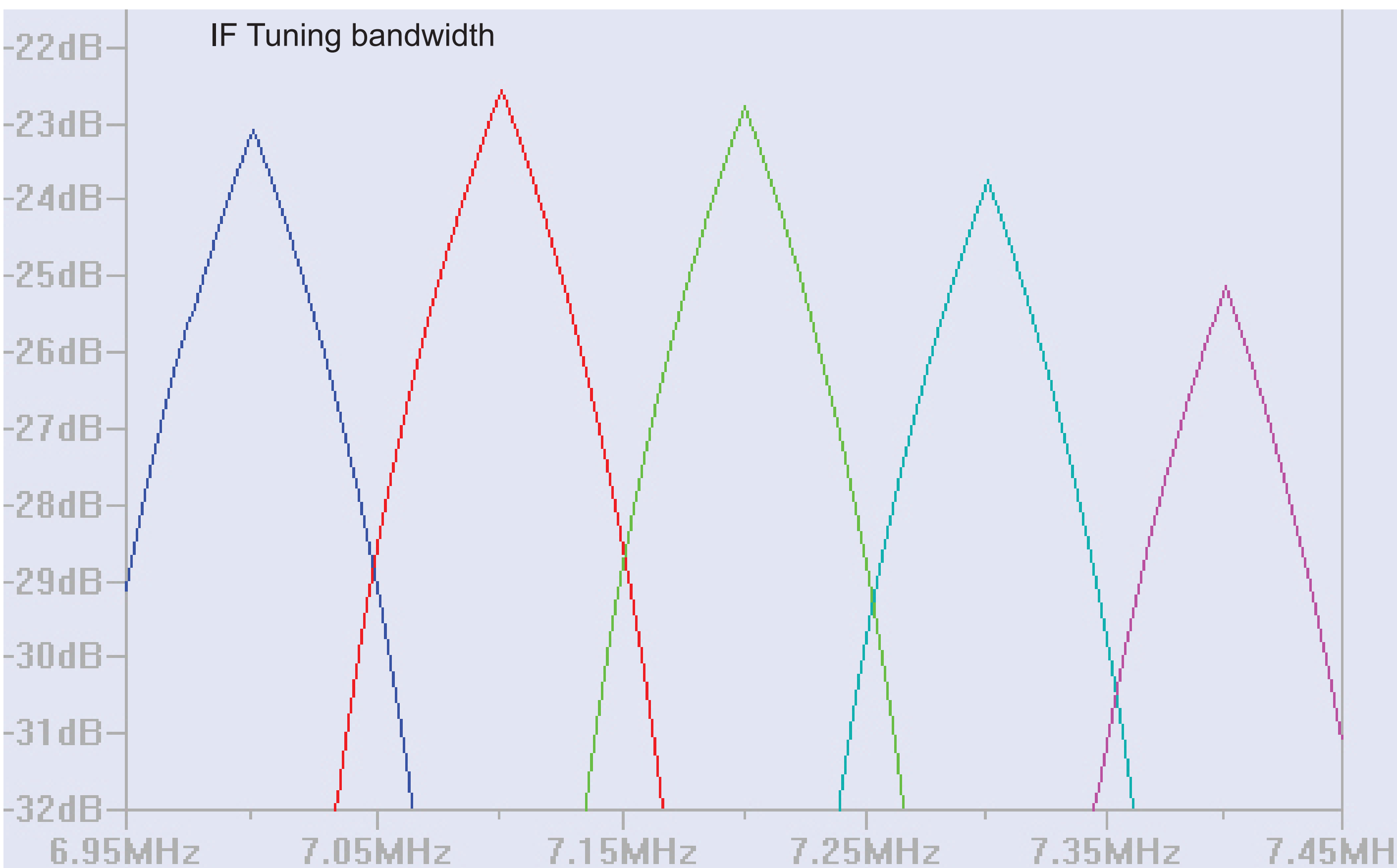
Comparison with a Diode-Ring Mixer and broadband post amplifier

This mixer has several performance and cost advantages over the industry-standard Diode Ring and IF post amplifier combination for superhet receivers [Hayward Progressive Communications Receiver]. The cost of commercial packaged Diode Ring Mixers such as the TUF-3 is now approaching $10, and the cost of a J310 FET is about $0.20. The noise figure of the passive FET mixer-amplifier combination is a few dB higher than the diode ring and post-amp, but this is much more than offset by a 9 dB improvement in input intercept, which permits the use of an LNA to give the passive FET mixer a significant noise figure advantage. Narrow band circuitry requires that that passive FET mixer be designed for a particular frequency range, but that also eases the requirement that the associated electronics present broadband resistive terminations to the mixer ports. The RF, IF, and LO ports of this mixer are relatively tolerant of impedance excursions, while the diode ring is notoriously not. Since the LO port is a high impedance, the required LO voltage may be obtained with a tuned or untuned transformer, and the LO drive power requirement is then lower than a standard level diode ring. Finally, in the area of intercept efficiency--(Input 3rd order intercept)/(DC operating power) the passive FET mixer and common gate amplifier combination excells. The diode ring mixer has a clear advantage in 2nd order intercept performance.

Rick Campbell 26 April 2007

Design Examples for other RF and IF



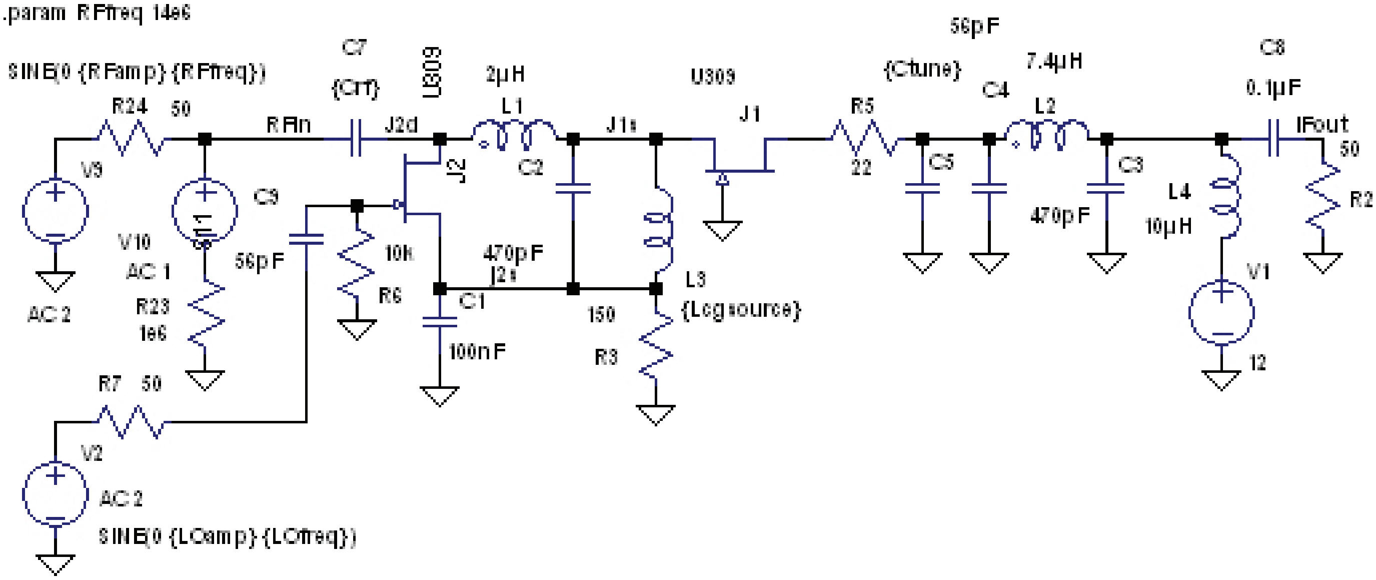


Design Examples for other RF and IF

New Mixer

R. Campbell 10/3/06 — 14 MHz RF and 21 MHz LO version

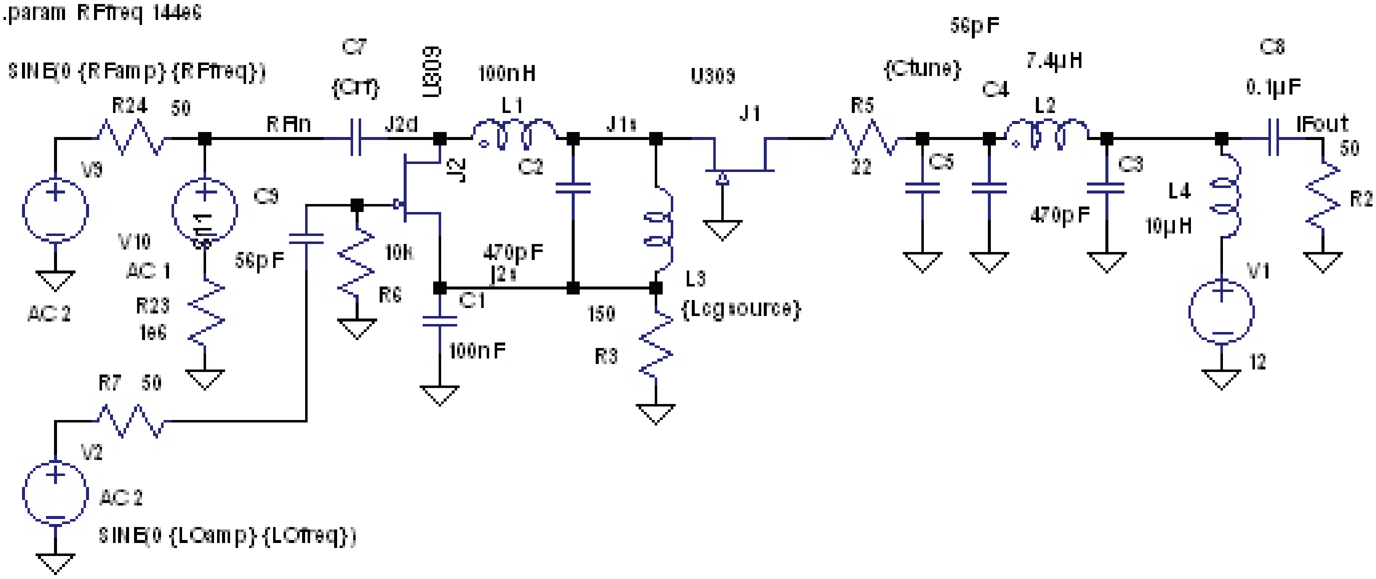
.tran 0 2us 1us 1ns
.step param RFfreq 14e6 14.4e6 1e5
.param RFamp 0.1
.param Ctune 15pF .param Crf 100pF ;step param Crf 80pF 120pF 20pF
.param LOamp 2
.param Lcgsource 1.2uH
.param LOfreq 21.4e6
;step param Lcgsource 0.8uH 1.4uH 0.2uH
.param RFfreq 14e6



New Mixer

R. Campbell 10/3/06 — 144 MHz RF 7 MHz IF version

.tran 0 2us 1us 1ns
.step param RFfreq 144e6 144.4e6 1e5
.param RFamp 0.1
.param Ctune 15pF .param Crf 10pF ;step param Crf 80pF 120pF 20pF
.param LOamp 2
.param Lcgsource 1.2uH
;step param Lcgsource 0.8uH 1.4uH 0.2uH
.param LOfreq 137e6
.param RFfreq 144e6



Design Examples for other RF and IF

New Mixer

R. Campbell 10/3/06 3.5 MHz IF components

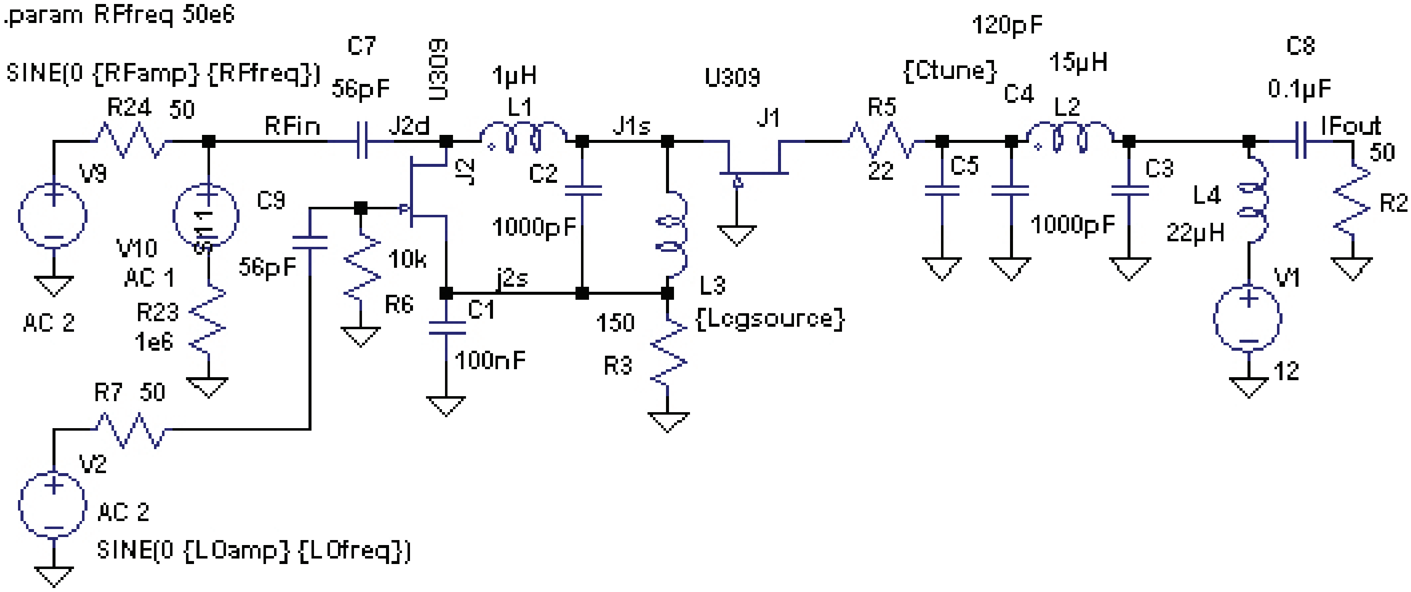
.tran 0 14us 10us 1ns ;step param RFfreq 50e6 50.4e6 1e5

.param RFamp 0.1 .param Ctune 24pF

.param LOamp 2 .param Lcgsource 2.3uH

.param LOfreq 46.5e6 ;step param Lcgsource 1uH 10uH 9uH

.param RFfreq 50e6



New Mixer

R. Campbell 10/3/06 3.5 MHz IF 7 MHz RF 10 MHz LO

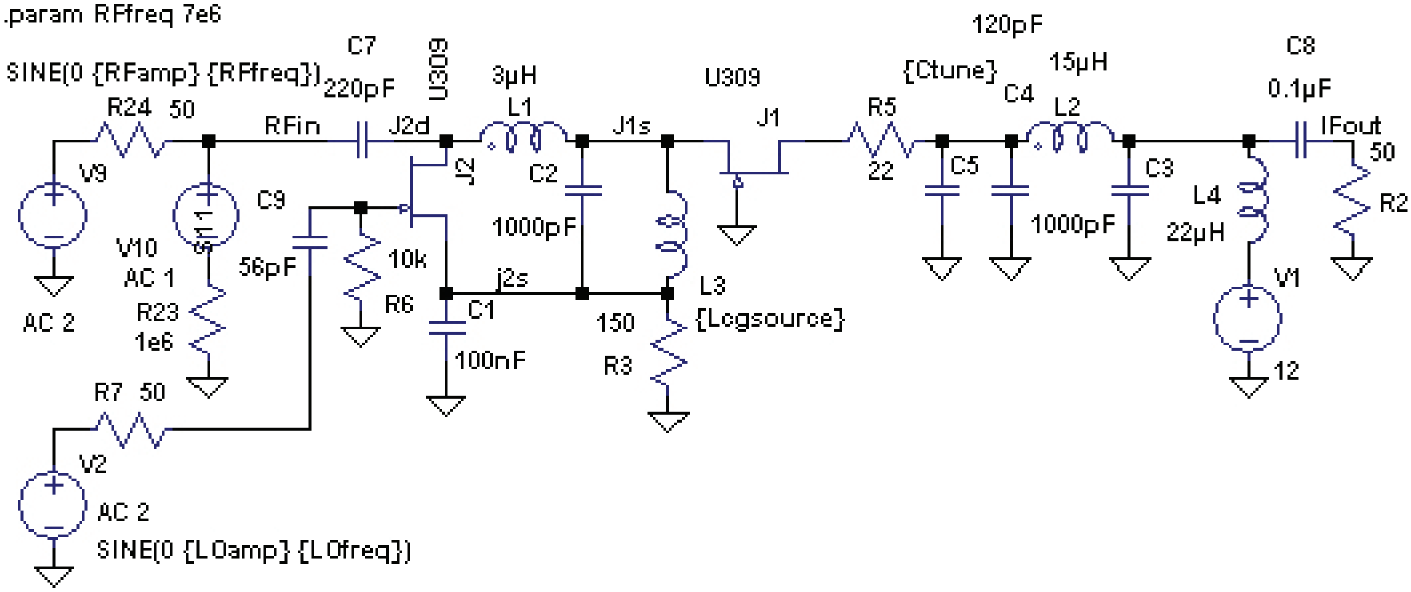
.tran 0 14us 10us 1ns .step param RFfreq 7.0e6 7.3e6 1e5

.param RFamp 0.1 .param Ctune 24pF

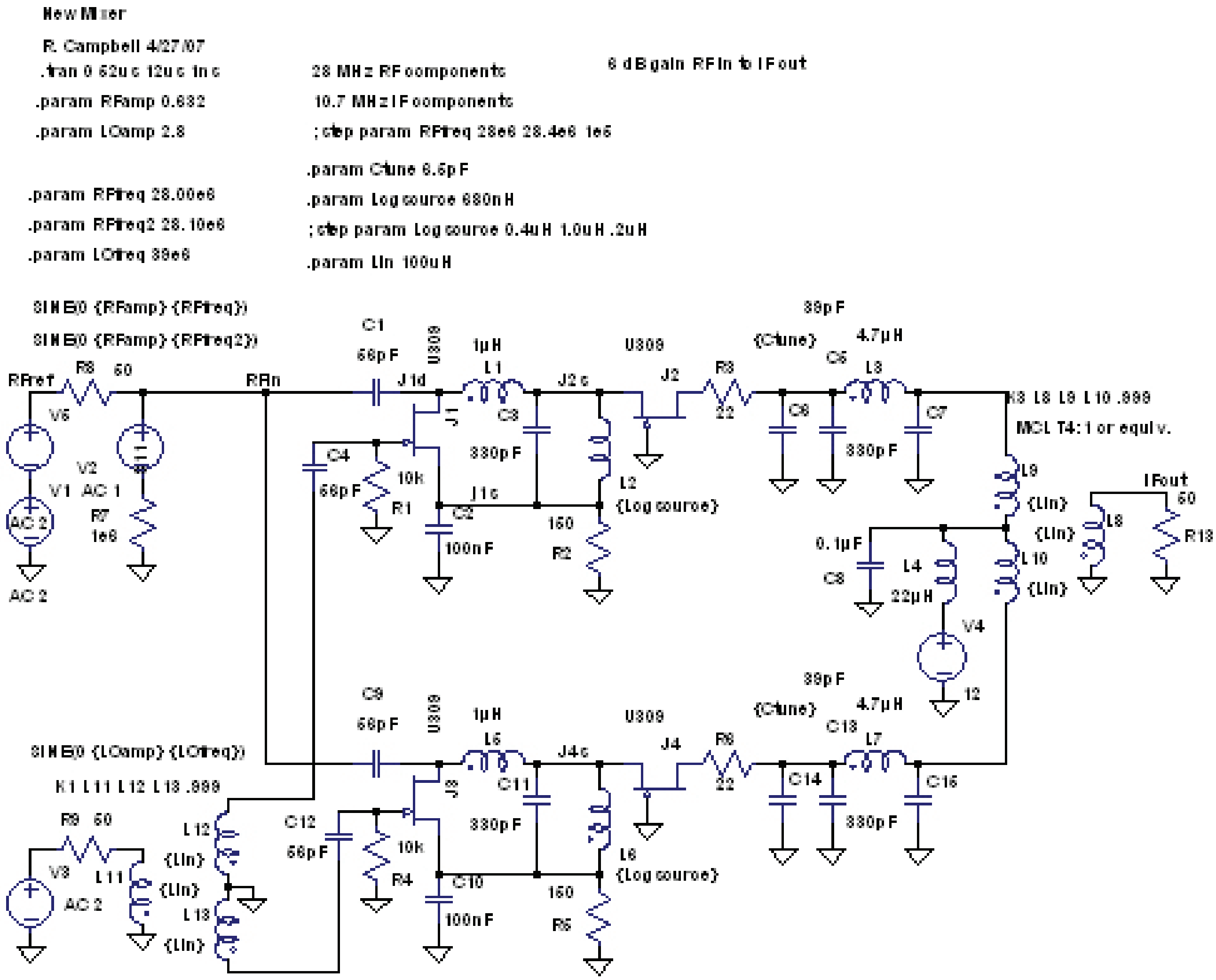
.param LOamp 2 .param Lcgsource 2.3uH

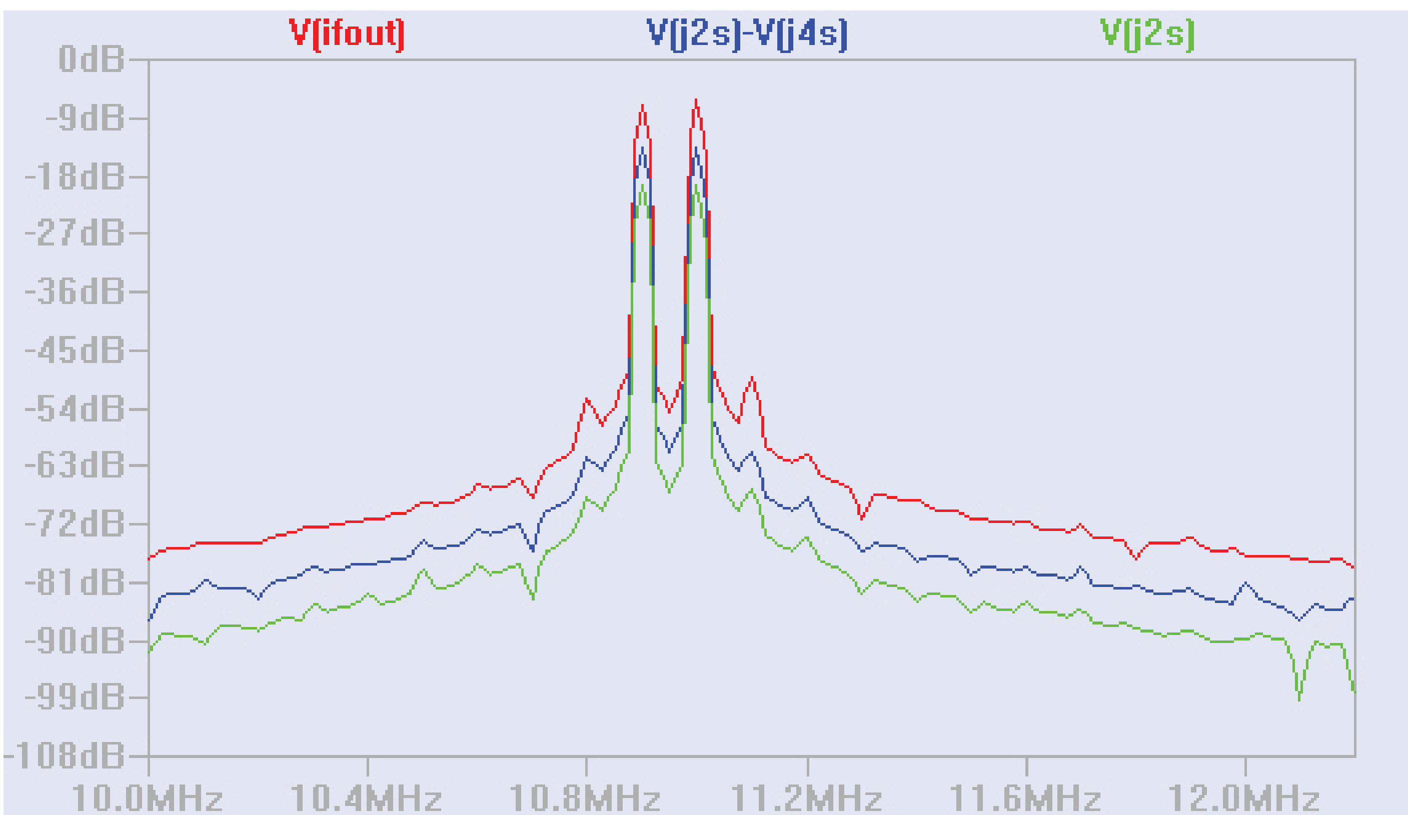
.param LOfreq 10.7e6 ;step param Lcgsource 1uH 10uH 9uH

.param RFfreq 7e6

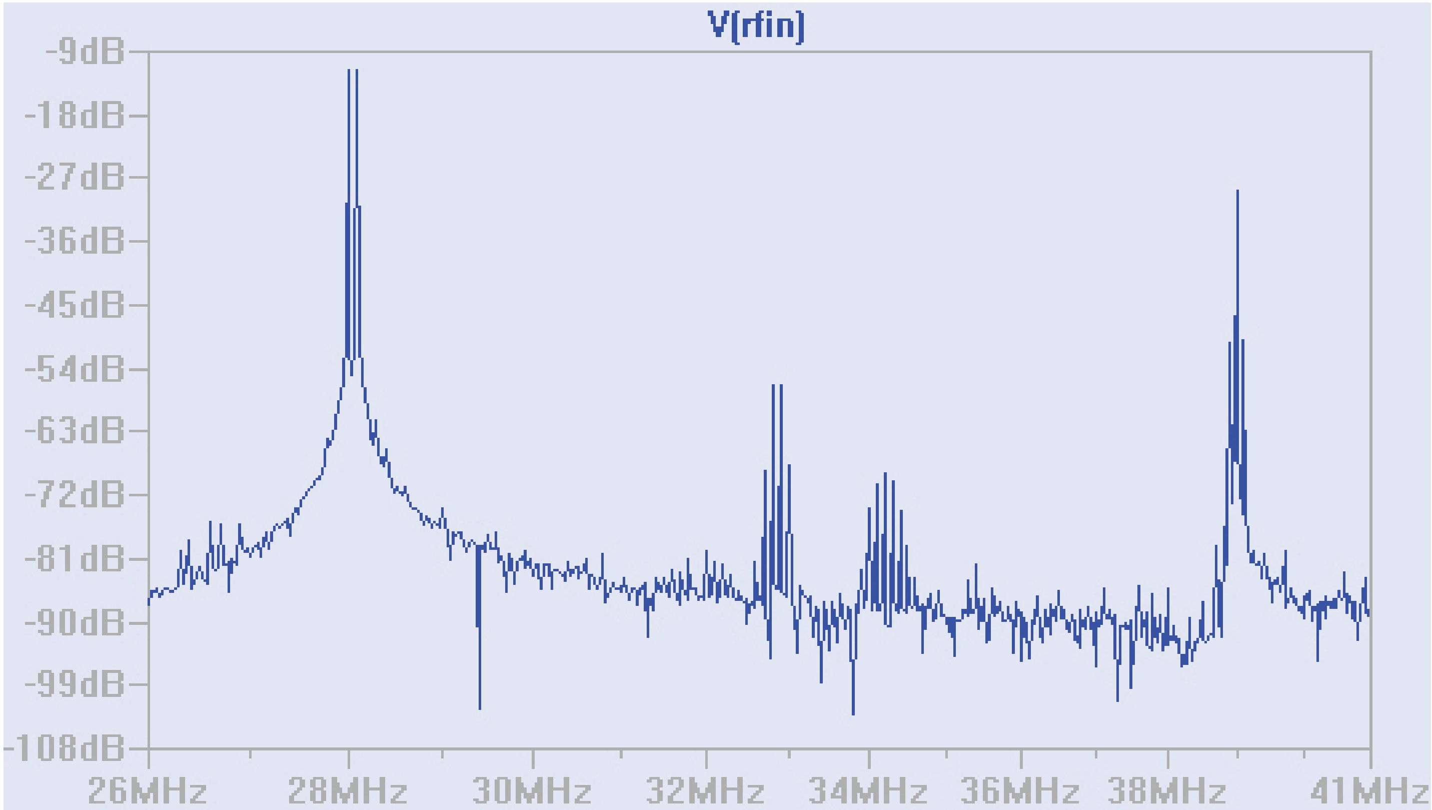


Single Balanced version for improved LO-RF isolation and IM performance

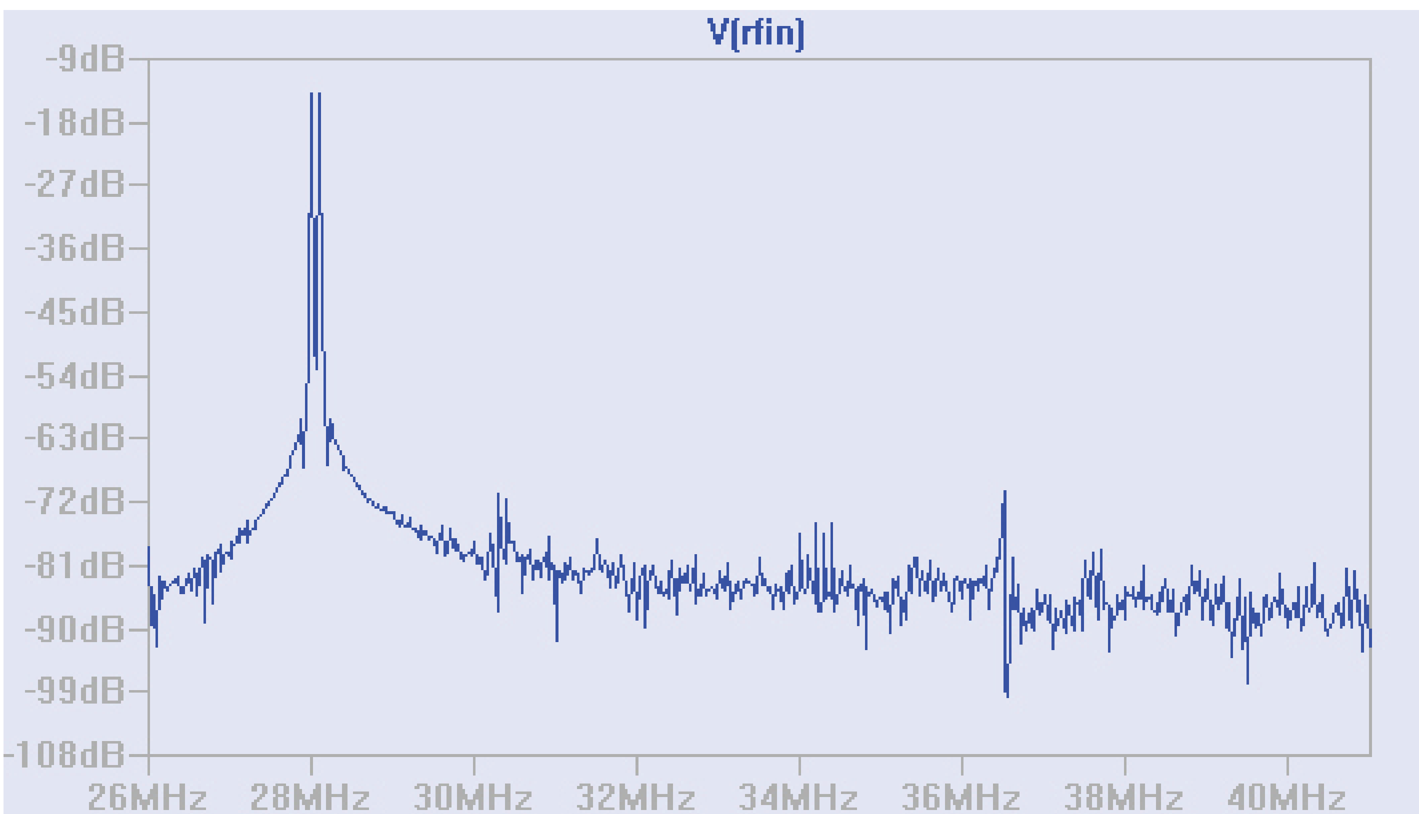




Comparison of Single-ended and Balanced Mixer LO level at RF port



Single-Ended



Balanced