TriQuint SEMICONDUCTOR®

Application Note -- Elimination of Bias Circuit Induced Oscillations

Introduction

TriQuint GaAs MMICs are designed to be stable across all operating conditions when biased and assembled per factory recommended methods. Careful characterization of each new device is performed during design verification testing to establish the proper component values and assembly layout required for stable operation. However, under certain conditions, low frequency bias related oscillations may be observed. Generally these types of oscillations are induced by external bias components value or placement relative to the MMIC. The purpose of this applications note is to emphasize the need for careful design of the external networks used to feed the bias voltages to the MMIC.

Users of TriQuint GaAs MMICs are recommended to follow the applications circuits provided on the data sheets. These circuits should ensure that the device is stable in a particular application. However, users may not always follow these circuits exactly which can lead to potential for low frequency instabilities. These instabilities are usually observed as unwanted spectral lines arising from the oscillations themselves, harmonics of these, or beats between the wanted signal(s) and the oscillation(s). In some cases the onset of oscillations may be accompanied by a jump in the drain current or the onset of gate current. Other symptoms of low frequency oscillations are noise sidebands on the wanted carrier and/or discontinuities in transfer charactistics such as Pout/Pin or Gain/Pin.

This application note example is based on a TriQuint mmwave device (TGA1073G, datasheet may be found on TriQuint web) that exhibited oscillations at low temperature. The device was stable at room temperature, but produced spurious signals when operated below -30^{o}C . As the operating temperature is decreased, device gain will increase to a value that is higher than at room temperature. Oscillations were observed with no rf drive signal and consisted of a signal near 3GHz, and harmonics thereof up to at least 27GHz.

Circuit Layout Details

The TGA1073G MMIC was mounted on a carrier, together with the recommended 100pF external shunt decoupling capacitors. The 0.01uF shunt capacitors were not mounted on the carrier as recommended, but on a softboard substrate some 0.335” away connected to the 100pF capacitor by a bondwire and a 0.008” wide circuit trace.

For simplicity, only the bias network feeding the drain of the first stage was considered. The bias network employed by the user is shown below.

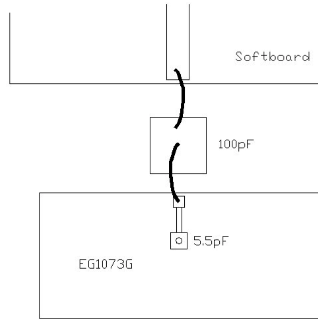

Figure 1 – Stage 1 Drain Bias Network

The 0.01uF capacitor is not shown, but was located on the softboard and grounded with a plated-through hole. Single 0.001” diameter bondwires were used to join the softboard trace to the 100pF decoupling capacitor and the capacitor to the MMIC. The MMIC has an 5.5pF on-chip shunt decoupling capacitor to provide adequate decoupling at the operating frequency.

The external components are required to provide adequate decoupling at low frequencies. Without these, the part cannot be guaranteed stable. A common problem is that while the external components may be physically present, resonance effects, usually involving the on-chip decoupling capacitor and the bondwire between the MMIC and the external decoupling capacitor, may cause the decoupling to be almost completely ineffective at a certain frequency or frequencies..

Analysis and Results

Analysis shows that a parallel resonance between the 5.5pF on-chip capacitor and the ~0.4nH bondwire occurs near 3GHz, producing a near open-circuit to the MMIC, instead of the desired short. The equivalent circuit of this loop is shown below.

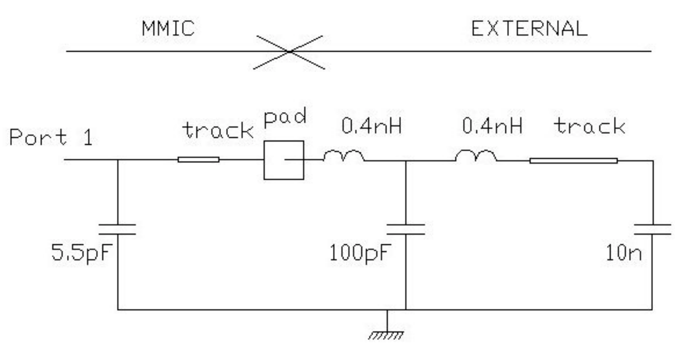

Figure 2 – Equivalent Network for Drain Bias Circuit

It is highly likely that this lack of any significant decoupling at 3GHz is responsible for the observed 3GHz oscillation. A second parallel resonance is also shown by the analysis, near 200MHz. This is caused by the combination of the 100pF capacitor and the trace on the softboard resonating. However, the impedance presented to the MMIC is not as high as at 3GHz, and it does not appear to cause any oscillations. Analysis results and circuit netlist is included in the Appendix.

Choice and Location of Decoupling Components

The majority of applications circuits for TriQuint MMICs call for more than one decoupling capacitor to cover a wide range of frequencies. Typical values are 100pF and 0.01uF. The 100pF capacitor is low-inductance SLC type, mounted as close as possible to the MMIC. The 0.01uF is usually a low-Q MLC capacitor with metalized end terminations. This capacitor may be mounted end-on with conductive epoxy close to the 100pF capacitor for evaluation circuits. Actual production implementation will require a layout that considers a close proximity layout to the 100pF capacitor. Decoupling capacitors are normally mounted on the chip carrier with the MMIC and in general should be placed as close to the MMIC as possible.

While the exact value of a decoupling capacitor is not normally critical, TriQuint does not recommend the use of different values to those specified in the applications circuit for a particular MMIC. Also, it should be noted that over temperature, the value of a typical capacitor may vary significantly, and that a part which works well at room temperature, may not provide adequate decoupling over all temperature ranges. Careful consideration of dielectric temperature coefficients are important for applications that must operate over wide temperature ranges.

Recommendations

1. Departures from TriQuint's recommended applications circuits should be avoided, but when other than recommended values are chosen, networks should be analyzed for any unwanted resonance effects.

2. If resonance effects are suspected as a cause for oscillations, analysis of the bias circuit should help to identify the critical elements.

3. Troubleshooting techniques include changing external bias components and bondwire and trace lengths. Often this is instructive and can be used to identify if resonances are responsible for oscillations, either by moving the oscillation to another frequency, or by stopping the oscillation. In the case of the TGA1073G,

the oscillation at low temperature was suppressed by using the recommended 2 bonds for the drain bias feeds and by reducing their length.

4. Gate circuits are usually free from resonance effects. Most MMIC designs incorporate low-value series resistors on the chip to "de-Q" any such resonances. In cases where no such resistors are provided on chip, they can be added externally. The same is true for drain feeds, but in general the associated voltage drop is not acceptable.

Applications Support

Low frequency oscillations associated with bias circuit resonances can generally be controlled by proper attention to circuit layout and component selection. When difficulties arise, a few simple troubleshooting steps can aid in quickly identifying the cause and solving the problem. For additional assistance with MMIC applications, please contact TriQuint Semiconductor Texas directly and ask for factory applications support.

US, Canada and Asia Customers please call	972-994-8465
European Customers please call	44 1933 311560

TriQuint SEMICONDUCTOR®

Appendix 1 -- APPROXIMATE MODEL FOR BIAS FEED CIRCUIT TO FIRST STAGE OF TGA1073G

```
DIM
FREQ GHZ
RES OH
LNG MIL
TIME PS
IND NH
CAP PF
COND /OH
ANG DEG


CKT
!GAAS SUBSTRATE
MSUB ER=12.9 H=4 T=.2 RHO=1.5 RGH=0 !4 MIL SUBSTRATE
CAP 1 0 C=5.5!ON-CHIP DECOUPLING CAPACITOR
TAND TAND=.0004
MLIN 1 2 W=2 L=9!ON-CHIP TRACK
MSTEP 2 3 W1=2 W2=4!STEP FROM LINE TO BOND PAD
MLIN 3 4 W=4 L=2!HALF OF BOND PAD
MLEF 4 W=4 L=2!OTHER HALF OF BOND PAD
IND 4 5 L=.4!SINGLE BOND WIRE 20 MILS LONG
CAP 5 0 C=100!EXTERNAL DECOUPLING CAPACITOR
IND 5 6 L=.4!BOND FROM 100P TO S0FTBOARD
!SOFTBOARD SUBSTRATE
MSUB ER=2.2 H=10 T=.25 RHO=1 RGH=0
MLIN 6 7 W=8 L=335!TRACK ON SOFTBOARD
CAP 7 8 C=10000!EXTERNAL DECOUPLING CAPACITOR
IND 8 0 L=1!INDUCTANCE OF CAP AND PTH
DEF1P 1 BIASNET
!************************

FREQ

SWEEP .01 .3 .01
SWEEP .3 5 .1

OUT

BIASNET S11
```

Freq (GHz)	Mag [S11]	Ang [S11]
0.01000	0.992	-177.211
0.02000	0.992	-179.846
0.03000	0.991	178.703
0.04000	0.991	177.521
0.05000	0.991	176.416
0.06000	0.990	175.312
0.07000	0.990	174.168
0.08000	0.989	172.947
0.09000	0.988	171.614
0.10000	0.987	170.128

TriQuint SEMICONDUCTOR®

0.11000	0.985	168.436
0.12000	0.983	166.466
0.13000	0.980	164.116
0.14000	0.976	161.232
0.15000	0.971	157.575
0.16000	0.962	152.749
0.17000	0.948	146.046
0.18000	0.924	136.103
0.19000	0.880	120.009
0.20000	0.793	90.975
0.21000	0.672	35.226
0.22000	0.699	-40.804
0.23000	0.829	-91.222
0.24000	0.907	-117.533
0.25000	0.945	-132.388
0.26000	0.965	-141.686
0.27000	0.976	-148.000
0.28000	0.982	-152.559
0.29000	0.986	-156.008
0.30000	0.989	-158.712
0.40000	0.997	-170.671
0.50000	0.998	-175.074
0.60000	0.998	-177.725
0.70000	0.998	-179.696
0.80000	0.998	178.656
0.90000	0.998	177.171
1.00000	0.998	175.764
1.10000	0.997	174.381
1.20000	0.997	172.981
1.30000	0.997	171.531
1.40000	0.997	169.998
1.50000	0.996	168.349
1.60000	0.996	166.545
1.70000	0.995	164.540
1.80000	0.995	162.275
1.90000	0.994	159.674
2.00000	0.993	156.634
2.10000	0.991	153.011
2.20000	0.989	148.600
2.30000	0.987	143.098
2.40000	0.983	136.040
2.50000	0.977	126.694
2.60000	0.969	113.883
2.70000	0.956	95.746
2.80000	0.939	69.722
2.90000	0.923	34.063
3.00000	0.921	-7.705
3.10000	0.936	-46.147
3.20000	0.955	-75.275
3.30000	0.969	-95.679
3.40000	0.978	-109.957
3.50000	0.984	-120.231
3.60000	0.988	-127.877
3.70000	0.991	-133.747
3.80000	0.993	-138.380
3.90000	0.994	-142.123

4.00000	0.995	-145.206
4.10000	0.996	-147.790
4.20000	0.997	-149.986
4.30000	0.997	-151.876
4.40000	0.998	-153.520
4.50000	0.998	-154.964
4.60000	0.998	-156.243
4.70000	0.999	-157.385
4.80000	0.999	-158.409
4.90000	0.999	-159.335
5.00000	0.999	-160.176