Application Brief
SWRA020A

TRF3520 GSM RF Modulator/Driver Amplifier EVM

Wireless Communication Business Unit

This document describes the Texas Instruments (TI™) TRF3520 evaluation module (EVM) board and associated EVM software, which allows the evaluation and the demonstration of the TRF3520 GSM RF Modulator/Driver Amplifier.

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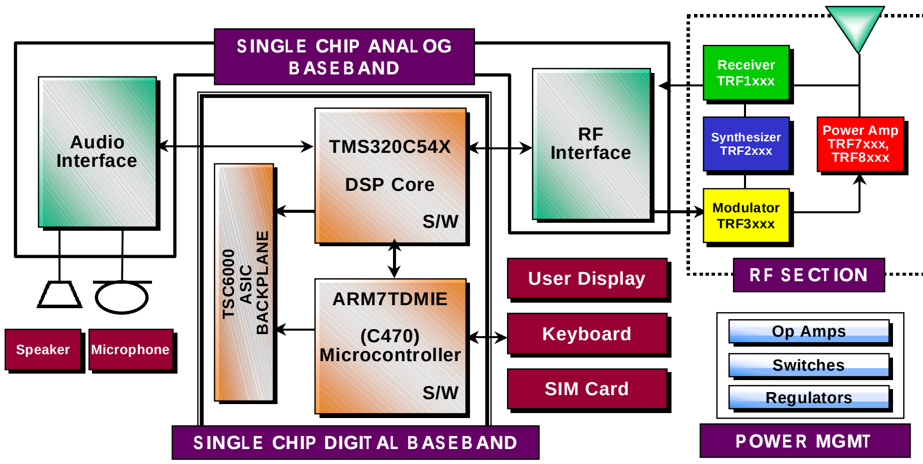
Product Support

The TI Advantage Extends Beyond RF to Every Other Major Wireless System Block



Digital Baseband

TI's single-chip Digital Baseband Platform, combines two high-performance core processors – a digital signal processor tailored for digital wireless applications and a microcontroller designed specifically for low-power embedded systems. The customizable platform helps wireless digital telephone manufacturers lower component counts, save board space, reduce power consumption, introduce new features, save development costs and achieve faster time to market, at the same time giving them flexibility and performance to support any standard worldwide.

Analog Baseband

TI analog baseband components provide a Mixed-signal bridge between the real world of analog signals and digital signal processors, the key enabling technology of the digital wireless industry. Using a seamless architecture for wireless communications technology, TI matches its baseband interfaces, radio frequency ICs and power management ICs to digital signal processing engines to create complete DSP Solutions for digital wireless systems.

Power Management

TI provides power management solutions with integration levels designed to meet the needs of a range of wireless applications. From discrete LDOs and voltage supervisors to complete power supplies for the baseband section, TI power management solutions play an important role in increasing wireless battery life, time-to-market and system functionality.

For more information visit the Wireless Communications web site at www.ti.com/sc/docs/wireless/home.htm.

Introduction

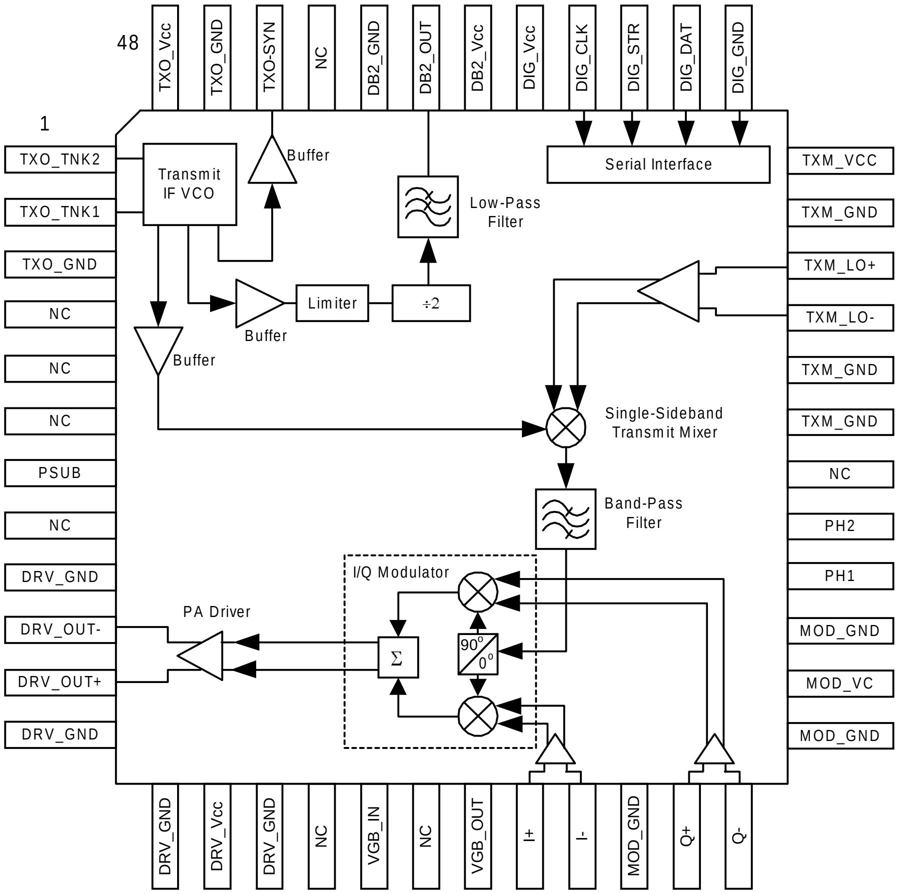
The TRF3520 evaluation board is comprised of a multi-layer printed circuit board and required components. The following information is included to aid in the assessment of this device:

- Block Diagram and Functional Description
- Schematic
- Parts List
- PCB Layout
- Design notes
- Test Set-up
- Typical Performance
- EVM Software

TRF3520 Block Diagram and Functional Description

The Texas Instruments TRF3520 radio frequency Modulator/Driver Amplifier is a single chip RF Integrated circuit (IC). The TRF3520 is suitable for 900 MHz wireless global systems for mobile communications (GSM) applications. It combines a buffered IF voltage controlled oscillator (VCO), single sideband suppressed carrier (SSBSC) mixer, RF filter, direct conversion RF I/Q modulator, a power amplifier driver, and a serial interface into one small package. Few external components are required. During idle operation, the individual functional blocks may be selectively placed in standby mode for minimum power consumption.

Figure 1. TRF3520 Functional Block Diagram



Transmit IF VCO

The function of the Transmit IF VCO is to generate a CW signal in the 200MHz range that can be controlled by the voltage applied to the varactors on the external tank circuit. Through on chip buffers, the Transmit IF VCO output is sent to the SSB mixer and the Divide-by-Two functional blocks in the TRF3520, as well as to an external Synthesizer, where the Transmit IF VCO frequency is controlled and phase-locked. The error signal generated by the Synthesizer is sent to the Transmit IF VCO varactors tuning port, therefore completing the PLL function.

Divide-by-Two

This functional block halves the IF VCO frequency and provides a buffered, amplitude-limited and low pass filtered signal, which could become the LO signal for the TRF1020 GSM Receiver IC second down conversion stage.

Single Sideband Suppressed Carrier (SSBSC) Transmit Mixer

The SSBSC Transmit Mixer combines the external LO signal, applied to the TXM_LO terminals, with the signal generated by the Transmit IF VCO and performs a downconversion function. The SSB Tx mixer is designed to suppress the upper side band and carrier signals. The internal Low-Pass Filter further suppresses any undesired sidebands or spurious signals. This feature has the added advantage of eliminating any external filtering.

I/Q Modulator

The I/Q Modulator provides direct single sideband I/Q modulation from baseband to RF. The differential baseband I/Q input signal must have a Common Mode Voltage of 1.35V nominal at the I and Q input terminals and a level of $+1.4V_{peak\ to\ peak}$ nominal. Other types of complex I/Q modulations are possible with the TRF3520, but the device is optimized to meet GSM requirements using GMSK modulation.

PA Driver Output

The output of the I/Q Modulator is fed to the PA Driver, which is a high-gain, low distortion fixed gain amplifier. The PA has differential outputs that can be converted to a single ended output by a simple LC impedance matching network and a 4:1 balun.

Serial Control Interface

All TRF3520 functional blocks can be individually powered up or down via the serial interface.

The TRF3520 device register is manipulated via a synchronous serial data port. The Serial Control Interface provides power up / power down capability for each one of functional blocks just described. One 17 bit word is clocked into a temporary holding register with the least significant bit clocked first. The operation register is loaded with the new data residing in the temporary registers using the rising edge of the STROBE input.

Table 1 lists the format of the control word.

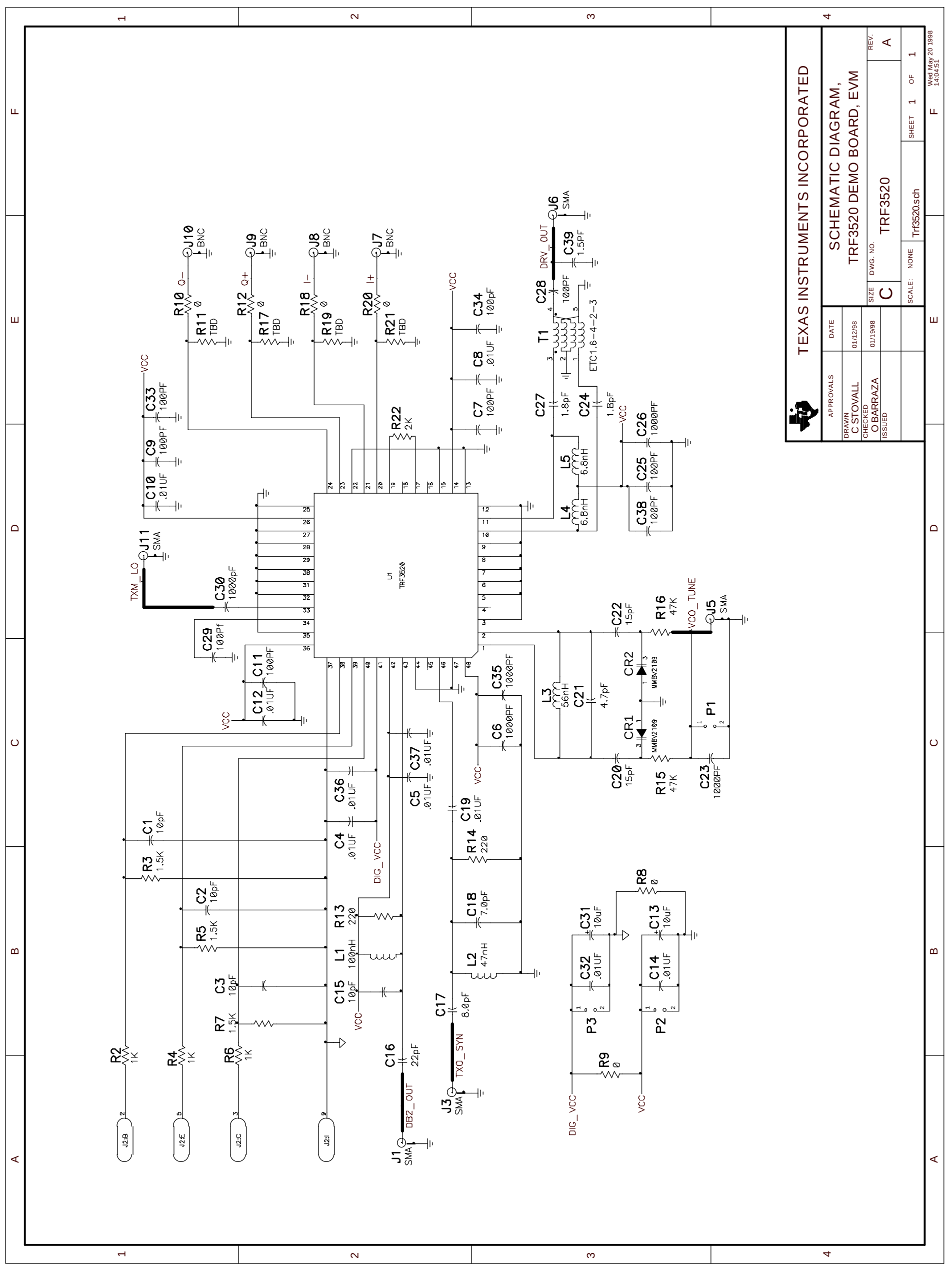
Table 1. Control Word Bit Assignment

BIT	FUNCTION	FUNCTIONAL IF
0	Reserved	-
1	Reserved	-
2	Reserved	-
3	Transmit oscillator and buffer amplifier	1
4	Transmit mixer, LO buffer amplifier	1
5	Modulator	1
6	PA driver amplifier	1
7	Divide-by-two and limiter	1
8	Reserved	-
9	Reserved	-
10	Reserved	-

11	Reserved	-
12	Reserved	-
13	Reserved	-
14	Reserved	-
15	Reserved	-
16	Reserved	-

Schematic

Figure 2. TRF3520 Schematic



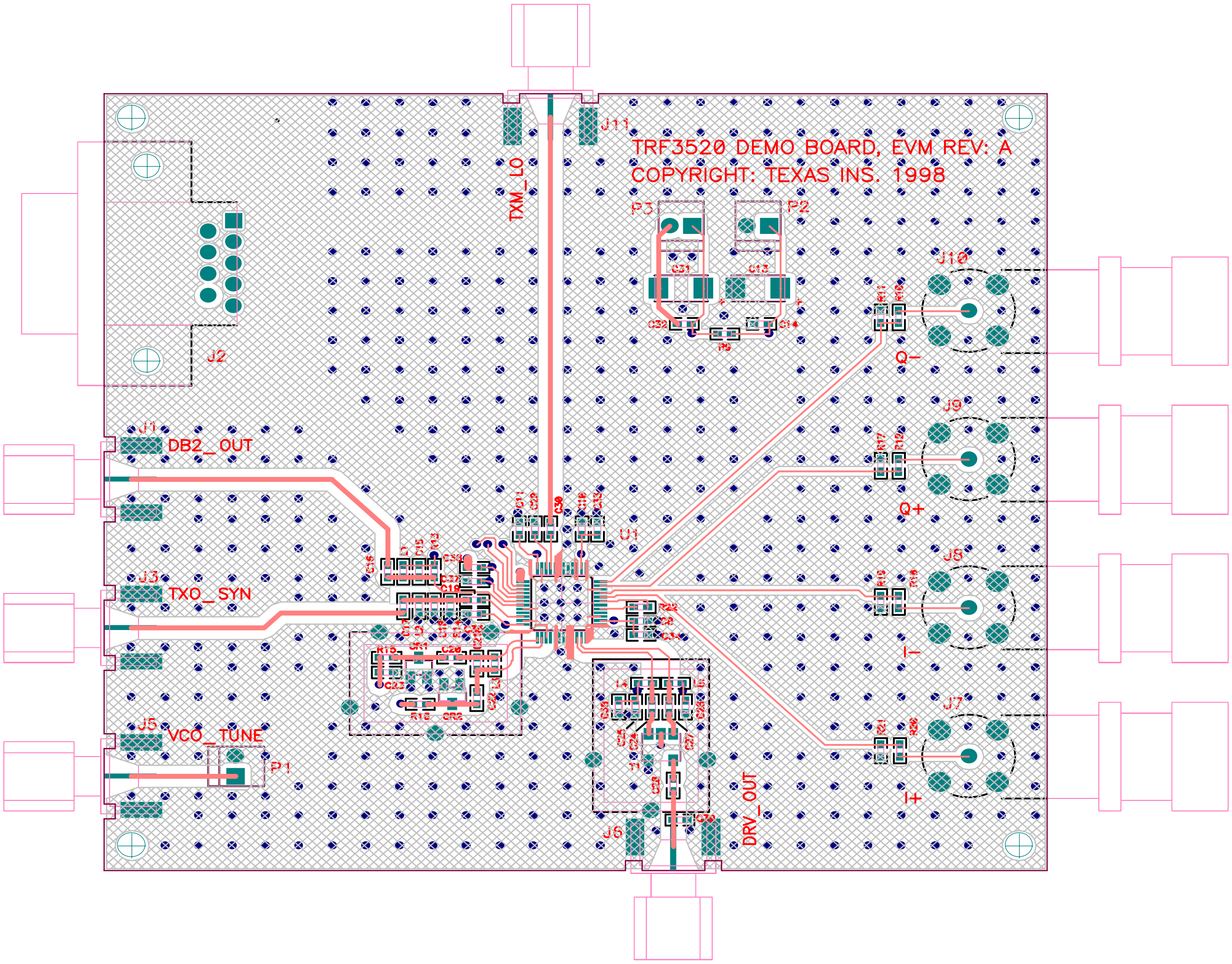
Part List

Ref. Designator	Value	Description	QTY	Part Number	Manufacturer
C1,2,3,15	10pF	Capacitor	4	GRM39COG Series	Murata
C4,5,8,10,12,14, 19,32,36,37	.01µF	Capacitor	10	GRM39COG Series	Murata
C6,23,26,30,35	1000µF	Capacitor	5	GRM39COG Series	Murata
C7,9,11,25,28, 29,33,34,38	100pF	Capacitor	9	GRM39COG Series	Murata
C13,31	10µF	Capacitor	2	GRM39COG Series	Murata
C16	22pf	Capacitor	1	GRM39COG Series	Murata
C17	8pF	Capacitor	1	GRM39COG Series	Murata
C18	7pF	Capacitor	1	GRM39COG Series	Murata
C20,22	15pF	Capacitor	1	GRM39COG Series	Murata
C21	4.7pF	Capacitor	1	GRM39COG Series	Murata
C24,27	1.8pF	Capacitor	1	GRM39COG Series	Murata
C39	1.5pF	Capacitor	1	GRM39COG Series	Murata
L1	100nH	Inductor	1	GRM39COG Series	Murata
L2	47nH	Inductor	1	GRM39COG Series	Murata
L3	56nH	Inductor	1	GRM39COG Series	Murata
L4,5	6.8nH	Inductor	2	GRM39COG Series	Murata
J1,3,5,6,11		SMA connector	5	142-0701-801	EF Johnson
J2		Connector	1	747250-4	Amp
J4,17,18		Connector	3	46F522	Molex
P1,P2,P3		BNC connector	4	413631-1	Amp
R2,4,6	1KΩ	Resistor	3	P1.0KGCT-ND	Panasonic
R3,5,7	1.5KΩ	Resistor	3	P1.5KGCT-ND	Panasonic
R8,9,10,12,18, 20	0Ω	Resistor	6	P0.0GCT-ND	Panasonic
R13,14	220Ω	Resistor	2	P220GCT-ND	Panasonic
R15,16	47kΩ	Resistor	2	P47KGCT-ND	Panasonic
R22	2KΩ	Resistor	1	P2.0KGCT-ND	Panasonic
U1		IC	1	TRF3520	TI
CR1, CR2		Varactor	2	Motorola	MMBV2109LT1
T1		4:1 Balun	1	MA/COM	ETC1.6-4-2-3

PCB Layout

The EVM board is comprised of a multi-layer printed circuit board, a TRF3520 device, SMA connectors, and the necessary peripheral discrete components.

Figure 3. PCB Layout



TRF3520 DEMO BOARD, EVM REV: A
COMPONENT SIDE SILKSCREEN

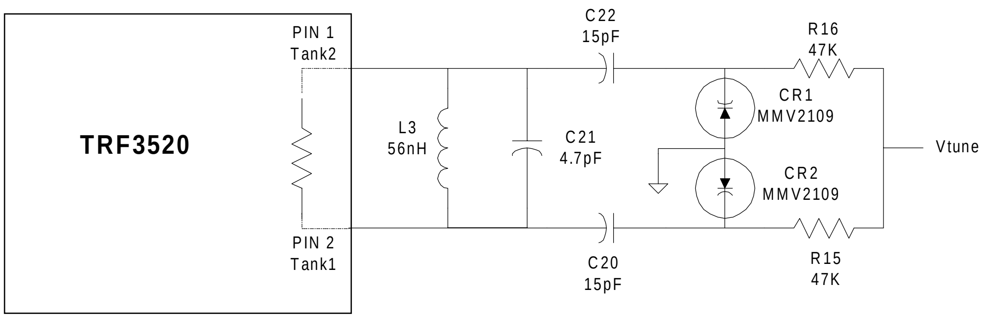
EVM Design Notes

Tank Circuit

The TXIF_VCO generates a signal in the 200 MHz range that is used by the SSBSC downconverter to produce the carrier.

Carrier = TXM_LO - TXIF_VCO

Figure 4. Varactor Controlled LC Tank Circuit



The tank resonant frequency is defined by the following formula:

$$f_{resonance} = \frac{1}{2\pi\sqrt{L_3 C_{eq}}}$$

where

$$C_{eq} = C_{21} + \left[\frac{1}{C_{20}} + \frac{1}{C_{22}} + \frac{1}{C_{CR1}} + \frac{1}{C_{CR2}}\right]^{-1}$$, C_{CR} = Varactor's capacitance

On the EVM board, the Transmit IF synthesizer was designed to operate at 194 MHz. The calculated resonance frequency is as follows:

$C_{CR1} = C_{CR2}$ = 50 pF (at 1.5V, measured on the EVM board)

$$C_{eq} = 4.7\text{pF} + \left[\frac{1}{15\text{pF}} + \frac{1}{15\text{pF}} + \frac{1}{50\text{pF}} + \frac{1}{50\text{pF}}\right]^{-1} = 10.47\text{pF}$$,

with L_3= 56 nH

$$f_{resonance} = \frac{1}{2\pi\sqrt{L_3 C_{eq}}} = 207.86\text{MHz}$$

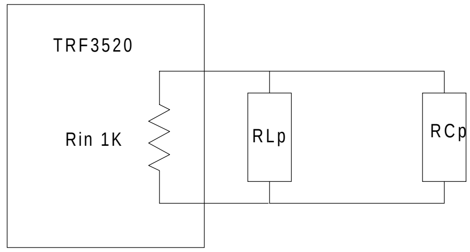
The actual tank circuit resonates at 194 MHz. The difference between the calculated and measured frequencies is due to a combination of TRF3520 internal capacitance and actual inductor and capacitor component values. If a 1.5 pF shunt capacitance is added to C_{21}, to account for the device's internal capacitance, the calculated resonant frequency is 194.4 MHz, which agrees with the measured results.

The oscillator frequency tuning range is approximately 10 MHz. The tuning range is controlled by the varactor's change in capacitance when the tuning voltage, Vtune, is adjusted from 0V to 3.75 V.

High Q components are required as they affect the impedance seen by the TRF3520. The Q's of the inductor, the capacitors, and the varactors in the tank circuit are very critical, as the selection of these component affect the attenuation that the tank circuit will provide as it is loaded by the TRF3520 1kΩ differential input impedance. An increase in attenuation reduces the tank resonant signal level and, if not designed properly, degrades the oscillator start up properties.

The loaded tank circuit can be modeled as shown in Figure 5. The inductor and varactor have the lowest Q and therefore determine the attenuation level.

Figure 5. Loaded Tank Circuit Model



RLp and RCp are the equivalent parallel resistances of the inductor and the combined capacitance of the fixed capacitor and varactors, *for the condition when the tank is at resonance*. The equivalent parallel resistance is defined as follows:

for Q>10, $R_p=Q^2R_s$

where,

R_p= equivalent parallel resistance of the device at the ***resonant frequency***

Q = Q of the device

R_s = Device series resistance = Reactance/Q

$R_{parallel}$ = parallel resistance of RLp and RCp

$$\text{Attenuation, dB} = 20\log\left[\frac{R_{parallel}}{R_{in} + R_{parallel}}\right]$$

As the component Q's decrease, Rp decreases and the attenuation increases. This effect reduces the tank oscillator signal, which could affect the start up. On the TRF3520 EVM board, the tank circuit component parameters are as follows:

Inductor; L_3=56 nH, Q ≈ 15 at 200 MHz

$$R_s = \frac{X_L}{Q} = \frac{2\pi \times 200^{e6} \times 56^{e-9}}{15} = 4.691\Omega$$

$$Rp = Q^2R_S = 15^2 \times 4.691 = 1055.58\Omega$$

Varactor; C_{R1}=C_{R2}=50 pF, $R_s \approx 0.5\Omega$ at 155 MHz

$$R_S = \frac{X_C}{Q} = \frac{1}{2\pi \times 200^{e+6} \times 55^{e-12} \times 40} = 0.398 \quad Rp = Q^2R_S = 40^2 \times 0.398 = 638.62\Omega$$

Series capacitor: C_{21}=4.7pF, Q=460

$$R_s = \frac{X_C}{Q} = \frac{1}{2\pi \times 200^{e6} \times 3.7^{e-12} \times 460} = 0.468\Omega$$

$$R_p = Q^2 R_s = 460^2 \times 0.468 = 98.934k\Omega$$

Series capacitor: 15 pF, Q=1000

$$R_s = \frac{X_C}{Q} = \frac{1}{2\pi \times 200^{e6} \times 15^{e-12} \times 1000} = 0.053\Omega$$

$$R_p = Q^2 R_s = 1000^2 \times 0.053 = 53k\Omega$$

Which results in the following attenuation:

$$\text{Attenuation, dB} = 20\log\left[\frac{RLp}{RLp + Rin}\right] = 20\log\left[\frac{1055.58}{1055.58 + 1000}\right] = 5.78dB$$

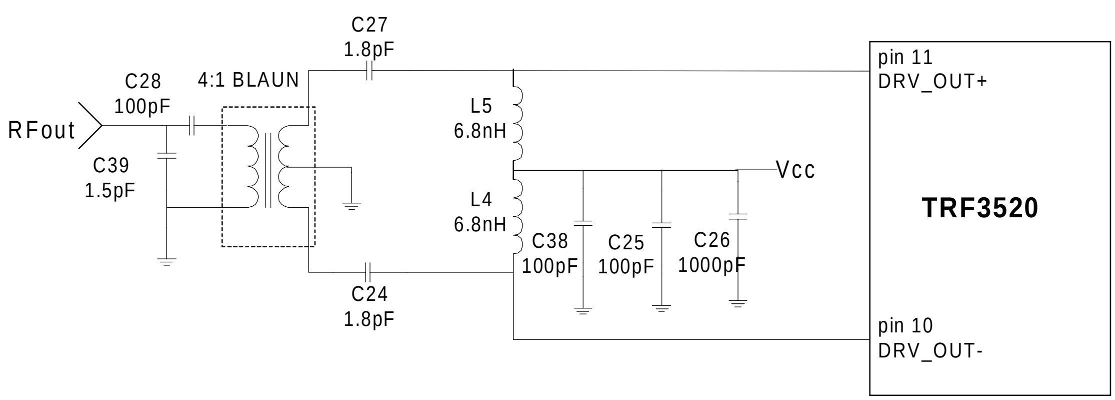
The combined equivalent parallel resistance for the series capacitors and the varactors is much greater than the equivalent resistance for the shunt inductor. This analysis concludes that the total amount of attenuation is dependent on the inductor's Q since Rin for the TRF3520 is fixed at 1KΩ differential. It is desirable to design for the lowest attenuation possible to provide enough signal for the VCO to operate properly. The tank circuit in the TRF3520 EVM board is designed with high Q components, to assure reliable operation of the TXIF oscillator.

PA Driver Impedance Match

Variable Gain Amplifier (VGA) and the PA Driver

The output of the I/Q modulator is fed to the PA Driver. The PA Driver is capable of delivering +6dBm, nominal.

Figure 6. Typical Differential-to-Single Ended Configuration

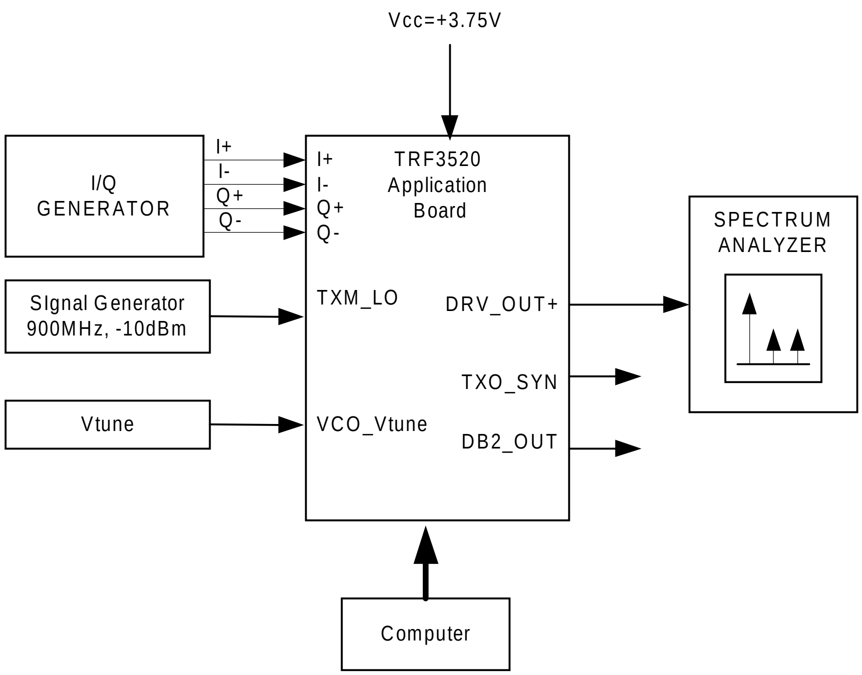


The PA driver linearity and output power is dependent on the pcb layout. For tuning purposes, a small shunt capacitor, C39, is placed between the balun and the SMA connector. The position and value of C39 are used to optimize for maximum output power and linearity.

EVM Tests

Test Setup

Figure 7. Typical Test Setup for the TRF3520 EVM



Test Conditions

The tests are performed at room temperature.

- Vcc = +3.75 V
- I & Q signals, Vdc=+1.35V, 0.7Vpeak , @ 67.7 kHz
- All tests performed per the nominal conditions specified below:
- LO = 1094 MHz, @ -10 dBm
- Vtune = Set to obtain a TXIF of 194 MHz

Test Data Sheet

Test No	Parameter	Conditions	Specification			Units
			Min	Typ	Max	
1	Output power	notes 1,2,3,4		+6		dBm
2	Carrier Suppression	notes 1,2,3,4	30	35		dBc
3	Sideband Suppression	notes 1,2,3,4	35	45		dBc
4	3rd order IM suppression	notes 2,3,4,5	20			dBc

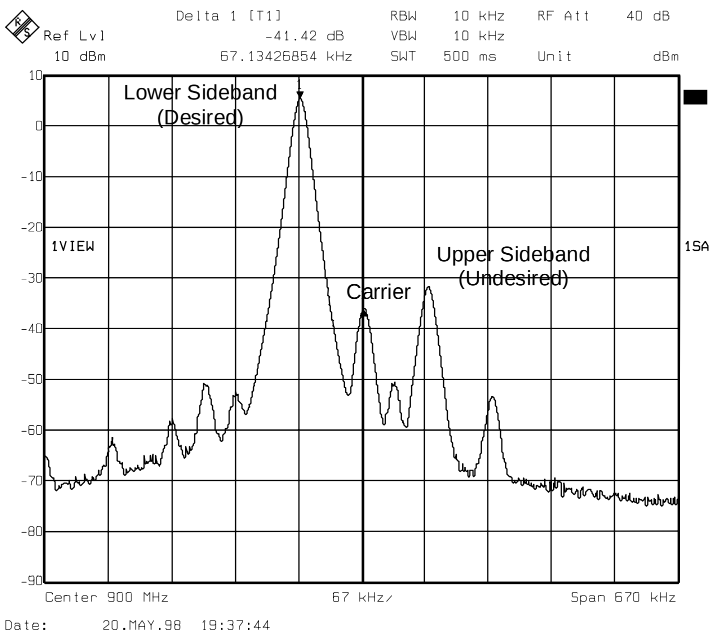
Test No	Parameter	Conditions	Specification			Units
			Min	Typ	Max	
5	Frequency	note 4	141	194	247	MHz
6	Output power	note 4	-20	-15		dBm
7	Phase Noise @ 200 kHz offset	note 4		110		dBc/Hz

Test No	Parameter	Conditions	Specification			Units
			Min	Typ	Max	
8	Frequency	note 4		194/2		MHz
9	Output power	note 4	-25	-20	-10	dBm
10	Spurious 100kHz to 2.5 GHz	note 4		20		dBc

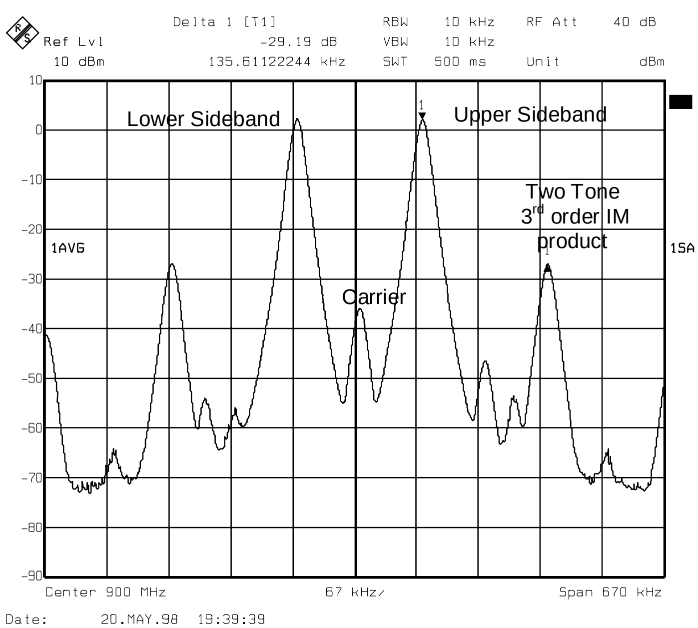
Notes: 1) $V_{I/Q}$=1.40Vpp, common mode voltage is 1.35 V, frequency=67.7kHz, I&Q in quadrature
2) 1 dB loss due to the balun is included
3) LO= 1094 MHz, @ -10dBm
4) Transmit IF VCO tuned to 194 MHz
5) $V_{I/Q}$=1.40Vpp, common mode voltage is 1.35 V, frequency=67.7kHz, I&Q in phase

Typical Performance

Typical Modulator DUALTX Output:



- **Carrier/Sideband Suppression**
- **PA Driver Output**
- **Fcarrier = 900 MHz**
- **I/Q frequency = 67.7 kHz**
- **I/Q in quadrature**
- **I/Q Common Mode Voltage, +1.35V Nominal**
- **$V_{I/Q}$=1.40Vpp, (Single Ended)**



- **Carrier/Sideband Suppression**
- **PA Driver Output**
- **Fcarrier = 900 MHz**
- **I/Q frequency = 67.7 kHz**
- **I/Q in phase**
- **I/Q Common Mode Voltage, +1.35V Nominal**
- **$V_{I/Q}$=1.40Vpp, (Single Ended)**

EVM Software

Windows-based software is supplied with the evaluation board. The software is intended for use in a Windows environment, 3.11or later version. No special memory is required to use the software. Five files are contained on the provided disk:

- TRF3520.EXE
- INIT.CFG
- Three (3) DLL files

All of these files should be placed in the same directory on a fixed disk or the program may be executed from the disk provided. To execute the program from the provided disk, simply type the following.

A:\TRF3520 ↵ (*Enter)*

The program executes from the TRF3520.EXE file. The program reads the INIT.CFG file to setup the program parameters.

Each of the TRF3520 functional blocks can be selected individually by selecting the corresponding button on the EVM software display.

Connect the interface cable to the computer’s LPT port. The EVM software allows you to select the correct LPT port.

Once the functional blocks have been selected, select ***SEND*** to enable the device. ***SEND*** can be found at the top of the EVM software window.

Evaluation Board Disclaimer

Please note that the enclosed evaluation boards are experimental Printed Circuit Boards and are therefore only intended for device evaluation.

We would like to draw your attention to the fact that these boards have been processed through one or more of Texas Instruments’ external subcontractors which have not been production qualified.

Device parameters measured, using these boards, are not representative of any final datasheet or of a final production version. Texas Instruments does not represent or guarantee that a final version will be made available after device evaluation.

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References

TRF3520 GSM RF Modulator/Driver Amplifier, Literature number SLWS060A.

INTERNET

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***TI** Wireless Communications web site*
www.ti.com/sc/docs/wireless/home.htm

TI Distributors
http://www.ti.com/sc/docs/distmenu.htm

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Indonesia	001-801-10
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Korea	080-551-2804
Malaysia	1-800-800-011
TI Number	-800-800-1450
New Zealand	+000-911
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