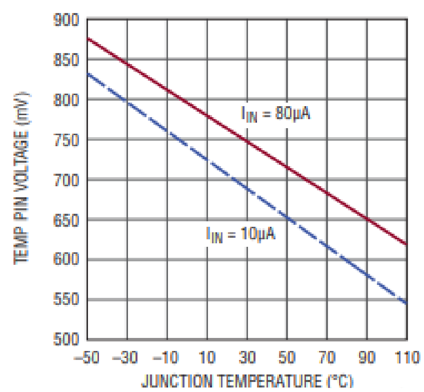
<table>
<tr><th></th><th>Section Reference</th><th>Question</th><th>Response</th></tr>
<tr><td>1</td><td>3 & 7</td><td>What measurements are taken in the Temperature Monitor Test?</td><td>By forcing a current through a diode and measuring the resulting anode-cathode voltage, the junction temperature can be estimated.

The current through the junction is a function of temperature in addition to the voltage across the PN junction. This is due to the dependence of charge carrier energy levels on junction temperature.</td></tr>
<tr><td>2</td><td>3 & 7</td><td>What is the junction temperature?</td><td>Junction temperature is the temperature at the region between the P-type and N-type semiconductors in diodes and transistors. As the built-in field at the junction is reduced (by applying an opposing field externally), more current diffuses across the channel, leading to a rise in junction temperature. This phenomenon occurs due to finite conductivity of the channel and its resultant energy dissipation.</td></tr>
<tr><td>3</td><td>3 & 7</td><td>Temperature Monitor Test

Calculated vs expected result agree?</td><td>

T_j (10µA) = (V_D – 742.4)/ –1.796

T_j(80µA) = (V_D – 795.6)/ –1.609



<table>
<tr><th colspan="5">Temperature Monitor Pin (TEMP)</th></tr>
<tr><td>DC Voltage at T_J = 25°C</td><td>I_{IN} = 10µA
I_{IN} = 80µA</td><td></td><td>697
755</td><td>mV
mV</td></tr>
<tr><td>Voltage Temperature Coefficient</td><td>I_{IN} = 10µA
I_{IN} = 80µA</td><td>●
●</td><td>–1.80
–1.61</td><td>mV/°C
mV/°C</td></tr>
</table>

Calculated

* used the above relations with V_D from the datasheet (attached below)

T_j **(10µA)** = (697 – 742.4)/ –1.796 = **25.28℃**

T_j**(80µA)** = (755 – 795.6)/ –1.609 = **25.23℃**

Expected (Test Result)

* used the measured voltages from the tester (**Appendix A – Figure 1**) for the calculations. Also provided test results below as reference:

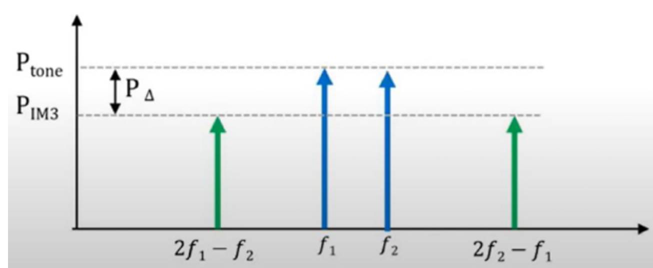
T_j **(10µA)** ~ **32.05℃** (direct test result)

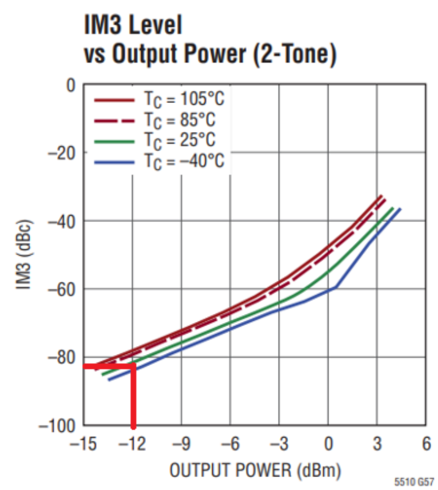
T_j**(80µA)** ~ **28.77℃** (direct test result)

T_j **(10µA)** = (684. 837 – 742.4)/ –1.796 = **32.05℃** (calculated with test Vd)
</td></tr>
</table>

			T_j**(80µA)** = $(749.3 - 795.6)/-1.609$ = **25.78℃** (calculated with test Vd) **Summary**: there are several variables that cause the calculated and expected results to be different: - Self-heating, parasitic resistance on traces and connectors, variations in active device node voltages within the current source, and noise
4	10	Describe you see in the spectrum for the mixerSumAndDiff test.	The spectrum exhibits two mixed signals as well as the LO-feedthrough. The feedthrough is not desired and the output of the pre-driver (first VGA) in the Tx path is filtered to remove this signal. The filtering does not remove the signal ideally and simply provides a manageable rejection level to avoid generating blockers at the Tx output (OOB bad for other designated spectrum users; in-band bad for the Rx)
5	10	For test mixerSumAndDiff, take snapshot and report the following. 1. LO frequency and power 2. RF_IN frequency and power 3. RF_OUT (frequency and power of images and LO feedthrough)	**Appendix A – Figure 2** shows the spectrum result for this test. 1. LO - fLO = 526MHz - pLO = 0dBm 2. RF_IN (IF) - fIF = 70MHz - pIF = -20dBm 3. RF_OUT - Tone 1 (lower) ~ **+30.5dBm (-49.2dBc) @456MHz** - LO (center) ~ **-18.7dBm @526MHz** - Tone 2 (upper) ~ **+30.2dBm (-48.9dBc) @596MHz**
6	10	What is the conversion Gain of the DUT (RF Mixer)? Does it meet the data sheet spec?	Mean value: **1.28dB** The datasheet specifies roughly **1.1dB** of conversion gain at fIF = 70MHz, Vcc = 5V, Pin = -10dBm, pLO = 0dBm (**Appendix B – Figure 6**). We note that in our case, pRF = -20dBm. This result meets the datasheet specification.
7	10	What is ACLR? Report the following for the ACLR test: Carrier Power Adj (ch1) upper power (in dBC) Adj (ch1) lower power (in dBC) NOTE: dBC is dB relative to the carrier (a delta measurement)	ACLR: Adjacent Channel Leakage is the ratio of the transmitted power on the assigned channel to the power measured in a receive filter in the adjacent channel(s). - LO ~ **-18.7dBm @526MHz** - Tone 1 (lower, fRF1) ~ **-49.2dBc @456MHz** - Tone 2 (upper, fRF2) ~ **-48.9dBc @596MHz** Since the LO (in demo board) is in discussion, the ACLR must be calculated by considering the two RF tones as desired and the LO leakage as undesired. The key idea is that the mixer did its job by displacing energy from IF power to RF

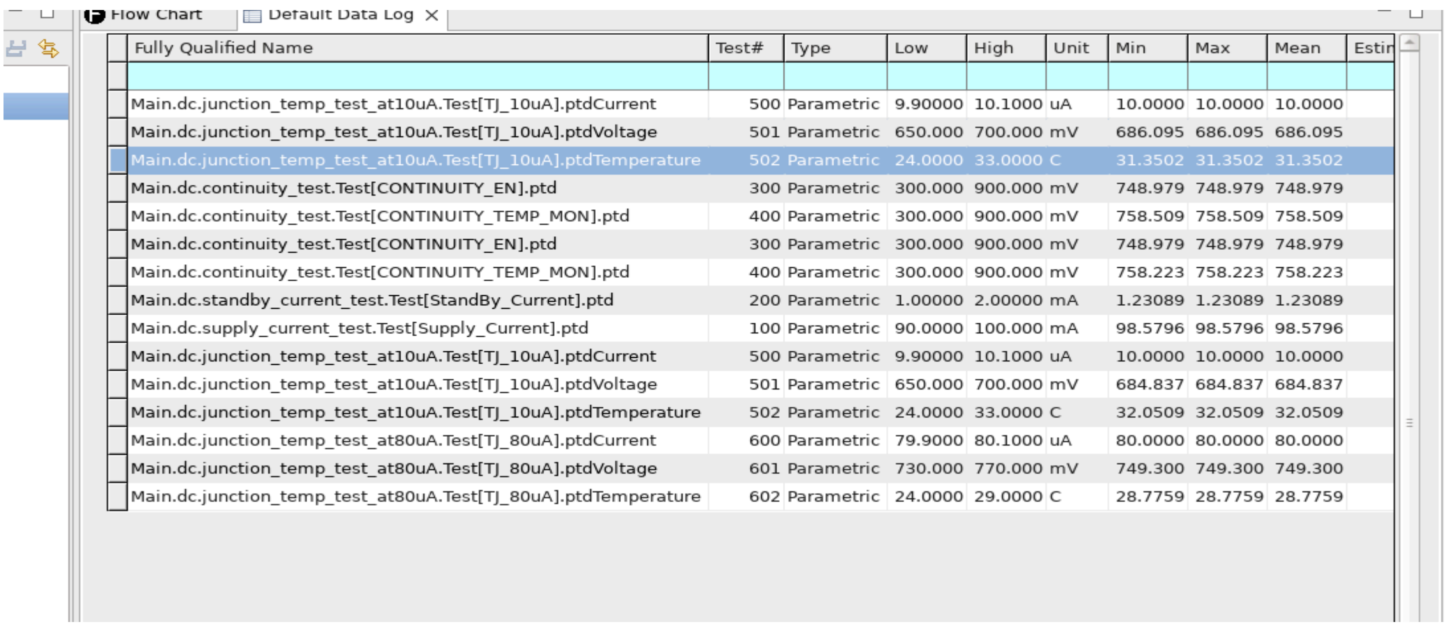
			power with a certain “efficiency” so to speak. When the ACLR is poor, the root cause could may be one of a few factors: DUT IM3, DUT harmonics, IF bandwidth of measurement instrument, and so on $$ACLR = -18.7dBm - (33.362dBm)$$ $$ACLR \sim -52.6dB$$
8	10	What issues could cause ACLR to suffer (spectral power leaking into adjacent channels)?	Factors leading to poor ACLR: - Poor linearity of active device - Excessive Pin - Insufficient rejection levels from external filter(s)

9	10	Describe the stimulus needed for the oip3 (IMD) test. Does the DUT need to be in its the linear operating region or can this test be done with the DUT in compression (non-linear)? If the fundament tones of the output increase (by changing stim power) how much does the spectral power in 3rd order intermod products increase by (hint: it is in relation to the power of the fundamental tones)?	1. The stimulus for performing the IMD test must have the following properties - Two signals of **<u>equal</u>** amplitude that are well below the 1-dB compression point of the DUT. If this criterion is not met, the measured IMD will not be accurate as the DUT is compressed and the linear equation below is no longer accurate $$TOI = Ptone + \frac{p\Delta}{2}$$ - Δf sufficiently small to ensure $2f_1 - f_2$ and $2f_2 - f_1$ fall in-band and accurately characterize the IMD (otherwise it will be a harmonics test)  2. The tones must have amplitudes that are below the DUT’s P1dB, otherwise the equation above no longer holds and the predicted IIP3 will be inaccurate. 3. An increase of 1dB in the fundamental results in an increase of 3dB in the power of third-order products. This is due to third-order products introducing exponents of order three and that dB scale is defined vis-à-vis logarithms

10	10	There are many names for oip3 (IMD) including Third order Intercept (TOI) Does the DUT meet the data sheet spec for Two-Tone Output 3rd Order Intercept?	1. **Yes**. Based on the calculations from datasheet results, the DUT meets specifications since the measured values are about 1dBm higher than datasheet values 2. Per the datasheet (**Appendix B – Figure 7**) and for similar test conditions as our use case, the IIP3 is calculated as follows (with $P_{out} =- 12dBm$ reference point for most accurate calculations): $P_{tone} = P_{in} = P_{out} - G_{conversion} =- 12dBm - 1.14dB$ $P_{tone} \sim - 13.4dB$ $TOI = P_{tone} + \frac{\Delta P}{2} \sim - 13.4dBm + \frac{(-13.4dBm-(-83dBm))}{2}$ $TOI \sim 21.4dBm$ (input referred) - $IIP_3 \sim 21.4dBm$ - $OIP_3 = IIP_3 + G_{conversion} = 21.4dBm + 1.14dBm$ - $OIP_3 \sim 22.54dBm$ 3. The **measured** results are: - $IIP_3 \sim 22.48dBm$ - $OIP_3 \sim 23.74dBm$ 
11	10	Based on your observations, what would indicate better linearity (comparing one device vs another) a	A larger TOI would indicate that the DUT is better. The implication is that the intercept point occurs at a higher Pin, giving the DUT a larger dynamic range at the input (i.e. DUT is more linear than one with a smaller TOI).

		larger TOI or a smaller TOI?	
12	10	In the P1dB test we do a sweep of input power vs output power, what are we looking for? Please report the conversion gain for the linear region and the P1dB.	1. The purpose of the P1dB test is to observe the Pout Vs. Pin sweeps and find the Pin value for which Pout drops 1dB from its predicted 1dB trajectory. The 1dB point is arbitrary but very common. One can specify P2dB, P3dB, and so on, depending on the application. In PA selection for radar design, P3dB-P5dB can be used. 2. Measurements - Conversion gain (mean) = **1.14dB** - P1dB (mean) = **11.45dBm**

Appendix A: Test Result Screenshots



Fully Qualified Name	Test#	Type	Low	High	Unit	Min	Max	Mean	Estir
Main.dc.junction_temp_test_at10uA.Test[TJ_10uA].ptdCurrent	500	Parametric	9.90000	10.1000	uA	10.0000	10.0000	10.0000	
Main.dc.junction_temp_test_at10uA.Test[TJ_10uA].ptdVoltage	501	Parametric	650.000	700.000	mV	686.095	686.095	686.095	
Main.dc.junction_temp_test_at10uA.Test[TJ_10uA].ptdTemperature	502	Parametric	24.0000	33.0000	C	31.3502	31.3502	31.3502	
Main.dc.continuity_test.Test[CONTINUITY_EN].ptd	300	Parametric	300.000	900.000	mV	748.979	748.979	748.979	
Main.dc.continuity_test.Test[CONTINUITY_TEMP_MON].ptd	400	Parametric	300.000	900.000	mV	758.509	758.509	758.509	
Main.dc.continuity_test.Test[CONTINUITY_EN].ptd	300	Parametric	300.000	900.000	mV	748.979	748.979	748.979	
Main.dc.continuity_test.Test[CONTINUITY_TEMP_MON].ptd	400	Parametric	300.000	900.000	mV	758.223	758.223	758.223	
Main.dc.standby_current_test.Test[StandBy_Current].ptd	200	Parametric	1.00000	2.00000	mA	1.23089	1.23089	1.23089	
Main.dc.supply_current_test.Test[Supply_Current].ptd	100	Parametric	90.0000	100.000	mA	98.5796	98.5796	98.5796	
Main.dc.junction_temp_test_at10uA.Test[TJ_10uA].ptdCurrent	500	Parametric	9.90000	10.1000	uA	10.0000	10.0000	10.0000	
Main.dc.junction_temp_test_at10uA.Test[TJ_10uA].ptdVoltage	501	Parametric	650.000	700.000	mV	684.837	684.837	684.837	
Main.dc.junction_temp_test_at10uA.Test[TJ_10uA].ptdTemperature	502	Parametric	24.0000	33.0000	C	32.0509	32.0509	32.0509	
Main.dc.junction_temp_test_at80uA.Test[TJ_80uA].ptdCurrent	600	Parametric	79.9000	80.1000	uA	80.0000	80.0000	80.0000	
Main.dc.junction_temp_test_at80uA.Test[TJ_80uA].ptdVoltage	601	Parametric	730.000	770.000	mV	749.300	749.300	749.300	
Main.dc.junction_temp_test_at80uA.Test[TJ_80uA].ptdTemperature	602	Parametric	24.0000	29.0000	C	28.7759	28.7759	28.7759	

Figure 1. DC Test Results

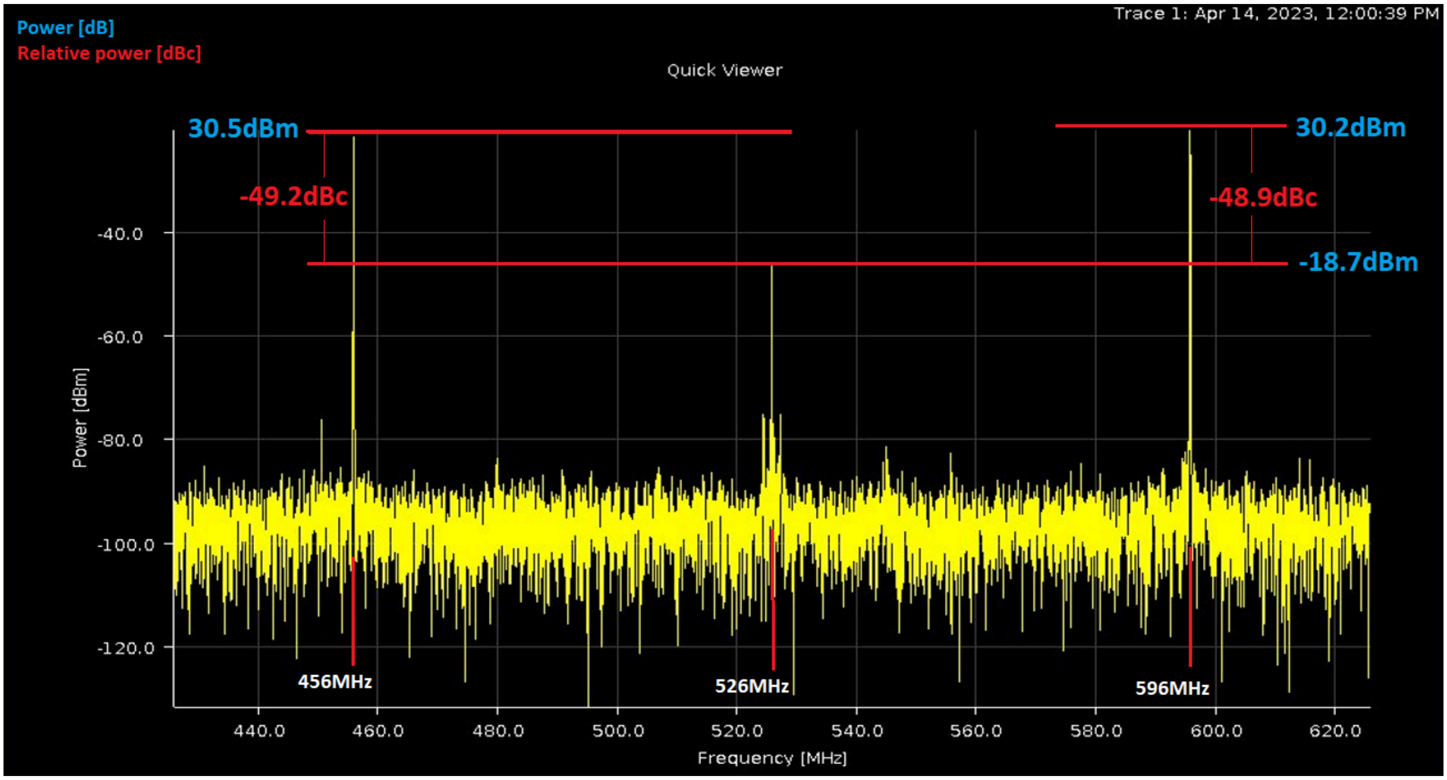


Figure 2. Up-Conversion Test - Spectrum

Fully Qualified Name	Test#	Type	Low	High	Unit	Min	Max	Mean	Estimated Median	Sdev	Cpk	Cpl
Main.rf.gain.Test[fin70MHz].ptdConvGain	700	Parametric	0.200000	2.00000	dB	1.28028	1.28028	1.28028	1.28028	0	N/A	N/A
Main.rf.gain.Test[fin70MHz].ptdTemperature	701	Parametric	24.0000	29.0000	C	28.0293	28.0293	28.0293	28.0293	0	N/A	N/A
Main.rf.aclr.ptdCarrierPower	800	Parametric	-20.0000	-15.0000	dBm	-18.7139	-18.7139	-18.7139	-18.7139	0	N/A	N/A
Main.rf.aclr.ptdCh1Upper	801	Parametric	-60.0000	-46.0000	dBc	-48.9697	-48.9697	-48.9697	-48.9697	0	N/A	N/A
Main.rf.aclr.ptdCh1Lower	802	Parametric	-60.0000	-46.0000	dBc	-49.2569	-49.2569	-49.2569	-49.2569	0	N/A	N/A
Main.rf.aclr.ptdGain	803	Parametric	0.200000	2.00000	dB	1.28606	1.28606	1.28606	1.28606	0	N/A	N/A
Main.rf.aclr.ptdTemperature	804	Parametric	24.0000	29.0000	C	27.8516	27.8516	27.8516	27.8516	0	N/A	N/A
Main.rf.oip3.Test[Power_m10p00].MinTonePower	1003	Parametric	Double.MAX	-Double.M...		-8.74122	-8.74122	-8.74122	-8.74122	0	N/A	N/A
Main.rf.oip3.Test[Power_m10p00].MaxIMDPower	1004	Parametric	Double.MAX	-Double.M...		-73.7089	-73.7089	-73.7089	-73.7089	0	N/A	N/A
Main.rf.oip3.Test[Power_m10p00].OIP3	1006	Parametric	Double.MAX	-Double.M...		23.7426	23.7426	23.7426	23.7426	0	N/A	N/A
Main.rf.oip3.Test[Power_m10p00].IIP3	1005	Parametric	Double.MAX	-Double.M...		22.4839	22.4839	22.4839	22.4839	0	N/A	N/A
Main.rf.oip3.Test[Power_m10p00].Temperature	1007	Parametric	Double.MAX	-Double.M...		28.0649	28.0649	28.0649	28.0649	0	N/A	N/A
Main.rf.p1db.Test[fin70MHz].gain	1000	Parametric	0.200000	2.00000	dB	1.14656	1.14656	1.14656	1.14656	0	N/A	N/A
Main.rf.p1db.Test[fin70MHz].p1db	1001	Parametric	9.00000	14.0000	dBm	11.4597	11.4597	11.4597	11.4597	0	N/A	N/A
Main.rf.p1db.Test[fin70MHz].temperature	1002	Parametric	24.0000	29.0000	C	28.1004	28.1004	28.1004	28.1004	0	N/A	N/A

Figure 3. Up-Conversion Test – Measured Values

Appendix B: LTC5510 – 1MHz to 6GHz Wideband, High Linearity Active Mixer Datasheet

FEATURES

- Input Frequency Range to 6GHz
- 50Ω Matched Input from 30MHz to >3GHz
- Capable of Up- or Down-Conversion
- **OIP3: 27dBm at f_{OUT} = 1575MHz**
- **1.5dB Conversion Gain**
- Noise Figure: 11.6dB at f_{OUT} = 1575MHz
- **High Input P1dB: 11dBm at 5V**
- 5V or 3.3V Supply at 105mA
- Shutdown Control
- LO Input Impedance Always Matched
- 0dBm LO Drive Level
- On-Chip Temperature Monitor
- –40°C to 105°C Operation (T_C)
- 16-Lead (4mm × 4mm) QFN Package

TYPICAL APPLICATION

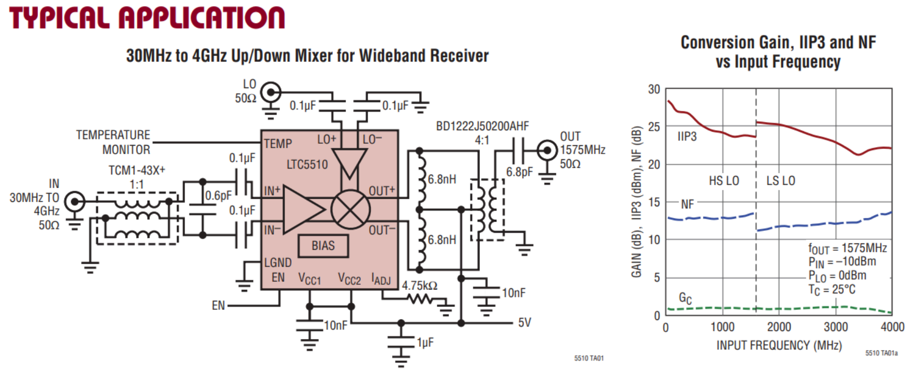


Figure 5. LTC5510 High Level Information

AC ELECTRICAL CHARACTERISTICS The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_C = 25°C. EN = High, P_{LO} = 0dBm, P_{IN} = –10dBm (–10dBm/tone for two-tone tests), unless otherwise noted. Test circuit shown in Figure 1. (Notes 2, 3, 4)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
5V Wideband Upmixer Application: f_{IN} = 30MHz to 1000MHz, f_{OUT} = 2140MHz, f_{LO} = f_{IN} + f_{OUT}, V_{CC} = 5V, R1 = 4.75kΩ						
Conversion Gain	f_{IN} = 190MHz			1.1		dB
	f_{IN} = 450MHz			1.0		dB
	f_{IN} = 900MHz			1.0		dB
Conversion Gain vs Temperature	T_C = –40°C to 105°C, f_{IN} = 190MHz	●		–0.006		dB/°C
Two-Tone Output 3rd Order Intercept (Δf = 2MHz)	f_{IN} = 190MHz			25.6		dBm
	f_{IN} = 450MHz			24.6		dBm
	f_{IN} = 900MHz			23.9		dBm
SSB Noise Figure	f_{IN} = 190MHz			12.0		dB
	f_{IN} = 450MHz			12.2		dB
	f_{IN} = 900MHz			12.4		dB
SSB Noise Floor at P_{IN} = +5dBm	f_{IN} = 800MHz, f_{LO} = 3040MHz, f_{OUT} = 2140MHz			–151.4		dBm/Hz
LO-IN Leakage	f_{LO} = 2100MHz to 3500MHz			<–50		dBm
LO-OUT Leakage	f_{LO} = 2100MHz to 3500MHz			<–31		dBm
IN-OUT Isolation	f_{IN} = 30MHz to 1100MHz			>40		dB
IN-LO Isolation	f_{IN} = 30MHz to 1100MHz			>50		dB
Input 1dB Compression	f_{IN} = 190MHz			11.5		dBm
	f_{IN} = 450MHz			11.5		dBm
	f_{IN} = 900MHz			11.7		dBm

Figure 6. LTC5510 – Key Specifications (Data Points: <u>closest</u> to fRF = 70MHz)

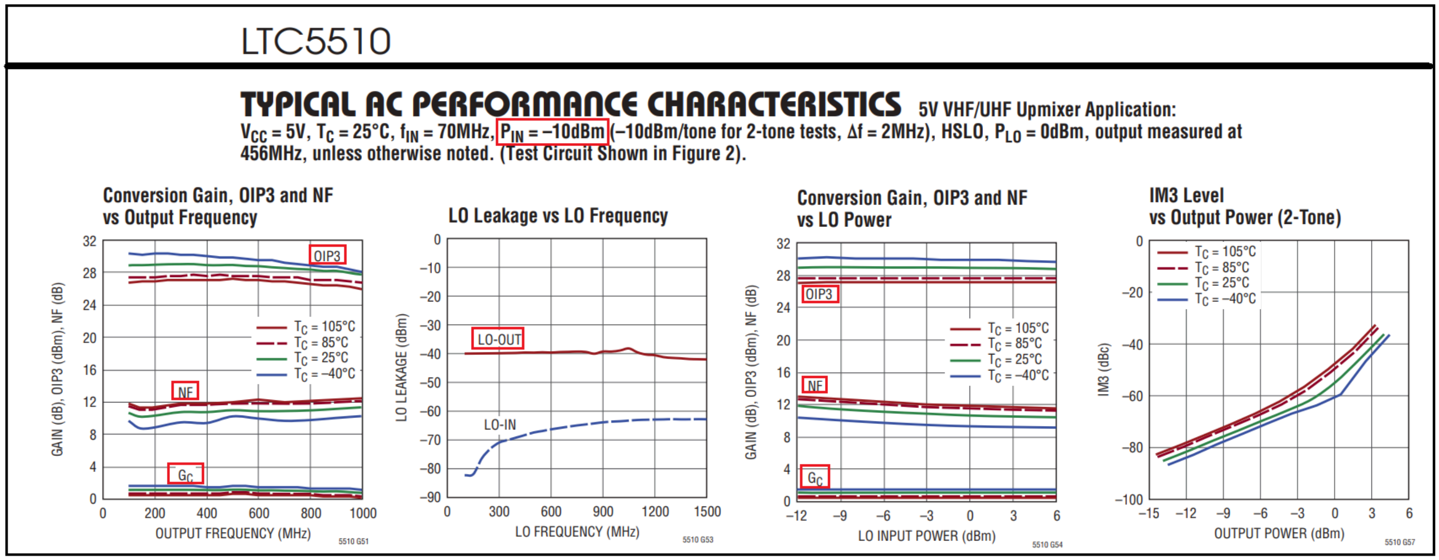


Figure 7. LTC5510 – Key Performance Characterization Data (Plots: to observe trends at fRF = 70MHz)