

Pulsed Laser Single-Event Transient Testing of the Hittite HMC422 MMIC GaAs Mixer

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1. Introduction

The HMC422MS8 is a double balanced mixer gallium arsenide (GaAs) integrated circuit with integrated local oscillator (LO) amplifiers. This mixer can operate as an upconverter or downconverter between 1.2 GHz and 2.5 GHz. With the integrated LO amplifier, the mixer requires an LO drive level of only 0 dBm, and requires only 30 mA from a single positive 3 V rail. The mixer has 8 dB of conversion loss, an input P1dB of +8 dBm and an input third order intercept point of +15 dBm at 2 GHz. The device was monitored for transients on the RF output and for any destructive events induced by exposing it to a pulsed laser beam at the Naval Research Laboratory (NRL) laser test facility.

2. Devices Tested

2.1 Hittite HMC422MS8 Background

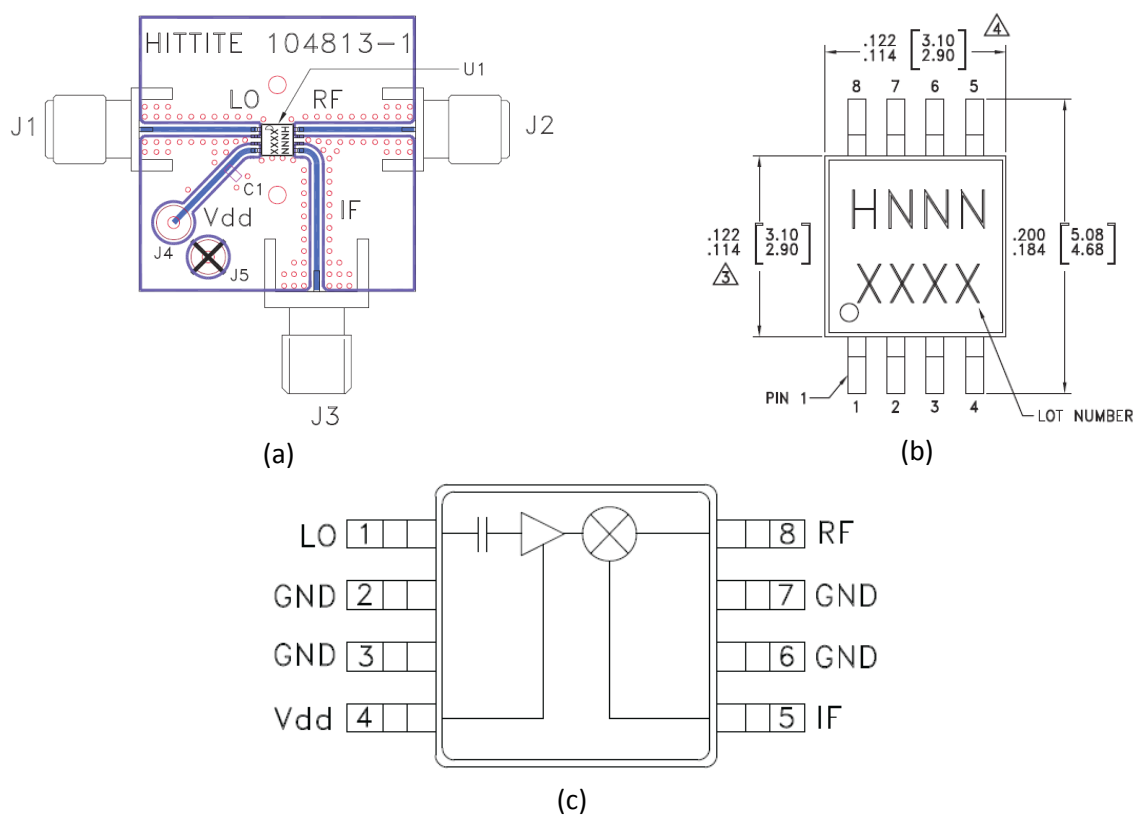


Figure 1: (a) Schematic drawing of the DUT evaluation card for the Hittite HMC422MS8, (b) package dimensions of the HMC422MS8, and (c) the pin assignments for the HMC422MS8. The passive component values are given in Table 1.

Table 1: Passive component values for the evaluation PCB shown in Figure 1

COMPONENT	VALUE
C1	10k pF chip capacitor in 0603 package
J1-J3	SMA connectors
J4-J5	DC pins

The configuration of the Hittite evaluation board is shown in Figure 1. DC bias was applied to the V_{DD} and GND pins, J4 and J5. SMA cables were connected to RF, LO, and IF during the test, which implemented the mixer as a downconverter. The component values of the evaluation board shown in Figure 1 are given in Table 1.

After removing the lid of the package, the die within was photographed at modest magnification to reveal the sensitive structures. These images, along with the evaluation board (Hittite part number PCB 105188), are shown in Figure 2.

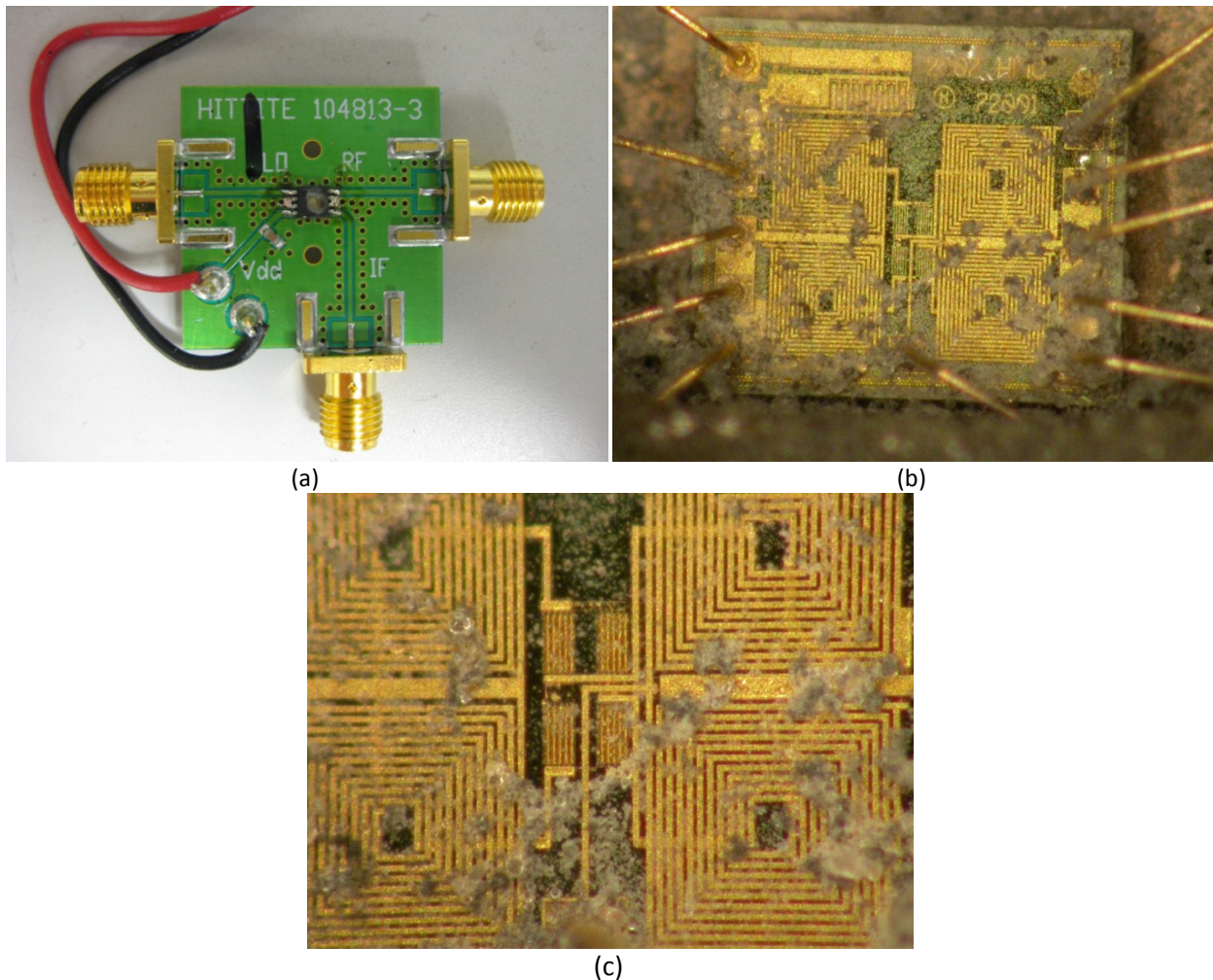


Figure 2: PCB and die images of the HMC422 following acid etching. Note that the remaining encapsulant was cleaned further before testing. The sensitive transistor targets are visible in (b) and closer in (c) as the group of four small fingered structures in the middle of the die. The four large coils are presumably inductors. The integrated LO amplifier is most likely the structure in the top left of (b). These structures produced transients when stimulated with the pulsed laser.

2.2 Device Under Test Information

Two devices were exposed to the pulsed laser beam at the NRL. The device lot date code was JX22. The DUT was packaged in a plastic MSOP-8 package with a copper alloy leadframe. The DUT was prepped for test by Timothy Irwin by acid etching the package after a flight lot DUT was soldered to the evaluation board.¹ This analog single-event transient (ASET) test is not strictly application-specific and simply uses

¹ The eval PCB used in this experiment was a 104813 PCB, which is different than the eval board called out in the datasheet, though it is compatible.

the factory-provided evaluation board show in Figure 1, however, the RF and LO frequencies are close the final application. Table 2 lists the pertinent information about the DUT.

Table 2: HMC422 Sample Information

Part Number:	HMC422MS8 (SMD: Non-DSCC Audited Part)
Manufacturer:	Hittite Microwave Corp.
Date Code:	JX22 24 th week of 2009
Additional Case Markings:	HNNN
Quantity Tested:	2
Part Function:	GaAs MMIC mixer with integrated LO amplifier
Part Technology:	Triquint Oregon MESFET process
Package Style:	MSOP-8 (MS8)

3. Test Setup

The test setup is shown in Figure 4 and consists of laptop running LabVIEW for instrument control and data capture, a Tektronix DSA72004B digital storage oscilloscope (20 GHz, 50 GS/s), two HP 83712B synthesized CW generators, and an Agilent N6702A MPS mainframe 4-channel power supply². The DUT evaluation board schematic diagram and photo are shown in Figure 1. The two function generators had their 10 MHz synchronization lines tied to the NRL function generator sync I/O. This allowed the laser pulse firing to be used as the trigger source for the oscilloscope enabling the laser pulse to move throughout all 2π of the CW input on RF and LO.

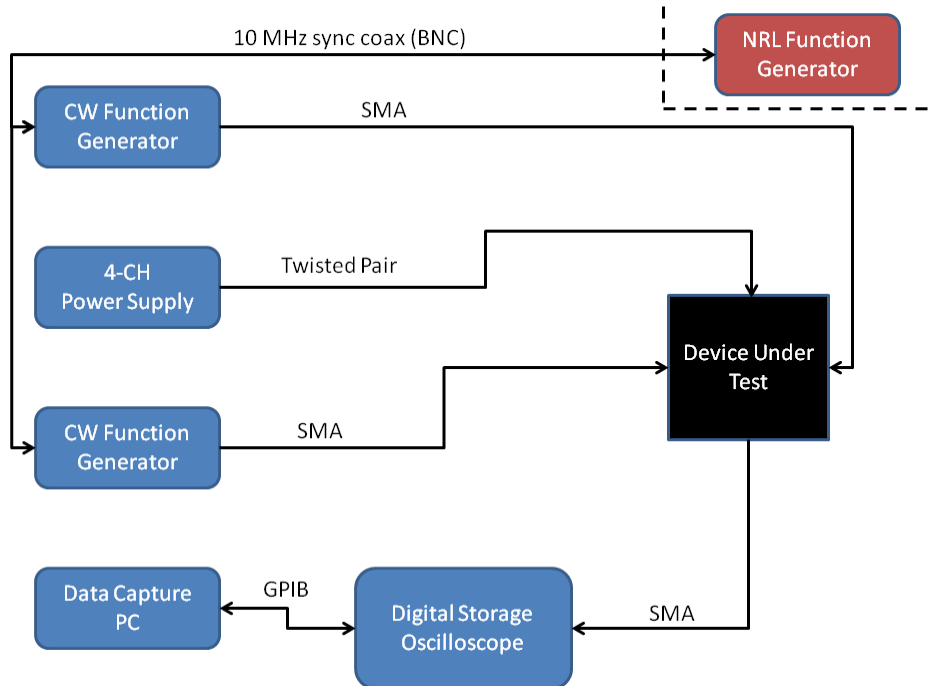


Figure 3: Block diagram for test setup for the HMC422MS8.

4. Test Description

4.1 Irradiation Conditions

The tests were performed at the NRL using their single-photon absorption (SPA) setup. This system has been discussed in several refereed publications and will not be covered in detail [1-3]. The laser wavelength is 590 nm, has a pulse width of approximately 1 ps, and is operated at a 1 kHz repetition rate. A 100x microscope objective was used to focus the laser beam down to a full width half maximum (FWHM) Gaussian spot of approximately $1.2 \mu\text{m}$. Throughout the test, the pulse intensity, as measured on a NRL oscilloscope, was varied using a waveplate polarizer and multiple neutral density filters with different optical densities for logarithmic coverage. Given these conditions, the resulting charge generation in the sensitive layers beneath the back end of line (BEOL) material stack is sufficient to conduct a conservative ASET analysis.

² A separate function generator specific to the NRL test facility was used to synchronize the 2 GSFC function generators to the delivery of the laser pulse so that different points within the clock period could be sampled.

4.2 Test Parameters and Bias Conditions

The laser was focused onto the HMC422MS8 die and scanned across the surface to produce transients on the IF output. This was done for two different input (RF and LO) conditions, which are detailed in Table 3. This was not an application specific test, but the input frequencies were relevant for the end users; the only variables were the RF and LO input conditions and the laser pulse energy. Transients were captured for all test conditions. In order to convert from laser pulse voltage to pulse energy, the conversion applied is 0.224 pJ/mV at an optical density of 1. The optical density of the neutral density filters used logarithmically modulates the laser pulse irradiance according to $(I/I_0) = 10^{-d}$, where I_0 is the un-attenuated irradiance and d is the optical density.

The usual material considered for SPA is silicon, however, this is GaAs. The difference is in the $1/e$ penetration depth, which is based on the absorption coefficient of the laser. The linear absorption coefficient, α , is dependent on the target material and the photon wavelength. For silicon it is 6385 cm^{-1} and for GaAs it is 51083 cm^{-1} . Therefore, the $1/e$ penetration depth in GaAs at this wavelength is 8x shorter than silicon – about $0.2 \mu\text{m}$ versus $1.6 \mu\text{m}$. This is one of the limitations of this technique when using GaAs. However, since the energy deposition is conserved, the charge generation density is also that much higher, perhaps adding some additional margin.

Table 3: Test Conditions Examined

Laser Pulse Voltage (mV) [†]	Neutral Density Filter Optical Density	RF Input Frequency (MHz)	LO Input Frequency (MHz)	Laser Pulse Energy (pJ)
0.015	1.0	1530	1500	3.36
0.015	1.0	DC	DC	3.36

- The relative humidity throughout the test was constant at 45%.
- The ambient temperature was constant at 21° C.

† Note that laser pulse voltage is a relative measure of the laser pulse energy and depends upon an independent calibration to calculate the pulse energy.

5. Results

We scanned the laser across the HMC422MS8 die for each of the input conditions specified in Table 3. The GaAs MESFETs on the die were capable of producing transients at the IF output port of the evaluation board under DC input conditions on RF and LO and were recorded by the oscilloscope. The transient was on the order of a nanosecond with a negative amplitude of approximately 40 mV. These results are summarized in Figure 4.

The charts shown in Figure 5 demonstrate what the transient looks like with realistic input conditions on RF and LO. The downconverted signal on IF (30 MHz), including the higher harmonics, are visible as is the transient. The ASET from Figure 4 is essentially superimposed on the output signal with little additional distortion.

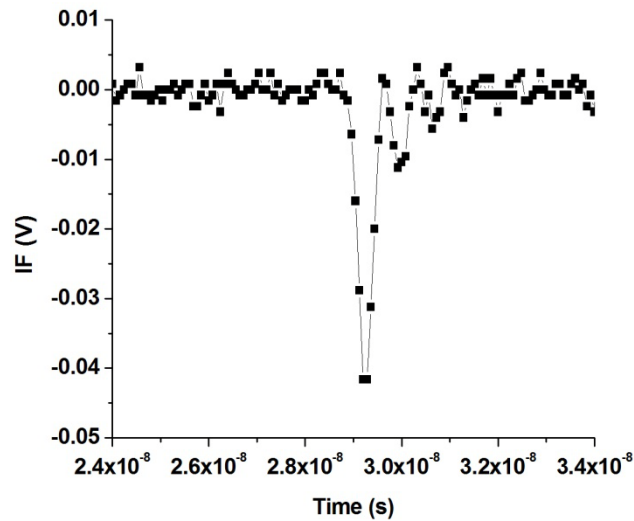


Figure 4: Example ASET for DC input conditions on RF and LO. The MESFETs in the center of the die were the only source of transients – the LO amplifier did not appear to contribute. All transients are negative, which makes sense since the targets were all n-channel devices. These transients were recorded at a laser pulse energy of 3.6 pJ.

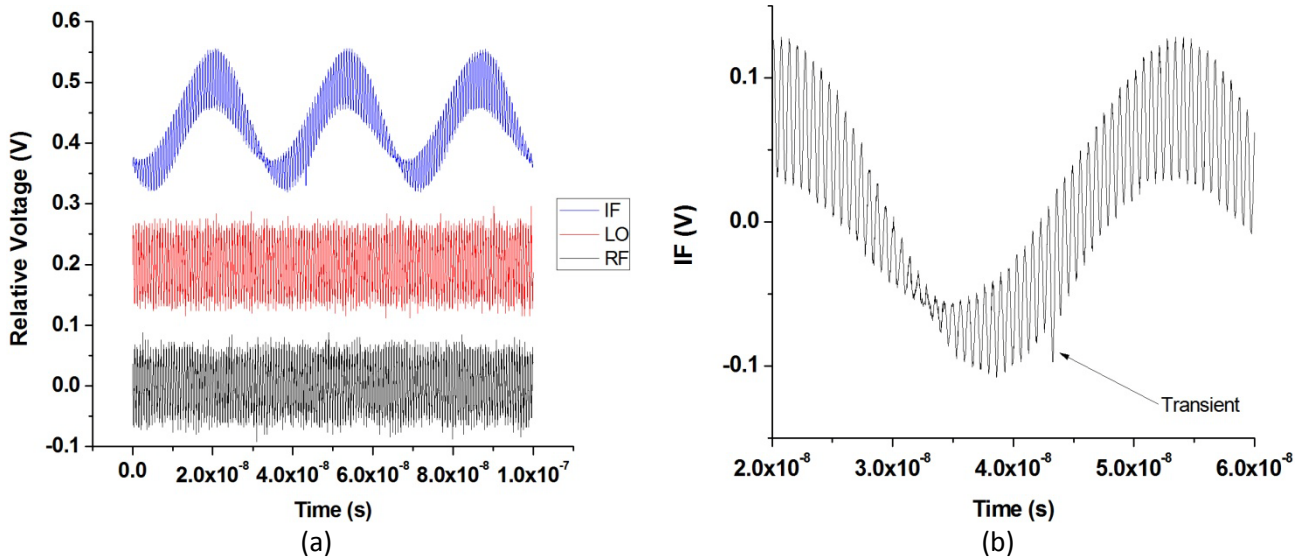


Figure 5: These figures show ASETs for AC RF and LO input characteristics at a pulse energy of 3.6 pJ. (a) shows an ASET on IF as well as the raw RF and LO signals from the CW generators; (b) shows a zoomed image of the ASET from the top trace of (a). Note that the voltages shown in (a) are arbitrary and simply relative within each trace's range – the data were stacked to show them on the same abscissa.

6. Conclusions and Recommendations

The Hittite HMC422MS8 tested here showed transients less than 0.5 V in amplitude for DC and AC input conditions on RF and LO up to a laser pulse energy of 3.6 pJ. The transients widths, measured at 10% of the peak voltage, were approximately 1 ns. The DC input condition ASETs measured on IF appeared to be simply superimposed on the IF signal and cause no further distortion during AC input conditions. The amplitude and width remained unchanged. The laser pulse energy used is sufficiently conservative to be confident that the worst case behavior has been bounded assuming that charge generation depth is not a serious contributor to device response. In space this assumption may be violated, but the intended application employs both hardware and software filtering techniques that should mitigate ASET glitches.

GaAs technologies generally suffer from large single-event cross sections due to large charge collection efficiencies. The results shown here seem to indicate that the response saturated quickly with increasing laser pulse energy. We assume that these ASETs bound the heavy ion response of the device, taking into account the caveat spelled out in the previous paragraph.

Based on this pulsed laser test's results, the Hittite HMC422MS8 is recommended for use in NASA/GSFC spaceflight applications, but may require transient mitigation (*i.e.*, filtering) techniques to reduce the effect of ion-generated transients.

7. References

- [1] Melinger, J. S.; Buchner, S.; McMorrow, D.; Stapor, W. J.; Weatherford, T. R.; Campbell, A. B.; and Eisen, H., "Critical evaluation of the pulsed laser method for single event effects testing and fundamental studies," *IEEE Trans. Nucl. Sci.*, vol. 41, no. 6, pp. 2574-2584, Dec. 1994.
- [2] McMorrow, D.; Melinger, J. S.; Buchner, S.; Scott, T.; Brown, R. D.; and Haddad, N. F., "Application of a pulsed laser for evaluation and optimization of SEU-hard designs," *IEEE Trans. Nucl. Sci.*, vol. 47, no. 3, pp. 559-565, Jun. 2000.
- [3] Buchner, S.; McMorrow, D.; Sternberg, A.; Massengill, L.; Pease, R. L.; and Maher, M., "Single-event transient (SET) characterization of an LM119 voltage comparator: an approach to SET model validation using a pulsed laser," *IEEE Trans. Nucl. Sci.*, vol. 49, no. 3, pp. 1502-1508, Jun. 2002.