

# Keysight TC700/702

## Traveling Wave Amplifier

### Environmental Data

#### Technical Overview

This application note provides information regarding the operation and performance of the TC700 and TC702 traveling wave amps under a variety of environmental conditions. Included in this application note are:

- TC700, TC702 reliability data.
- Test results in humid and condensing environments.
- Electrostatic discharge damage thresholds.
- RF input power damage.
- Thermal resistance measurements.
- Environmental test check list.

The data is intended to aid the designer in determining the necessary guard bands and precautions required (on reliability, thermal, and environmental issues) to insure a successful end product. This data is supplemental and does not imply any guaranteed specifications.

## 1.0 High Temperature Operating Life (HTOL) Test Results

High Temperature Operating Life (HTOL) Test Results The TC700 and TC702 TWAs have been subjected to HTOL life tests at the test and bias conditions shown in Table 1. The failure criteria was defined as  $\pm 1$  dB drift in  $S_{21}$  measured at 26.5 GHz. The results from these tests show that the failure rate of both the TC700 and TC702 TWAs will be less than 100 FITS (or .01% failure/1000 hours.), after one year of continuous operation at the bias and temperature conditions listed in the following table.

Table 1.

TWA HTOL reliability test				
Test conditions				
Device	$V_{ds}$ (V)	$I_{ds}$ (mA)	$T_{ch}$ (°C)	$T_{ch}$ (°C)
TC700	7	150	154 <sup>1</sup>	115
TC702	8	250	217 <sup>2</sup>	126

<sup>1</sup> TC700:  $T_{ch}$  (°C) = 1.105  $T_{bs}$  + 26.4 for 1.05 W dc power dissipation, where  $T_{bs}$  = backside temperature.

<sup>2</sup> TC702:  $T_{ch}$  (°C) = 1.174  $T_{bs}$  + 43.6 for 2.00 W dc power dissipation.

## 2.0 Test Results in Humid Conditions

Although WPTC's GaAs ICs are passivated, this passivation does not guarantee hermeticity. The fact that GaAs devices can be etched by water suggests that operation of GaAs devices in humid or condensing environments will impact performance and reliability. As a result, hermetic packaging of GaAs devices and circuits is recommended. Successful application of GaAs devices in non-hermetic environments is a complex function of application-specific variables:

- End use environment
- Bias conditions
- Thermal design of package
- Thermal dissipation

WPTC has characterized the performance of TWAs in a 65 °C/95% R.H.<sup>1</sup> environment under two bias conditions:

- High (standard) power dissipation bias in 65 °C/95% R.H. after 200 hours.
- Low power dissipation bias in 65 °C/95% R.H. after 200 hours.

<sup>1</sup> R.H. = relative humidity

## 2.1 Unbiased Humidity Test

Over 50 TWA wafers have been subjected to a three day (72 hour) 65 °C/95% R.H. soak. S-parameters were measured before and after the humidity soak.  $S_{21}$  was the only parameter exhibiting a measurable drift. The change in  $S_{21}$  was on the average  $-0.17$  dB, with a standard deviation of  $.08$  dB. The cumulative distribution is shown in Figure 1. This drift is recoverable when the wafers are “baked out” at  $150$  °C for 8 hours.

## 2.2 Biased Humidity Tests

Performance of TWAs under bias, in humidity, was investigated on several wafers. Two bias conditions were tested: high dc power dissipation bias, and low dc power dissipation bias. In standard, or high dc power dissipation bias, the TC700 is dissipating approximately 1 watt of dc power (2 watts for the TC702). In the low bias state the current in the TWA is adjusted, using an externally applied second gate voltage, to approximately 20% of  $I_{dss}$  (or  $\sim .2$  to  $.4W$   $P_{dc}$  dissipation). See Figures 2 and 3.

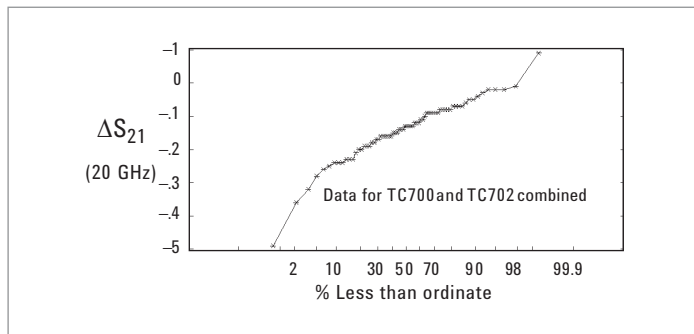


Figure 1.

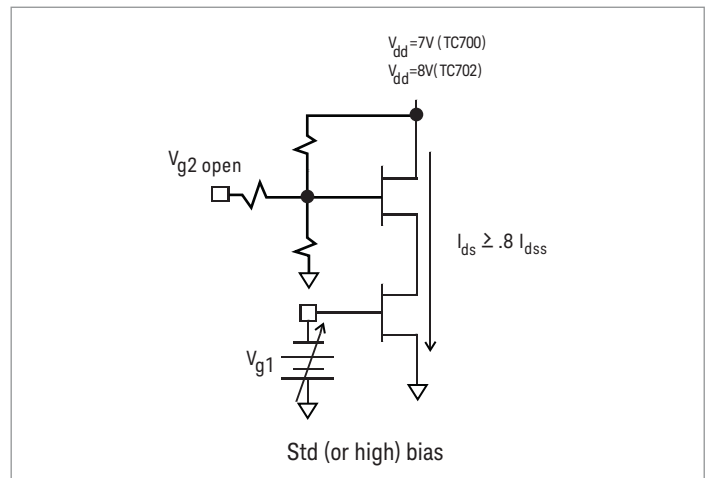


Figure 2.

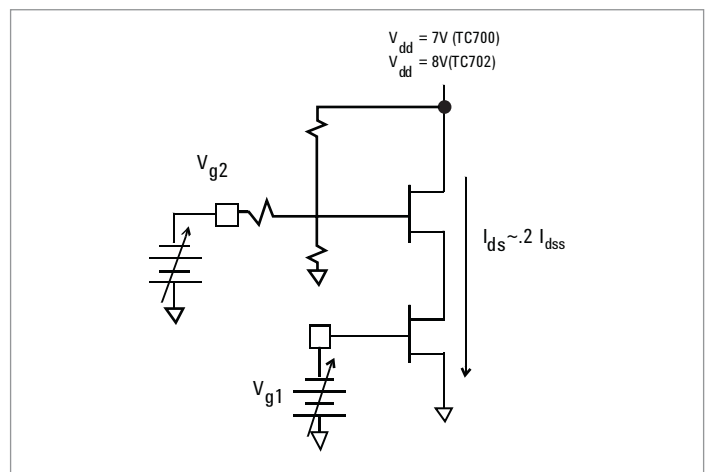


Figure 3.

1. R.H. = relative humidity
2. The “low bias” state was achieved during this test by first adjusting  $V_{g1}$  to set  $I_{ds} \sim .8 I_{dss}$ . Second,  $V_{g2}$  was adjusted until  $I_{ds} \sim .1$  to  $.2 I_{dss}$

The low bias state is of particular interest to customers, providing external bias to the second gate of the TWA for AGC or pulse modulation applications. The results of these tests (see Table 2) indicate that TWAs biased at standard or high bias conditions will exhibit the same level of humidity sensitivity, measured by changes in  $S_{21}$ , as in the unbiased 65 °C/95% R.H. test (i.e., approximately  $-0.2$  dB drift in  $S_{21}$ ). In the low bias state, catastrophic failures have resulted after several days of exposure to humidity.

It is postulated that the low bias state does not generate enough “self heating” to drive the moisture away from the active areas of the TWA FETs. The combination of high humidity, high voltage differentials and low dc power dissipation can significantly degrade TWA performance and ultimately lead to catastrophic failure. As a result, hermetic packaging is strongly recommended for any TWA applications where operation at low dc power dissipations in humid environments is likely. This is not a problem in non-humid environments.

Table 2.

Biased humidity results		
Atmosphere: 65 °C/95% R.H. for 200 hours		
Bias condition		
Parameter	Standard (High)	Low
$\Delta S_{21}$	$-0.2$ dB	$-3$ to $-10$ dB

Table 3.

TWA power ratings		
Device	Absolute maximum input power	Continuous maximum input power
TC700	28 dBm	23 dBm
TC702	28 dBm	23 dBm

### 3.0 RF Input Power

There are two maximum input power ratings on the TC700 and TC702 TWAs. The Absolute Maximum Input Power rating should be interpreted as the damage level. Applied power equal to or greater than the quoted Absolute Maximum Input Power rating may result in immediate, non-recoverable damage to the IC. The continuous RF Input Power rating represents the maximum input power that can be continuously applied to the device without degradation.<sup>1</sup> For both cases the power limiting element on the TWA is the 50 thin film termination resistor. The power ratings are shown in Table 3.

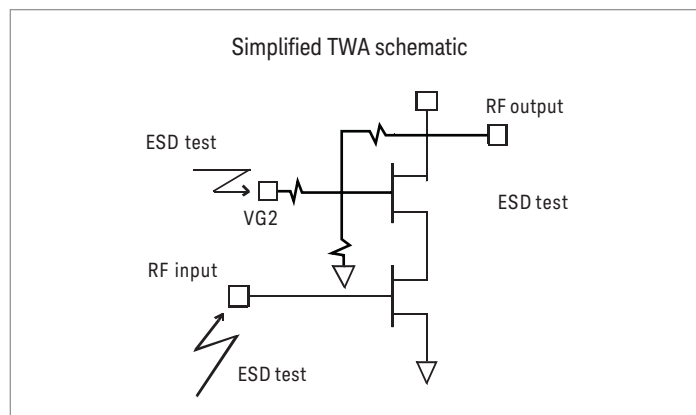


Figure 4.

1. These tests were conducted in a dry environment at a 70 °C ambient temperature.

## 4.0 Electrostatic Discharge Sensitivity (ESD)

The ESD damage threshold was characterized on the RF input, output, and auxiliary second gate pads (see Figure 4).

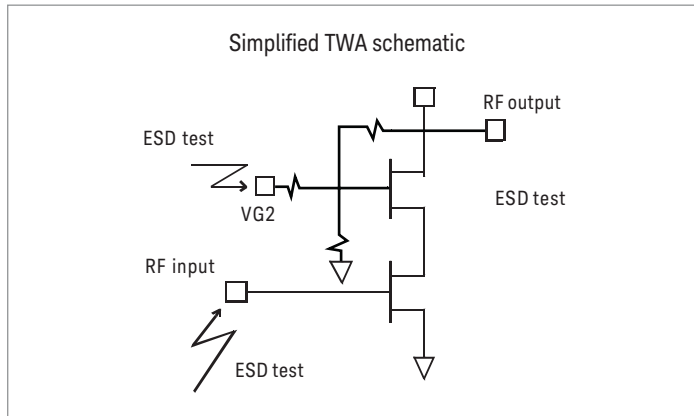


Figure 4.

The testing was performed with the source grounded with no drain or gate bias to simulate conditions typically experienced during hybrid assembly. The damage threshold is defined as the voltage required to induce at 10% change in pinch off current or  $I_{dss}$ , or a catastrophic open/short, whichever occurs first. Figure 5 is a block diagram of the test system. The results are shown in Table 4.

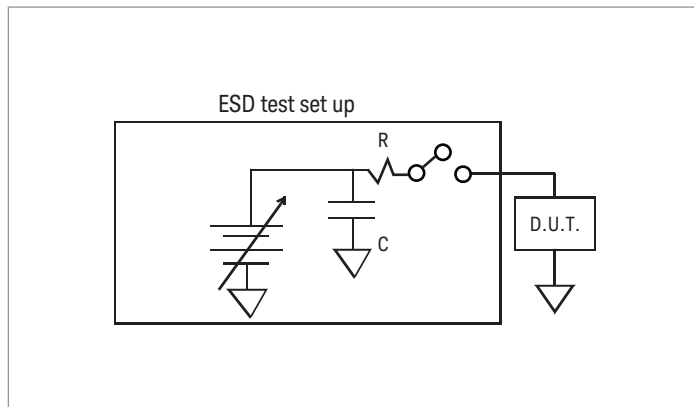


Figure 5.

Table 4.

ESD damage thresholds			
	Voltage		
Device type	RF input	RF output	Aux. 2nd Gate ( $V_{G2}$ )
TC70026	1100	5500	1500
TC702	600	7500	700

## 5.0 Thermal Resistance

The thermal resistance of the TC700 and TC702s was measured using liquid crystal thermography. Thermal resistance measurements are very dependent on the assembly technique and thermal environment surrounding the IC. The assembly technique and materials used for these measurements are shown in Figure 6. The results are shown in Table 5.<sup>1</sup>

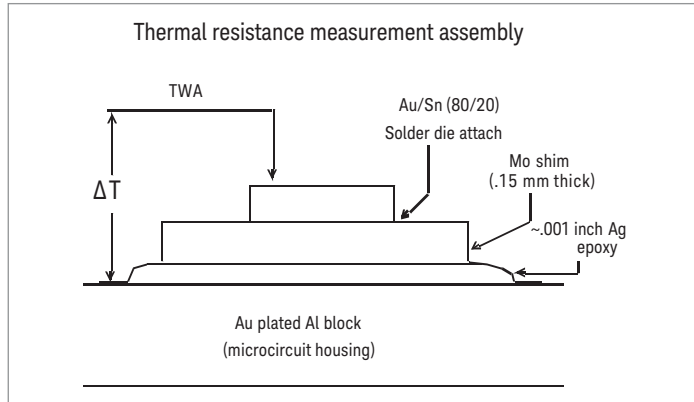


Figure 6.

Table 5.

Thermal resistance measurement results		
Device	Temp. (°C)	Therm. res. (°C/W)
TC700	116	35
TC702	116	29

Table 6.

Environmental checklist	
Test	TWA results
Temperature cycling survival	Not tested
Vibration survival	Not tested
Vapor phase moisture test	Will not pass
Condensing moisture test	Will not pass
Operating temperature	Passed

## 6.0 Microcircuit Environmental Qualification Checklist

Most microcircuits designed at Keysight Technologies are subjected to a series of environmental qualification tests. These tests are intended to evaluate how the microcircuit will function under the specified environment. The results will be a complex function of bias condition, thermal design, internal microcircuit components and other application-specific variables. As a result, the performance of a microcircuit under a specific set of environmental conditions can not always be predicted from environmental tests performed on an isolated component used in the microcircuit.

With this qualification in mind, Table 6 lists a number of tests a typical microcircuit is subjected to during production qualification.<sup>2</sup> Performance of the TC700 and TC702 TWAs is noted for each test as: Passed (in device form), Will Not Pass, or Not Tested.

<sup>1</sup> These tests were conducted in a dry environment at a 70 ° ambient temperature.

<sup>2</sup> This test list is derived from NMD's Microcircuit Evaluation Standard (Dwg. No. A-5090-3231-1). Results from other tests, with different test conditions, may vary.

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