X-711-66-449

NASA TM X-55572

DEGRADATION OF TRANSISTOR PERFORMANCE DUE TO PASSAGE OF SMALL-COULOMB HIGH-VOLTAGE SURGES

BY
NORMAN M. GARRAHAN

GPO PRICE $ ______

CFSTI PRICE(S) $ ______

Hard copy (HC) 1.00

Microfiche (MF) .50

ff 653 July 65

SEPTEMBER 1966

NASA — GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

X-711-66-449

DEGRADATION OF TRANSISTOR PERFORMANCE DUE TO PASSAGE OF SMALL-COULOMB HIGH-VOLTAGE SURGES

By

Norman M. Garrahan
Flight Data Systems Branch

SEPTEMBER 1966

GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland

DEGRADATION OF TRANSISTOR PERFORMANCE DUE TO PASSAGE OF SMALL-COULOMB HIGH-VOLTAGE SURGES

By

Norman M. Garrahan
Flight Data Systems Branch

ABSTRACT

In order to determine the effects of high-voltage-pulse transients on transistor life and beta stability, a few selected transistors were subjected to a series of randomly applied high-voltage pulses across the base-emitter junction. It was found that successive high-voltage pulses caused a gradual beta degradation and drop in junction resistance, with a need for increased base-current drive for a measureable non-zero beta. As the amplitude of the pulses was increased, a point was reached where the transistor open-circuited. This report describes a brief empirical qualitative check made on a few selected transistors to help arrive at a quick solution to production failures of transistors in potting molds.

AUTHOR

CONTENTS

DEGRADATION OF TRANSISTOR PERFORMANCE DUE TO PASSAGE OF SMALL-COULOMB HIGH-VOLTAGE SURGES

INTRODUCTION

In the past, several experiments have suffered transistor failure and degradation of transistor performance. In some cases the difficulty arose in circuits associated with high-voltage interfacing units such as photomultiplier detector tubes; and in other instances damage was believed to have resulted from a static discharge that occurred when a molded sub-module was removed from a potting mold. The instant of in-circuit failure seems to be when the high-voltage supply is switched on, suggesting that a capacitance charge was forcing a surge current through the transistor junction. An empirical check on a few selected transistors has indicated that this is indeed a cause of failure, and that the capacitance involved does not have to be very large if voltages over 400 volts are being switched. No attempt was made to simulate the potting mold failures.

TEST PROGRAM

The test transistors were randomly pulsed with successively higher positive and negative voltages across the base-emitter junction in the forward and reverse-bias directions using a 25 pf capacitor charged via a switching arrangement. The pulse discharge amplitude was measured on a scope by switching the charged capacitor into a 10 meg/5 pf probe and was found to be (with transistor removed) roughly one-half the charging voltage of the high-voltage supply.

Test No. 1

Positive Pulse/Forward Bias—Transistor type 2N2369, a fast response (f_T = 500MHz) NPN, was checked with the following results:

a) For a positive pulse of 500 volts applied in the forward-bias direction 10 to 20 times there was no observable beta degradation on the curve tracer at 1 microampere base current drive.

b) For positive pulses over 500 volts (in the 600 volt range) applied in the forward-bias direction, degradation in transistor beta occurs. For repeated pulses the transistor degraded successively to a higher base drive requirement for a measureable non-zero beta. Concurrent with the successive degradation steps in the beta, the multimeter measured emitter-to-base forward and reverse junction resistances reduced in value from the nominal 11K ohms forward resistance and 70K ohms reverse resistance. For the early steps of the beta degradation this reduction in junction resistance was small, about 10%. This explains why the measurement of junction resistances has not always been successful in locating a defective in-circuit transistor.

As additional pulses were applied and the amplitude was increased to 600-800 volts, the base-emitter junction resistance fell more rapidly to a low value of 2-3K ohms in both directions. At this time the transistor may require 1 milliampere of drive current for a measureable non-zero beta, as compared to the normal 1 microampere.

If the pulses are continued to a maximum of 1500 volts, the emitter-base junction resistances may drop down to 100-200 ohms and zero beta, although one sample stabilized at 3K ohms.

Negative Pulse/Reverse Bias—For negative pulses applied in the reverse-bias direction the degradation followed the same pattern as above but commenced 100 volts lower, around 400 volts pulse amplitude.

Test No. 2

Positive Pulse/Forward Bias—The second transistor checked was an NPN type 2N703, (f_T = 70MHz). In this case, beta degradation did occur for positive pulses of 400 volts in the forward-bias direction. In the early stages of the degradation the fall in beta for the low driving currents was not as rapid as for the previous transistor under test. In this transistor (type 2N2369), the initial pulses moved the base drive requirements from 1 microamp to the 100-500 microampere range for a measureable non-zero beta. For transistor type 2N703, the initial pulses moved the base drive requirement from 1 microampere to about 10 microamperes for a measureable non-zero beta. As in the case of the type 2N2369 transistor, the emitter-base junction resistances of the type 2N703 transistor did not change significantly until the beta degradation had reached its maximum after repeated high-voltage pulses from the capacitor.

Type 2N703 appeared more resistant to complete short-circuit across the emitter-base junction than type 2N2369, although the degradation was complete as far as useable beta was concerned.

Negative Pulse/Reverse Bias—For negative pulses applied in the reverse-bias direction, degradation set in at about a pulse amplitude of 400 volts, approximately the same as for type 2N2369.

Test No. 3

Positive Pulse/Forward Bias—Transistor type SN-100, an NPN (f_T = 30MHz) was tested next. The SN-100 showed less susceptibility to degradation of beta for pulses under 500 volts amplitude in the forward-bias direction than the other two types checked, although two out of the five units tested were destroyed immediately when the pulse amplitude was raised over 500 volts. Similar to the other types tested, the change in measured junction resistances was not significant enough to detect signs of degradation.

Negative Pulse/Reverse Bias—With negative pulses applied across the base-emitter junction in the reverse-biase direction, the SN-100 appeared to be more susceptible to a complete "open" than the others. It occurred at a pulse amplitude of 250 volts.

CONCLUSION

Although the results of this brief test program indicates the need for a more thorough investigation, it is obvious that short-duration low-current high-voltage pulses are very apt to cause permanent transistor degradation. The experimental results are summarized in the following table.

Table 1

Pulse Threshold Degradation Level

TRANSISTOR TYPE	BIAS DIRECTION	
	FORWARD	REVERSE
2N2369	500 v	400 v
2N703	400 v	400 v
SN-100	500 v	250 v