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Proton Test Report Micropac 66212-300 Optocoupler

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1. Introduction and Purpose

The purpose of this test was to determine the displacement damage and total ionizing dose sensitivity of a specific lot of Micropac's 66212-300 optocoupler. During the test, the device was exposed to 63 MeV protons. Device parameters such as current transfer ratio (CTR), reverse current, and forward voltage were investigated to a total of 29.3 krad(Si).

2. Device Description

The Micropac 66212 is advertised as a radiation tolerant 4-pin optocoupler with an 850nm GaAlAs LED and silicon phototransistor. A large quantity of flight parts are necessary for this project; all LEDs used derive from the same wafer, while the phototransistors were sourced from four wafers processed in the same diffusion lot by the manufacturer. The devices were provided in a hermetic 4-pin leadless chip carrier (LCC) package.

Twelve (12) were tested for DDD. All specifications and descriptions are according to the datasheet. More information can be found in Table 1.

Table I. Part description

Part Number	66212-300
Flight Part Number	66212-300
REAG Internal ID	21-027
Manufacturer	Micropac Industries, Inc.
Lot Date Code	2051; phototransistors from diffusion lots 2509-5 and 2509-7
Quantity Tested	12
Part Function	Optocoupler
Part Technology	Hybrid
Package	4-pin LCC 850 nm GaAlAs LED

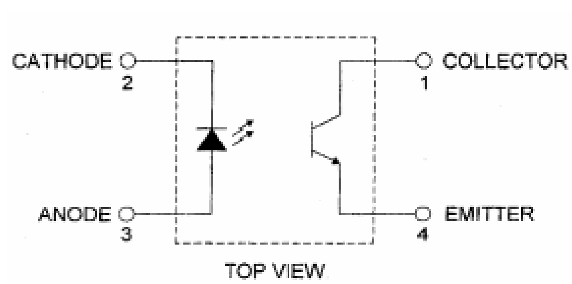

Fig. 1. Pinout of 66212.

3. Proton Test Setup

Parts were serialized randomly and not decapsulated for testing. ESD procedures were followed during test and transfer of the devices between irradiation chamber and characterization. Exposures were performed at ambient laboratory temperature.

Each DUT was soldered to a custom daughter card. Fig. 2 is a schematic of the tester circuit. A photograph of the tester circuit with a DUT is shown in Fig. 3.

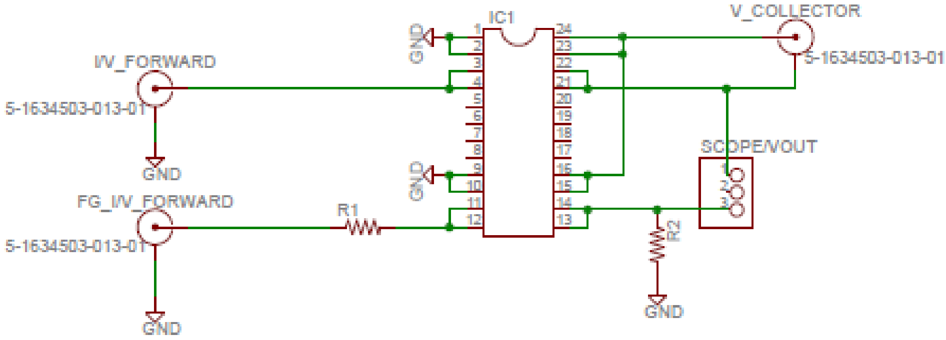

Fig. 2. Schematic of tester circuit

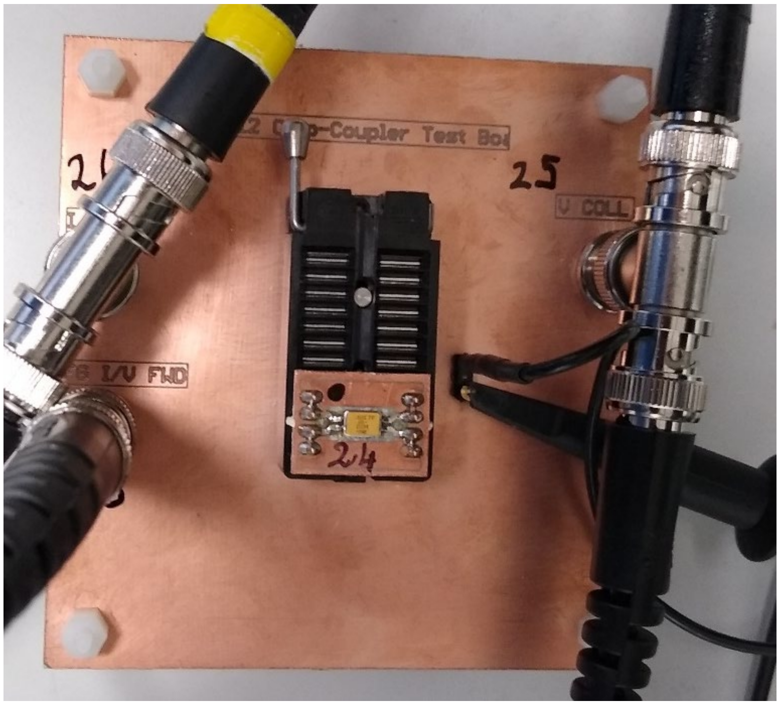

Fig. 3. 66212 on test board

4. Test Facility

Facility:	Crocker Nuclear Lab, University of California, Davis
Type of Radiation:	63 MeV protons at DUT
Facility Configuration:	67.5 MeV beamline with 20 mil Ta degrader; 3" diameter circle effective spot size
Flux:	$1x10^8$ to $1x10^9$/cm^2/s
Fluence:	Maximum: $2.2x10^{11}$/cm^2 (approximately 29.3 krad (Si))

5. Test Conditions

Temperature:	Irradiation: Ambient room temperature, ~25C
In-Air or Vacuum:	In-air
Supply Voltages:	V_{CE} = 12 V; V_{IN} = 0 V

6. Test Methods and Results

Radiation testing was performed at Crocker Nuclear Laboratory on the campus of The University of California at Davis, with a proton energy of 63 MeV measured at the DUT. Twelve (12) parts were exposed to protons and two were used as controls (SN 22, 23). Prior to the first radiation dose, all fourteen (14) parts were electrically tested. After each exposure level, the parts were tested again and returned to radiation. Six parts were biased (SN 2, 3, 4, 5, 6, 7) and six were unbiased (SN 8, 9, 10, 11, 12, 13) during the irradiation steps. See Table II for the fluence and total dose steps for each exposure. Parts were irradiated to a total fluence of 2.2 x 10^{11} cm^{-2} to meet programmatic requirements. The total ionizing dose received by the devices is approximately 29.3 krad(Si).

Table II. Irradiation Steps

Run Number	Part/Batch	Total Accumulated Dose (krad-Si)	Per Run Fluence (#/cm^2)	Accumulated Fluence (#/cm^2)
1	unbiased	2.2	1.66E+10	1.66E+10
2	biased	2.2	1.66E+10	1.66E+10
3	unbiased	11	6.63E+10	8.29E+10
4	biased	11	6.64E+10	8.29E+10
5	unbiased	22	8.28E+10	1.66E+11
6	biased	22	8.3E+10	1.66E+11
7	unbiased	29.3	5.47E+10	2.2E+11
8	biased	29.3	5.45E+10	2.2E+11

The devices actively biased during irradiation were placed in ZIF socket adapters on a copper board. During irradiation, biased DUTs were powered with V_{CE} = 12 V and V_{IN} = 0 V (i.e. LED current approximately zero). All unbiased DUTs were grounded with pins tied together.

6.1. Electrical Tests

This test is primarily a characterization of degradation for a specific application, and no determination of pass or failure was made. However, specification thresholds are referenced to the commercially-available 66212 datasheet. All data from the electrical tests in Table III were logged in Excel spreadsheet files.

Table III. List of Electrical Tests Performed

Parameter	Symbol	Conditions	Notes
Input Static Reverse Current	I_R	V_R=2V	Max: 100 uA
Input Static Fwd Voltage	V_F	I_F=10mA	0.80< V_F<1.5; extracted from I_F sweep
C-E Breakdown Voltage	$V_{BR,CEO}$	I_C=1mA, I_F=0	Min: 40 V; test will be limited to 50 V
C-E Dark Current	I_{CEO}	V_{CE}=20V, I_F=0	Max 100 nA
On State Collector Current	$I_{C(ON)1}$	V_{CE}=1V, I_F = 1mA	Min 2 mA
On State Collector Current	$I_{C(ON)2}$	V_{CE}=5V, I_F=10mA	Min 40 mA
C-E Saturation Voltage	$V_{CE,SAT}$	I_C=10mA, I_F=20mA	Max .22V
E-C Breakdown Voltage	$V_{BR,ECO}$	I_E=100uA, I_F=0	Min 5 V
Rise Time	t_r	V_{CC}=10V, I_F=10mA, R_L=100 Ω	Max 20 uS
Fall Time	t_f	V_{CC}=10V, I_F=10mA, R_L=100 Ω	Max 20 uS
Current Transfer Ratio Sweep	**CTR**	V_{CE}=5V, I_F=0 to 10mA in .5 mA steps	Record I_F and I_C
Current Transfer Ratio, application-specific points	**CTR**	I_F=1.2 mA, V_{CE}=1V I_F=1.2 mA, V_{CE}=5V	min CTR=0.15 min CTR=0.04

6.2. Summary of Results

The irradiated 66212 devices did not measure outside of datasheet specifications at any point including the final dose step of approximately 29.3 krad (Si). Figures 4 through 11 show parameters that showed clear (i.e. beyond run-to-run variation) change during the experiment. Table IV displays parametric data after 29.3 krad(Si) with statistical bounds for the full irradiated sample size. Note that some parameters slightly exceed the datasheet specifications when 99/90 statistical limits are considered. Consideration of the application circuit is necessary to ensure acceptability of data at this dose level.

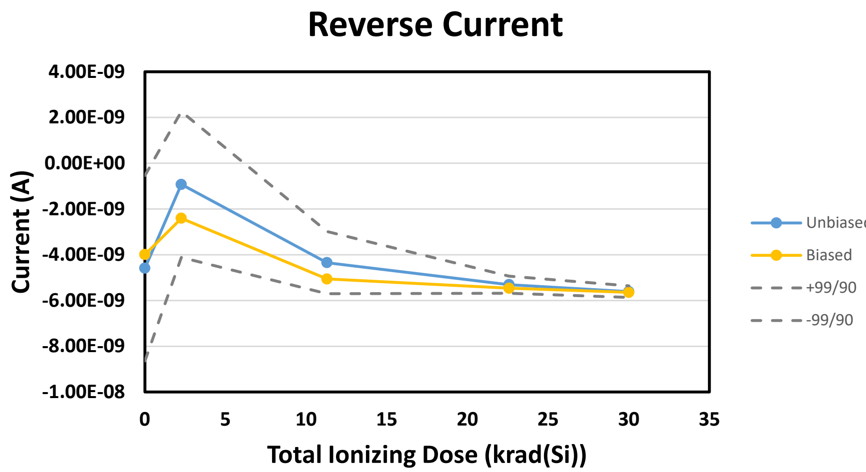

Fig. 4. Reverse Current over dose.

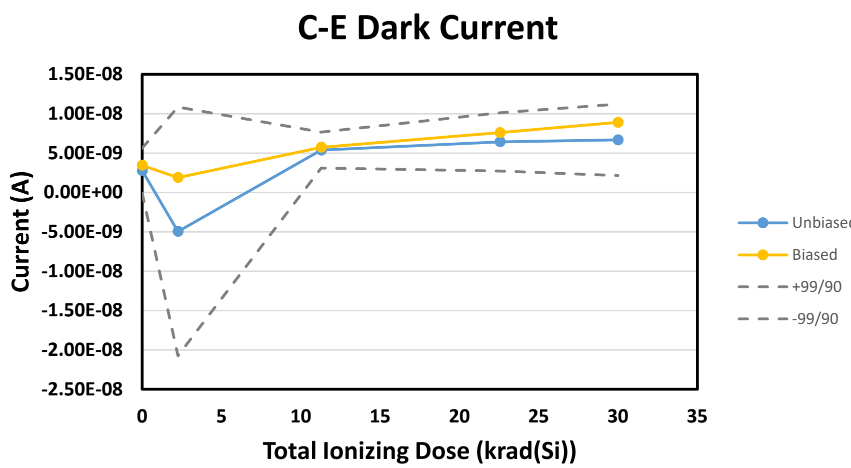

Fig. 5. Collector-Emitter Dark Current over dose.

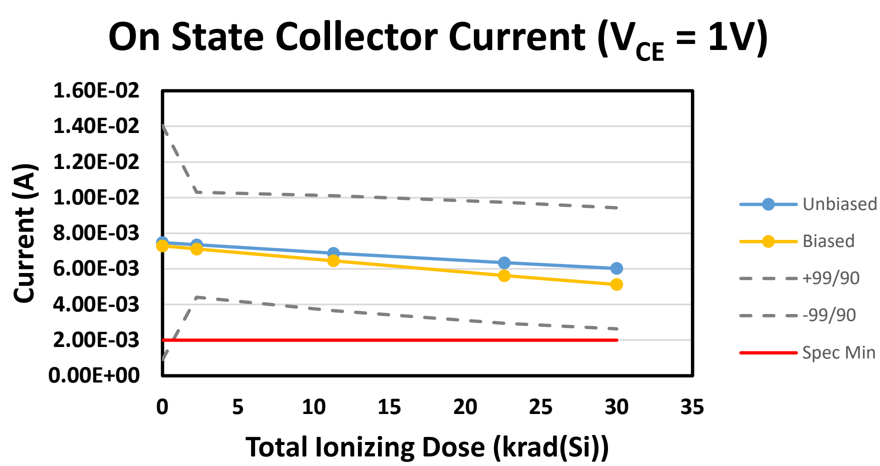

Fig. 6. On State Collector Current with V_{CE} = 1V over dose.

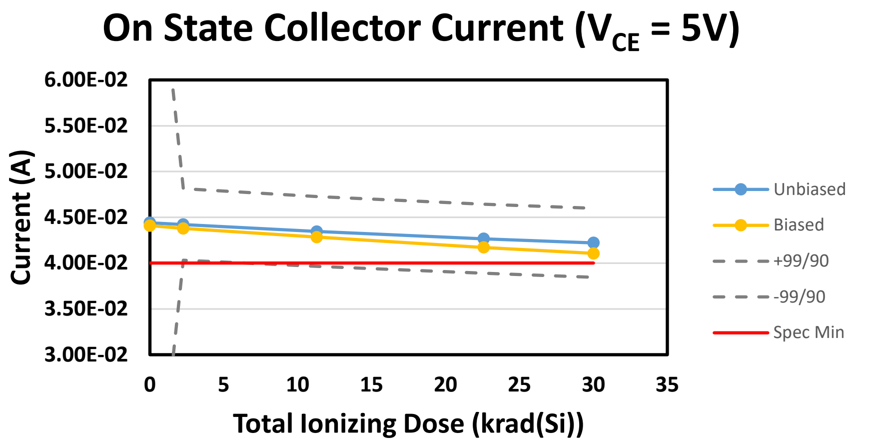

Fig. 7. On State Collector Current with V_{CE} = 5V over dose.

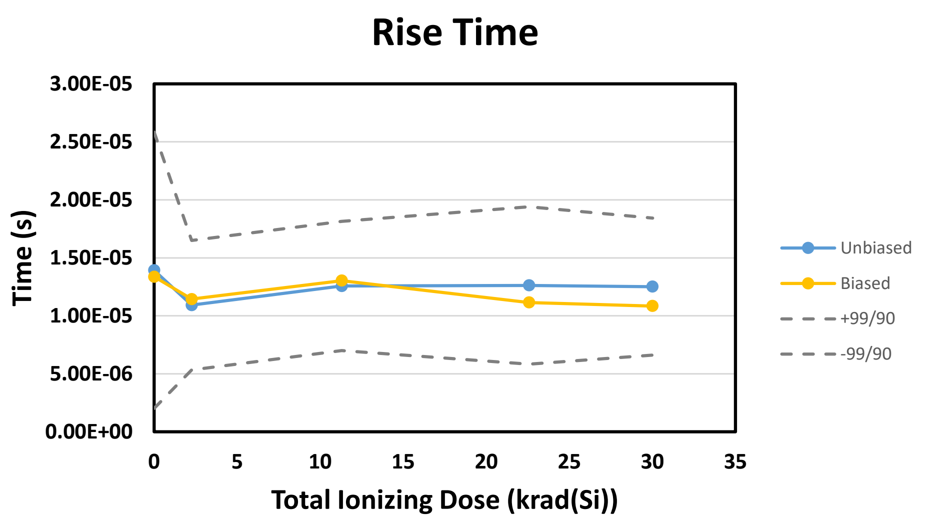

Fig. 8. Rise Time over dose.

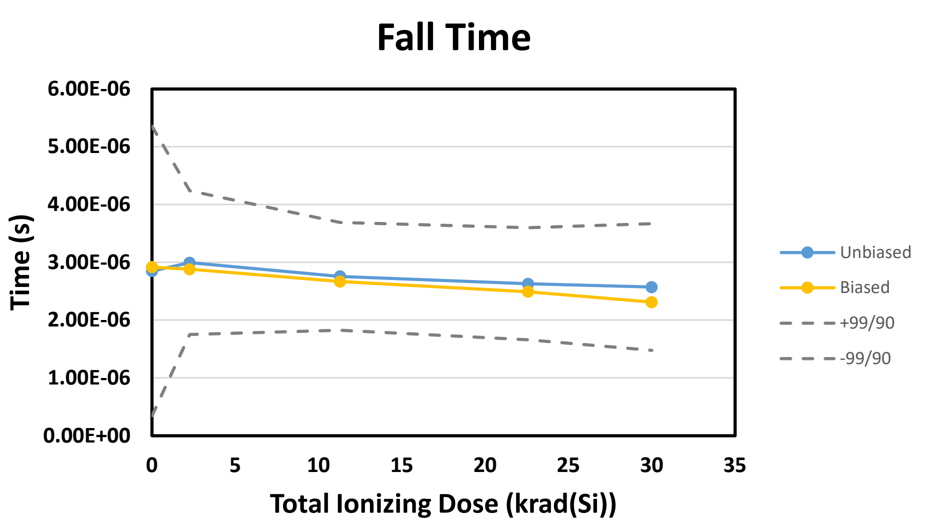

Fig. 9. Fall Time over dose.

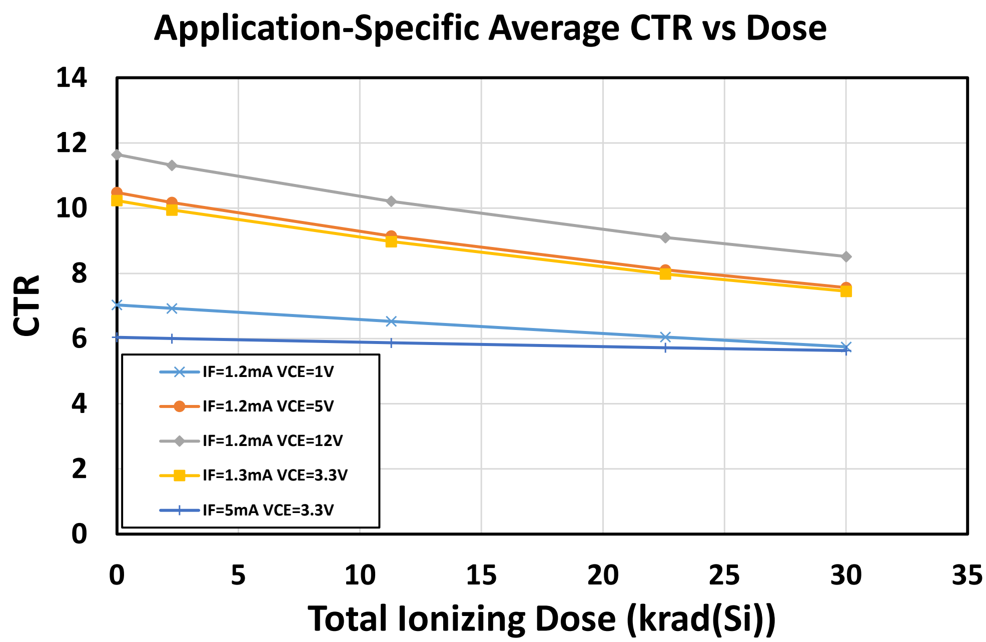

Fig. 10. Application Specific CTR over dose.

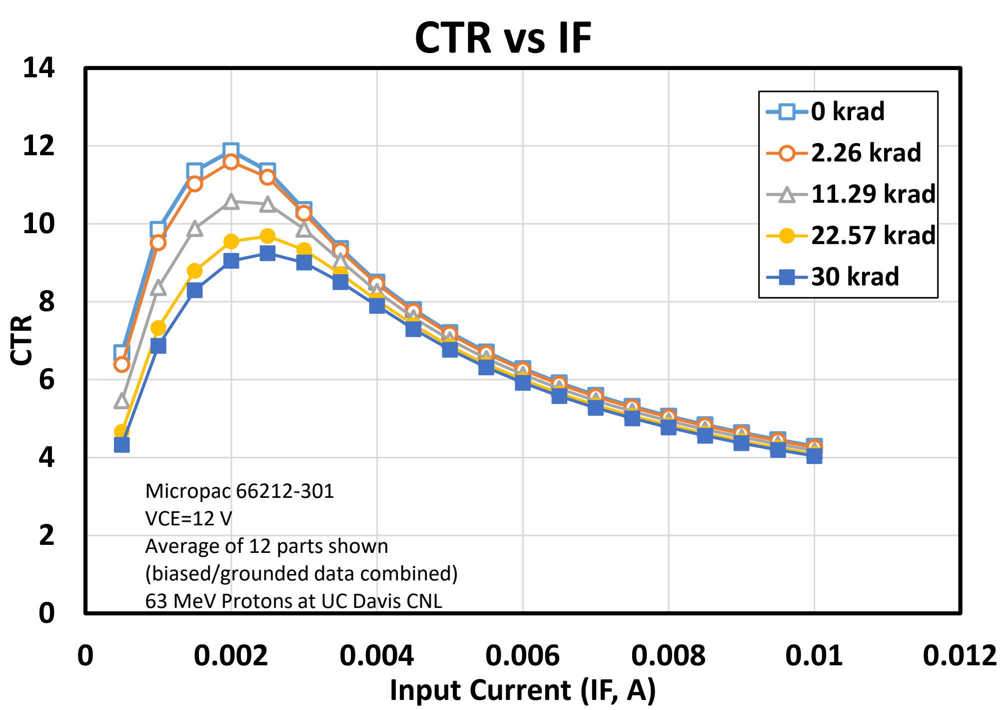

Fig. 11. CTR sweeps over dose.

Table IV. Parametric Results after 29.3 krad (Si)

Parameter	Symbol	Post Irradiation			Spec
		Average	StdDev	99/90 bound	
Input Static Reverse Current	I_R	5.62 nA	74.3 pA	5.87 nA	Max: 100 uA
Input Static Fwd Voltage	V_F	1.33 V	0	1.34 V	0.80< V_F<1.5; extracted from I_F sweep
C-E Breakdown Voltage	$V_{BR,CEO}$	>50	N/A	N/A	Min: 40 V; test will be limited to 50 V
C-E Dark Current	I_{CEO}	8.65 nA	2.89 nA	18.4 nA	Max 100 nA
On State Collector Current	$I_{C(ON)1}$	5.25 mA	1.38 mA	.61 mA	Min 2 mA
On State Collector Current	$I_{C(ON)2}$	41.2 mA	1.63 mA	35.7 mA	Min 40 mA
C-E Saturation Voltage	$V_{CE,SAT}$	.17 V	.01 V	.223 V	Max .22V
E-C Breakdown Voltage	$V_{BR,ECO}$	8.43 V	.04 V	8.31	Min 5 V
Rise Time	t_r	11.0 us	2.74 us	20.2 us	Max 20 us
Fall Time	t_f	2.36 us	408 ns	3.73 us	Max 20 us
Current Transfer Ratio, application-specific points:	**CTR**				
1.2 mA; 1 V		5.47	.81	2.75	N/A
1.2 mA; 5 V		6.85	1.47	1.91	N/A
1.2 mA; 12 V		7.73	1.69	2.05	N/A
1.3 mA; 3.3 V		6.79	1.39	2.09	N/A
5.0 mA; 3.3 V		5.55	.19	4.92	N/A