Neutron Irradiation Test Results of the RH1009MW 2.5V Reference

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Acknowledgements

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Part Type Tested: RH1009MW 2.5V Reference

Traceability Information: Fab Lot# WP1399.1; Wafer # 5; Assembly Lot # 601397.1, Date Code 1047A. See photograph of unit under test in Appendix A.

Quantity of Units: 7 units received, 2 units for control, and 5 units for unbiased irradiation. Serial numbers 335-339 were placed in an anti-static foam during irradiation. Serial numbers 345 and 346 were used as control. See Appendix B for the radiation bias connection tables.

Radiation Dose: Total fluence of 1E12 neutron/cm^2.

Radiation Test Standard: MIL-STD-883 TM1017 and Linear Technology RH1009 I.D. No. 66-10-0174 Rev. C 0607.

Test Hardware and Software: LTX test program EQ1CR136.00

Facility and Radiation Source: University of Massachusetts, Lowell and Reactor Facility-FNI.

Irradiation and Test Temperature: Room temperature controlled to 24°C±6°C per MIL-STD-883 and MIL-STD-750.

SUMMARY

ALL FIVE PARTS PASSED THE ELECTRICAL TEST LIMITS AS SPECIFIED IN THE DATASHEET AFTER IRRADIATION TO 1E12 N/cm^2. ADDITIONAL INFORMATION CAN BE PROVIDED PER REQUEST.

1.0 Overview and Background

Neutron particles incident on semiconductor materials lose energy along their paths. The energy loss produces electron-hole pairs (ionization) and displaces atoms in the material lattice (displacement damage defects or DDD). DDD induces a mixture of isolated and clustered defects or broken bonds. Such defects elevate the energy level of the material and consequently change material and electrical properties. The altering energy level creates the combination of any of the following processes, thermal generation of electron-hole pairs, recombination, trapping, compensation, tunneling, affecting hence the devices' basic features.

Bipolar technology is susceptible to neutron displacement damage around a fluence level of 1E12 neutron/cm^2. The neutron radiation test for the RH1009MW determines the change in device performance as a function of neutrons' fluence.

2.0 Radiation Facility:

Five samples were irradiated unbiased at the University of Massachusetts, Lowell, using the Reactor Facility-FNI. The neutron flux was determined by system S/P-32, method ASTM E-265, to be 4.05E9 N/cm^2-s (1MeV equivalent) for each irradiation step. Refer to Appendix C for the certificate of dosimetry.

3.0 Test Conditions

Five samples and two control units were electrically tested at 25°C prior to irradiation. The testing was performed on the two control units to confirm the operation of the test system prior to the electrical testing of the 7 units (5 irradiated and 2 control). During irradiation, devices were placed into an anti-static bag. Devices were then vertically aligned with the radiation source.

The criteria to pass the neutron displacement damage test is that five irradiated samples must pass the datasheet limits. If any of the tested parameters of these five units do not meet the required limits then a failure-analysis of the part should be conducted in accordance with method 5004, MIL-STD-883, and if valid the lot will be scrapped.

4.0 Tested Parameters

The following parameters were measured pre- and post-irradiations:

- Reverse Breakdown Voltage V_z (V)
- Reverse Breakdown Voltage Change with Current $\Delta V_z/\Delta I_z$ (mV)
- Reverse Dynamic Impedance r_z (Ω)

Appendix D details the test conditions, minimum and maximum values at different accumulated doses.

5.0 Test Results

All five samples passed the post-irradiation electrical tests. All measurements of the three listed parameters in section 4.0 are within the specification limits.

The used statistics in this report are based on the tolerance limits, which are bounds to gage the quality of the manufactured products. It assumes that if the quality of the items is normally distributed with known mean and known standard deviation, the two-sided tolerance limits can be calculated as follows:

$+K_{TL}$ = mean + (K_{TL}) (standard deviation)

$-K_{TL}$ = mean - (K_{TL}) (standard deviation)

Where $+K_{TL}$ is the upper tolerance limit and $-K_{TL}$ is the lower tolerance limit.
These tolerance limits are defined in a table of inverse normal probability distribution.

However, in most cases, mean and standard deviations are unknown and therefore it is practical to estimate both of them from a sample. Hence the tolerance limit depends greatly on the sample size. The Ps90%/90% K_{TL} factor for a lot quality P of 0.9, confidence C of 0.9 with a sample size of 5, can be found from the tabulated table (MIL-HDBK-814, page 94, table IX-B). The K_{TL} factor in this report is 2.742.

In the plots, the dashed lines with X-markers are the measured data points of five post-irradiated samples. The solid lines with square symbols are the computed KTL values of five post-irradiated samples with the application of the K_{TL} statistics. The orange solid lines with circle markers are the datasheet specification limits.

The post-irradiation test limits are using Linear Technology datasheets 100 Krads(Si) specification limits.

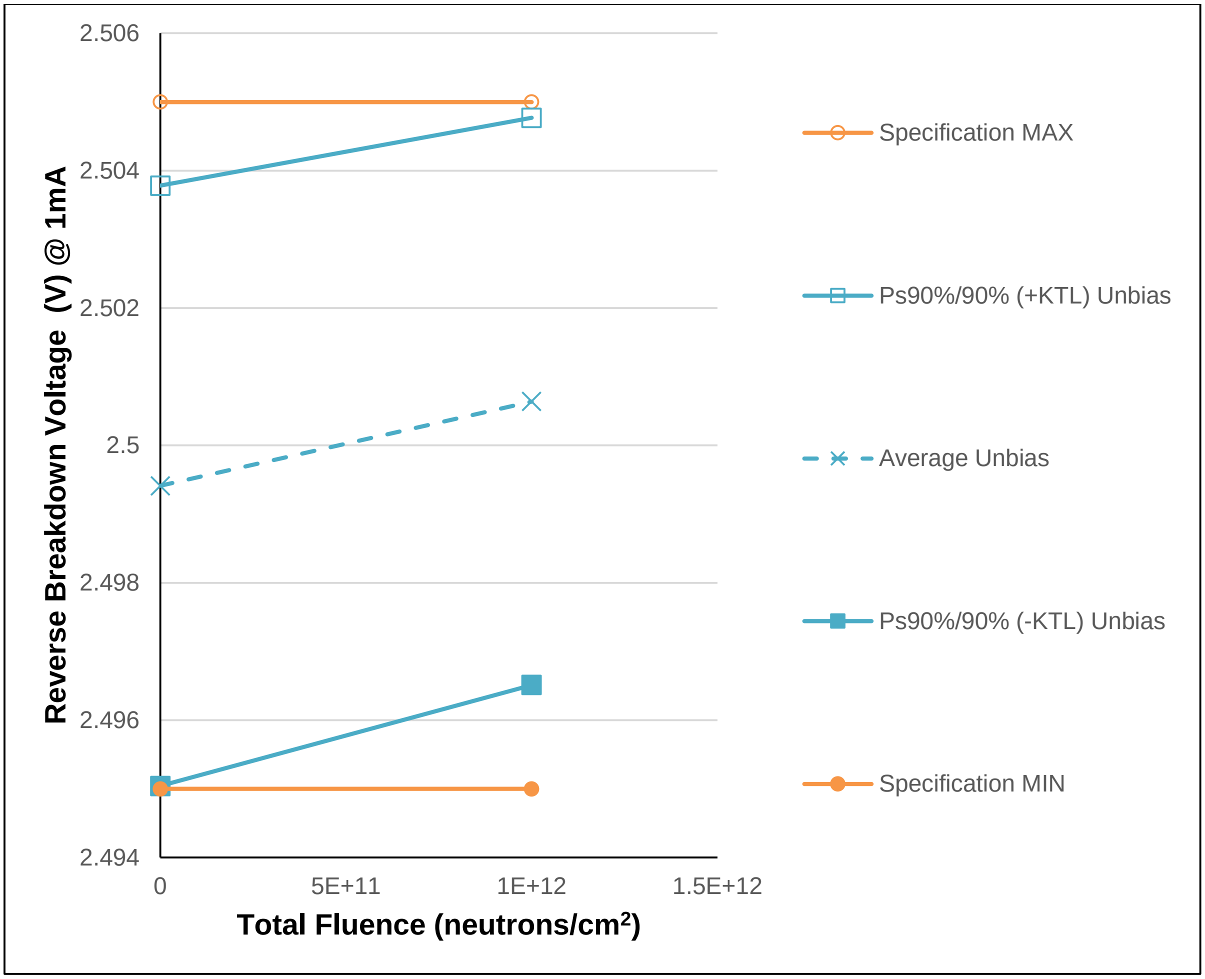

Figure 5.1 Plot of Reverse Breakdown Voltage V_{ref} versus Total Fluence

Table 5.1: Raw data table for Reverse Breakdown Voltage of pre- and post-irradiation (1E12 N/cm^2) including the statistical calculations, maximum specification, and the status of the test (PASS/FAIL).

Parameter	Reverse Breakdown Voltage @1mA	Total Fluences (N/cm^2)	
Units	(V)	0	1E+12
335	Unbias Irradiation	2.49930	2.4994
336	Unbias Irradiation	2.49987	2.5011
337	Unbias Irradiation	2.49917	2.5010
338	Unbias Irradiation	2.49714	2.4990
339	Unbias Irradiation	2.50158	2.5028
345	Control Unit	2.50212	2.5021
346	Control Unit	2.50222	2.5022
	Unbias Irradiation Statistics		
	Average Unbias	2.49941	2.50064
	Std Dev Unbias	0.00159	0.00151
	Ps90%/90% (+KTL) Unbias	2.50378	2.50477
	Ps90%/90% (-KTL) Unbias	2.49504	2.49651
	Specification MIN	2.495	2.495
	Status (Measurements)	PASS	PASS
	Specification MAX	2.505	2.505
	Status (Measurements)	PASS	PASS
	Status (-KTL) Unbias	PASS	PASS
	Status (+KTL) Unbias	PASS	PASS

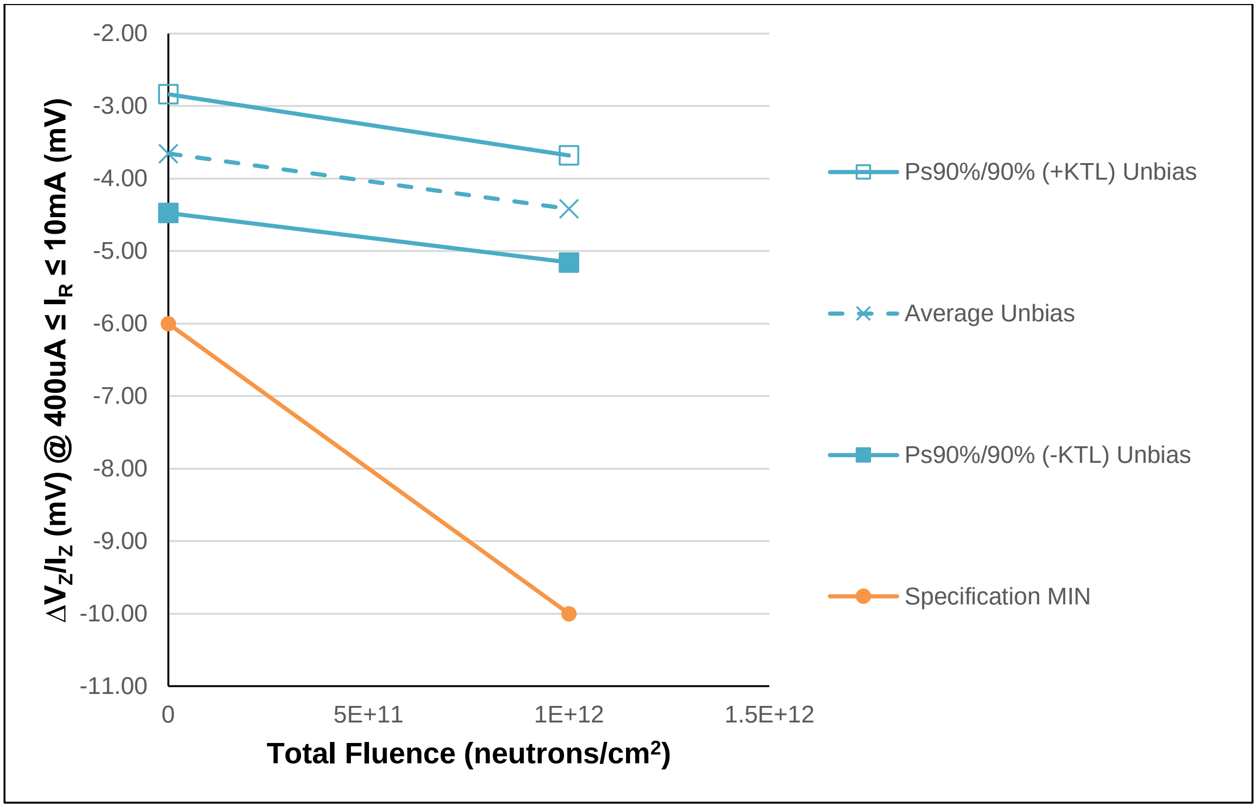

Figure 5.2: Plot of Delta V_Z/I_z versus Total Fluence

Table 5.2: Raw data table for Delta V_Z/I_Z of pre- and post-irradiation (1E12 N/cm^2) including the statistical calculations, maximum specification, and the status of the test (PASS/FAIL).

Parameter	Delta V_Z/I_Z @ I_R=400uA TO 10mA	Total Fluence (N/cm^2)	
Units	(mV)	0	1E+12
335	Unbias Irradiation	-3.90911	-4.22287
336	Unbias Irradiation	-3.47710	-4.35066
337	Unbias Irradiation	-4.03786	-4.80652
338	Unbias Irradiation	-3.35693	-4.14276
339	Unbias Irradiation	-3.49522	-4.56238
345	Control Unit	-3.47233	-3.55148
346	Control Unit	-3.53909	-3.57533
	Unbias Irradiation Statistics		
	Average Unbias	-3.65524	-4.41704
	Std Dev Unbias	0.29882	0.26933
	Ps90%/90% (+KTL) Unbias	-2.83588	-3.67854
	Ps90%/90% (-KTL) Unbias	-4.47461	-5.15554
	Specification MIN	-6	-10
	Status (Measurements)	PASS	PASS
	Specification MAX		
	Status (Measurements)		
	Status (-KTL) Unbias	PASS	PASS
	Status (+KTL) Unbias		

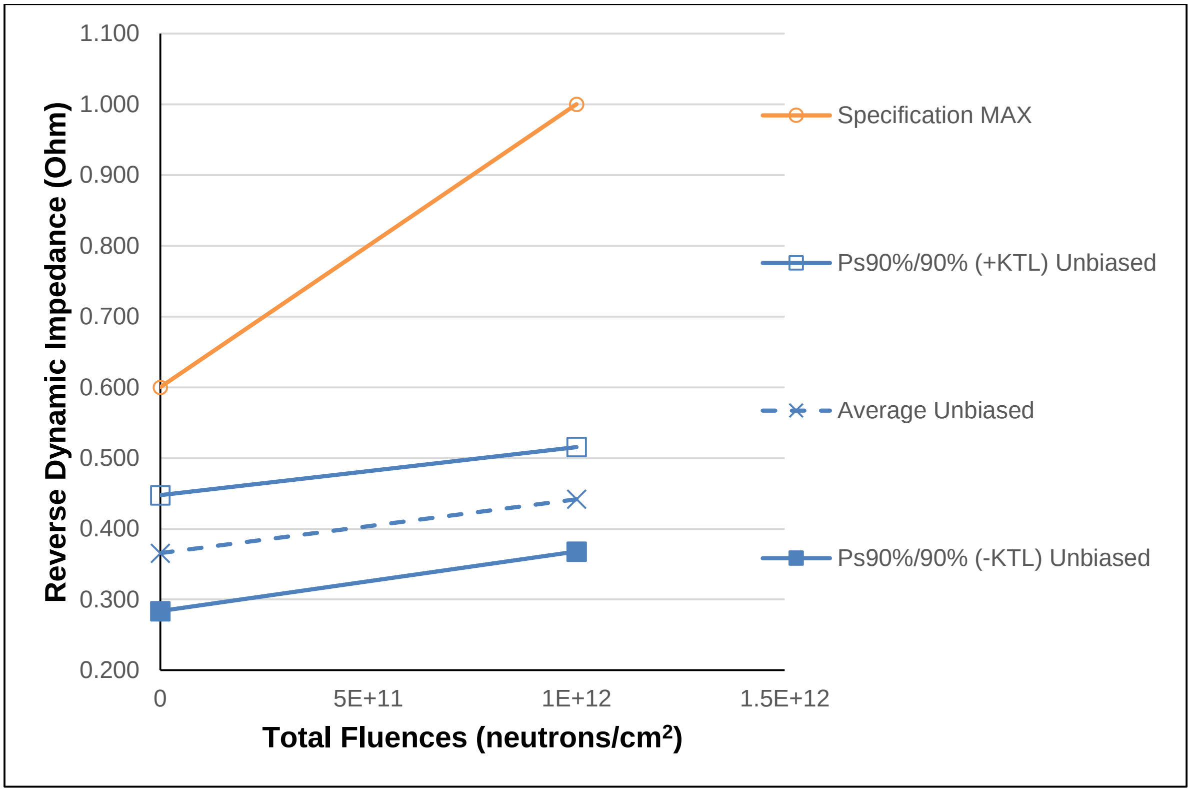

Figure 5.3: Plot of Reverse Dynamic Impedance R_Z versus Total Fluence

Table 5.3: Raw data table for Reverse Dynamic Impedance of pre- and post-irradiation (1E12 N/cm^2) including the statistical calculations, minimum specification, maximum specification, and the status of the test (PASS/FAIL).

Parameter	Reverse Dynamic Impedance	Total Fluences (N/cm^2)	
Units	(Ohms)	0	1E+12
335	Unbiased Irradiation	0.39091	0.42229
336	Unbiased Irradiation	0.34771	0.43507
337	Unbiased Irradiation	0.40379	0.48065
338	Unbiased Irradiation	0.33569	0.41428
339	Unbiased Irradiation	0.34952	0.45624
345	Control Unit	0.34723	0.35515
346	Control Unit	0.35391	0.35753
	Unbiased Irradiation Statistics		
	Average Unbiased	0.36552	0.44170
	Std Dev Unbiased	0.02988	0.02693
	Ps90%/90% (+KTL) Unbiased	0.44746	0.51555
	Ps90%/90% (-KTL) Unbiased	0.28359	0.36785
	Specification MIN		
	Status (Measurements) Unbiased		
	Specification MAX	0.6	1
	Status (Measurements) Unbiased	PASS	PASS
	Status (+KTL) Unbiased		
	Status (-KTL) Unbiased	PASS	PASS

Appendix A

Pictures of one among five samples used in the test.

Figure A1: Top View showing part number and date code

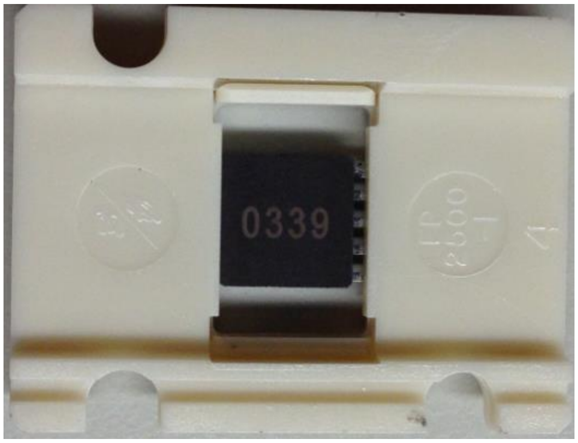

Figure A2: Bottom View showing serial number

Appendix B

Radiation Bias Connection Table

Table B1: Unbiased condition

Pin	Function	Connection
1	NC	Float
2	NC	Float
3	NC	Float
4	V^-	Float
5	NC	Float
6	NC	Float
7	ADJ	Float
8	V^+	Float
9	NC	Float
10	NC	Float

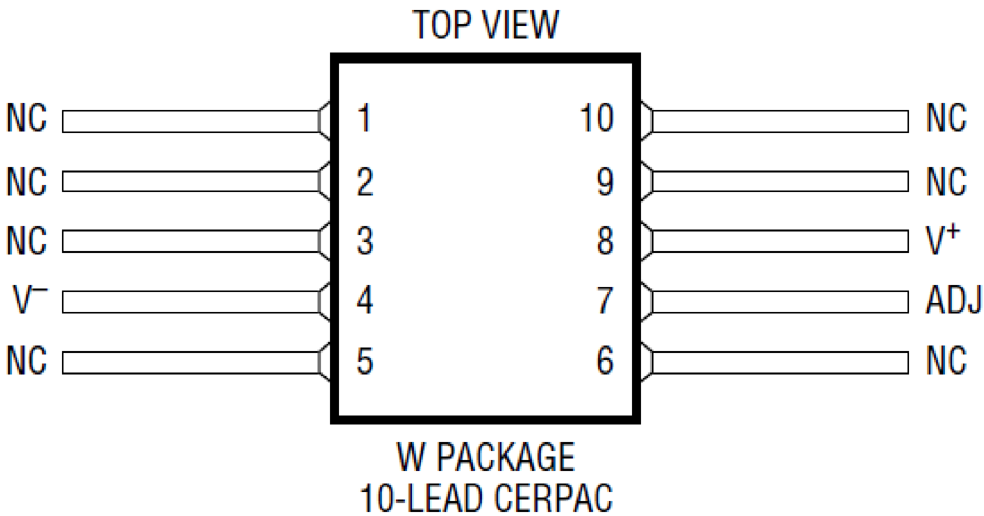

Figure B1: Pin-Out

Appendix C

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RADIATION LABORATORY

7/2/2012
Linear Technology Corporation
Attention: Sana Rezgui
1530 Buckeye Drive
Milpitas, CA 95035

Subject: **Certificate of Neutron Exposure**

Product: Multiple products see attached table

Irradiation Date: June, 27th, 2012
Irradiation Facility: Reactor Facility- FNI
Dosimetry system: S/P-32, ASTM E-265

Neutron Dosimetry Results:

Irradiation	Requested Fluence (n/cm^2)	Reactor Power (kW)	Time (s)	Fluence Rate (n/cm^2-s)(2,3)	Gamma Dose rad (Si) (1)	Measured Fluence (n/cm^2)(4)	Total Integral Fluence (n/cm^2)
Group 1	1.00E+12	45.0	228	4.05E+09	117	1.03E+12	1.03E+12
Group 2	1.00E+12	45.0	228	4.05E+09	117	9.41E+11	9.41E+11
Group 3	1.00E+13	475	234	4.28E+10	1266	9.22E+12	9.22E+12
Group 4	1.00E+13	90	1235	8.10E+09	1266	9.03E+12	9.03E+12

(1) Based on reactor power at 1,000kW, the gamma dose is 41+/- 5.3% krad(Si)/hr as mapped by TLD-based dosimetry
(2) Dosimetry method: ASTM E-265
(3) The neutron fluence rate is determined from "Initial Testing of the New Ex-Core Fast Neutron Irradiator at UMass Lowell " (6/18/02)
(4) Validated by S-32 flux monitors

The neutron fluence for this irradiation was determined using the previously measured neutron radiation field for this facility, measured with ASTM E-265 "Measuring Reaction Rates and Fast Neutron Fluence by Radioactivation of Sulfur-32" and correlated to the measured reactor power level.

Group 1 **Average Integrated Neutron Fluence (1 MeV Si Eq.) =1.03E12 n/cm^2**
Group 2 **Average Integrated Neutron Fluence (1 MeV Si Eq.) =9.41E11 n/cm^2**
Group 3 **Average Integrated Neutron Fluence (1 MeV Si Eq.) =9.22E12 n/cm^2**
Group 4 **Average Integrated Neutron Fluence (1 MeV Si Eq.) =9.03E12 n/cm^2**

Reviewed by ______
Thomas Regan
Reactor Engineer

Appendix D

Table D1: Electrical Characteristics of Device-Under-Test

Parameter	Pre-irradiation MIN	Pre-irradiation MAX	10 Krad(Si) MIN	10 Krad(Si) MAX	20 Krad(Si) MIN	20 Krad(Si) MAX	50 Krad(Si) MIN	50 Krad(Si) MAX	100 Krad(Si) MIN	100 Krad(Si) MAX	200 Krad(Si) MIN	200 Krad(Si) MAX	Units
V_z	2.495	2.505	2.495	2.505	2.495	2.505	2.495	2.505	2.495	2.505	2.495	2.505	V
Delta V_z/I_z		6		6		6		8		10		12	mV
r_z		0.6		0.6		0.6		0.8		1.0		1.4	ohm