Raytheon

HEAVY IONS SINGLE EVENT EFFECTS (SEE) TEST REPORT

Part Number: OP484

Generic: OP484

Date Code: 0019

Device Function: Precision Rail-to-Rail Op-Amp

Manufacturer: Analog Devices

Test Dates: Dec 12, 2001; Feb 21, 2002; and Mar 20, 2002

Responsible Engineers:

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I. SUMMARY

Five Analog Devices (AD) OP484 Precision Rail-to-Rail Input & Output Operational Amplifiers were evaluated for Single-Event Transient (SET) and latch-up (SEL) tests. The SET and SEL testing with heavy ions were conducted on December 12, 2001 for rail-to-rail application; On February 21, 2002 for single-supply application; And on March 20, 2002 for both configurations at the Lawrence Berkeley National Laboratory (LBL) by Raytheon.

The test results are summarized as follows:

- Single-supply configuration: transient events were detected starting at LET = 7 MeV-cm^2/mg. No latched-up was seen on any of the tested devices up to an effective LET = 120 MeV-cm^2/mg under worst case application voltage (V_{S+}= 13.5V) and temperature (T_C= 100°C) in vacuum.
- Rail-to-rail configuration: output voltages were extremely unstable at lower LET, all parts that subjected to the rail-to-rail test conditions became non-functional starting at Krypton (LET = 30 MeV-cm^2/mg) under normal operating temperature and in vacuum.

II. TECHNICAL DISCUSSION

1. Device Information

1.1 General Device Process/Description

The OP484 is a quad single-supply, 4 MHz bandwidth amplifier featuring rail-to-rail input and outputs. The device is guaranteed to operate from +3V to +26V (or ±1.5V to ±18V) and will function with a single supply as low as+1.5V. Refer to Figure 1 for a simplified schematic diagram.

The OP484 is a bipolar with the substrate (die backside) is connected to V-. The die measures 80 mil x 110 mil, and 12 mils thick.

1.2 Test Sample Description

Each of the samples supplied for the SEE testing was in a 14-pin plastic/epoxy Dual-in-Line package (DIP), industrial-temperature grade. Refer to Figure 2 for photographs of a device showing cavity, die, and markings.

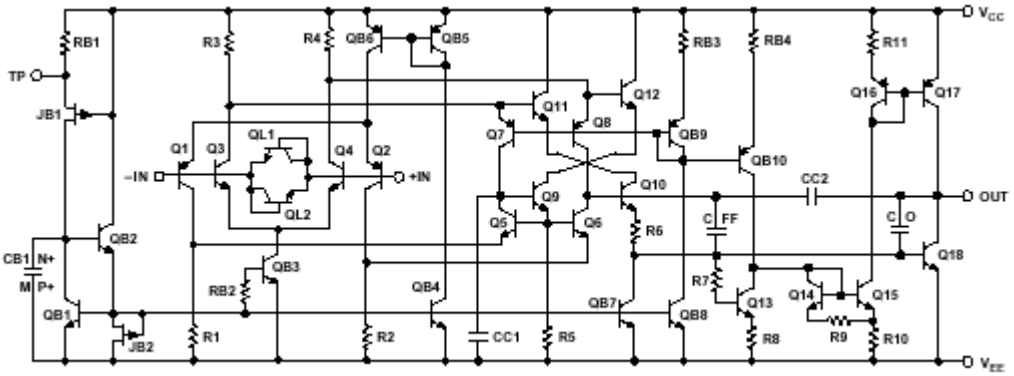
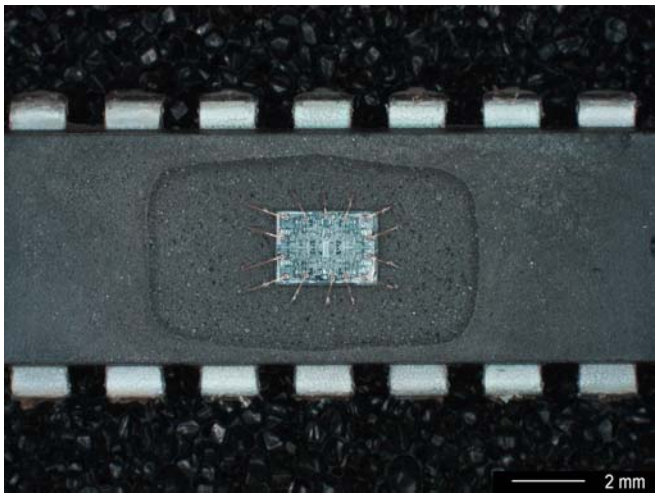
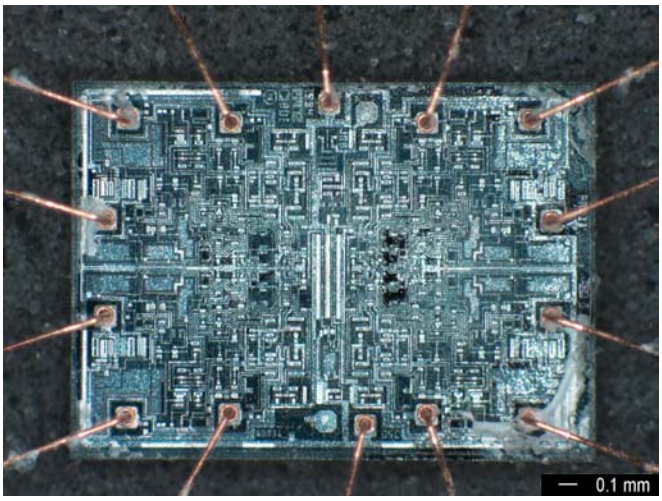


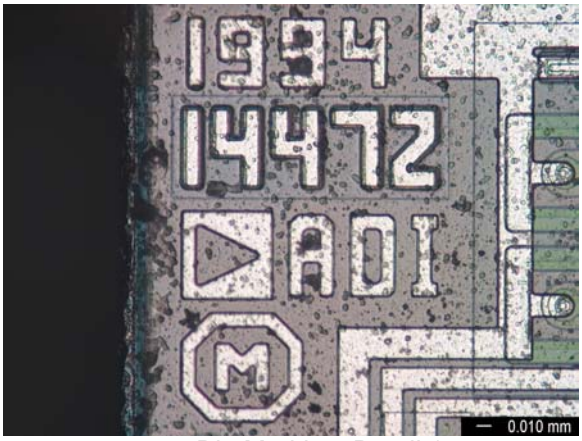
FIGURE 1. **OP484 simplified schematic diagram**



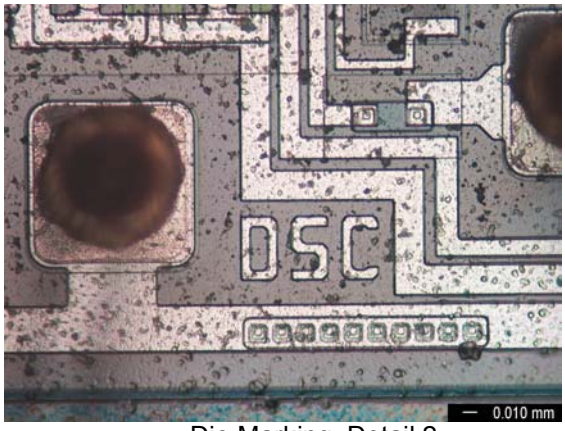
Overall Etched Device



Die, Full View



Die Marking, Detail 1



Die Marking, Detail 2

Figure 2. **OP484 Overall and marking photos on die**

2. Electrical Testing

The samples were electrically tested to the SMD 5962-00517 specification at room ambient, prior to and following the SEU and SEL testing. The devices were tested for Supply Current (I_{SY}), Input Offset Voltage (V_{OS}), Input Bias Current (I_B), Input Offset Current (I_{OS}), Large Signal Voltage Gain (A_{VO}), Power Supply Rejection Ratio (PSRR), Common-mode Rejection Ratio (CMRR), Slew Rate (SR), and Output High (V_{OH}).

Table I summarizes the results of the electrical testing.

Table I. Summary of Pre and Post SEE Electrical Test Data

Part Number: OP-484F
Test Spec: 5962-00517 rev
Test Date: 18-DEC-01
Manufacturer: ANALOG DEVICES

Date code: T0019
Lot: C11607 0
Generic: OP-484

Job#: K2600A
Ref: EMAIL

		Pre SEE	Post SEE	Min Limit	Max Limit	Delta	Units
C 9001	T 1.0; + Supply Current (Vs=+/-15V)	4.425	4.426	0	8	0.001	mA
232	T 1.0; + Supply Current (Vs=+/-15V)	4.127	6.765	0	8	2.638	mA
235	T 1.0; + Supply Current (Vs=+/-15V)	4.171	5.715	0	8	1.544	mA
C 9001	T 2.0; - Supply Current (Vs=+/-15V)	-4.426	-4.425	-8	0	0.001	mA
232	T 2.0; - Supply Current (Vs=+/-15V)	-4.126	-72.485	-8	0	-68.359	mA
235	T 2.0; - Supply Current (Vs=+/-15V)	-4.170	-80.701	-8	0	-76.531	mA
C 9001	T 3.0; + Supply Current (Vs=18V)	4.610	4.608	0	9	-0.002	mA
232	T 3.0; + Supply Current (Vs=18V)	4.292	7.656	0	9	3.364	mA
235	T 3.0; + Supply Current (Vs=18V)	4.336	6.281	0	9	1.945	mA
C 9001	T 4.0; - Supply Current (Vs=18V)	-4.607	-4.607	-9	0	0.000	mA
232	T 4.0; - Supply Current (Vs=18V)	-4.290	-101.832	-9	0	-97.542	mA
235	T 4.0; - Supply Current (Vs=18V)	-4.333	-101.345	-9	0	-97.012	mA
C 9001	T 5.1; V Offset (Vs=15/-15V)	-0.018	-0.019	-0.25	0.25	-0.001	mV
232	T 5.1; V Offset (Vs=15/-15V)	0.043	Alarm	-0.25	0.25	#VALUE!	mV
235	T 5.1; V Offset (Vs=15/-15V)	-0.143	Alarm	-0.25	0.25	#VALUE!	mV
C 9001	T 5.2; V Offset (Vs=15/-15V)	-0.123	-0.124	-0.25	0.25	-0.001	mV
232	T 5.2; V Offset (Vs=15/-15V)	0.033	Alarm	-0.25	0.25	#VALUE!	mV
235	T 5.2; V Offset (Vs=15/-15V)	0.032	6.240	-0.25	0.25	6.208	mV
236	T 5.2; V Offset (Vs=15/-15V)	-0.011	-0.012	-0.25	0.25	-0.001	mV
C 9001	T 5.3; V Offset (Vs=15/-15V)	-0.026	-0.026	-0.25	0.25	0.000	mV
232	T 5.3; V Offset (Vs=15/-15V)	0.011	2.899	-0.25	0.25	2.888	mV
235	T 5.3; V Offset (Vs=15/-15V)	-0.006	Alarm	-0.25	0.25	#VALUE!	mV
C 9001	T 5.4; V Offset (Vs=15/-15V)	-0.120	-0.122	-0.25	0.25	-0.002	mV
232	T 5.4; V Offset (Vs=15/-15V)	0.013	4.915	-0.25	0.25	4.902	mV
235	T 5.4; V Offset (Vs=15/-15V)	0.017	2.323	-0.25	0.25	2.306	mV
C 9001	T 6.1; + I Bias (Vs=15/-15V)	-127.243	-127.082	-350	350	0.161	nA
232	T 6.1; + I Bias (Vs=15/-15V)	-180.563	-28.775	-350	350	151.788	nA
235	T 6.1; + I Bias (Vs=15/-15V)	-176.387	-8.529	-350	350	167.858	nA
C 9001	T 6.2; + I Bias (Vs=15/-15V)	-120.582	-120.445	-350	350	0.137	nA
232	T 6.2; + I Bias (Vs=15/-15V)	-164.159	0.420	-350	350	164.579	nA
235	T 6.2; + I Bias (Vs=15/-15V)	-171.732	136.734	-350	350	308.466	nA
C 9001	T 6.3; + I Bias (Vs=15/-15V)	-118.600	-118.442	-350	350	0.158	nA
232	T 6.3; + I Bias (Vs=15/-15V)	-171.233	-38.416	-350	350	132.817	nA
235	T 6.3; + I Bias (Vs=15/-15V)	-174.901	-9.023	-350	350	165.878	nA
C 9001	T 6.4; + I Bias (Vs=15/-15V)	-133.149	-132.885	-350	350	0.264	nA
232	T 6.4; + I Bias (Vs=15/-15V)	-163.617	-36.553	-350	350	127.064	nA
235	T 6.4; + I Bias (Vs=15/-15V)	-175.375	-34.535	-350	350	140.840	nA
C 9001	T 7.1; - I Bias (Vs=15/-15V)	-128.288	-128.185	-350	350	0.103	nA
232	T 7.1; - I Bias (Vs=15/-15V)	-185.313	30.425	-350	350	215.738	nA
235	T 7.1; - I Bias (Vs=15/-15V)	-175.857	6.754	-350	350	182.611	nA
C 9001	T 7.2; - I Bias (Vs=15/-15V)	-121.315	-121.261	-350	350	0.054	nA
232	T 7.2; - I Bias (Vs=15/-15V)	-163.323	-0.014	-350	350	163.309	nA
235	T 7.2; - I Bias (Vs=15/-15V)	-168.272	-99.153	-350	350	69.119	nA
C 9001	T 7.3; - I Bias (Vs=15/-15V)	-118.718	-118.611	-350	350	0.107	nA
232	T 7.3; - I Bias (Vs=15/-15V)	-172.357	-8.236	-350	350	164.121	nA
235	T 7.3; - I Bias (Vs=15/-15V)	-175.787	7.041	-350	350	182.828	nA
C 9001	T 7.4; - I Bias (Vs=15/-15V)	-129.011	-128.852	-350	350	0.159	nA
232	T 7.4; - I Bias (Vs=15/-15V)	-164.487	-1.066	-350	350	163.421	nA
235	T 7.4; - I Bias (Vs=15/-15V)	-174.207	-21.766	-350	350	152.441	nA
C 9001	T 8.1; I Offset (Vs=15/-15V)	2.520	2.476	-50	50	-0.044	nA
232	T 8.1; I Offset (Vs=15/-15V)	5.894	-30.708	-50	50	-36.602	nA
235	T 8.1; I Offset (Vs=15/-15V)	0.900	-1.978	-50	50	-2.878	nA
C 9001	T 8.2; I Offset (Vs=15/-15V)	2.100	2.151	-50	50	0.051	nA
232	T 8.2; I Offset (Vs=15/-15V)	0.236	-0.321	-50	50	-0.557	nA
235	T 8.2; I Offset (Vs=15/-15V)	-2.176	20.016	-50	50	22.192	nA
C 9001	T 8.3; I Offset (Vs=15/-15V)	1.499	1.492	-50	50	-0.007	nA
232	T 8.3; I Offset (Vs=15/-15V)	2.339	-21.320	-50	50	-23.659	nA

		Pre SEE	Post SEE	Min Limit	Max Limit	Delta	Units
235	T 8.3; I Offset (Vs=15/-15V)	2.164	-14.125	-50	50	-16.289	nA
C 9001	T 8.4; I Offset (Vs=15/-15V)	-2.741	-2.775	-50	50	-0.034	nA
232	T 8.4; I Offset (Vs=15/-15V)	1.935	-18.134	-50	50	-20.069	nA
235	T 8.4; I Offset (Vs=15/-15V)	0.089	16.306	-50	50	16.217	nA
C 9001	T 9.1; Open Loop Gain (Vs=15V, RL=2K)	1371.86	1354.13	150	1.00E+12	-17.73	V/mV
232	T 9.1; Open Loop Gain (Vs=15V, RL=2K)	929.74	463.44	150	1.00E+12	-466.30	V/mV
235	T 9.1; Open Loop Gain (Vs=15V, RL=2K)	659.73	Alarm	150	1.00E+12	#VALUE!	V/mV
C 9001	T 9.2; Open Loop Gain (Vs=15V, RL=2K)	3594.45	3393.40	150	1.00E+12	-201.05	V/mV
232	T 9.2; Open Loop Gain (Vs=15V, RL=2K)	905.24	Alarm	150	1.00E+12	#VALUE!	V/mV
235	T 9.2; Open Loop Gain (Vs=15V, RL=2K)	1540.76	Alarm	150	1.00E+12	#VALUE!	V/mV
C 9001	T 9.3; Open Loop Gain (Vs=15V, RL=2K)	1457.84	1457.73	150	1.00E+12	-0.11	V/mV
232	T 9.3; Open Loop Gain (Vs=15V, RL=2K)	972.76	Alarm	150	1.00E+12	#VALUE!	V/mV
235	T 9.3; Open Loop Gain (Vs=15V, RL=2K)	927.22	Alarm	150	1.00E+12	#VALUE!	V/mV
C 9001	T 9.4; Open Loop Gain (Vs=15V, RL=2K)	3108.91	3106.34	150	1.00E+12	-2.57	V/mV
232	T 9.4; Open Loop Gain (Vs=15V, RL=2K)	963.06	Alarm	150	1.00E+12	#VALUE!	V/mV
235	T 9.4; Open Loop Gain (Vs=15V, RL=2K)	1481.38	Alarm	150	1.00E+12	#VALUE!	V/mV
C 9001	T 10.1; PSRR (Vs=+/-2V,+/-18V)	132.99	132.72	90	200	-0.27	dB
232	T 10.1; PSRR (Vs=+/-2V,+/-18V)	125.70	115.22	90	200	-10.48	dB
235	T 10.1; PSRR (Vs=+/-2V,+/-18V)	122.67	116.96	90	200	-5.71	dB
C 9001	T 10.2; PSRR (Vs=+/-2V,+/-18V)	113.90	113.89	90	200	-0.01	dB
232	T 10.2; PSRR (Vs=+/-2V,+/-18V)	131.61	111.38	90	200	-20.23	dB
235	T 10.2; PSRR (Vs=+/-2V,+/-18V)	128.46	77.86	90	200	-50.60	dB
C 9001	T 10.3; PSRR (Vs=+/-2V,+/-18V)	151.30	150.61	90	200	-0.69	dB
232	T 10.3; PSRR (Vs=+/-2V,+/-18V)	122.30	77.85	90	200	-44.45	dB
235	T 10.3; PSRR (Vs=+/-2V,+/-18V)	140.88	118.12	90	200	-22.76	dB
C 9001	T 10.4; PSRR (Vs=+/-2V,+/-18V)	120.40	120.45	90	200	0.05	dB
232	T 10.4; PSRR (Vs=+/-2V,+/-18V)	125.45	81.67	90	200	-43.78	dB
235	T 10.4; PSRR (Vs=+/-2V,+/-18V)	120.73	88.38	90	200	-32.35	dB
C 9001	T 11.1; CMRR2 (Vs=+/-15V,VCM=+/-15V)	103.05	103.04	80	200	-0.01	dB
232	T 11.1; CMRR2 (Vs=+/-15V,VCM=+/-15V)	95.98	92.05	80	200	-3.93	dB
235	T 11.1; CMRR2 (Vs=+/-15V,VCM=+/-15V)	103.64	Alarm	80	200	#VALUE!	dB
C 9001	T 11.2; CMRR2 (Vs=+/-15V,VCM=+/-15V)	99.09	99.10	80	200	0.01	dB
232	T 11.2; CMRR2 (Vs=+/-15V,VCM=+/-15V)	110.63	Alarm	80	200	#VALUE!	dB
235	T 11.2; CMRR2 (Vs=+/-15V,VCM=+/-15V)	91.38	Alarm	80	200	#VALUE!	dB
C 9001	T 11.3; CMRR2 (Vs=+/-15V,VCM=+/-15V)	112.14	112.13	80	200	-0.01	dB
232	T 11.3; CMRR2 (Vs=+/-15V,VCM=+/-15V)	118.42	Alarm	80	200	#VALUE!	dB
235	T 11.3; CMRR2 (Vs=+/-15V,VCM=+/-15V)	105.37	Alarm	80	200	#VALUE!	dB
C 9001	T 11.4; CMRR2 (Vs=+/-15V,VCM=+/-15V)	96.26	96.25	80	200	-0.01	dB
232	T 11.4; CMRR2 (Vs=+/-15V,VCM=+/-15V)	103.62	Alarm	80	200	#VALUE!	dB
235	T 11.4; CMRR2 (Vs=+/-15V,VCM=+/-15V)	102.64	Alarm	80	200	#VALUE!	dB
C 9001	T 12.1; + Slew Rate (Vs=+/-15V)	4.83	4.84	2.4	20	0.01	V/uS
232	T 12.1; + Slew Rate (Vs=+/-15V)	4.30	0.00	2.4	20	-4.30	V/uS
235	T 12.1; + Slew Rate (Vs=+/-15V)	4.36	0.00	2.4	20	-4.36	V/uS
C 9001	T 12.2; + Slew Rate (Vs=+/-15V)	4.51	4.50	2.4	20	-0.01	V/uS
232	T 12.2; + Slew Rate (Vs=+/-15V)	4.19	0.00	2.4	20	-4.19	V/uS
235	T 12.2; + Slew Rate (Vs=+/-15V)	4.17	0.00	2.4	20	-4.17	V/uS
C 9001	T 12.3; + Slew Rate (Vs=+/-15V)	4.63	4.59	2.4	20	-0.04	V/uS
232	T 12.3; + Slew Rate (Vs=+/-15V)	4.23	0.00	2.4	20	-4.23	V/uS
235	T 12.3; + Slew Rate (Vs=+/-15V)	4.26	0.00	2.4	20	-4.26	V/uS
C 9001	T 12.4; + Slew Rate (Vs=+/-15V)	4.81	4.77	2.4	20	-0.04	V/uS
232	T 12.4; + Slew Rate (Vs=+/-15V)	4.25	0.00	2.4	20	-4.25	V/uS
235	T 12.4; + Slew Rate (Vs=+/-15V)	4.30	0.00	2.4	20	-4.30	V/uS
C 9001	T 13.1; - Slew Rate (Vs=+/-15V)	-3.75	-3.74	-10	-2.4	0.01	V/uS
232	T 13.1; - Slew Rate (Vs=+/-15V)	-3.46	0.00	-10	-2.4	3.46	V/uS
235	T 13.1; - Slew Rate (Vs=+/-15V)	-3.50	0.00	-10	-2.4	3.50	V/uS
C 9001	T 13.2; - Slew Rate (Vs=+/-15V)	-3.71	-3.73	-10	-2.4	-0.02	V/uS
232	T 13.2; - Slew Rate (Vs=+/-15V)	-3.31	-48.02	-10	-2.4	-44.71	V/uS
235	T 13.2; - Slew Rate (Vs=+/-15V)	-3.35	-0.03	-10	-2.4	3.32	V/uS
C 9001	T 13.3; - Slew Rate (Vs=+/-15V)	-3.72	-3.73	-10	-2.4	-0.01	V/uS
232	T 13.3; - Slew Rate (Vs=+/-15V)	-3.35	0.00	-10	-2.4	3.35	V/uS
235	T 13.3; - Slew Rate (Vs=+/-15V)	-3.39	0.00	-10	-2.4	3.39	V/uS
C 9001	T 13.4; - Slew Rate (Vs=+/-15V)	-3.76	-3.77	-10	-2.4	-0.01	V/uS
232	T 13.4; - Slew Rate (Vs=+/-15V)	-3.48	0.00	-10	-2.4	3.48	V/uS
235	T 13.4; - Slew Rate (Vs=+/-15V)	-3.53	-0.17	-10	-2.4	3.36	V/uS
C 9001	T 14.1; + V OUT (Vs=+/-15V,RL=2K)	14.971	14.962	14.8	20	-0.009	V
232	T 14.1; + V OUT (Vs=+/-15V,RL=2K)	14.977	Alarm	14.8	20	#VALUE!	V
235	T 14.1; + V OUT (Vs=+/-15V,RL=2K)	14.977	Alarm	14.8	20	#VALUE!	V

		Pre SEE	Post SEE	Min Limit	Max Limit	Delta	Units
C 9001	T 14.2; + V OUT (Vs=+/-15V,RL=2K)	14.977	14.968	14.8	20	-0.009	V
232	T 14.2; + V OUT (Vs=+/-15V,RL=2K)	14.983	Alarm	14.8	20	#VALUE!	V
235	T 14.2; + V OUT (Vs=+/-15V,RL=2K)	14.989	Alarm	14.8	20	#VALUE!	V
C 9001	T 14.3; + V OUT (Vs=+/-15V,RL=2K)	14.971	14.962	14.8	20	-0.009	V
232	T 14.3; + V OUT (Vs=+/-15V,RL=2K)	14.971	Alarm	14.8	20	#VALUE!	V
235	T 14.3; + V OUT (Vs=+/-15V,RL=2K)	14.976	Alarm	14.8	20	#VALUE!	V
C 9001	T 14.4; + V OUT (Vs=+/-15V,RL=2K)	14.967	14.956	14.8	20	-0.011	V
232	T 14.4; + V OUT (Vs=+/-15V,RL=2K)	14.965	Alarm	14.8	20	#VALUE!	V
235	T 14.4; + V OUT (Vs=+/-15V,RL=2K)	14.971	Alarm	14.8	20	#VALUE!	V
C 9001	T 15.1; - V OUT (Vs=+/-15V,RL=2K)	-15.101	-15.103	-20	-14.875	-0.002	V
232	T 15.1; - V OUT (Vs=+/-15V,RL=2K)	-15.099	-14.899	-20	-14.875	0.200	V
235	T 15.1; - V OUT (Vs=+/-15V,RL=2K)	-15.100	Alarm	-20	-14.875	#VALUE!	V
C 9001	T 15.2; - V OUT (Vs=+/-15V,RL=2K)	-15.101	-15.100	-20	-14.875	0.001	V
232	T 15.2; - V OUT (Vs=+/-15V,RL=2K)	-15.095	-5.777	-20	-14.875	9.318	V
235	T 15.2; - V OUT (Vs=+/-15V,RL=2K)	-15.095	-13.600	-20	-14.875	1.495	V
C 9001	T 15.3; - V OUT (Vs=+/-15V,RL=2K)	-15.101	-15.098	-20	-14.875	0.003	V
232	T 15.3; - V OUT (Vs=+/-15V,RL=2K)	-15.096	Alarm	-20	-14.875	#VALUE!	V
235	T 15.3; - V OUT (Vs=+/-15V,RL=2K)	-15.099	-5.840	-20	-14.875	9.259	V
C 9001	T 15.4; - V OUT (Vs=+/-15V,RL=2K)	-15.101	-15.103	-20	-14.875	-0.002	V
232	T 15.4; - V OUT (Vs=+/-15V,RL=2K)	-15.101	Alarm	-20	-14.875	#VALUE!	V
235	T 15.4; - V OUT (Vs=+/-15V,RL=2K)	-15.101	-13.646	-20	-14.875	1.455	V

Part Number: OP-484F
Test Spec: 5962-00517 rev
Manufacturer: ANALOG DEVICES

Datecode: T0019
Lot: C11607 0
Generic: OP-484

Job#: K2600B
Ref:
EMAIL

Test Dates: SN		14-Feb-02 Pre SEE	1-Mar-02 Post SEE1	1-Apr-02 Post SEE2	Min Limit	Max Limit	SEE1-Pre Delta	SEE2-SEE1 Delta	Units
C 9001	T 1.0; + Supply Current (Vs=+/-15V)	4.255	4.251	4.253	0	8	-0.004	0.002	mA
31	T 1.0; + Supply Current (Vs=+/-15V)	3.647	3.650	5.122	0	8	0.003	1.472	mA
81	T 1.0; + Supply Current (Vs=+/-15V)	4.378	4.261	4.225	0	8	-0.117	-0.036	mA
99	T 1.0; + Supply Current (Vs=+/-15V)	4.234	4.120	6.280	0	8	-0.114	2.160	mA
C 9001	T 2.0; - Supply Current (Vs=+/-15V)	-4.253	-4.251	-4.254	-8	0	0.002	-0.003	mA
31	T 2.0; - Supply Current (Vs=+/-15V)	-3.652	-3.649	-28.999	-8	0	0.003	-25.350	mA
81	T 2.0; - Supply Current (Vs=+/-15V)	-4.380	-4.260	-4.246	-8	0	0.120	0.014	mA
99	T 2.0; - Supply Current (Vs=+/-15V)	-4.237	-4.118	-27.234	-8	0	0.119	-23.116	mA
C 9001	T 3.0; + Supply Current (Vs=18V)	4.428	4.435	4.438	0	9	0.007	0.003	mA
31	T 3.0; + Supply Current (Vs=18V)	3.805	3.813	5.316	0	9	0.008	1.503	mA
81	T 3.0; + Supply Current (Vs=18V)	4.581	4.465	4.419	0	9	-0.116	-0.046	mA
99	T 3.0; + Supply Current (Vs=18V)	4.399	4.283	6.344	0	9	-0.116	2.061	mA
C 9001	T 4.0; - Supply Current (Vs=18V)	-4.426	-4.431	-4.435	-9	0	-0.005	-0.004	mA
31	T 4.0; - Supply Current (Vs=18V)	-3.808	-3.813	-100.396	-9	0	-0.005	-96.583	mA
81	T 4.0; - Supply Current (Vs=18V)	-4.580	-4.460	-4.444	-9	0	0.120	0.016	mA
99	T 4.0; - Supply Current (Vs=18V)	-4.394	-4.279	-82.134	-9	0	0.115	-77.855	mA
C 9001	T 5.1; V Offset (Vs=15/-15V)	0.011	0.008	0.003	-0.25	0.25	-0.003	-0.005	mV
31	T 5.1; V Offset (Vs=15/-15V)	0.048	0.042	Alarm	-0.25	0.25	-0.006	#VALUE!	mV
81	T 5.1; V Offset (Vs=15/-15V)	-0.012	0.003	Alarm	-0.25	0.25	0.015	#VALUE!	mV
99	T 5.1; V Offset (Vs=15/-15V)	0.043	0.032	Alarm	-0.25	0.25	-0.011	#VALUE!	mV
C 9001	T 5.2; V Offset (Vs=15/-15V)	-0.067	-0.060	-0.062	-0.25	0.25	0.007	-0.002	mV
31	T 5.2; V Offset (Vs=15/-15V)	0.031	0.036	6.067	-0.25	0.25	0.005	6.031	mV
81	T 5.2; V Offset (Vs=15/-15V)	0.031	0.029	0.306	-0.25	0.25	-0.002	0.277	mV
99	T 5.2; V Offset (Vs=15/-15V)	0.082	0.055	Alarm	-0.25	0.25	-0.027	#VALUE!	mV
C 9001	T 5.3; V Offset (Vs=15/-15V)	0.007	0.015	0.011	-0.25	0.25	0.008	-0.004	mV
31	T 5.3; V Offset (Vs=15/-15V)	-0.051	-0.042	Alarm	-0.25	0.25	0.009	#VALUE!	mV
81	T 5.3; V Offset (Vs=15/-15V)	-0.018	0.003	0.306	-0.25	0.25	0.021	0.303	mV
99	T 5.3; V Offset (Vs=15/-15V)	0.011	0.009	0.306	-0.25	0.25	-0.002	0.297	mV
C 9001	T 5.4; V Offset (Vs=15/-15V)	0.053	0.060	0.058	-0.25	0.25	0.007	-0.002	mV
31	T 5.4; V Offset (Vs=15/-15V)	0.033	0.028	Alarm	-0.25	0.25	-0.005	#VALUE!	mV
81	T 5.4; V Offset (Vs=15/-15V)	-0.047	-0.035	Alarm	-0.25	0.25	0.012	#VALUE!	mV
99	T 5.4; V Offset (Vs=15/-15V)	0.031	0.003	Alarm	-0.25	0.25	-0.028	#VALUE!	mV
C 9001	T 6.1; + I Bias (Vs=15/-15V)	-213.166	-214.483	-214.870	-350	350	-1.317	-0.387	nA
31	T 6.1; + I Bias (Vs=15/-15V)	-165.995	-167.188	-3.891	-350	350	-1.193	163.297	nA
81	T 6.1; + I Bias (Vs=15/-15V)	-211.492	-371.436	1.285	-350	350	-159.944	372.721	nA
99	T 6.1; + I Bias (Vs=15/-15V)	-172.424	-290.890	-10.869	-350	350	-118.466	280.021	nA
C 9001	T 6.2; + I Bias (Vs=15/-15V)	-206.303	-207.748	-214.133	-350	350	-1.445	-6.385	nA
31	T 6.2; + I Bias (Vs=15/-15V)	-159.462	-160.572	10.096	-350	350	-1.110	170.668	nA
81	T 6.2; + I Bias (Vs=15/-15V)	-192.154	-340.847	-251.117	-350	350	-148.693	89.730	nA
99	T 6.2; + I Bias (Vs=15/-15V)	-172.669	-279.789	11.250	-350	350	-107.120	291.039	nA
C 9001	T 6.3; + I Bias (Vs=15/-15V)	-225.948	-227.575	-229.595	-350	350	-1.627	-2.020	nA
31	T 6.3; + I Bias (Vs=15/-15V)	-154.588	-155.631	-11.644	-350	350	-1.043	143.987	nA
81	T 6.3; + I Bias (Vs=15/-15V)	-190.246	-330.537	-275.781	-350	350	-140.291	54.756	nA
99	T 6.3; + I Bias (Vs=15/-15V)	-174.890	-290.795	-193.431	-350	350	-115.905	97.364	nA
C 9001	T 6.4; + I Bias (Vs=15/-15V)	-221.500	-222.821	-221.603	-350	350	-1.321	1.218	nA
31	T 6.4; + I Bias (Vs=15/-15V)	-162.692	-164.014	-6.305	-350	350	-1.322	157.709	nA
81	T 6.4; + I Bias (Vs=15/-15V)	-218.046	-376.208	-17.408	-350	350	-158.162	358.800	nA
99	T 6.4; + I Bias (Vs=15/-15V)	-174.738	-290.700	-9.879	-350	350	-115.962	280.821	nA
C 9001	T 7.1; - I Bias (Vs=15/-15V)	-217.604	-218.711	-218.790	-350	350	-1.107	-0.079	nA
31	T 7.1; - I Bias (Vs=15/-15V)	-169.086	-169.775	-6.213	-350	350	-0.689	163.562	nA
81	T 7.1; - I Bias (Vs=15/-15V)	-216.670	-373.725	-6.062	-350	350	-157.055	367.663	nA
99	T 7.1; - I Bias (Vs=15/-15V)	-179.360	-318.122	11.965	-350	350	-138.762	330.087	nA
C 9001	T 7.2; - I Bias (Vs=15/-15V)	-207.451	-208.545	-209.324	-350	350	-1.094	-0.779	nA
31	T 7.2; - I Bias (Vs=15/-15V)	-160.475	-161.159	-134.743	-350	350	-0.684	26.416	nA
81	T 7.2; - I Bias (Vs=15/-15V)	-195.595	-339.823	-252.862	-350	350	-144.228	86.961	nA
99	T 7.2; - I Bias (Vs=15/-15V)	-175.116	-284.538	-11.713	-350	350	-109.422	272.825	nA
C 9001	T 7.3; - I Bias (Vs=15/-15V)	-223.766	-224.922	-226.119	-350	350	-1.156	-1.197	nA

Test Dates: SN		14-Feb-02 Pre SEE	1-Mar-02 Post SEE1	1-Apr-02 Post SEE2	Min Limit	Max Limit	SEE1-Pre Delta	SEE2-SEE1 Delta	Units
31	T 7.3; - I Bias (Vs=15/-15V)	-151.897	-152.417	7.734	-350	350	-0.520	160.151	nA
81	T 7.3; - I Bias (Vs=15/-15V)	-189.520	-339.517	-250.773	-350	350	-149.997	88.744	nA
99	T 7.3; - I Bias (Vs=15/-15V)	-173.338	-286.653	-161.315	-350	350	-113.315	125.338	nA
C 9001	T 7.4; - I Bias (Vs=15/-15V)	-220.333	-221.341	-219.757	-350	350	-1.008	1.584	nA
31	T 7.4; - I Bias (Vs=15/-15V)	-161.914	-162.556	1.713	-350	350	-0.642	164.269	nA
81	T 7.4; - I Bias (Vs=15/-15V)	-213.980	-366.230	12.091	-350	350	-152.250	378.321	nA
99	T 7.4; - I Bias (Vs=15/-15V)	-185.139	-293.401	9.367	-350	350	-108.262	302.768	nA
C 9001	T 8.1; I Offset (Vs=15/-15V)	5.535	5.713	5.460	-50	50	0.178	-0.253	nA
31	T 8.1; I Offset (Vs=15/-15V)	4.026	4.178	7.923	-50	50	0.152	3.745	nA
81	T 8.1; I Offset (Vs=15/-15V)	5.853	3.834	11.419	-50	50	-2.019	7.585	nA
99	T 8.1; I Offset (Vs=15/-15V)	7.437	28.704	-10.318	-50	50	21.267	-39.022	nA
C 9001	T 8.2; I Offset (Vs=15/-15V)	2.203	2.132	-3.131	-50	50	-0.071	-5.263	nA
31	T 8.2; I Offset (Vs=15/-15V)	1.881	1.996	62.785	-50	50	0.115	60.789	nA
81	T 8.2; I Offset (Vs=15/-15V)	4.215	0.324	3.518	-50	50	-3.891	3.194	nA
99	T 8.2; I Offset (Vs=15/-15V)	2.959	5.733	11.590	-50	50	2.774	5.857	nA
C 9001	T 8.3; I Offset (Vs=15/-15V)	-0.986	-1.137	-1.861	-50	50	-0.151	-0.724	nA
31	T 8.3; I Offset (Vs=15/-15V)	-1.677	-1.832	-3.774	-50	50	-0.155	-1.942	nA
81	T 8.3; I Offset (Vs=15/-15V)	-0.171	10.064	-23.961	-50	50	10.235	-34.025	nA
99	T 8.3; I Offset (Vs=15/-15V)	-1.159	-2.785	-32.227	-50	50	-1.626	-29.442	nA
C 9001	T 8.4; I Offset (Vs=15/-15V)	0.010	-0.049	-0.236	-50	50	-0.059	-0.187	nA
31	T 8.4; I Offset (Vs=15/-15V)	0.058	-0.027	19.193	-50	50	-0.085	19.220	nA
81	T 8.4; I Offset (Vs=15/-15V)	-3.432	-8.487	-3.678	-50	50	-5.055	4.809	nA
99	T 8.4; I Offset (Vs=15/-15V)	10.723	3.965	-7.324	-50	50	-6.758	-11.289	nA
C 9001	T 9.1; Open Loop Gain (Vs=15V, RL=2K)	8492.36	11143.76	11997.36	150	1.00E+12	2651.40	853.60	V/mV
31	T 9.1; Open Loop Gain (Vs=15V, RL=2K)	613.09	631.52	Alarm	150	1.00E+12	18.43	#VALUE!	V/mV
81	T 9.1; Open Loop Gain (Vs=15V, RL=2K)	19517.79	363427.70	Alarm	150	1.00E+12	343909.91	#VALUE!	V/mV
99	T 9.1; Open Loop Gain (Vs=15V, RL=2K)	1460.59	3002.88	518.47	150	1.00E+12	1542.29	-2484.41	V/mV
C 9001	T 9.2; Open Loop Gain (Vs=15V, RL=2K)	7252.32	7489.54	8411.45	150	1.00E+12	237.22	921.91	V/mV
31	T 9.2; Open Loop Gain (Vs=15V, RL=2K)	1143.66	1091.39	Alarm	150	1.00E+12	-52.27	#VALUE!	V/mV
81	T 9.2; Open Loop Gain (Vs=15V, RL=2K)	1225.09	979.59	429.54	150	1.00E+12	-245.50	-550.05	V/mV
99	T 9.2; Open Loop Gain (Vs=15V, RL=2K)	1744.04	1133.30	Alarm	150	1.00E+12	-610.74	#VALUE!	V/mV
C 9001	T 9.3; Open Loop Gain (Vs=15V, RL=2K)	223.96	223.60	227.31	150	1.00E+12	-0.36	3.71	V/mV
31	T 9.3; Open Loop Gain (Vs=15V, RL=2K)	6359.67	8373.92	469.74	150	1.00E+12	2014.25	-7904.18	V/mV
81	T 9.3; Open Loop Gain (Vs=15V, RL=2K)	1055.60	1128.69	3105.38	150	1.00E+12	73.09	1976.69	V/mV
99	T 9.3; Open Loop Gain (Vs=15V, RL=2K)	1337.05	1148.71	Alarm	150	1.00E+12	-188.34	#VALUE!	V/mV
C 9001	T 9.4; Open Loop Gain (Vs=15V, RL=2K)	191.85	194.40	194.50	150	1.00E+12	2.55	0.10	V/mV
31	T 9.4; Open Loop Gain (Vs=15V, RL=2K)	419.46	435.84	Alarm	150	1.00E+12	16.38	#VALUE!	V/mV
81	T 9.4; Open Loop Gain (Vs=15V, RL=2K)	339.37	347.22	Alarm	150	1.00E+12	7.85	#VALUE!	V/mV
99	T 9.4; Open Loop Gain (Vs=15V, RL=2K)	14253.44	2496.67	Alarm	150	1.00E+12	-11756.77	#VALUE!	V/mV
C 9001	T 10.1; PSRR (Vs=+/-2V,+/-18V)	138.65	138.73	138.73	90	200	0.08	0.00	dB
31	T 10.1; PSRR (Vs=+/-2V,+/-18V)	115.88	116.16	116.34	90	200	0.28	0.18	dB
81	T 10.1; PSRR (Vs=+/-2V,+/-18V)	116.73	115.58	141.06	90	200	-1.15	25.48	dB
99	T 10.1; PSRR (Vs=+/-2V,+/-18V)	137.58	126.43	117.57	90	200	-11.15	-8.86	dB
C 9001	T 10.2; PSRR (Vs=+/-2V,+/-18V)	126.58	126.56	126.69	90	200	-0.02	0.13	dB
31	T 10.2; PSRR (Vs=+/-2V,+/-18V)	131.36	131.15	75.82	90	200	-0.21	-55.33	dB
81	T 10.2; PSRR (Vs=+/-2V,+/-18V)	132.57	132.27	107.59	90	200	-0.30	-24.68	dB
99	T 10.2; PSRR (Vs=+/-2V,+/-18V)	144.16	129.67	Alarm	90	200	-14.49	#VALUE!	dB
C 9001	T 10.3; PSRR (Vs=+/-2V,+/-18V)	121.74	121.86	121.81	90	200	0.12	-0.05	dB
31	T 10.3; PSRR (Vs=+/-2V,+/-18V)	118.30	118.29	Alarm	90	200	-0.01	#VALUE!	dB
81	T 10.3; PSRR (Vs=+/-2V,+/-18V)	112.15	111.54	104.64	90	200	-0.61	-6.90	dB

Test Dates: SN		14-Feb-02 Pre SEE	1-Mar-02 Post SEE1	1-Apr-02 Post SEE2	Min Limit	Max Limit	SEE1-Pre Delta	SEE2-SEE1 Delta	Units
99	T 10.3; PSRR (Vs=+/-2V,+/-18V)	154.85	141.57	100.25	90	200	-13.28	-41.32	dB
C 9001	T 10.4; PSRR (Vs=+/-2V,+/-18V)	121.45	121.49	122.06	90	200	0.04	0.57	dB
31	T 10.4; PSRR (Vs=+/-2V,+/-18V)	126.40	127.33	Alarm	90	200	0.93	#VALUE!	dB
81	T 10.4; PSRR (Vs=+/-2V,+/-18V)	107.14	107.33	Alarm	90	200	0.19	#VALUE!	dB
99	T 10.4; PSRR (Vs=+/-2V,+/-18V)	137.20	127.19	Alarm	90	200	-10.01	#VALUE!	dB
C 9001	T 11.1; CMRR2 (Vs=+/-15V,VCM=+/-15V)	97.48	97.58	97.62	80	200	0.10	0.04	dB
31	T 11.1; CMRR2 (Vs=+/-15V,VCM=+/-15V)	114.87	115.53	96.66	80	200	0.66	-18.87	dB
81	T 11.1; CMRR2 (Vs=+/-15V,VCM=+/-15V)	86.27	86.12	90.31	80	200	-0.15	4.19	dB
99	T 11.1; CMRR2 (Vs=+/-15V,VCM=+/-15V)	100.46	100.93	93.42	80	200	0.47	-7.51	dB
C 9001	T 11.2; CMRR2 (Vs=+/-15V,VCM=+/-15V)	93.92	93.96	94.01	80	200	0.04	0.05	dB
31	T 11.2; CMRR2 (Vs=+/-15V,VCM=+/-15V)	98.20	98.26	76.10	80	200	0.06	-22.16	dB
81	T 11.2; CMRR2 (Vs=+/-15V,VCM=+/-15V)	96.56	96.36	79.89	80	200	-0.20	-16.47	dB
99	T 11.2; CMRR2 (Vs=+/-15V,VCM=+/-15V)	101.26	100.81	Alarm	80	200	-0.45	#VALUE!	dB
C 9001	T 11.3; CMRR2 (Vs=+/-15V,VCM=+/-15V)	104.12	104.13	104.15	80	200	0.01	0.02	dB
31	T 11.3; CMRR2 (Vs=+/-15V,VCM=+/-15V)	104.85	105.04	105.30	80	200	0.19	0.26	dB
81	T 11.3; CMRR2 (Vs=+/-15V,VCM=+/-15V)	83.65	83.77	79.36	80	200	0.12	-4.41	dB
99	T 11.3; CMRR2 (Vs=+/-15V,VCM=+/-15V)	111.29	112.81	94.50	80	200	1.52	-18.31	dB
C 9001	T 11.4; CMRR2 (Vs=+/-15V,VCM=+/-15V)	115.83	115.92	115.95	80	200	0.09	0.03	dB
31	T 11.4; CMRR2 (Vs=+/-15V,VCM=+/-15V)	97.79	98.07	76.82	80	200	0.28	-21.25	dB
81	T 11.4; CMRR2 (Vs=+/-15V,VCM=+/-15V)	83.14	83.08	79.50	80	200	-0.06	-3.58	dB
99	T 11.4; CMRR2 (Vs=+/-15V,VCM=+/-15V)	116.31	111.61	95.72	80	200	-4.70	-15.89	dB
C 9001	T 12.1; + Slew Rate (Vs=+/-15V)	4.46	4.41	4.42	2.4	20	-0.05	0.01	V/uS
31	T 12.1; + Slew Rate (Vs=+/-15V)	4.13	4.02	0.00	2.4	20	-0.11	-4.02	V/uS
81	T 12.1; + Slew Rate (Vs=+/-15V)	4.75	4.60	0.00	2.4	20	-0.15	-4.60	V/uS
99	T 12.1; + Slew Rate (Vs=+/-15V)	4.37	4.23	0.00	2.4	20	-0.14	-4.23	V/uS
C 9001	T 12.2; + Slew Rate (Vs=+/-15V)	4.32	4.31	4.32	2.4	20	-0.01	0.01	V/uS
31	T 12.2; + Slew Rate (Vs=+/-15V)	3.84	3.86	0.00	2.4	20	0.02	-3.86	V/uS
81	T 12.2; + Slew Rate (Vs=+/-15V)	4.42	4.30	2.31	2.4	20	-0.12	-1.99	V/uS
99	T 12.2; + Slew Rate (Vs=+/-15V)	4.18	4.17	0.00	2.4	20	-0.01	-4.17	V/uS
C 9001	T 12.3; + Slew Rate (Vs=+/-15V)	4.06	4.14	4.12	2.4	20	0.08	-0.02	V/uS
31	T 12.3; + Slew Rate (Vs=+/-15V)	3.96	3.98	0.00	2.4	20	0.02	-3.98	V/uS
81	T 12.3; + Slew Rate (Vs=+/-15V)	4.51	4.37	2.33	2.4	20	-0.14	-2.04	V/uS
99	T 12.3; + Slew Rate (Vs=+/-15V)	4.19	4.18	0.00	2.4	20	-0.01	-4.18	V/uS
C 9001	T 12.4; + Slew Rate (Vs=+/-15V)	4.54	4.58	4.50	2.4	20	0.04	-0.08	V/uS
31	T 12.4; + Slew Rate (Vs=+/-15V)	3.91	3.88	0.00	2.4	20	-0.03	-3.88	V/uS
81	T 12.4; + Slew Rate (Vs=+/-15V)	4.74	4.63	0.00	2.4	20	-0.11	-4.63	V/uS
99	T 12.4; + Slew Rate (Vs=+/-15V)	4.37	4.24	0.00	2.4	20	-0.13	-4.24	V/uS
C 9001	T 13.1; - Slew Rate (Vs=+/-15V)	-3.65	-3.61	-3.59	-10	-2.4	0.04	0.02	V/uS
31	T 13.1; - Slew Rate (Vs=+/-15V)	-3.02	-3.05	0.00	-10	-2.4	-0.03	3.05	V/uS
81	T 13.1; - Slew Rate (Vs=+/-15V)	-3.74	-3.57	0.00	-10	-2.4	0.17	3.57	V/uS
99	T 13.1; - Slew Rate (Vs=+/-15V)	-3.48	-3.43	0.00	-10	-2.4	0.05	3.43	V/uS
C 9001	T 13.2; - Slew Rate (Vs=+/-15V)	-3.41	-3.47	-3.45	-10	-2.4	-0.06	0.02	V/uS
31	T 13.2; - Slew Rate (Vs=+/-15V)	-3.14	-3.16	-0.16	-10	-2.4	-0.02	3.00	V/uS
81	T 13.2; - Slew Rate (Vs=+/-15V)	-3.58	-3.53	-2.41	-10	-2.4	0.05	1.12	V/uS
99	T 13.2; - Slew Rate (Vs=+/-15V)	-3.39	-3.27	-2.64	-10	-2.4	0.12	0.63	V/uS
C 9001	T 13.3; - Slew Rate (Vs=+/-15V)	-3.37	-3.39	-3.41	-10	-2.4	-0.02	-0.02	V/uS
31	T 13.3; - Slew Rate (Vs=+/-15V)	-3.21	-3.22	0.00	-10	-2.4	-0.01	3.22	V/uS
81	T 13.3; - Slew Rate (Vs=+/-15V)	-3.63	-3.54	-2.44	-10	-2.4	0.09	1.10	V/uS
99	T 13.3; - Slew Rate (Vs=+/-15V)	-3.42	-3.30	-0.88	-10	-2.4	0.12	2.42	V/uS
C 9001	T 13.4; - Slew Rate (Vs=+/-15V)	-3.62	-3.58	-3.60	-10	-2.4	0.04	-0.02	V/uS

Test Dates: SN		14-Feb-02 Pre SEE	1-Mar-02 Post SEE1	1-Apr-02 Post SEE2	Min Limit	Max Limit	SEE1-Pre Delta	SEE2-SEE1 Delta	Units
31	T 13.4; - Slew Rate (Vs=+/-15V)	-2.75	-2.77	0.00	-10	-2.4	-0.02	2.77	V/uS
81	T 13.4; - Slew Rate (Vs=+/-15V)	-3.71	-3.56	-5.05	-10	-2.4	0.15	-1.49	V/uS
99	T 13.4; - Slew Rate (Vs=+/-15V)	-3.54	-3.40	0.00	-10	-2.4	0.14	3.40	V/uS
C 9001	T 14.1; + V OUT (Vs=+/-15V,RL=2K)	14.981	14.969	14.967	14.8	20	-0.012	-0.002	V
31	T 14.1; + V OUT (Vs=+/-15V,RL=2K)	14.993	14.982	Alarm	14.8	20	-0.011	#VALUE!	V
81	T 14.1; + V OUT (Vs=+/-15V,RL=2K)	14.981	14.976	Alarm	14.8	20	-0.005	#VALUE!	V
99	T 14.1; + V OUT (Vs=+/-15V,RL=2K)	14.981	14.976	Alarm	14.8	20	-0.005	#VALUE!	V
C 9001	T 14.2; + V OUT (Vs=+/-15V,RL=2K)	14.993	14.977	14.979	14.8	20	-0.016	0.002	V
31	T 14.2; + V OUT (Vs=+/-15V,RL=2K)	14.999	14.986	Alarm	14.8	20	-0.013	#VALUE!	V
81	T 14.2; + V OUT (Vs=+/-15V,RL=2K)	14.987	14.982	14.961	14.8	20	-0.005	-0.021	V
99	T 14.2; + V OUT (Vs=+/-15V,RL=2K)	14.991	14.982	Alarm	14.8	20	-0.009	#VALUE!	V
C 9001	T 14.3; + V OUT (Vs=+/-15V,RL=2K)	14.981	14.967	14.967	14.8	20	-0.014	0.000	V
31	T 14.3; + V OUT (Vs=+/-15V,RL=2K)	14.993	14.976	Alarm	14.8	20	-0.017	#VALUE!	V
81	T 14.3; + V OUT (Vs=+/-15V,RL=2K)	14.975	14.970	14.949	14.8	20	-0.005	-0.021	V
99	T 14.3; + V OUT (Vs=+/-15V,RL=2K)	14.981	14.973	6.992	14.8	20	-0.008	-7.981	V
C 9001	T 14.4; + V OUT (Vs=+/-15V,RL=2K)	14.975	14.957	14.956	14.8	20	-0.018	-0.001	V
31	T 14.4; + V OUT (Vs=+/-15V,RL=2K)	14.999	14.982	Alarm	14.8	20	-0.017	#VALUE!	V
81	T 14.4; + V OUT (Vs=+/-15V,RL=2K)	14.969	14.969	Alarm	14.8	20	0.000	#VALUE!	V
99	T 14.4; + V OUT (Vs=+/-15V,RL=2K)	14.969	14.964	Alarm	14.8	20	-0.005	#VALUE!	V
C 9001	T 15.1; - V OUT (Vs=+/-15V,RL=2K)	-15.076	-15.102	-15.104	-20	-14.875	-0.026	-0.002	V
31	T 15.1; - V OUT (Vs=+/-15V,RL=2K)	-15.069	-15.090	Alarm	-20	-14.875	-0.021	#VALUE!	V
81	T 15.1; - V OUT (Vs=+/-15V,RL=2K)	-15.076	-15.102	-5.937	-20	-14.875	-0.026	9.165	V
99	T 15.1; - V OUT (Vs=+/-15V,RL=2K)	-15.064	-15.090	-14.905	-20	-14.875	-0.026	0.185	V
C 9001	T 15.2; - V OUT (Vs=+/-15V,RL=2K)	-15.076	-15.102	-15.098	-20	-14.875	-0.026	0.004	V
31	T 15.2; - V OUT (Vs=+/-15V,RL=2K)	-15.070	-15.090	-14.637	-20	-14.875	-0.020	0.453	V
81	T 15.2; - V OUT (Vs=+/-15V,RL=2K)	-15.070	-15.100	-14.331	-20	-14.875	-0.030	0.769	V
99	T 15.2; - V OUT (Vs=+/-15V,RL=2K)	-15.064	-15.090	-6.673	-20	-14.875	-0.026	8.417	V
C 9001	T 15.3; - V OUT (Vs=+/-15V,RL=2K)	-15.076	-15.102	-15.098	-20	-14.875	-0.026	0.004	V
31	T 15.3; - V OUT (Vs=+/-15V,RL=2K)	-15.070	-15.090	-14.989	-20	-14.875	-0.020	0.101	V
81	T 15.3; - V OUT (Vs=+/-15V,RL=2K)	-15.076	-15.102	-14.361	-20	-14.875	-0.026	0.741	V
99	T 15.3; - V OUT (Vs=+/-15V,RL=2K)	-15.064	-15.090	-6.074	-20	-14.875	-0.026	9.016	V
C 9001	T 15.4; - V OUT (Vs=+/-15V,RL=2K)	-15.076	-15.102	-15.104	-20	-14.875	-0.026	-0.002	V
31	T 15.4; - V OUT (Vs=+/-15V,RL=2K)	-15.072	-15.094	-14.473	-20	-14.875	-0.022	0.621	V
81	T 15.4; - V OUT (Vs=+/-15V,RL=2K)	-15.076	-15.102	-14.178	-20	-14.875	-0.026	0.924	V
99	T 15.4; - V OUT (Vs=+/-15V,RL=2K)	-15.064	-15.090	-5.959	-20	-14.875	-0.026	9.131	V

3. Test circuit description and condition

- Single-supply Configuration: Under the single-supply configuration as shown in Figure 3, two devices (S/N 81 and 99) were characterized for both SET and SEL. For SET, a Tektronix TDS640A Digitizing Oscilloscope was used to detect pulse amplitude changes and to capture voltage transients. The triggering mode was set to detect transients with amplitude ≥ 6.6V (≥600mV above the normal DC output voltage of 6V), and ≥ 8V (≥2V above the normal DC output voltage of 6V). The devices drew typically 16mA @ V_{S+} = 12V at normal operating temperature (T_C ~ 30°C). For SEL, the devices were characterized at worst case voltage (V_{S+} = 13.5V) and temperature (T_C= 100°C). Supply current was remotely controlled and monitored for any sudden increase in case of a latch-up event.

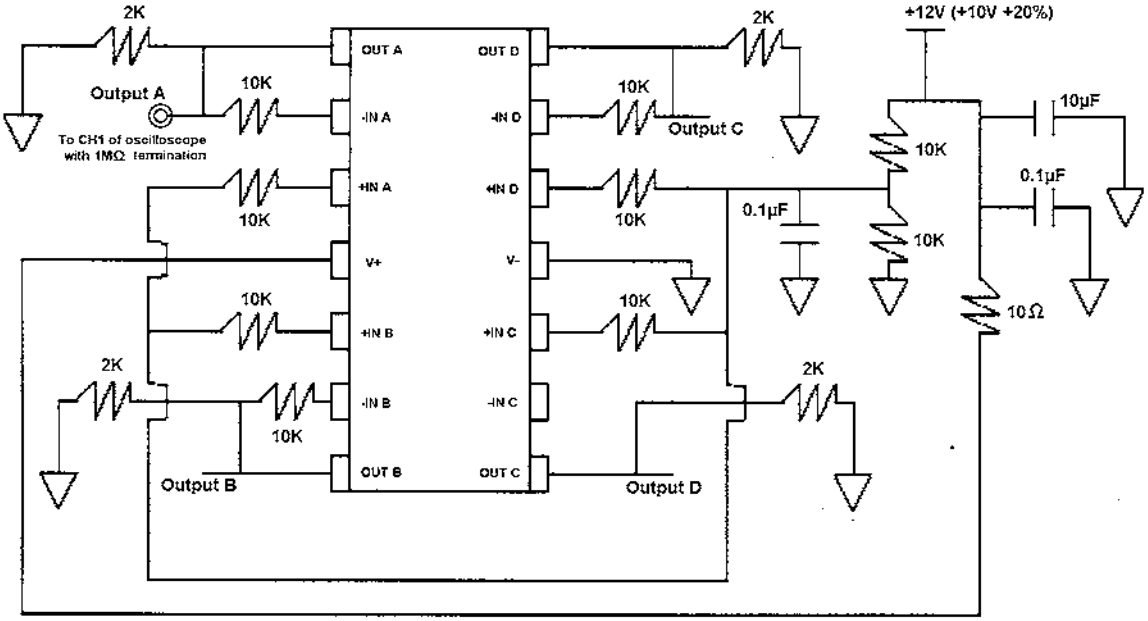


FIGURE 3. **Single-supply Configuration Test Circuit**.

- Rail-to-Rail Configuration: At first, two devices (S/N 232 and 235) were characterized for latch-up but were incorrectly biased during the test (the V+ /V- supplies were at +/-12.6V instead at +/-15V). However, the invalid bias condition did not seem to affect the operation of the devices until the devices were hit with heavy ions. The results of the subsequent SEL test with the correct bias conditions validated the presumption. In the repeated SEL test, three devices (S/N 31, 81, and 99) were characterized at both normal operating temperature (T_C~ 38°C) and worst case temperature (T_C~ 100°C). The devices drew typically 36mA @ V_{S+} = 15.5V, and -9mA @ V_{S-} = -15.5V. Both supplies were current limited to 1A.

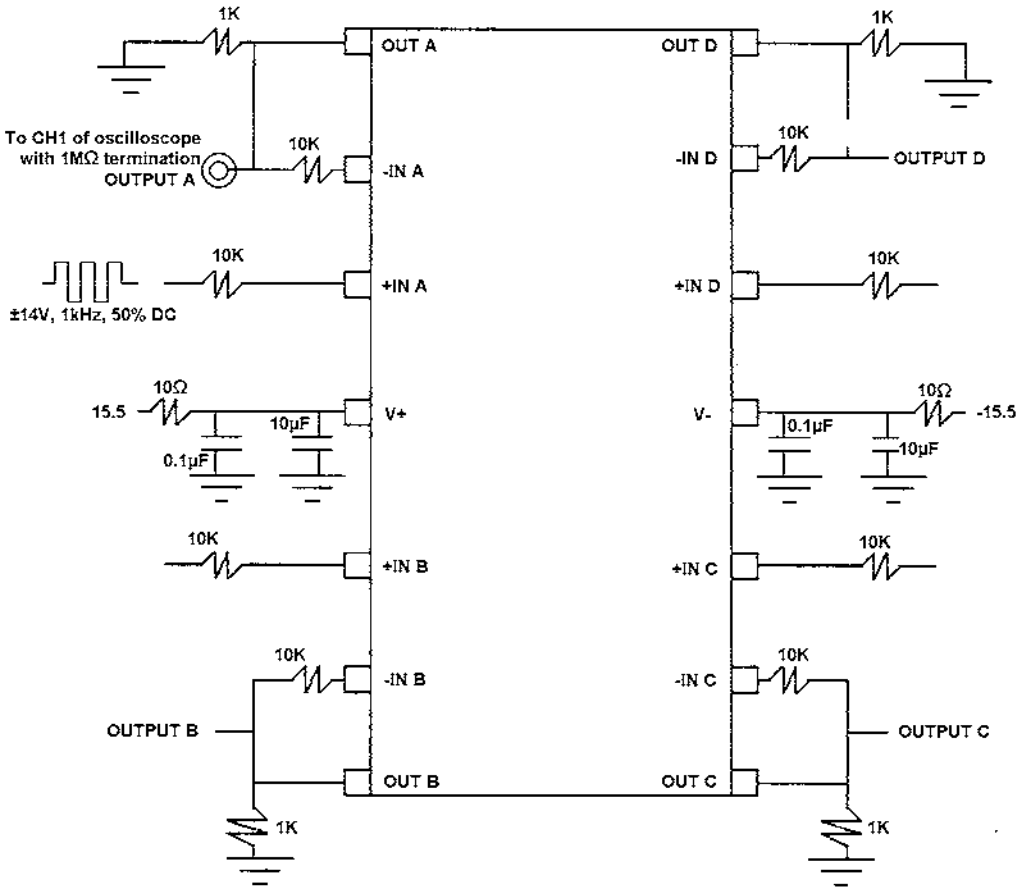


FIGURE 4. **Rail-to-rail Configuration Test Circuit**.

4. The particle beam

All five devices were exposed to heavy ions using the Berkeley Lab's 88-inch cyclotron. The aperture size of the particle beam is approximately ten centimeters (4 inches) in diameter, the particle stream itself has an approximate diameter of 7.5 cm (3 inches). The beam can be aimed with precision using a laser targeting system, allowing a single IC to be irradiated. The laser targeting technique was used for this evaluation.

Two separate ion cocktails were used to cover a wide range of LET from 3.4 MeV-cm^2/mg (Ne) to 120 MeV-cm^2/mg (Bi). Table II lists the test ions with their associated energies, equivalent LET, and approximate penetration range in Si for the 10 MeV/n and the 4.5 MeV/n cocktail beams.

Table II. List of test ions and characteristics

IONS	ENERGY (MeV)	ANGLE (°)	EFFECTIVE LET [MeV/(mg/cm^2)]	Range in Si (μm)
Ne	216	0	3.4	179
Ne	216	47.2	5	179
Ne	216	60.9	7	179
Ar	400	0	9.9	129
V^+	508	0	15	116
Cu	652	0	22	108
Kr	886	0	30	111
Kr	886	41.4	40	111
Kr	886	55.3	53	111
Xe	1330	0	54	110
Xe	1330	30	62.3	110
Xe	1330	60	108	110
Bi	950	0	95	50
Bi	950	37.7	120	50

5. **Test Results**

- Single Supply Configuration: Transients were detected at a LET_{TH} = 7 MeV-cm^2/mg for the 6.6V trigger level, and at a LET_{TH} = 53 MeV-cm^2/mg for the 8V trigger level. Refer to Table III for summary of the cross-section vs. LET, Table IV for heavy-ions induced ionizing dose, Figure 5 and 6 for Weibull curve fit, and Figure 7 for normal and typical SET waveforms.

Table III. Cross-section vs. LET

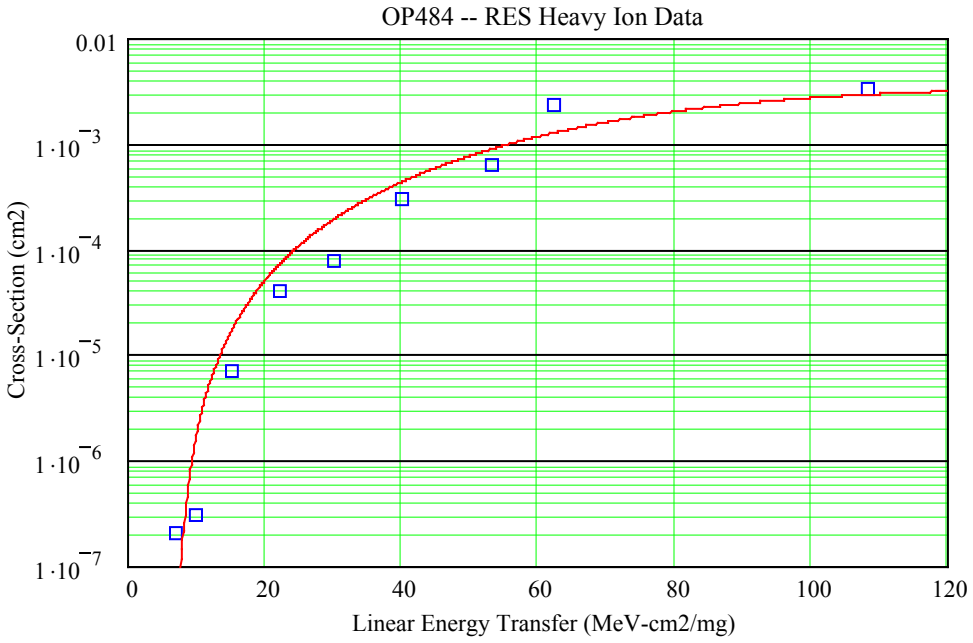
S/N	Trigger Level	LET MeV/(mg/cm^2)	Fluence	Error	Cross-section cm^2/device	Remarks 1/
81	6.6V	3.4 (Ne @ 0°)	1.0E7	0	9.94E-8	
81	6.6V	5 (Ne @ 47.2°)	1.0E7	0	1.46E-7	
81	6.6V	7 (Ne @ 60.9°)	1.0E7	1	2.05E-7	
81	6.6V	9.9 (Ar @ 0°)	1.0E7	3	2.98E-7	
81	6.6V	15 (V @ 0°)	6.27E6	44	7.01E-6	
81	6.6V	22 (Cu @ 0°)	6.79E6	279	4.10E-5	
81	6.6V	30 (Kr @ 0°)	1.03E6	80	7.74E-5	
81	6.6V	40 (Kr @ 41.4°)	1.06E6	239	3.02E-4	
81	6.6V	53 (Kr @ 55.5°)	1.04E6	374	6.38E-4	
81	6.6V	54 (Xe @ 0°)	5.55E5	1196	2.15E-3	
81	6.6V	62.3 (Xe @ 30°)	9.02E4	179	2.29E-3	
81	6.6V	108 (Xe @ 60°)	9.15E4	152	3.34E-3	
81	8V	30 (Kr @ 0°)	1.02E7	0	9.75E-8	
81	8V	53 (Kr @ 55.3°)	1.07E6	7	1.16E-5	
81	8V	54 (Xe @ 0°)	3.91E5	20	5.11E-5	
81	8V	62.3 (Xe @ 30°)	4.35E5	34	9.06E-5	
81	8V	108 (Xe @ 60°)	1.39E5	13	1.86E-4	
81	-	95 (Bi @ 0°)	1.00E7	-	-	Latch-up test @ V_{S+}= 13.5V, T_C= 100°C
81	-	108 (Xe @ 60°)	1.04E6	-	-	Latch-up test @ V_{S+}= 13.5V, T_C= 100°C
99	6.6V	9.9 (Ar @ 0°)	1.04E7	1	9.56E-8	
99	6.6V	15 (V^+ @ 0°)	1.00E6	13	1.29E-6	
99	6.6V	22 (Cu @ 0°)	1.05E7	96	9.11E-6	
99	6.6V	30 (Kr @ 0°)	1.16E6	53	4.54E-5	
99	6.6V	40 (Kr @ 41.4°)	1.07E6	160	2.00E-4	
99	6.6V	53 (Kr @ 55.5°)	5.83E5	171	5.18E-4	
99	6.6V	54 (Xe @ 0°)	6.95E5	1868	2.64E-3	
99	6.6V	62.3 (Xe @ 30°)	1.52E5	442	3.34E-3	
99	6.6V	108 (Xe @ 60°)	1.08E5	33	6.11E-4	Transient Voltage = 12V, ~1μs duration
99	8V	30 (Kr @ 0°)	1.47E5	0	6.82E-6	
99	8V	54 (Xe @ 0°)	5.34E5	3	5.61E-6	
99	8V	95 (Bi @ 0°)	4.35E5	3	6.90E-6	
99	8V	120 (Bi @ 37.7°)	4.57E5	6	1.66E-5	
99	-	54 (Xe @ 0°)	1.00E6	-	-	Latch-up test @ V_{S+}= 13.5V, T_C= 100°C

99	-	108 (Xe @ 60°)	1.00E6	-	-	Latch-up test @ V_{S+}= 13.5V, T_C= 100°C
99	-	120 (Bi @ 37.7°)	2.00E6	-	-	Latch-up test @ V_{S+}= 13.5V, T_C= 100°C

Note: 1/ T_C = ~30°C unless otherwise noted.

Table IV. Heavy-ions induced ionizing dose (Single-supply Configuration)

S/N	TID
81	~42 KRad (Si)
99	~22 KRad (Si)



Summary

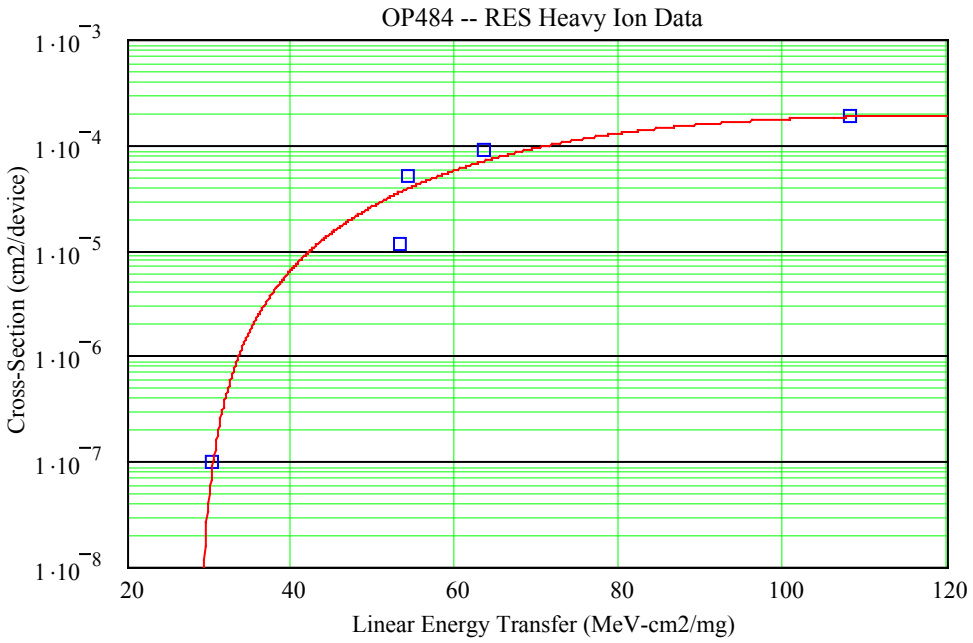
$$W = 76.209 \frac{MeV \cdot cm^2}{mg}$$

$$S = 2.395$$

$$Lo = 6.65 \frac{MeV \cdot cm^2}{mg}$$

$$\sigma sat = 3.373 \times 10^{-3} cm^2$$

Figure 5. Weibull Curve Fit for the 6.6V Trigger Level (Single-supply Configuration)



Summary

$W = 49.651 \frac{MeV \cdot cm^2}{mg}$

$S = 2.276$

$Lo = 28.5 \frac{MeV \cdot cm^2}{mg}$

$\sigma sat = 1.934 \times 10^{-4} cm^2$

Figure 6. Weibull Curve Fit for the 8V Trigger Level (Single-supply Configuration)

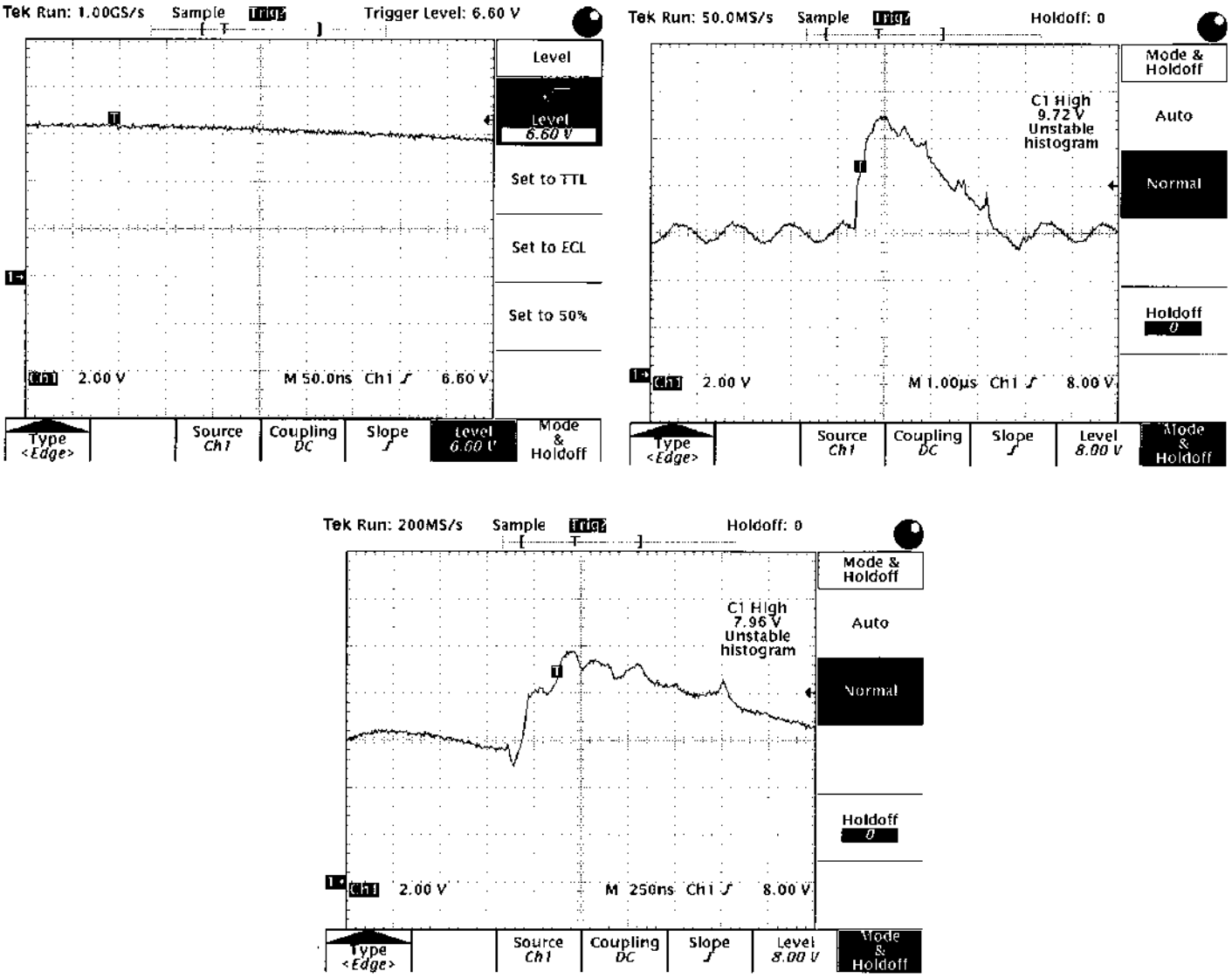


Figure 7. **Normal Output Waveform (Top Left), and Typical SET Waveforms For Single-supply Configuration**.

- Rail-to-Rail Configuration: All five devices (S/N 31, 81, 99, 232 and 235) became non-functional when exposed to heavy ions with LET of between 30 MeV-cm^2/mg (Kr) and 54 MeV-cm^2/mg (Xe). A failure analysis was performed on S/N 232 and 235 but the test result was inconclusive, refer to FA02-003 dated January 23, 2002 for details. All the devices became non-functional (no detectable output voltage) rather quickly before any latch-up current could be detected. Refer to Table V for summary of the rail-to-rail configuration test, and Figure 8 for typical waveforms before, during and after a device became non-functional.

Heavy-ions induced ionizing dose is summarized in Table VI.

Table V. **Cross-section vs. LET (Rail-to-Rail Configuration)**.

S/N	LET MeV/(mg/cm^2)	Fluence	Error	Cross-section cm^2/device	Remarks
31	9.9 (Ar @ 0°)	1.0E7	-	-	T_C =100°C
31	30 (Kr @ 0°)	1.0E7	-	-	T_C =100°C
31	54 (Xe @ 0°)	<1.0E6	-	-	Non-functional @ T_C =100°C
81	9.9 (Ar @ 0°)	1.0E7	-	-	
81	30 (Kr @ 0°)	1.8E6	-	-	Non-functional @ T_C = ~44°C
99	9.9 (Ar @ 0°)	8.2E6	-	-	Non-functional @ T_C =100°C
232	30 (Kr @ 0°)	1.6E5	57	3.56E-4	
232	54 (Xe @ 0°)	3.58E3	-	-	Non-functional @ T_C = ~44°C
235	30 (Kr @ 0°)	1.05E5	50	4.75E-4	
235	54 (Xe @ 0°)	1.69E3	-	-	Non-functional @ T_C = ~44°C

Table VI. **Heavy-ions induced ionizing dose (Rail-to-Rail Configuration)**.

S/N	TID
31	~ 7 KRad (Si)
81	~ 2 KRad (Si)
99	~ 1 KRad (Si)
232	~ 1 KRad (Si)
235	~ 0.1 KRad (Si)

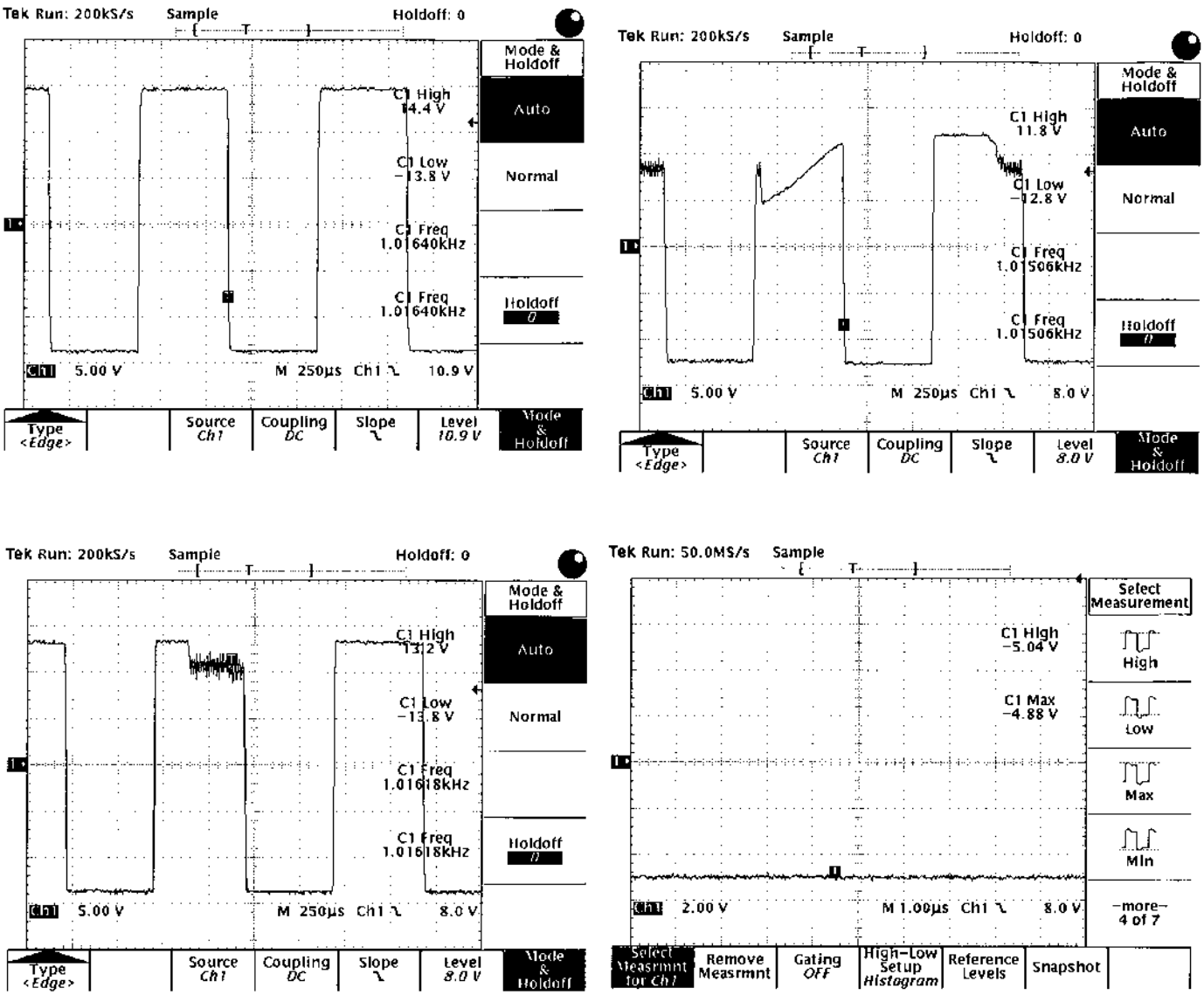


Figure 8. **Normal Ouput Waveform (Top Left), Typical Transient Waveforms (Middles), and Typical Non-functional Waveform (Bottom Right) for Rail-to-Rail Configuration**

III. CONCLUSION

The Analog Devices OP484 Precision Rail-to-Rail Input & Output Op-amps were tested for Single Event Transients and Latch-up with heavy ions in two different configurations - single supply and rail-to-rail. The device performed well in the single-supply configuration with no latch-up up to a LET = 120 MeV-cm^2/mg. In contrast, all of the devices subjected to the SEE in the rail-to-rail configuration became non-functional starting at a LET = 30 MeV-cm^2/mg. An internal failure analysis failed to identify the failures; However, the device was believed to be caused by single event gate rupture as reported in one of the IEEE papers [1].

It's not recommended that the OP484 be used in the rail-to-rail configuration with similar input conditions for spaceflight.

Reference:

[1] The Impact of Single Event Gate Rupture in Linear Devices - Gary K Lum, Hughes O'Donnell, and Nicholas Bouta. IEEE Transaction on Nuclear Science Vol 47, No 6, December 2000.