ISL75051SRH

Single Event Effects Testing of the ISL75051SRH LDO

AN1666
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SEE Testing: Summary and Conclusions

Single Event Burnout/Latch-up

No Single Event Burnout (SEB) was observed for the device up to an LET value of 86 MeV.cm^2 /mg (+125°C). No Single Event Latch-up (SEL) were observed for the device up to an LET value of 86 MeV.cm^2/mg (+125°C).

Single Event Transient

No SET on VOUT in excess of ±5% was observed at an effective LET of 86 MeV.cm^2/mg. SET of up to ±4% were observed for an LET of 43 MeV.cm^2/mg.

Table 1 provides an overall summary of SEE tests results.

Introduction

This application note describes the Single Event Effects (SEE) tests performed on the ISL75051SRH to characterize its Single Event Burnout (SEB), Single Event Latch-up (SEL) and Single Event Transient (SET) sensitivity. The test facility was the Cyclotron at Texas A&M Radiation Effects Test laboratory.

Reference Documents

- ISL75051SRH Datasheet
- AN1667 "ISL75051SRH High Performance 3A LDO Evaluation Board User Guide" showing ISL75051SRH evaluation board schematic and layout

Part Details

- Name: ISL75051SRH
- Function: 3A, radiation hardened, positive, ultra low dropout regulator
- Operating supply voltage: Minimum = 2.2V, Maximum = 6.0V
- Supply voltage absolute maximum: 6.7V
- Package hermetic 18 Ld dual in-line flatpack

The ISL75051SRH is a radiation hardened, low voltage, high current, single output LDO specified for up to 3.0A of continuous output current. These devices operate over an input voltage range of 2.2V to 6.0V and are capable of providing output voltages of 0.8V to 5V adjustable based on resistor divider setting. Dropout voltages as low as 65mV can be realized using the device. The OCP pin allows the short circuit output current limit threshold to be programmed by means of a resistor from the OCP pin to GND. The OCP setting range is from 0.5A minimum to 8.5A maximum. The resistor sets the constant current threshold for the output under fault conditions. The thermal shutdown feature disables the output if the device temperature exceeds the specified value, and it subsequently enters an ON/OFF cycle until the fault is removed. The ENABLE feature allows the part to be placed into a low current shutdown mode drawing about 1µA typical. When enabled, the device operates with a low ground current of 11mA typical, which provides for operation with low quiescent power consumption.

TABLE 1. OVERALL SEE TEST RESULTS (Note 1)

TEST	±1% < SET < ±4%	SET > ±5%	TEMP (°C)	LET (Note 5)	UNITS	REMARKS
SEB/L (Notes 2, 3)	–	–	+125	86	MeV.cm^2/mg	No Single Event Burnouts or Latch-up seen up to VDD = 7.1V at a fluence of 8E + 6 particles/cm^2.
SET (Note 4)	See report	None	+25	86	MeV.cm^2/mg	VIN = 2.2V/4.0V/6.0V (Note 6) VOUT = 1.8V/5.6V

NOTES:

1. SEE tests performed in a closed loop configuration. The acronym "LET" in this report is used to refer to Linear Energy Transfer.
2. SEB is said to have occurred if a 5% increase in IDD is measured after exposure to the beam. A 0.2µF capacitor was connected from the BYP pin to GND for the purpose of bypass. The 7.1V defines the absolute maximum VIN that can be applied to the device under beam. The acronym "SEB/L" in this report is used to refer to Single Effect Burnout and Latch-up.
3. SEL results: No latch-up condition observed. The acronym "SEB/L" in this report is used to refer to Single Effect Burnout and Latch-up.
4. The acronym "SET" in this report is used to refer to Single Event Transient.
5. LET of 86 was achieved by using a LET of 43 beam and rotating the test sample by 60°. The acronym "LET" in this application note is used to refer to linear energy transfer.
6. The recommended operating VIN for the device is 6.0V, which equates to a 15% derating from the Single Event Breakdown survival voltage of 7.1V.

Irradiation Test Facility

- Name: TAMU
- Location: College Station, TX
- Date: June 25, 2011
- Test Characteristics (15MeV Beam):
  - LET of 43: ^{109} Ag
  - LET of 86: ^{109} Ag at angle 60

For details on test conditions, fluence, and cross sections, see tables and plots in this application note.

Test Description

The objective of the test was to characterize the SEE performance of the LDO at the LET levels shown in “Irradiation Test Facility” on page 2. Single Event Latch-up or Burnout event occurrence (SEB/SEL) was measured under beam at a fluence of $1x10^6$ particles/cm². A permanent change in the device supply current after application of the beam is indicative of a burnout condition. If the increased current is reset by cycling power, it is termed a latch-up. Single Event Transient (SET) events were measured on the output of the LDO and were in the range of >±15mV to ±75mV under beam at a fluence of $1x10^6$ particles/cm². For details on SEE events and types detected during testing, see the tables and plots in this application note. Note that ±75mV is ±5% of the output when VOUT = 1.5V and is used as a worst case condition, so for an output voltage greater than 1.5V, the SET amplitude as a percentage is smaller.

Cross-section Calculation

Cross sections are calculated as shown by Equation 1:

$$CS\ (LET) = N/F \qquad \text{(EQ. 1)}$$

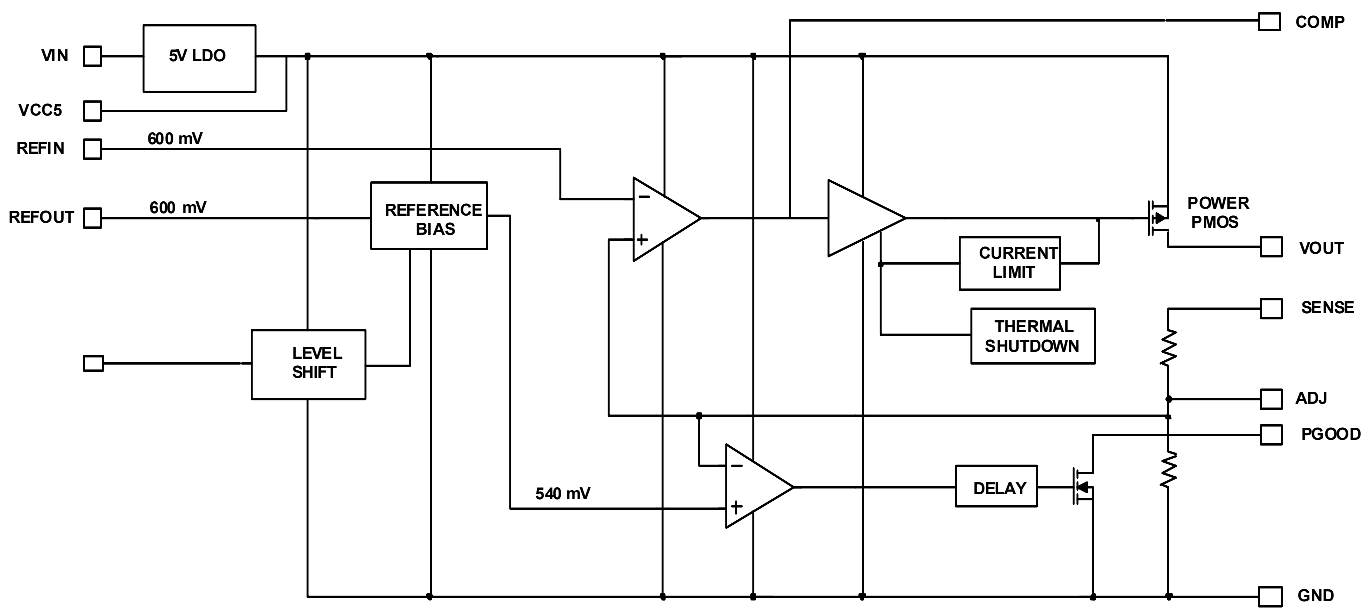
where:

- CS is the SET cross section (cm²), expressed as a function of the heavy ion LET
- LET is the Linear Energy Transfer in MeV.cm²/mg
- N is the total number of SET events
- F is Fluence in particles/cm², corrected according to the incident angle, if any.

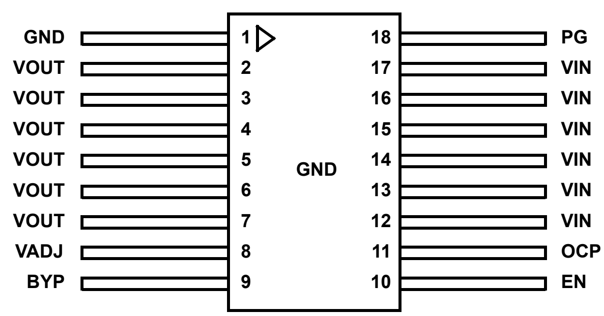
A value of 1/F is the assumed cross section when no event is observed.

Test Set-up Diagrams

Device Block Diagram



Device Pin Connections



SEE Evaluation PWB Layout

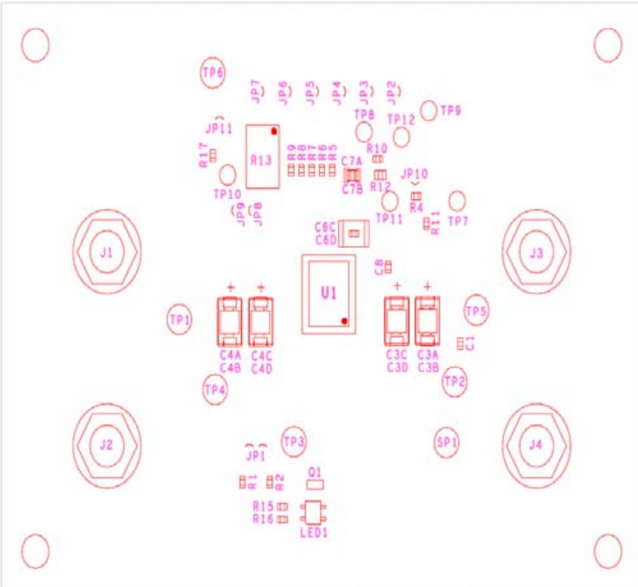


FIGURE 1. SILK SCREEN TOP

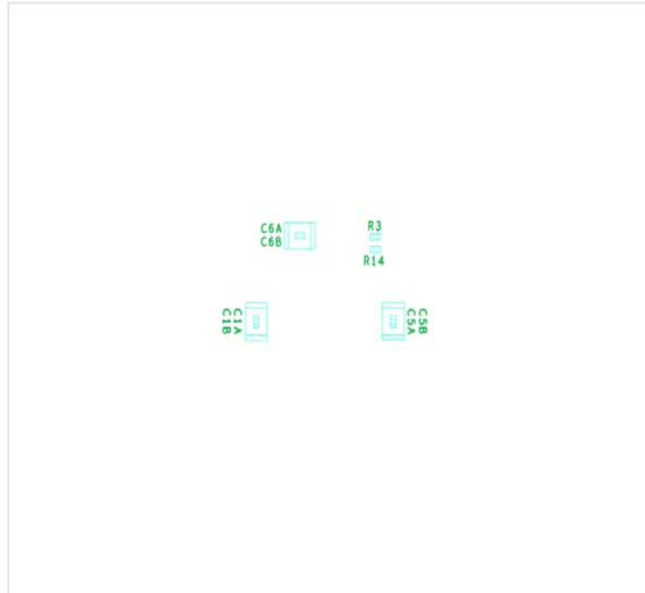
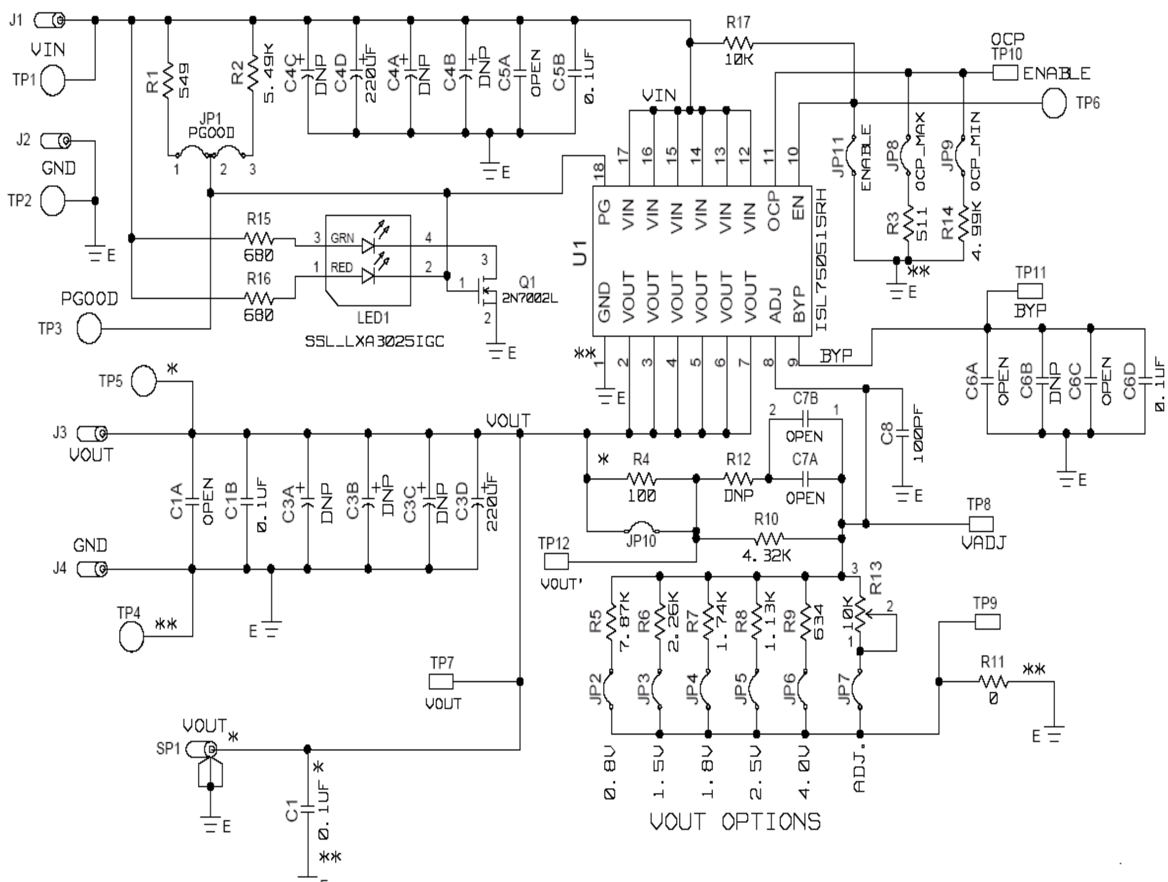


FIGURE 2. SILK SCREEN BOTTOM

Schematic of SEE Evaluation Board



Test Set-up Description

The SEE evaluation board was wired in the configuration shown in “Schematic of SEE Evaluation Board” on page 3. The silkscreen top and bottom for the evaluation board used are shown at figure 3 and 4. The overall test set-up includes the test jig containing two evaluation boards mounted and wired through a 20-ft cable to the data room. The end of the 20-ft cable in the data room was connected to a switch board. The switch board was wired to the power supplies and monitoring equipment and scopes.

Biasing used for SEE test runs was VIN = 2.2V/4.0V/6.0V for VOUT = 1.8V/1.8V/5.6V, respectively. Signals from the switch board were connected to four LECROY oscilloscopes: three set to capture transients due to VOUT, and a fourth set to monitor PGOOD events in real time.

Test Method

SET events are recorded when movement on V_{OUT} due to an ion strike causes it to exceed the set window trigger of ±15mV.

a. Oscilloscope 1 is set to trigger to a VOUT window of ±15mV and a trigger position at 10%. Measurements on Oscilloscope 1 are CH1 = VOUT, CH2 = OCP, CH3 = BYP, CH4 = PGOOD.
b. Oscilloscope 2 is set to trigger to a VOUT window of ±15mV and a trigger position at 90%. Measurements on Oscilloscope 1 are CH1 = VOUT, CH2 = OCP, CH3 = BYP, CH4 = PGOOD.
c. Oscilloscope 3 is set to trigger to a VOUT window of ±75mV and a trigger position at 10%. Measurements on Oscilloscope 1 are CH1 = VOUT, CH2 = OCP, CH3 = BYP, CH4 = PGOOD.
d. Oscilloscope 4 is set to trigger to a PGOOD falling of 200mV and a trigger position at 10%. Measurements on Oscilloscope 1 are CH1 = VOUT, CH2 = OCP, CH3 = BYP, CH4 = PGOOD.

The switch board at the end of the 20-ft cabling was found to require terminations of 10nF to keep the noise on the waveforms to a minimum. It should be noted that no events of greater than ±75mV were present at LET 86, so Oscilloscope 3 had no captures. All captured waveforms are in the range of ±15mV to ±75mV, resulting in captures on Oscilloscopes 1 and 2; therefore, analysis in this application note summarizes these events.

Test Overview

Details of the SET tests are summarized in Tables 2 and 3. The waveforms captured for each run are plotted as a composite, along with ±75mV limit lines that have been added to show that all captures are within the set window. The resultant plots are shown in Figures 3 through 26. The histogram plots in Figures 27 through 32 provide amplitude distribution on the Oscilloscope 1 and 2 captures.

Details of the SEB/L tests are summarized in Table 5. An overall summary of all SEE tests is shown in Table 1.

TABLE 2. DETAILS OF SET TESTS PERFORMED AT LIGHT LOAD BASED ON V_{OUT} CAPTURES

TEST ID	DEVICE#	ION	ANGLE (°)	EFF LET (MeV.cm^2/mg)	FLUENCE PER RUN (PARTICLES/cm^2)		TOTAL EVENTS		EVENT CROSS SECTION (cm^2)
SET +25°C LET of 86 V_{IN} = 2.2V, V_{OUT} = 1.8V, I_{OUT} = 0.1A, C_{OUT} = 220µF, ISL75051SRH									
405	26	^{109}Ag	60.00	86.60	2.0 x 10^{+6}		227		1.14 x 10^{-4}
429	11	^{109}Ag	60.00	86.60	2.0 x 10^{+6}		230		1.15 x 10^{-4}
444	10	^{109}Ag	60.00	86.60	2.0 x 10^{+6}		263		1.32 x 10^{-4}
446	15	^{109}Ag	60.00	86.60	2.0 x 10^{+6}		120		6.00x 10^{-4}
TOTAL FLUENCE IN PARTICLES/cm^2						8.0 x 10^{+6}	TOTAL EVENTS	840	1.05x 10^{-4}
SET +25°C LET of 86 V_{IN} = 4.0V, V_{OUT} = 1.8V, I_{OUT} = 0.1A, C_{OUT} = 220µF, ISL75051SRH									
407	26	^{109}Ag	60.00	86.60	2.0 x 10^{+6}		153		7.65 x 10^{-5}
431	11	^{109}Ag	60.00	86.60	2.0 x 10^{+6}		268		1.34x 10^{-4}
442	10	^{109}Ag	60.00	86.60	2.0 x 10^{+6}		199		9.95 x 10^{-5}
441	15	^{109}Ag	60.00	86.60	2.0 x 10^{+6}		97		4.85 x 10^{-5}
TOTAL FLUENCE IN PARTICLES/cm^2						8.0 x 10^{+6}	TOTAL EVENTS	717	8.96 x 10^{-5}
SET +25°C LET of 86 V_{IN} = 6.0V, V_{OUT} = 5.6V, I_{OUT} = 0.1A, C_{OUT} = 220µF, ISL75051SRH									
411	26	^{109}Ag	60.00	86.60	2.0 x 10^{+6}		508		2.54x 10^{-4}
437	11	^{109}Ag	60.00	86.60	2.0 x 10^{+6}		253		1.27x 10^{-4}
449	10	^{109}Ag	60.00	86.60	2.0 x 10^{+6}		440		2.20x 10^{-4}
451	15	^{109}Ag	60.00	86.60	2.0 x 10^{+6}		247		1.24x 10^{-4}
TOTAL FLUENCE IN PARTICLES/cm^2						8.0 x 10^{+6}	TOTAL EVENTS	1448	1.81x 10^{-4}

TABLE 3. DETAILS OF SET TESTS PERFORMED AT MAX LOAD BASED ON V_{OUT} CAPTURES

TEST ID	DEVICE#	ION	ANGLE (°)	EFF LET (MeV.cm²/mg)	FLUENCE PER RUN (PARTICLES/ (cm²)		TOTAL EVENTS		EVENT CROSS SECTION (cm²)
SET +25°C LET of 86 V_{IN} = 2.2V, V_{OUT} = 1.8V, I_{OUT} = 3.0A, C_{OUT} = 220µF, ISL75051SRH									
406	26	^{109}Ag	60.00	86.60	$2.0 \times 10^{+6}$		255		1.28×10^{-4}
430	11	^{109}Ag	60.00	86.60	$2.0 \times 10^{+6}$		246		1.23×10^{-4}
445	10	^{109}Ag	60.00	86.60	$2.0 \times 10^{+6}$		253		1.27×10^{-4}
447	15	^{109}Ag	60.00	86.60	$2.0 \times 10^{+6}$		618		3.09×10^{-4}
TOTAL FLUENCE IN PARTICLES/cm²						$8.0 \times 10^{+6}$	TOTAL EVENTS	1372	1.72×10^{-4}
SET +25°C LET of 86 V_{IN} = 4.0V, V_{OUT} = 1.8V, I_{OUT} = 1.0A, C_{OUT} = 220µF, ISL75051SRH									
408	26	^{109}Ag	60.00	86.60	$2.0 \times 10^{+6}$		655		3.28×10^{-4}
432	11	^{109}Ag	60.00	86.60	$2.0 \times 10^{+6}$		252		1.26×10^{-4}
443	10	^{109}Ag	60.00	86.60	$2.0 \times 10^{+6}$		253		1.27×10^{-4}
448	15	^{109}Ag	60.00	86.60	$2.0 \times 10^{+6}$		251		1.26×10^{-4}
TOTAL FLUENCE IN PARTICLES/cm²						$8.0 \times 10^{+6}$	TOTAL EVENTS	1411	1.76×10^{-4}
SET +25°C LET of 86 V_{IN} = 6.0V, V_{OUT} = 5.6V, I_{OUT} = 3.0A, C_{OUT} = 220µF, ISL75051SRH									
412	26	^{109}Ag	60.00	86.60	$2.0 \times 10^{+6}$		252		1.26×10^{-4}
439	11	^{109}Ag	60.00	86.60	$2.0 \times 10^{+6}$		252		1.26×10^{-4}
450	10	^{109}Ag	60.00	86.60	$2.0 \times 10^{+6}$		282		1.41×10^{-4}
452	15	^{109}Ag	60.00	86.60	$2.0 \times 10^{+6}$		251		1.26×10^{-4}
TOTAL FLUENCE IN PARTICLES/cm²						$8.0 \times 10^{+6}$	TOTAL EVENTS	1037	1.30×10^{-4}

TABLE 4. V_{OUT} SET HISTOGRAM DATA

V_{OUT} BIN (mV)	V_{IN} = 2.2V. I_{OUT} = 0.1A	V_{IN} = 4.0V I_{OUT} = 0.1A	V_{IN} = 6.0V I_{OUT} = 0.1A	V_{IN} = 2.2V I_{OUT} = 3.0A	V_{IN} = 4.0V I_{OUT} = 1.0A	V_{IN} = 6.0V I_{OUT} = 3.0A
-75	0	0	0	0	0	1
-70	0	0	0	0	0	1
-65	0	0	0	0	0	56
-60	0	0	0	2	0	174
-55	0	0	0	286	0	159
-50	0	0	0	188	0	133
-45	0	0	0	102	0	98
-40	0	0	0	292	0	47
-35	0	0	0	93	4	8
-30	0	0	12	55	270	4
-25	0	0	142	29	509	3
-20	0	0	412	17	126	45
-15	1	2	284	28	324	89
-10	39	40	164	61	54	41

TABLE 4. V_{OUT} SET HISTOGRAM DATA (Continued)

V_{OUT} BIN (mV)	V_{IN} = 2.2V. I_{OUT} = 0.1A	V_{IN} = 4.0V I_{OUT} = 0.1A	V_{IN} = 6.0V I_{OUT} = 0.1A	V_{IN} = 2.2V I_{OUT} = 3.0A	V_{IN} = 4.0V I_{OUT} = 1.0A	V_{IN} = 6.0V I_{OUT} = 3.0A
-5	548	341	226	165	84	70
0	252	334	211	54	40	108
5	52	35	316	5	0	109
10	107	47	28	85	7	81
15	169	142	44	660	26	17
20	104	160	359	461	849	58
25	79	88	331	66	437	69
30	53	35	198	59	16	24
35	45	47	140	36	24	237
40	73	36	29	0	20	254
45	65	41	0	0	15	150
50	30	23	0	0	4	36
55	43	16	0	0	8	2
60	20	23	0	0	3	0
65	0	24	0	0	2	0
70	0	0	0	0	0	0
75	0	0	0	0	0	0
See “SET V_{OUT} Histogram Plots for ISL75051SRH (Note 11)” on page 13	See Figure 27	See Figure 28	See Figure 29	See Figure 30	See Figure 31	See Figure 32

Typical SET Captures at I_{OUT} = 0.1A (Notes 7, 8)

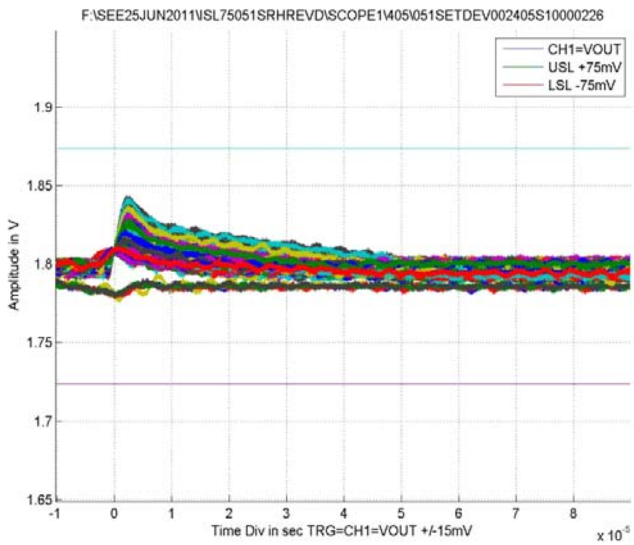


FIGURE 3. TYPICAL CAPTURE AT V_{IN} = 2.2V, RUN 405

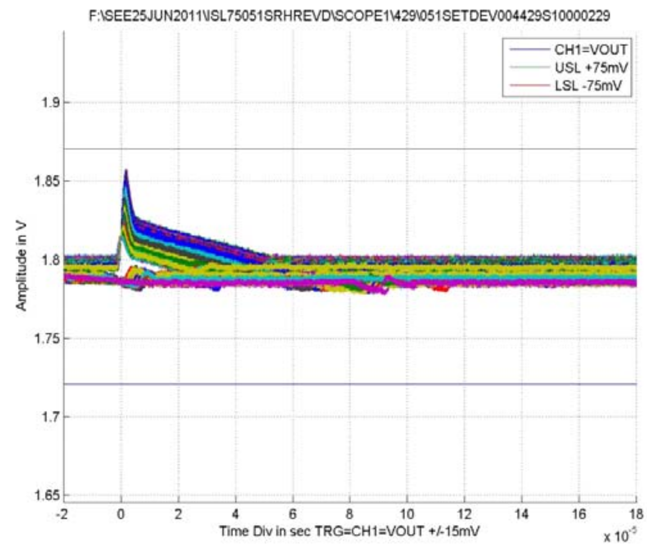


FIGURE 4. TYPICAL CAPTURE AT V_{IN} = 2.2V, RUN 429 (Note 8)

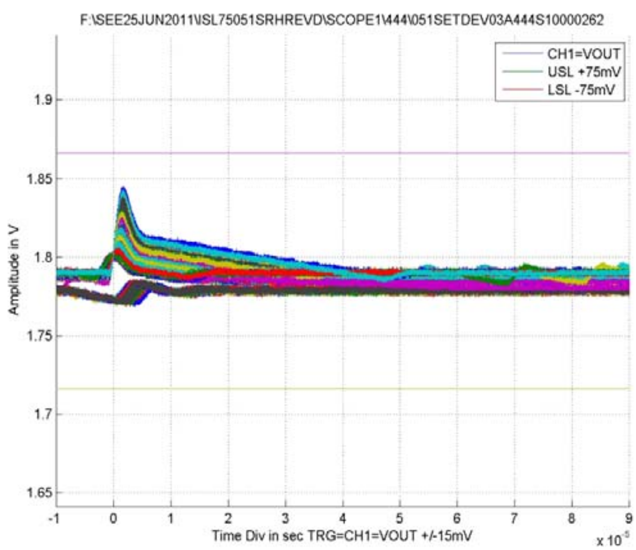


FIGURE 5. TYPICAL CAPTURE AT V_{IN} = 2.2V, RUN 444

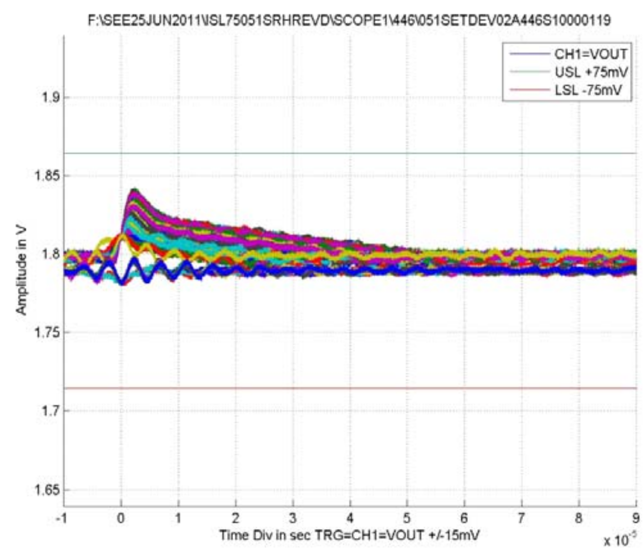


FIGURE 6. TYPICAL CAPTURE AT V_{IN} = 2.2V, RUN 446

Typical SET Captures at I_{OUT} = 0.1A (Notes 7, 8) (Continued)

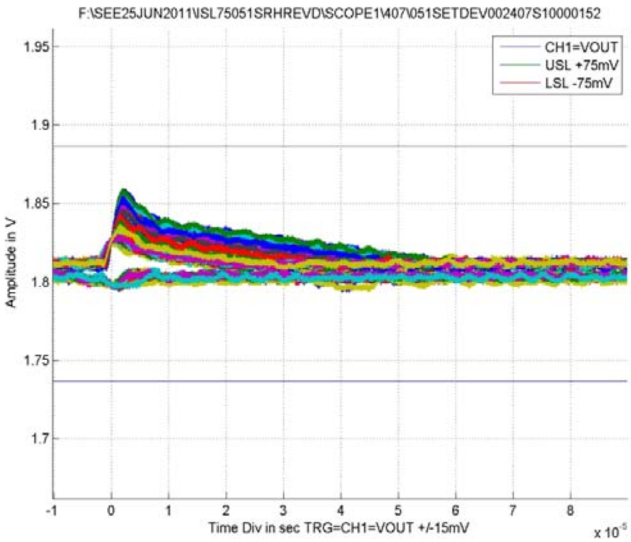


FIGURE 7. TYPICAL CAPTURE AT V_{IN} = 4.0V, RUN 407

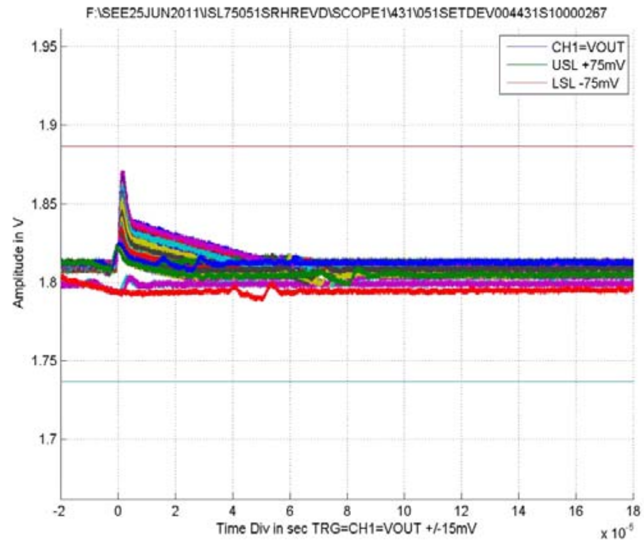


FIGURE 8. TYPICAL CAPTURE AT V_{IN} = 4.0V, RUN 431 (Note 8)

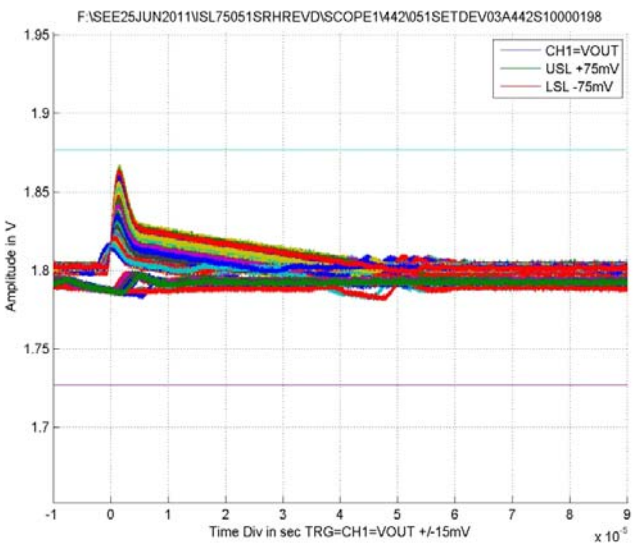


FIGURE 9. TYPICAL CAPTURE AT V_{IN} = 4.0V, RUN 442

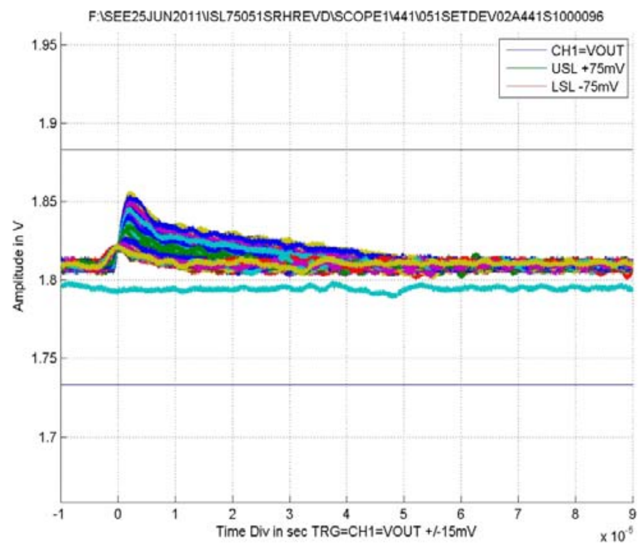


FIGURE 10. TYPICAL CAPTURE AT V_{IN} = 4.0V, RUN 441

Typical SET Captures at I_{OUT} = 0.1A (Notes 7, 8) (Continued)

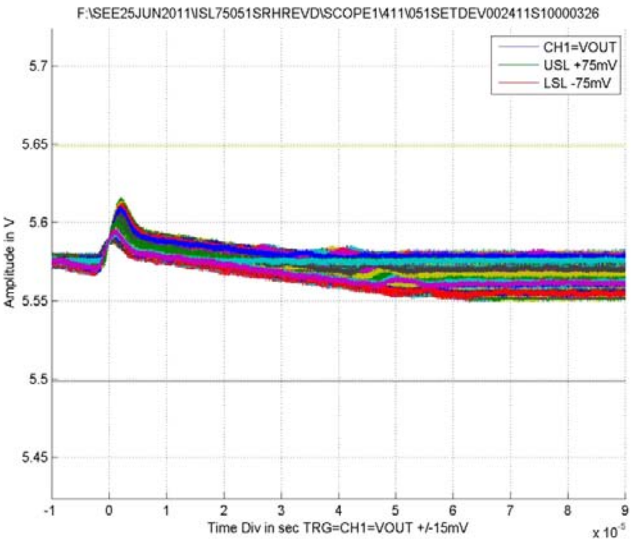


FIGURE 11. TYPICAL CAPTURE AT V_{IN} = 6.0V, RUN 411

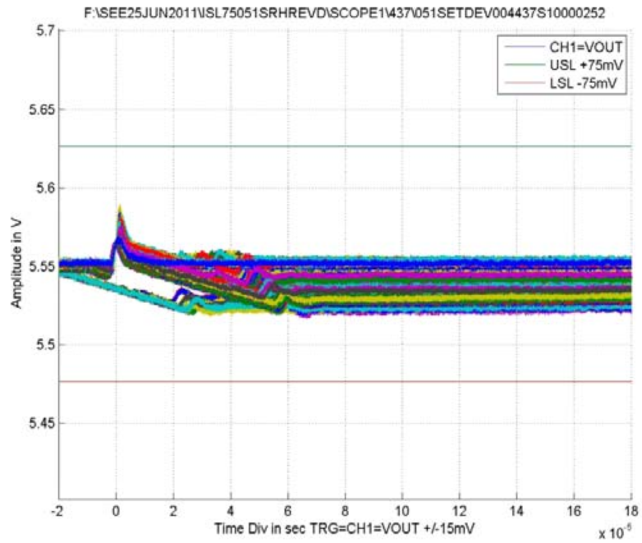


FIGURE 12. TYPICAL CAPTURE AT V_{IN} = 6.0V, RUN 437

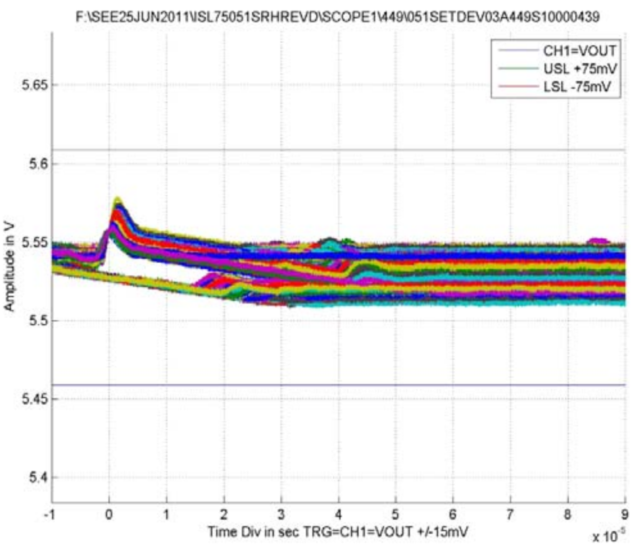


FIGURE 13. TYPICAL CAPTURE AT V_{IN} = 6.0V, RUN 449

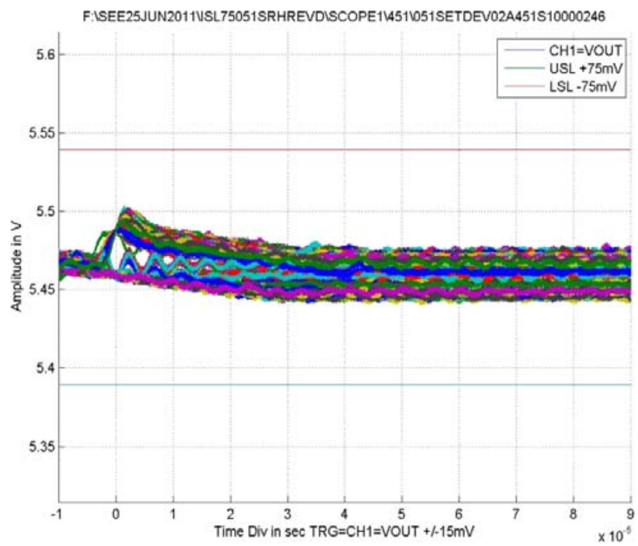


FIGURE 14. TYPICAL CAPTURE AT V_{IN} = 6.0V, RUN 451

NOTES:

7. Composite of all captured transients per run shown. For a distribution on the transients on V_{OUT}, see histogram data and histograms in “V_{OUT} SET HISTOGRAM DATA” on page 5 and “SET V_{OUT} Histogram Plots for ISL75051SRH (Note 11)” on page 13.
8. The horizontal axis time per division is 10µs except for Figures 4, 8, 12, 16, 20, and 24, which are at 20µs per division.

Typical SET Captures at I_{OUT} = 1A (Note 7,8,9)

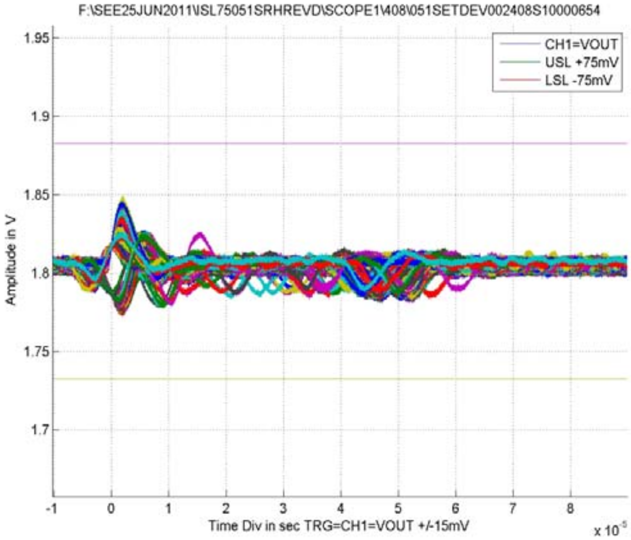


FIGURE 15. TYPICAL CAPTURE AT V_{IN} = 4.0V, RUN 408

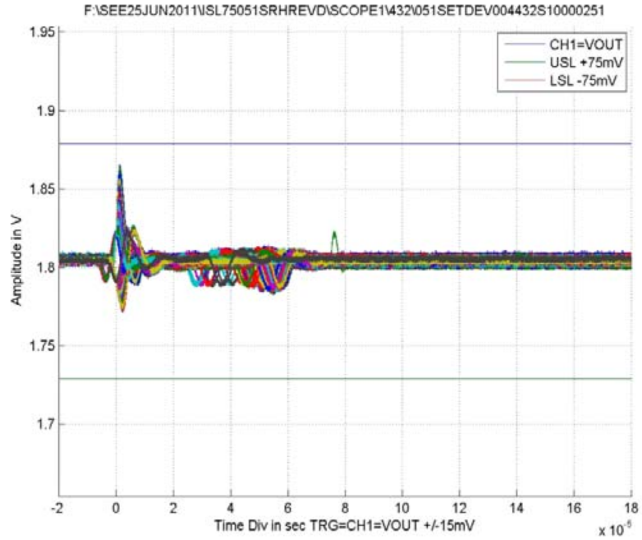


FIGURE 16. TYPICAL CAPTURE AT V_{IN} = 4.0V, RUN 432

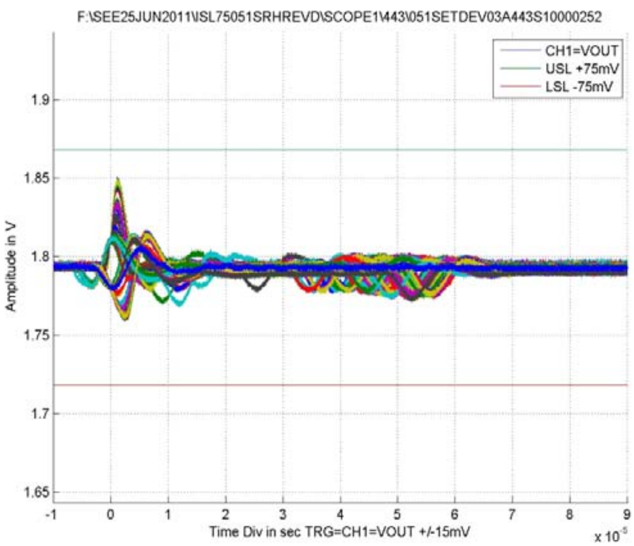


FIGURE 17. TYPICAL CAPTURE AT V_{IN} = 4.0V, RUN 443

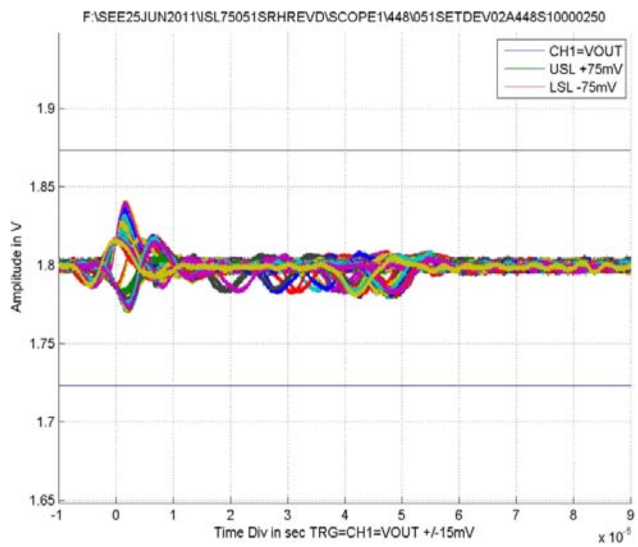


FIGURE 18. TYPICAL CAPTURE AT V_{IN} = 4.0V, RUN 448

NOTE:

9. The waveforms signature observed in Figures 15 through 18 is caused by the handoff between main and redundant references during an SET event. This does not affect normal operation of the device.

Typical SET Captures at I_{OUT} = 3A (Note 7, 8, 10)

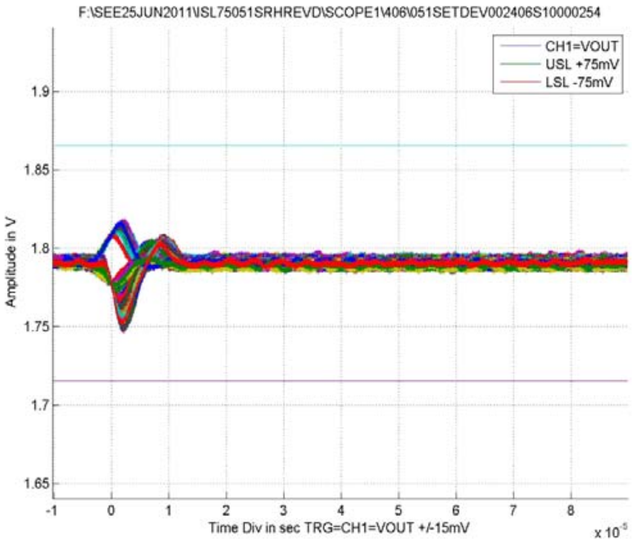


FIGURE 19. TYPICAL CAPTURE AT V_{IN} = 2.2V, RUN 406

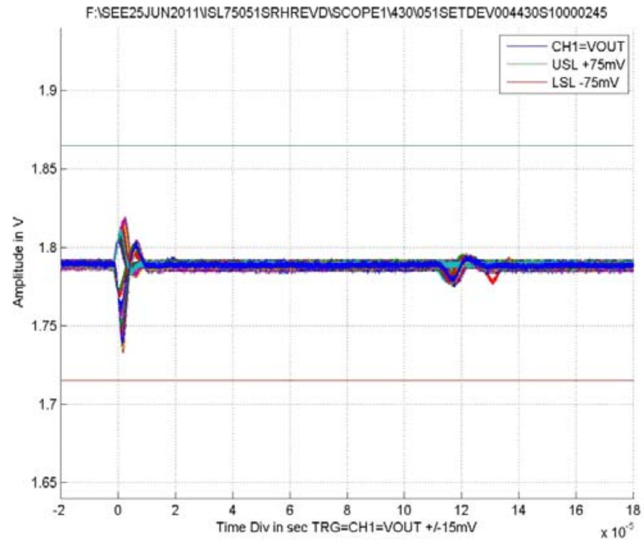


FIGURE 20. TYPICAL CAPTURE AT V_{IN} = 2.2V, RUN 430 (Note 8)

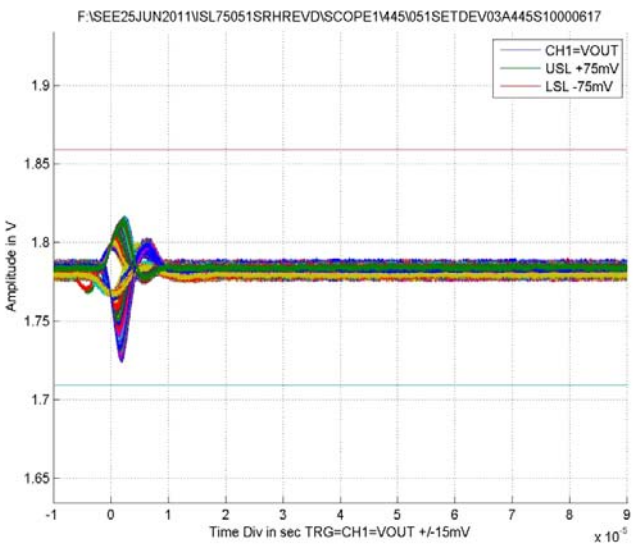


FIGURE 21. TYPICAL CAPTURE AT V_{IN} = 2.2V, RUN 445

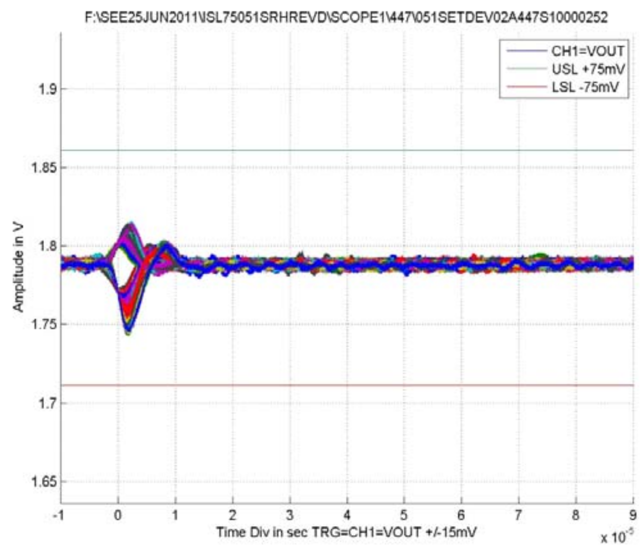


FIGURE 22. TYPICAL CAPTURE AT V_{IN} = 2.2V, RUN 447

Typical SET Captures at I_{OUT} = 3A (Note 7, 8, 10) (Continued)

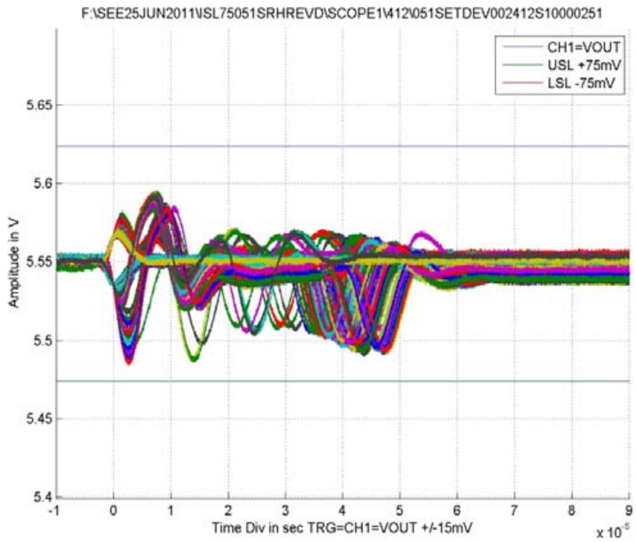


FIGURE 23. TYPICAL CAPTURES AT V_{IN} = 6.0V, RUN 412

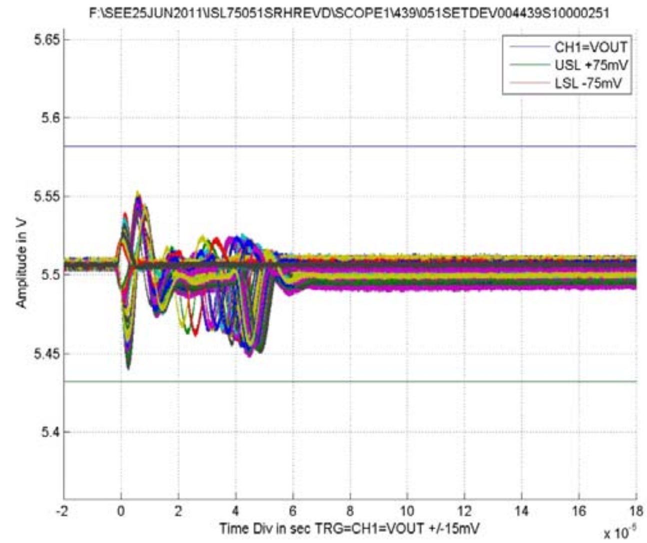


FIGURE 24. TYPICAL CAPTURES AT V_{IN} = 6.0V, RUN 439 (Note 8)

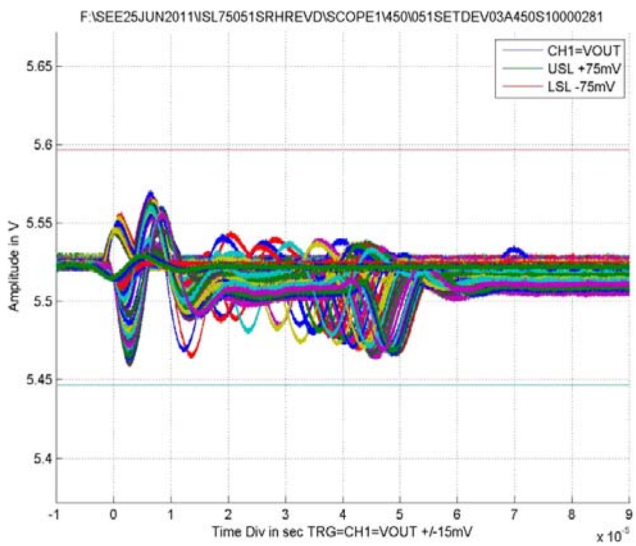


FIGURE 25. TYPICAL CAPTURE AT V_{IN} = 6.0V, RUN 450

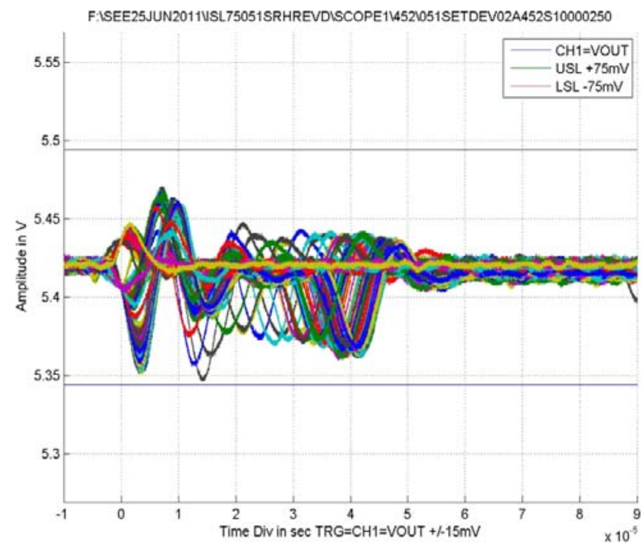
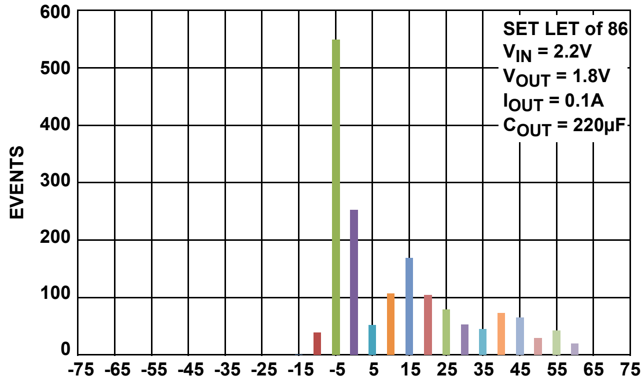


FIGURE 26. TYPICAL CAPTURE AT V_{IN} = 6.0V, RUN 452

NOTE:

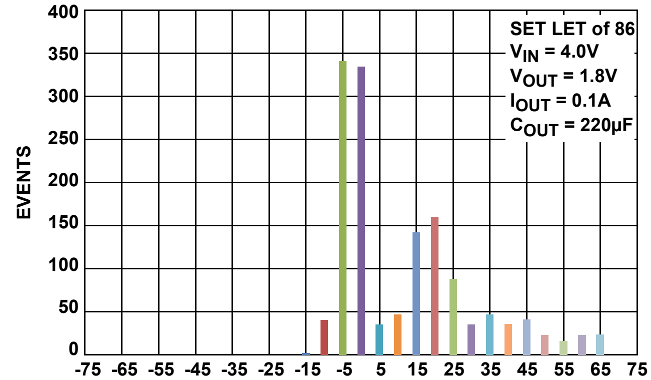
10. The waveforms signature observed in Figures 19 through 26 is caused by the handoff between main and redundant references during an SET event. This does not affect normal operation of the device.

SET V_{OUT} Histogram Plots for ISL75051SRH (Note 11)



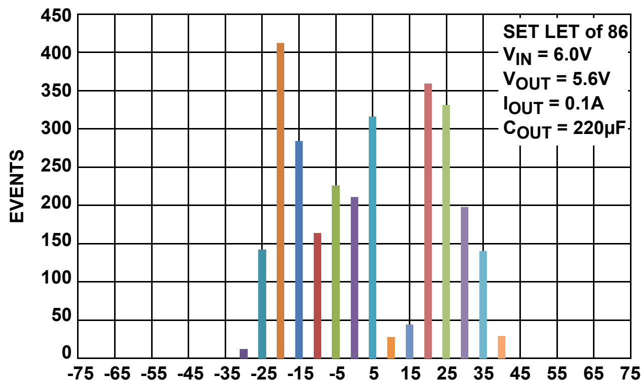
POSITIVE AND NEGATIVE OVERSHOOT IN mV
TOTAL EVENTS = 840, AREA OF CROSS SECTION = 1.05 x $10^{-4}cm^2$

FIGURE 27. V_{IN} = 2.2V at 0.1A



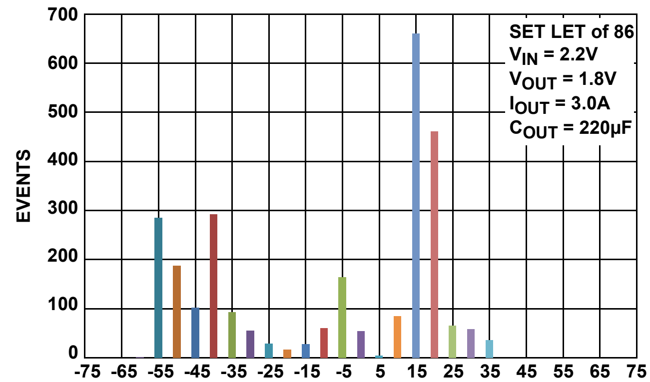
POSITIVE AND NEGATIVE OVERSHOOT IN mV
TOTAL EVENTS = 717, AREA OF CROSS SECTION = 0.89625 x $10^{-4}cm^2$

FIGURE 28. V_{IN} = 4.0V at 0.1A



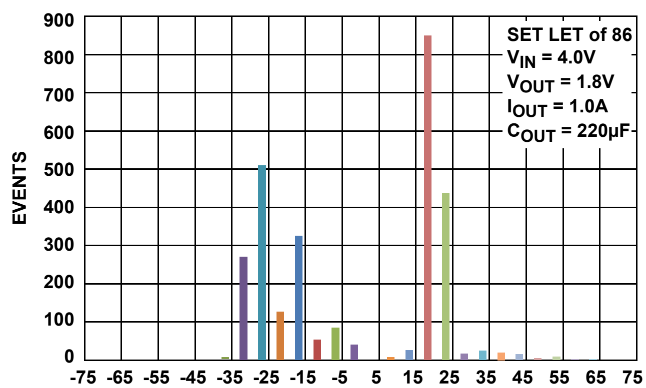
POSITIVE AND NEGATIVE OVERSHOOT IN mV
TOTAL EVENTS = 1448, AREA OF CROSS SECTION = 1.81 x $10^{-4}cm^2$

FIGURE 29. V_{IN} = 6.0V at 0.1A



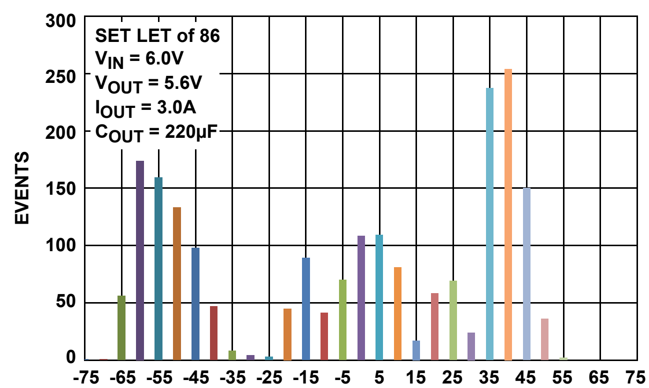
POSITIVE AND NEGATIVE OVERSHOOT IN mV
TOTAL EVENTS = 1372, AREA OF CROSS SECTION = 1.715 x $10^{-4}cm^2$

FIGURE 30. V_{IN} = 2.2V at 3.0A



POSITIVE AND NEGATIVE OVERSHOOT IN mV
TOTAL EVENTS = 1411, AREA OF CROSS SECTION = 1.76375 x $10^{-4}cm^2$

FIGURE 31. V_{IN} = 4.0V at 1.0A



POSITIVE AND NEGATIVE OVERSHOOT IN mV
TOTAL EVENTS = 1037, AREA OF CROSS SECTION = 1.29625x $10^{-4}cm^2$

FIGURE 32. V_{IN} = 6.0V at 3.0A

NOTE:

11. Oscilloscope set to trigger to V_{OUT} window of ±15mV over the nominal V_{OUT} value. The two peaks represent positive and negative transients.

TABLE 5. DETAILS OF SEB/L TESTS

TEMP (°C)	LET ($MeV.cm^2/mg$)	BYP CAP (µF)	VDD (V)	LATCH EVENTS	CUMULATIVE FLUENCE ($PARTICLES/cm^2$)	CUMULATIVE CROSS SECTION (cm^2)	DEVICE	SEB/L
125	86	0.2	7.1	0	$2.0 \times 10^{+6}$	5.0×10^{-7}	1	PASS
125	86	0.2	7.1	0	$2.0 \times 10^{+6}$	5.0×10^{-7}	2	PASS
125	86	0.2	7.1	0	$2.0 \times 10^{+6}$	5.0×10^{-7}	3	PASS
125	86	0.2	7.1	0	$2.0 \times 10^{+6}$	5.0×10^{-7}	4	PASS
			TOTAL EVENTS	0				
				OVERALL FLUENCE	$8.0 \times 10^{+6}$			
					OVERALL CROSS SECTION	1.25×10^{-7}		
						TOTAL UNITS	4	

Die Map and Mask Number

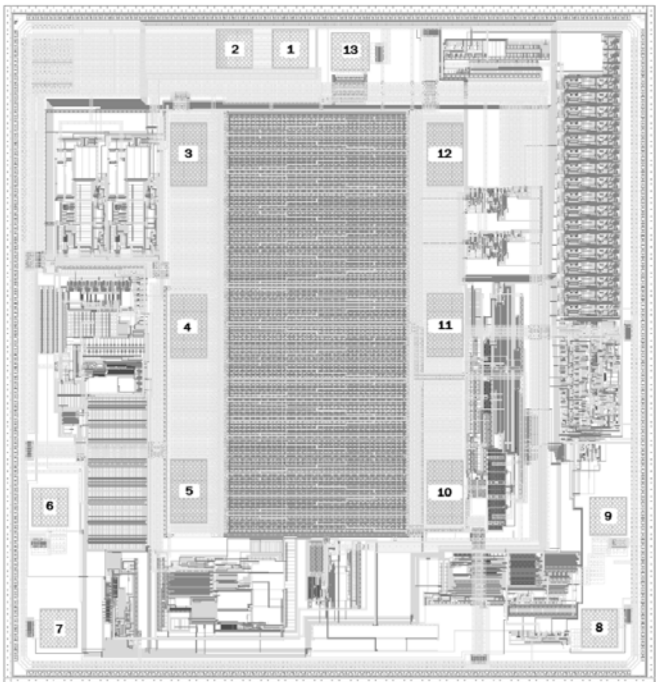


FIGURE 33. ISL75051SRH DIE MAP

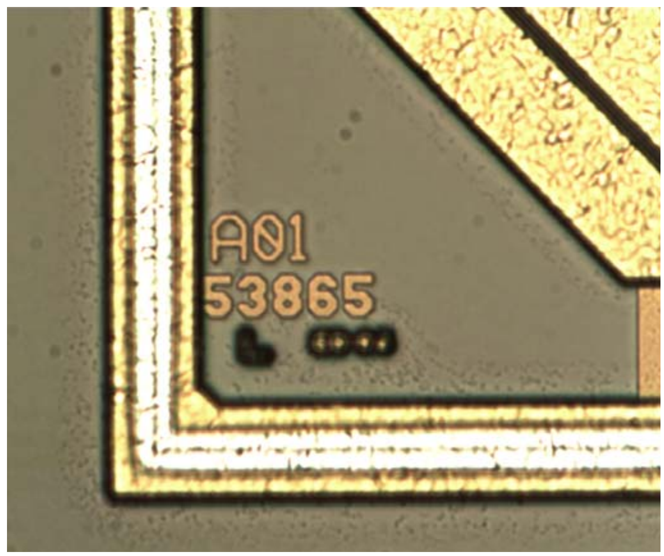


FIGURE 34. ISL75051SRH MASK NUMBER

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