SAND REPORT

SAND2002-0248
Unlimited Release
Printed January 2002

Semiconductor Bridge Cable Tests

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Abstract

The semiconductor bridge (SCB) is an electroexplosive device used to initiate detonators. A C cable is commonly used to connect the SCB to a firing set. A series of tests were performed to identify smaller, lighter cables for firing single and multiple SCBs. This report provides a description of these tests and their results. It was demonstrated that lower threshold voltages and faster firing times can be achieved by increasing the wire size, which reduces ohmic losses. The RF 100 appears to be a reasonable substitute for C cable when firing single SCBs. This would reduce the cable volume by 68% and the weight by 67% while increasing the threshold voltage by only 22%. In general, RG 58 outperforms twisted pair when firing multiple SCBs in parallel. The RG 58's superior performance is attributed to its larger conductor size.

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Semiconductor Bridge Cable Tests

Introduction

The semiconductor bridge (SCB) is an electroexplosive device used to initiate detonators. A C cable is commonly used to connect the SCB to a firing set (FS). A series of tests were performed to identify smaller, lighter cables for firing single and multiple SCBs. The eight cables tested are listed in order of decreasing size in Table 1. The MC4491/MC4492 firing set was used. It is a 50 µF capacitive discharge unit (CDU). Firing times were measured using photodetectors. The following is a description of the tests and their results.

Table 1. Cables tested

Cable	Part #	Manufacturer	AWG	OD (in)	lbs/1000 ft
C	167-2669	Reynolds Ind.	16	0.195	30
RG 58	88240	Belden Inc.	20	0.159	27
Twisted Pair	1292C	Alpha Wire Co.	22	0.17	14
RG 405	1671J	Belden Inc.	24	0.127	16
RF 100	7805R	Belden Inc.	25	0.110	10
RG 174	8216	Belden Inc.	26	0.110	8.4
RG 188	83269	Belden Inc.	26	0.108	10
RG 316	83284	Belden Inc.	26	0.098	10

Tests Performed

C Cable Threshold Voltage Test

The objective of this test was to measure the threshold voltage for firing a single SCB connected by 65 ft of C cable, as shown in Figure 1. For the purposes of this study, the threshold voltage is defined as the CDU voltage required to burst the SCB. The Neyer statistical program was employed to determine threshold voltages using experimental data. Table 2 shows that the threshold voltages are 18.5 V for the SCB32B1 and 14.5 V for the SCB50B1. The SCB50B1's lower threshold voltage is due to its smaller bridge dimensions.

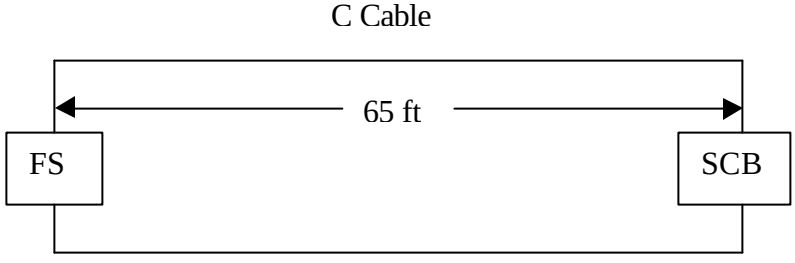

Figure 1. Layout for C cable test

Table 2. Threshold voltage test using C cable

SCB Type	V_{in} (V)	Fired?
SCB32B1	10	No
SCB32B1	15	No
SCB32B1	15	No
SCB32B1	17	No
SCB32B1	18	No
SCB32B1	19	Yes
SCB32B1	20	Yes
SCB32B1	22	Yes
SCB32B1	24	Yes
SCB32B1	24	Yes
SCB50B1	6	No
SCB50B1	10	No
SCB50B1	10	No
SCB50B1	12	No
SCB50B1	13	No
SCB50B1	14	No
SCB50B1	15	Yes
SCB50B1	17	Yes
SCB50B1	19	Yes
SCB50B1	20	Yes

Parallel SCB Test

The objective of this test was to determine how many SCBs fire when connected in parallel using RG 58 or twisted pair, as illustrated in Figure 2. Both SCB32B1s and SCB50B1s were used in sets of four and eight with the CDU charged to 30, 40 and 50 V, as shown in Table 3. Using four SCBs, the RG 58 outperformed the twisted pair at 30 V. Using eight SCBs, the RG 58 consistently outperformed the twisted pair. The SCBs that failed to fire were always the ones furthest from the CDU. The SCBs that fired did so sequentially. The numbers on the output current waveforms in Figure 3 identify the sequence in which the SCBs fired. Table 4 shows that the firing times are shorter for RG 58 than for the twisted pair.

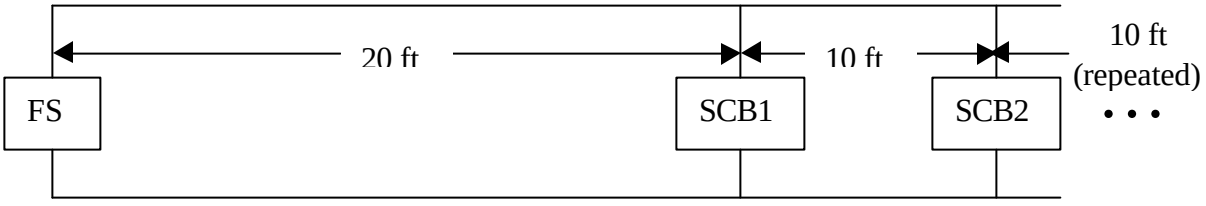

Figure 2. Layout for parallel SCB test

Table 3. Firing test for parallel SCBs

Cable	# SCBs	V_{in} (V)	SCB Type	# Fired	Comments
RG-58	4	50	SCB32B1	4	
RG-58	4	50	SCB50B1	4	
RG-58	4	40	SCB32B1	4	
RG-58	4	40	SCB50B1	4	
RG-58	4	30	SCB32B1	1	Last 3 SCBs still at 1 O.
RG-58	4	30	SCB50B1	4	
RG-58	8	50	SCB32B1	3	Last 5 SCBs still at 1 O.
RG-58	8	50	SCB50B1	6	Last 2 SCBs still at 1 O.
RG-58	8	40	SCB32B1	2	Last 6 SCBs still at 1 O.
RG-58	8	40	SCB50B1	3	Last 5 SCBs still at 1 O.
RG-58	8	30	SCB32B1	1	Last 7 SCBs still at 1 O.
RG-58	8	30	SCB50B1	2	Last 6 SCBs still at 1 O.
Twisted Pair	4	50	SCB32B1	4	
Twisted Pair	4	50	SCB50B1	4	
Twisted Pair	4	40	SCB32B1	4	
Twisted Pair	4	40	SCB50B1	4	
Twisted Pair	4	30	SCB32B1	0	All 4 SCBs still at 1 O.
Twisted Pair	4	30	SCB50B1	3	Last SCB still at 1 O.
Twisted Pair	8	50	SCB32B1	2	Last 6 SCBs still at 1 O.
Twisted Pair	8	50	SCB50B1	3	Last 5 SCBs still at 1 O.
Twisted Pair	8	40	SCB32B1	1	Last 7 SCBs still at 1 O.
Twisted Pair	8	40	SCB50B1	2	Last 6 SCBs still at 1 O.
Twisted Pair	8	30	SCB32B1	0	All 8 SCBs still at 1 O.
Twisted Pair	8	30	SCB50B1	1	Last 7 SCBs still at 1 O.

Table 4. Firing times for four parallel SCB32B1s using 50 V input

SCB #	Firing Times (μs)	
	RG 58	Twisted Pair
1	8	10
2	15	24
3	25	35
4	47	53

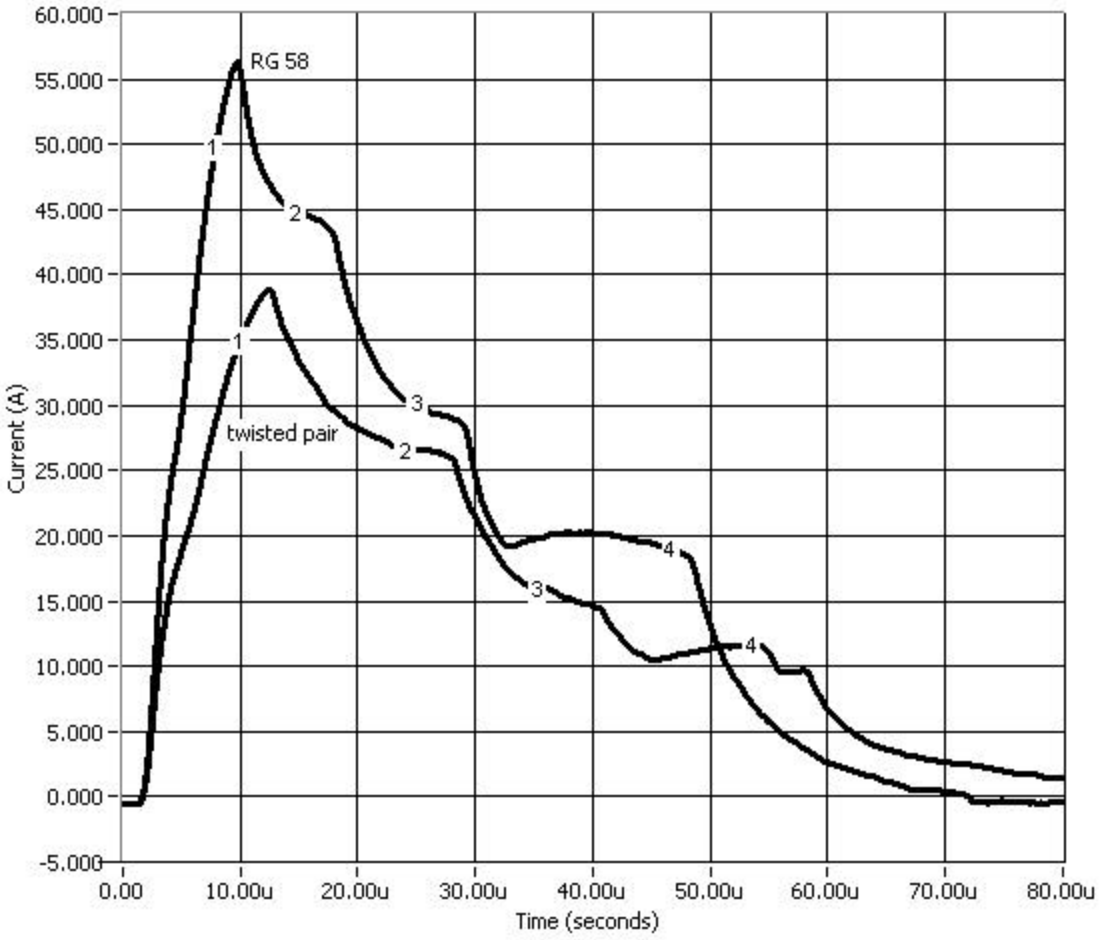

Figure 3. Current for four parallel SCB32B1s using 50 V input

Cable Length Test

The objective of this test was to determine which 40 ft cables will permit a single SCB32B1 or SCB50B1 to fire with the CDU charged to 40 V, as shown in Figure 4. The SCBs fired for all five cables tested, as summarized in Table 5. The SCBs fired near the current peak for RG 58 and on the falling edge for RG 405, RG 316, RG 188 and RG 174, as shown by the "x" on the waveforms in Figures 5 and 6. Table 6 indicates that the firing time decreases with increasing wire size.

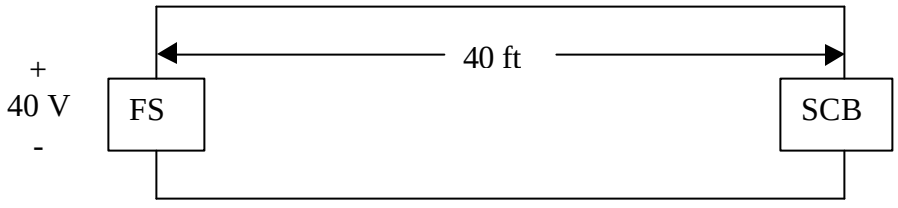

Figure 4. Layout for cable length test

Table 5. Cable length test

Cable	SCB Type	Fired?
RG 58	SCB32B1	Yes
RG 58	SCB50B1	Yes
RG 174	SCB32B1	Yes
RG 174	SCB50B1	Yes
RG 316	SCB32B1	Yes
RG 316	SCB50B1	Yes
RG 188	SCB32B1	Yes
RG 188	SCB50B1	Yes
RG 405	SCB32B1	Yes
RG 405	SCB50B1	Yes

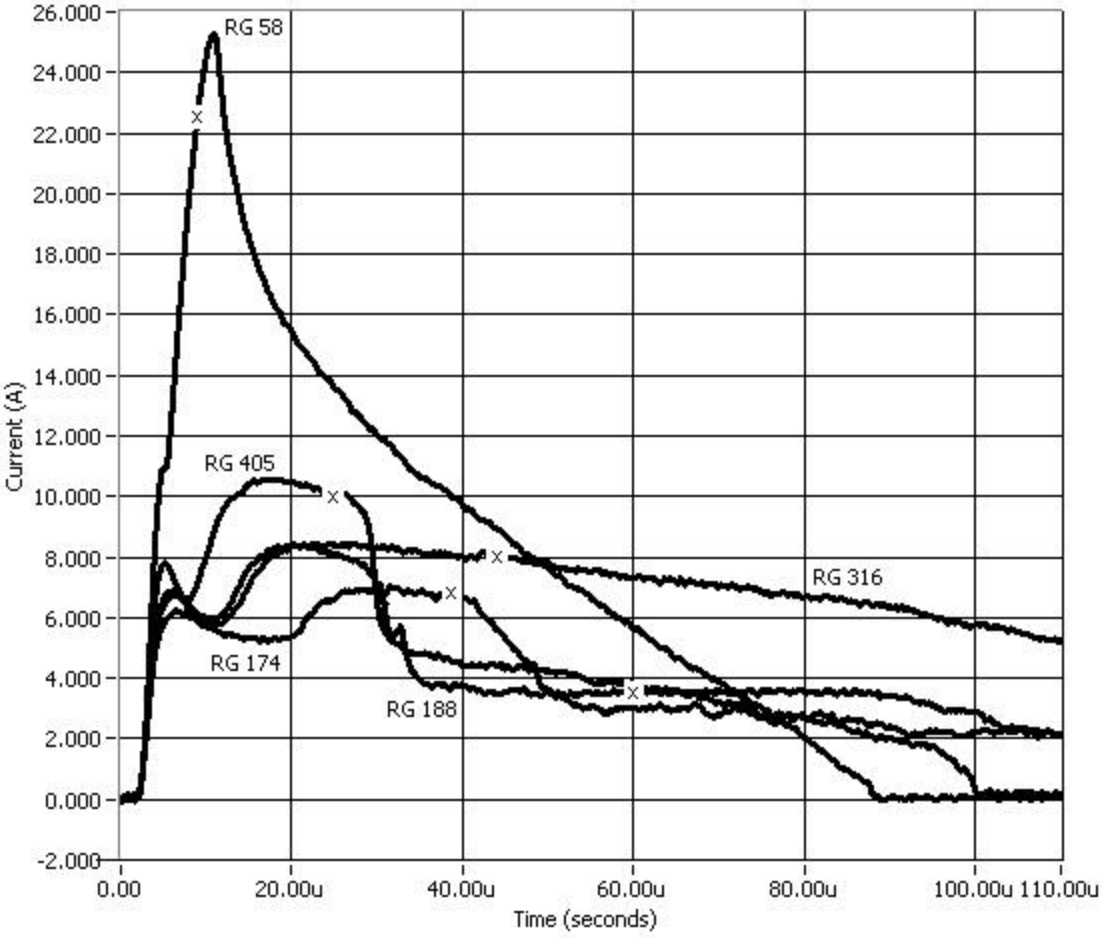

Figure 5. Current for an SCB32B1 using 40 ft cables

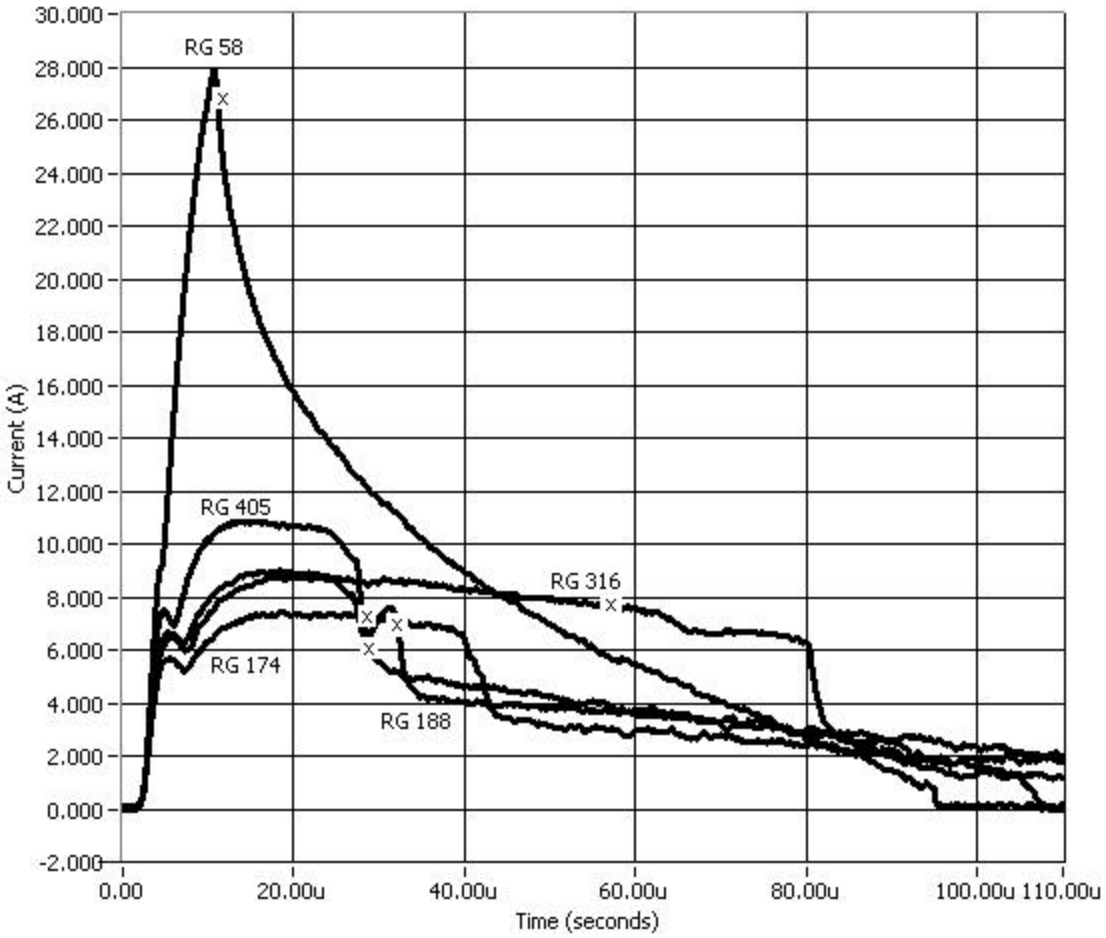

Figure 6. Current for an SCB50B1 using 40 ft cables

Table 6. Firing times using 40 ft cables

Cable	AWG	Firing Times (µs)	
		SCB32B1	SCB50B1
RG 58	20	9	11
RG 405	24	25	29
RG 174	26	39	29
RG 316	26	43	57
RG 188	26	60	32

Parallel/Series Test

The objective of this test was to determine how many SCBs fire when connected in a parallel/series configuration with the CDU charged to 40 V, as illustrated in Figure 7. Table 7 shows that, of the five cables used in the Cable Length Test, only the RG 58 connecting

SCB50B1s fired all four SCBs. This is also the case that produced the shortest range of firing times (see Table 8 and Figure 8).

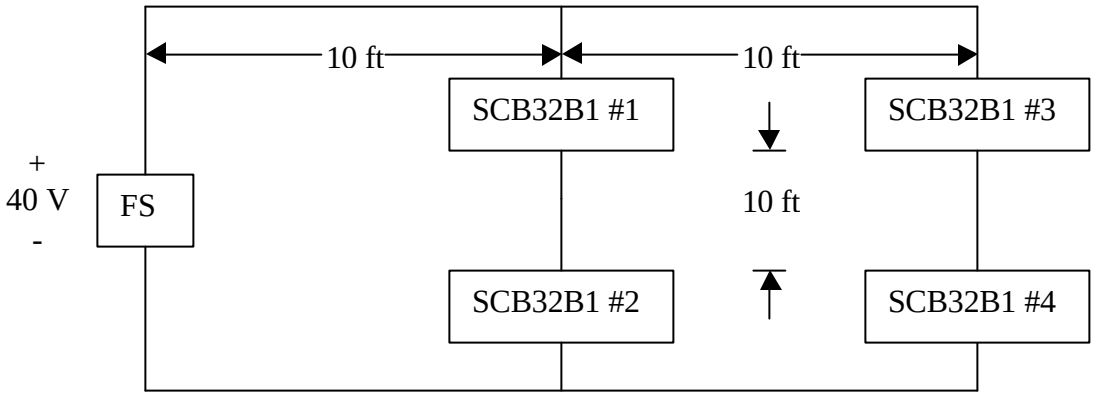

Figure 7. Layout for parallel/series test

Table 7. Firing tests using four SCBs in parallel/series combination

Cable	SCB Type	# Fired	Comments
RG 58	SCB32B1	2	SCB1 at 1.2 ohms. SCB3 at 3.5 O.
RG 58	SCB50B1	4	
RG 174	SCB32B1	0	All 4 SCBs still at 1 O.
RG 174	SCB50B1	2	SCB1 & 3 still at 1 O.
RG 316	SCB32B1	1	SCB1, 2 & 4 still at 1 O.
RG 316	SCB50B1	2	SCB2 at 4.1 ohms. SCB3 at 2.1 O.
RG 188	SCB32B1	0	All 4 SCBs still at 1 O.
RG 188	SCB50B1	2	SCB1 at 1.7 ohms. SCB4 at 16.8 O.
RG 405	SCB32B1	2	SCB2 & 4 still at 1 O.
RG 405	SCB50B1	2	SCB2 & 4 still at 1 O.

Table 8. Firing times for a parallel/series combination of SCBs using RG 58

SCB #	Firing Times (µs)	
	SCB32B1	SCB50B1
1	NA	13
2	11	13
3	NA	15
4	23	17

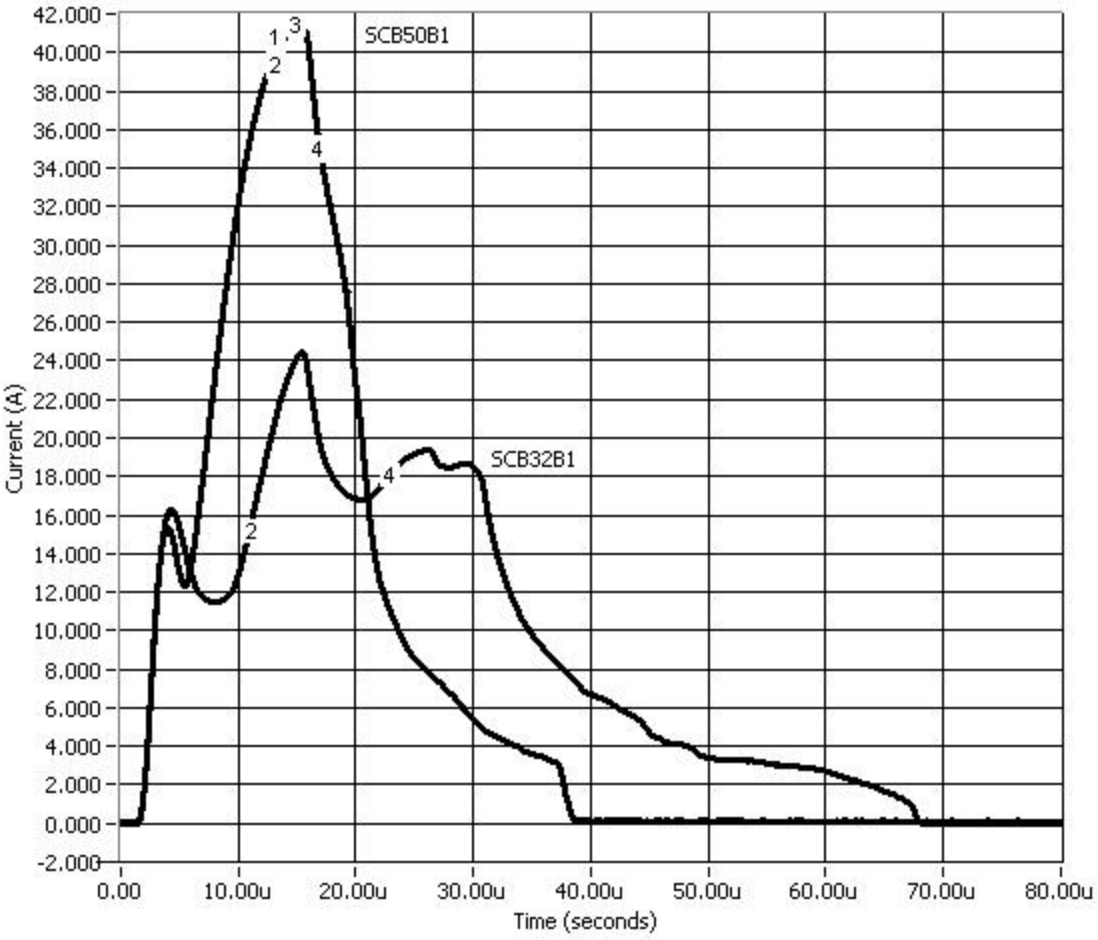

Figure 8. Current for a parallel/series combination of SCBs using RG 58

RG 316 Threshold Voltage Test

The objective of this test was to measure the threshold voltage for firing a single SCB32B1 connected by 40 ft of RG 316, as shown in Figure 9. Table 9 indicates that the threshold voltage is 33.9 V.

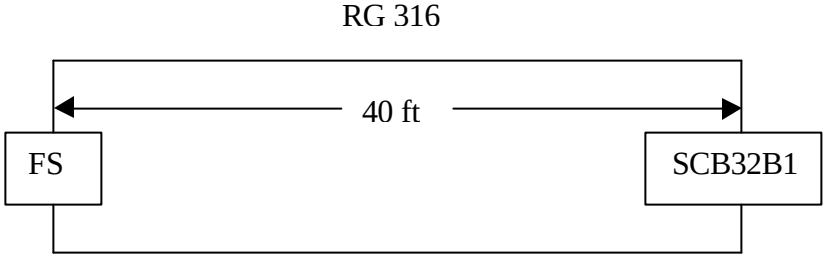

Figure 9. Layout for RG 316 threshold voltage test

Table 9. Threshold voltage test for an SCB32B1 using RG 316

V_{in} (V)	Fired?	Comments
25	No	SCB still at 1 O.
25	No	SCB still at 1 O.
27	No	SCB still at 1 O.
28	No	SCB still at 1 O.
29	No	SCB still at 1 O.
30	No	SCB still at 1 O.
30	No	SCB still at 1 O.
31	No	SCB still at 1 O.
31	Yes	
31	Yes	
35	No	SCB still at 1 O.
37	No	SCB still at 1 O.
38	Yes	
39	Yes	
39	Yes	
40	Yes	
40	Yes	
40	Yes	
40	Yes	
45	Yes	

RG 316 Parallel Test

The objective of this test was to determine whether a pair of SCBs will fire when connected in parallel with RG 316, as illustrated in Figure 10. Three SCB types (SCB32B1, SCB50B1 and SCB32B50) were used with the CDU charged to 40 and 50 V. The SCB32B50 is a nominal 50 O version of the SCB32B1. Table 10 shows that only the SCB50B1 pair using 50 V fired successfully. This is because it has a lower threshold voltage than the SCB32B1 and a lower resistance than the SCB32B50. There was a delay between firings, with SCB1 firing at 46 µs and SCB2 firing at 79 µs as indicated on the current waveform in Figure 11.

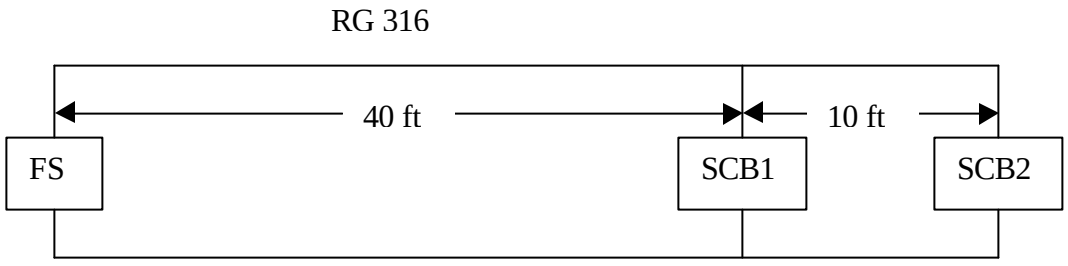

Figure 10. Layout for RG 316 parallel test

Table 10. Firing test for parallel pair of SCBs using RG 316

SCB Type	V_{in} (V)	# Fired	Comments
SCB32B1	40	0	Both SCBs still at 1 O.
SCB32B1	50	1	Last SCB still at 1 O.
SCB50B1	40	1	Last SCB still at 1 O.
SCB50B1	50	2	
SCB32B50	40	0	Both SCBs still at 63 O.
SCB32B50	50	1	Last SCB still at 63 O.

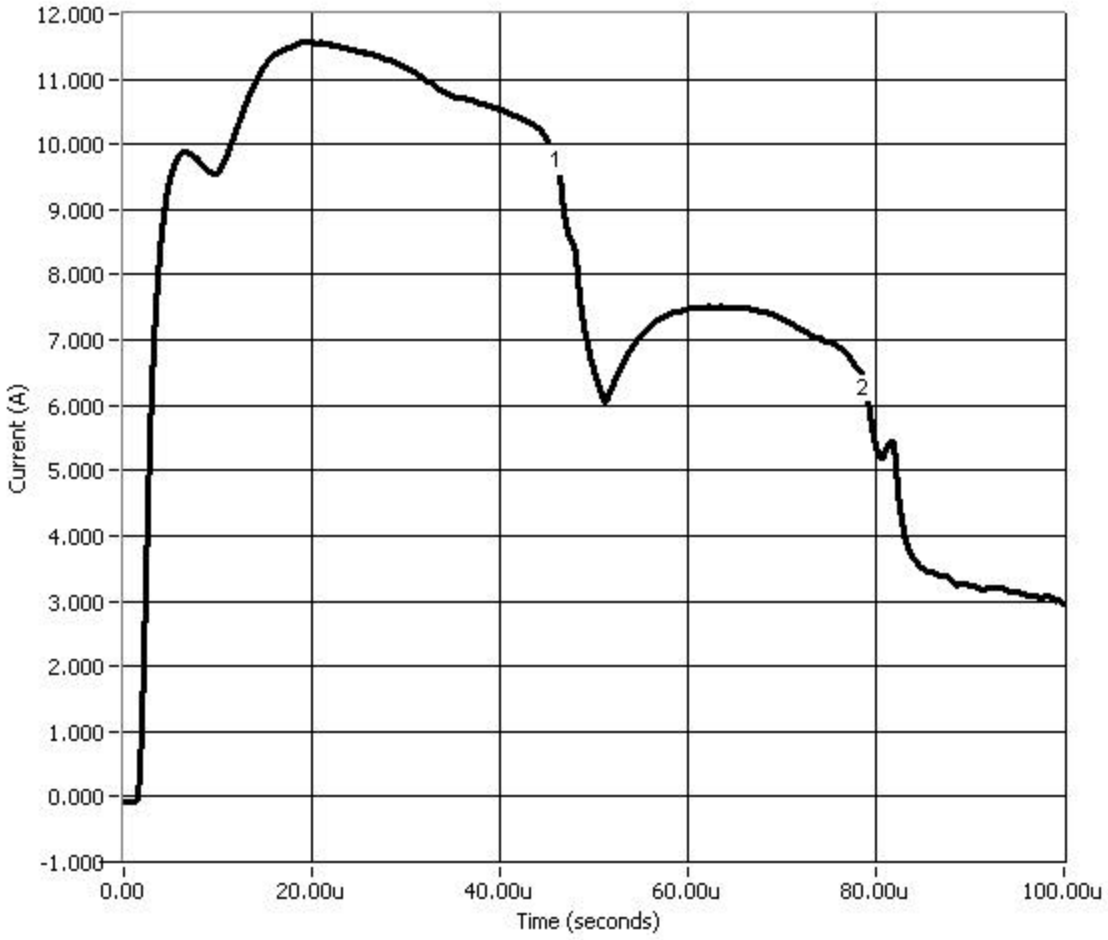

Figure 11. Current for a parallel pair of SCB50B1s using RG 316 and 50 V input

RG 316 Series Test

The objective of this test was to determine whether a pair of SCB32B1s fire when connected in series with RG 316, as shown in Figure 12. The CDU was charged to 40 and 50 V. Table 11 indicates that only the pair using 50 V fired successfully. As in the parallel test, there is a delay between firings in Figure 13, with SCB2 firing at 62 µs and SCB1 firing at 66 µs. It was possible for SCB1 to fire 4 µs after SCB2 began to burst because SCB2 fired for 5 µs.

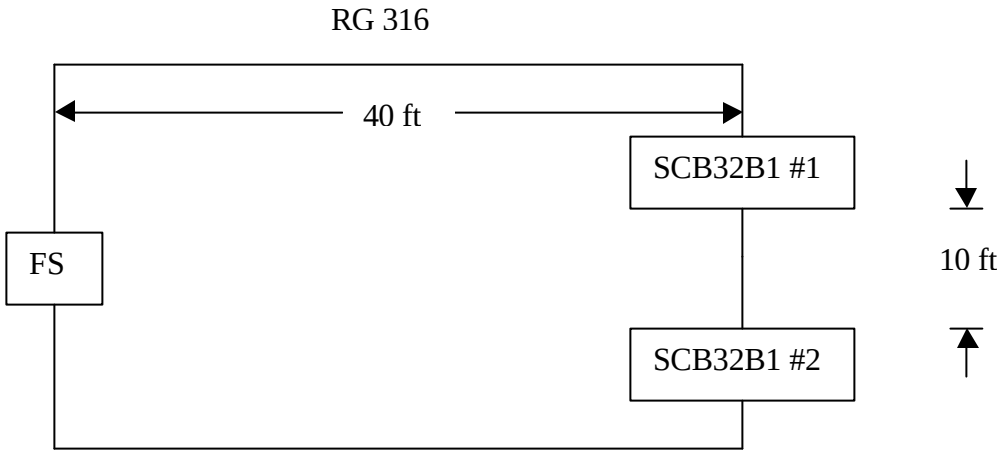

Figure 12. Layout for RG 316 series test

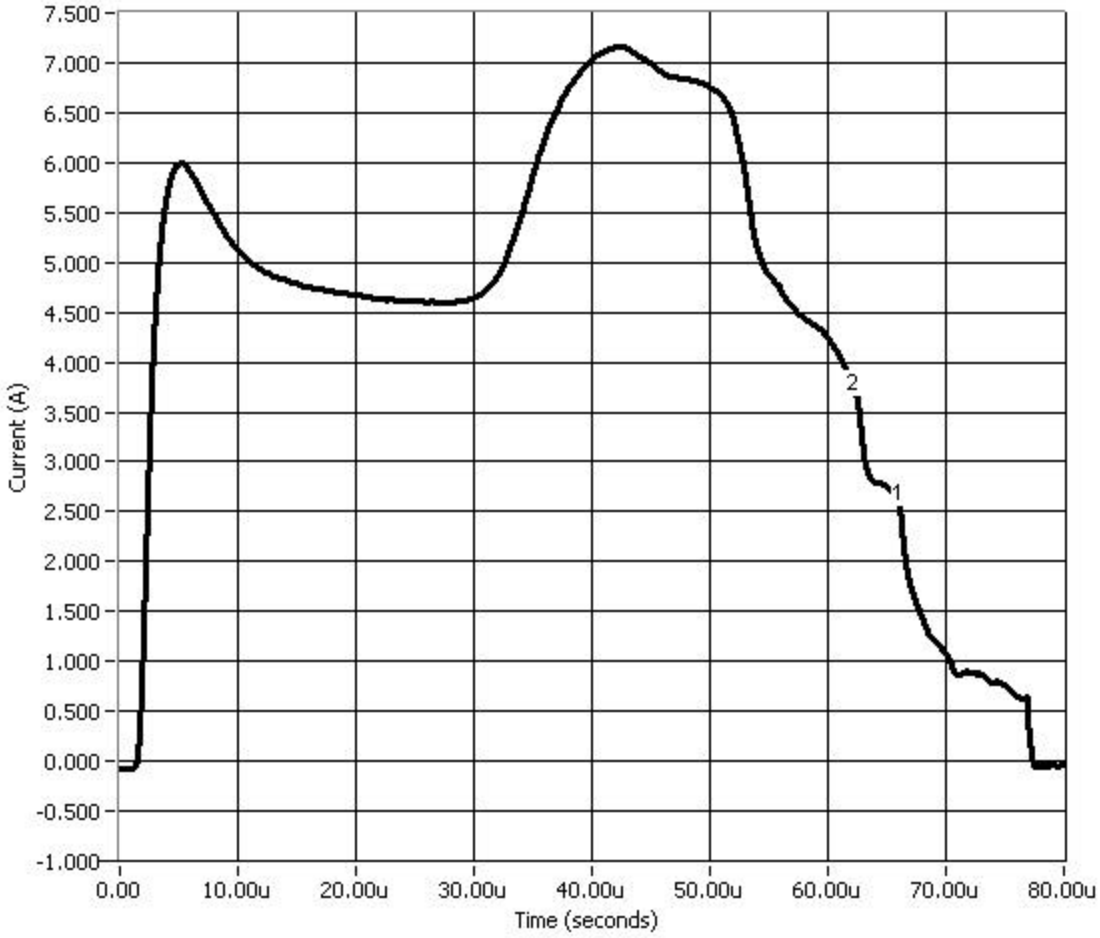

Figure 13. Current for a series pair of SCB32B1s using RG 316 and 50 V input

Table 11. Firing test for series pair of SCB32B1s using RG 316

V_{in} (V)	# Fired	Comments
40	0	Both SCBs still at 1 O.
50	2	

RF 100 Threshold Voltage Test

The objective of this test was to measure the threshold voltage for firing a single SCB32B1 connected by 40 ft of RF 100 as illustrated in Figure 14. Table 12 shows that the threshold voltage is 22.5 V.

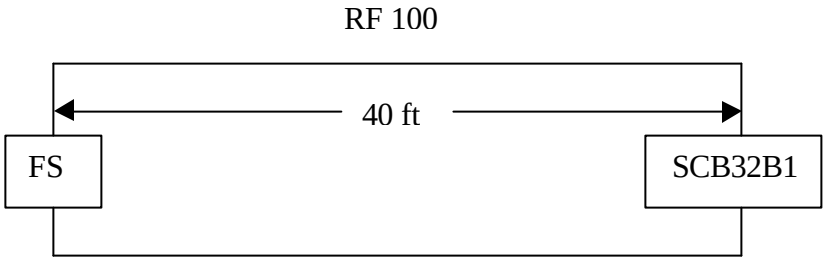

Figure 14. Layout for RF 100 threshold voltage test

Table 12. Threshold voltage test for an SCB32B1 using RF 100

V_{in} (V)	Fired?	Comments
15	No	SCB still at 1 O.
16	No	SCB still at 1 O.
18	No	SCB still at 1 O.
20	No	SCB still at 1 O.
20	No	SCB still at 1 O.
22	No	SCB still at 1 O.
23	Yes	
25	Yes	
26	Yes	
29	Yes	

Summary

Single SCBs

1. The firing time decreases with increasing wire size.
2. Table 13 lists the cables in order of increasing threshold voltage for the SCB32B1.

Table 13. SCB32B1 threshold voltages

Cable	AWG	Length (ft)	V_{in} (V)
C	16	65	18.5
RF 100	25	40	22.5
RG 316	26	40	33.9

Multiple SCBs

1. In no case did all eight SCBs fire when connected in parallel.
2. Four SCBs connected in parallel fire sequentially.
3. In only one case out of ten did all four SCBs fire in the parallel/series configuration. In this case, they all fired within a 4 µs time span.
4. In only one case out of six did two SCBs fire when connected in parallel using RG 316. Even then, they did so sequentially.
5. Firing two SCB32B1s connected in series using RG 316 required a CDU voltage exceeding 40 V. In this case they fired sequentially.

Conclusion

Lower threshold voltages and faster firing times can be achieved by increasing the wire size, which reduces ohmic losses. The RF 100 appears to be a reasonable substitute for C cable when firing single SCBs. This would reduce the cable volume by 68% and the weight by 67% while increasing the threshold voltage by only 22%. Figure 15 indicates that the firing time increases from 9.4 µs to 11.6 µs when the CDU is charged to 40 V.

In only one case did multiple SCBs all fire within a time span of a few microseconds (four SCB50B1s in the parallel/series configuration using RG 58). In general, RG 58 outperforms twisted pair when firing multiple SCBs in parallel. The RG 58's superior performance is attributed to its larger conductor size.

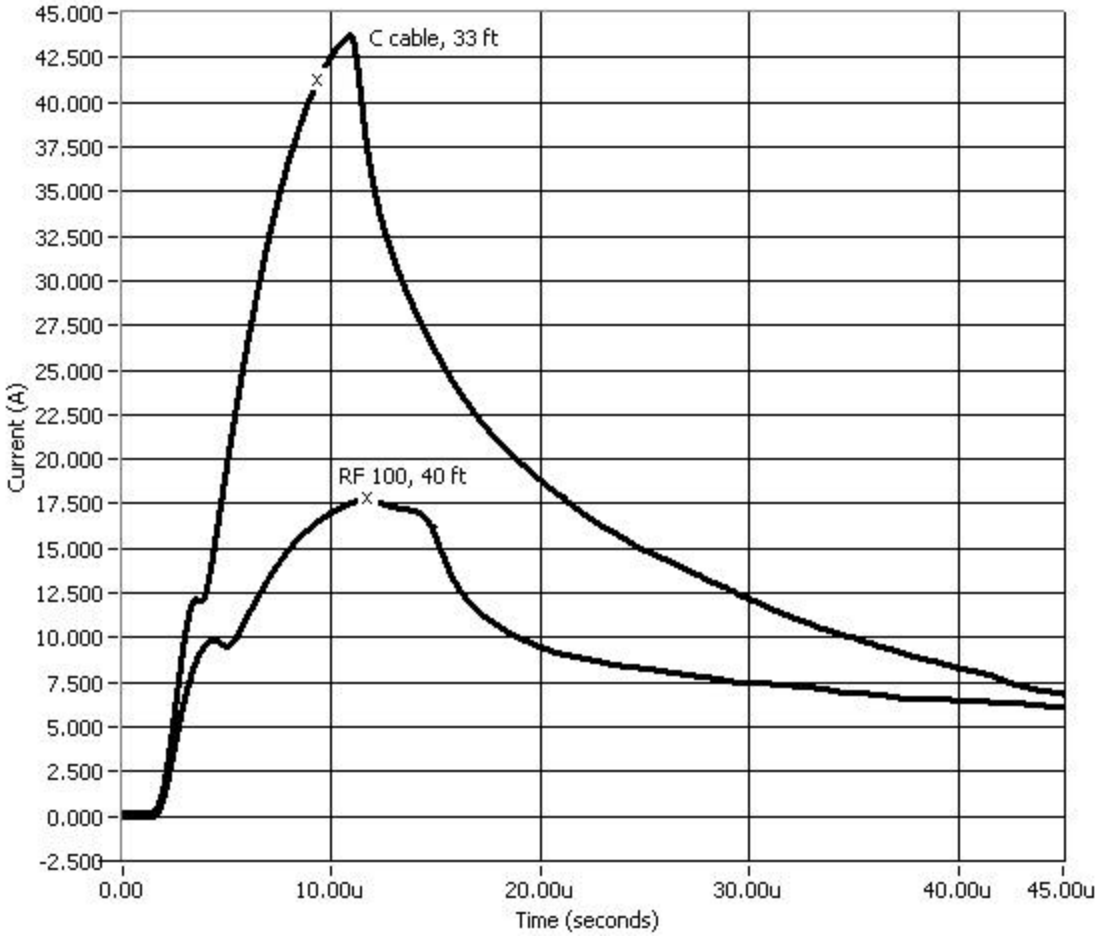

Figure 15. Current for an SCB32B1 using 40 V input

Distribution:

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