ISU Compact Plasma Radiation Source with X-Pinch Load

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IAC
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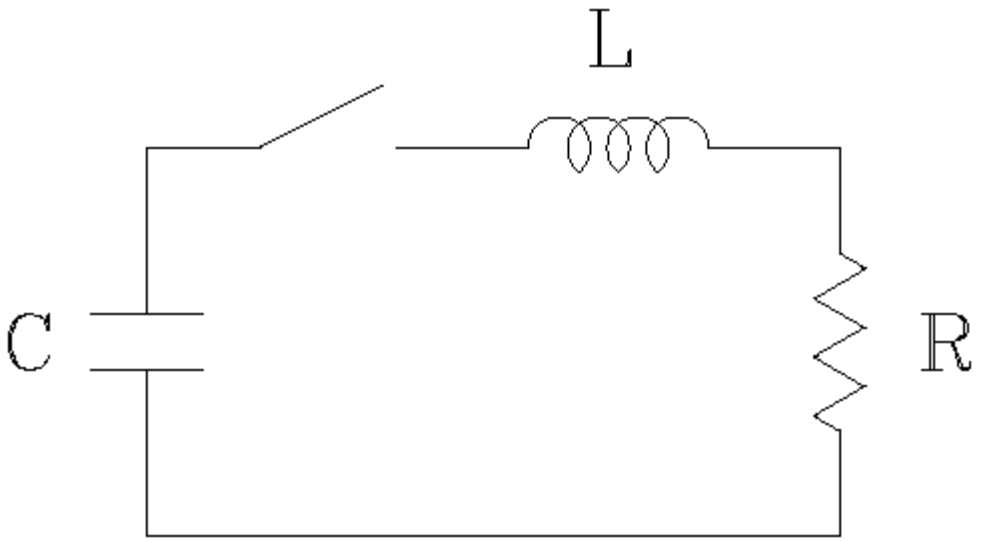
LRC circuit analysis*



$$L\,d^2i/d^2t + R\,di/dt + i/C = 0$$

"Damped"

$$R = \sqrt{L/C}$$

$$v_{peak} = 0.546293\,V_0$$

$$i_{peak} = 0.546293\,V_0/R$$

$$t_{peak} = 1.2092\sqrt{LC}$$

"Critical Damped"

$$R = 2\sqrt{L/C}$$

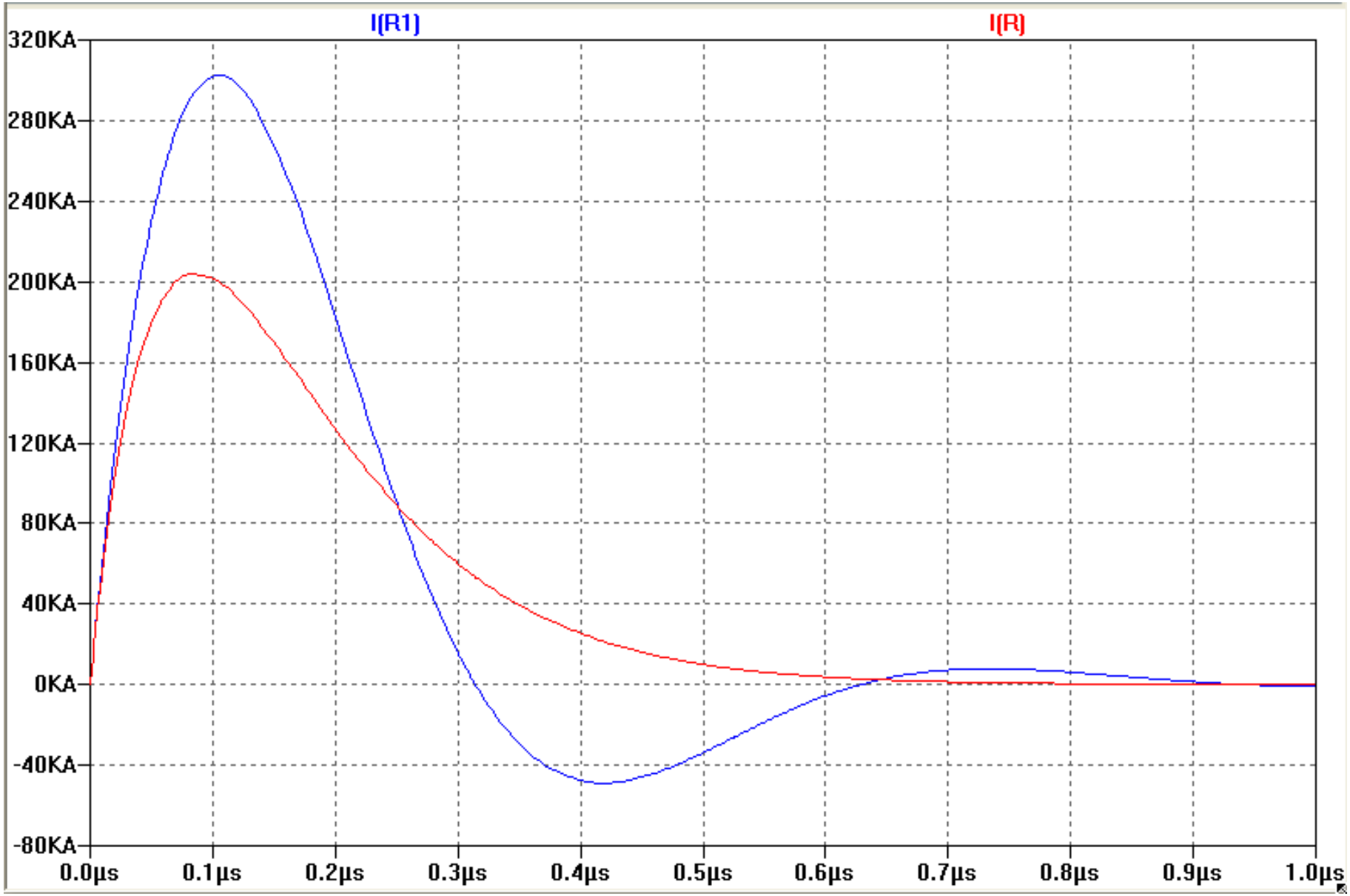
$$v_{peak} = 0.73576\,V_0$$

$$i_{peak} = 0.73576\,V_0/R$$

$$t_{peak} = \sqrt{LC}$$

*M.G.Mazarakis, and R.B.Spielman "A compact, high-voltage E-beam pulser" 1999 IEEE

LRC circuit example: damped vs critical damped



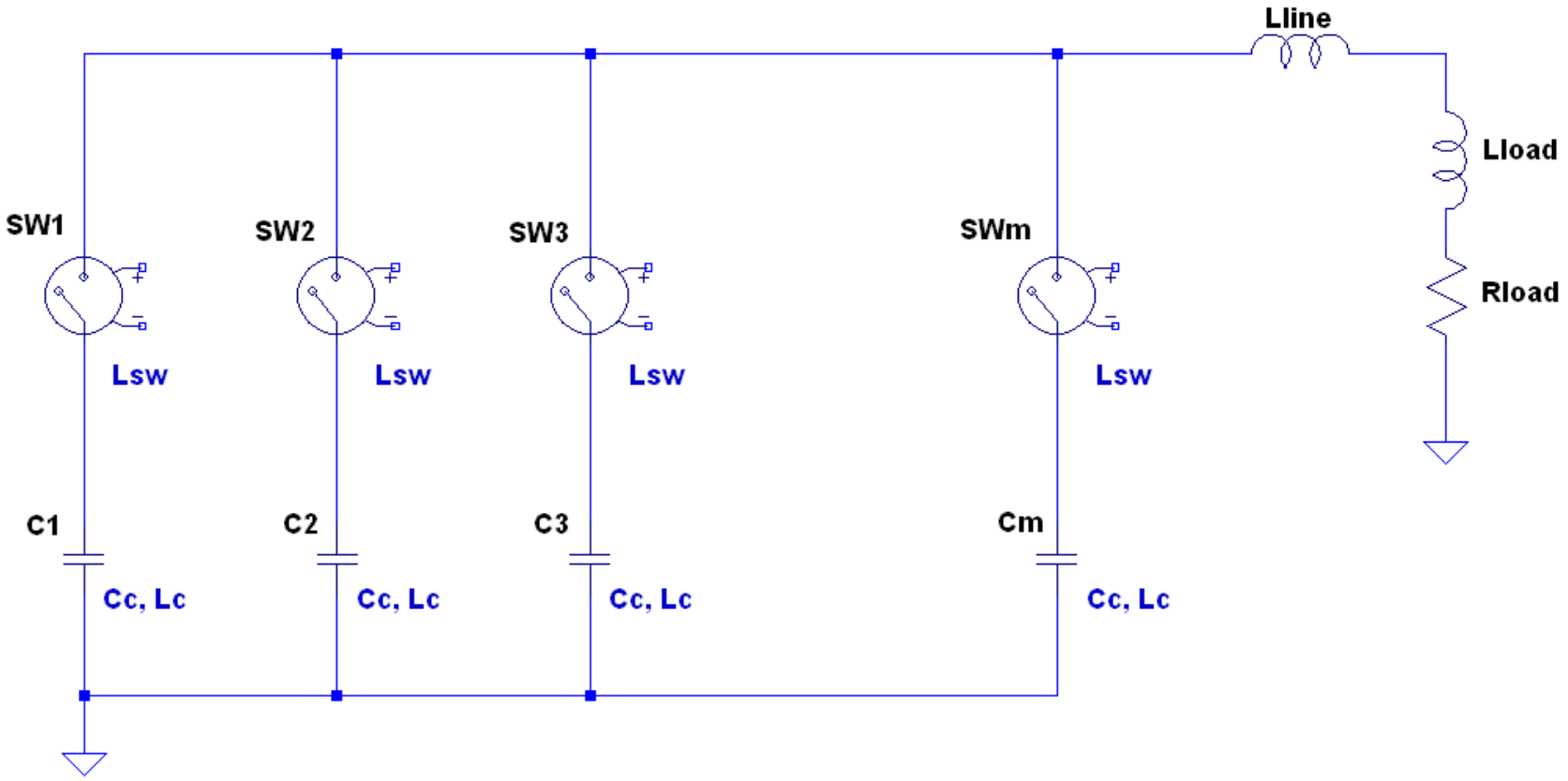
*M.G.Mazarakis, and R.B.Spielman "A compact, high-voltage E-beam pulser" 1999 IEEE

IAC Compact Plasma Radiation Source (CPRS)

X-Pinch

$I_{peak} = 100 - 300\ kA$ $\quad R_{load} = (0.1 - 0.5)\ \Omega$

$rise = 1 - 2\ kA/ns$ $\quad L_{load} = (13 - 20)\ nH$



General Atomics Electronics System: Capacitors*

Series PDS/PDSS - Fast Pulse Capacitors

Double-Ended Plastic Case Capacitors
Low Inductance, Low ESR (0.06 - 0.13 Ω)
Sub-microsecond pulse risetime to 100 kV

Part Number	Cap Rating (nF)	Voltage Rating (kV)	Rated Peak Current (kA)	Rated Voltage Reversal (%)	Design Life (at Rated VR)	Operating Temp Range (^{o}C)	Approx. Inductance (nH)
35460	8	100	25	20	1×10^5	-10 to +40	6
35467	20	100	25	10	1×10^5	-10 to +40	6
35473	40	100	25	10	5×10^4	-10 to +40	10
35479	80	100	25	10	4×10^4	-10 to +40	8
35478	80	100	60	30	5×10^4	-10 to +40	10
35462	100	100	25	10	3.4×10^4	-10 to +40	10
35477	100	100	50	45	5×10^3	-10 to +40	10

*http://www.ga-esi.com/EP/capacitors/series-pds.php

IAC X-Pinch CPRS: Four capacitors 35478

Capacitor 35477: $C_c = 80\,nF,\ L_c = 10\,nH,\ V_0 = 100\,kV,\ I_c = 60\,kA$

Switch: $L_{sw} = 10\,nH$

With 4 such capacitors we can easily design 200 kA, 0.25 Ω generator

$$L = (L_c + L_{sw})/m + L_{load+line} = (10+10)/4 + 15 = 20\,nH$$

$$C_c = m \times C_c = 4 \times 80 = 320\,nF$$

$$R_{load} = \sqrt{L/C} = 0.25\,\Omega$$

Say, we will charge our four capacitors up to $V_0 = 91.5\,kV < 100\,kV$

$$I_{peak} = (0.546293 \times V_0)/R = 200\,kA < 60 \times 4 = 240\,kA$$

$$V_{peak} = 0.546293 \times V_0 = 50\,kV$$

$$t_{peak} = 1.2092 \times \sqrt{LC} = 97\,ns$$

IAC X-Pinch CPRS: Four capacitors 35478

Capacitor 35477: $C_c = 80\,nF,\ L_c = 10\,nH,\ V_0 = 100\,kV,\ I_c = 60\,kA$

Switch: $L_{sw} = 10\,nH$

With 4 such capacitors we can expect

$I_{peak} = 200\,kA$

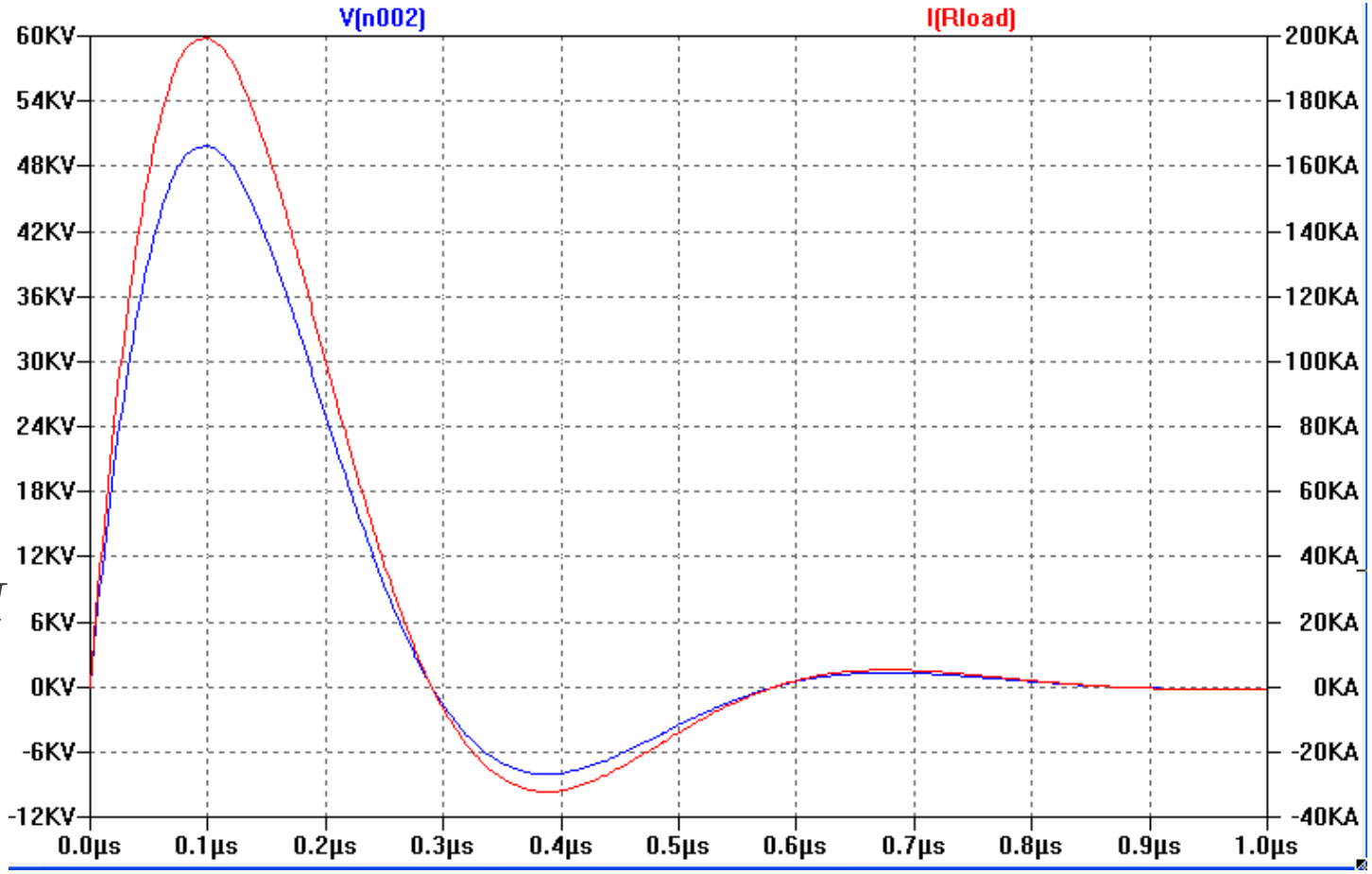
$V_{peak} = 50\,kV$

$t_{peak} = 97\,ns$

$2.06\,kA/ns$

$L_{load+line} = 15\,nH$

$R_{load} = 0.25\,\Omega$



IAC X-Pinch CPRS: less capacitors, more capacitors

Capacitor 35477: $C_c = 80\,nF, L_c = 10\,nH, V_0 = 100\,kV, I_c = 60\,kA$

Switch: $L_{sw} = 10\,nH$

With 2 - 10 such capacitors we can expect:

m	C_C nF	L_C nH	L_{SW} nH	L_{load} nH	V_0, kV	C, nF	L, nH	R, Ω	I_{peak}, kA	V_{peak}, kA	t_{peak}, kA	kA/ns
2	80	10	10	15	86.8	160.0	25.0	0.40	120.0	47.4	76.48	1.57
3	80	10	10	15	99.0	240.0	21.7	0.30	180.0	54.1	87.20	2.06
4	80	10	10	15	100.0	320.0	20.0	0.25	218.5	54.6	96.74	2.26
5	80	10	10	15	100.0	400.0	19.0	0.22	250.7	54.6	105.42	2.38
6	80	10	10	15	100.0	480.0	18.3	0.20	279.5	54.6	113.43	2.46
7	80	10	10	15	100.0	560.0	17.9	0.18	305.9	54.6	120.92	2.53
8	80	10	10	15	100.0	640.0	17.5	0.17	330.4	54.6	127.97	2.58
9	80	10	10	15	100.0	720.0	17.2	0.15	353.2	54.6	134.65	2.62
10	80	10	10	15	100.0	800.0	17.0	0.15	374.8	54.6	141.02	2.66

IAC X-Pinch CPRS: other capacitors

Part Number	Cap Rating (nF)	Voltage Rating (kV)	Rated Peak Current (kA)	Rated Voltage Reversal (%)	Design Life (at Rated VR)	Operating Temp Range (^{o}C)	Approx. Inductance (nH)
35460	8	100	25	20	1×10^5	-10 to +40	6
35467	20	100	25	10	1×10^5	-10 to +40	6
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35479	80	100	25	10	4×10^4	-10 to +40	8
35478	80	100	60	30	5×10^4	-10 to +40	10
35462	100	100	25	10	3.4×10^4	-10 to +40	10
35477	100	100	50	45	5×10^3	-10 to +40	10

Capacitors	m	I_c, kA	C_C nF	L_C nH	L_{SW} nH	L_{load} nH	V_0, kV	R, Ω	I_{peak}, kA	V_{peak}, kA	t_{peak}, kA	kA/ns
35460	4	25	8	6	10	15	100.0	0.77	70.9	54.6	29.82	2.38
35467	4	25	20	6	10	15	90.0	0.49	100.9	49.2	47.14	2.14
35473	4	25	40	10	10	15	65.0	0.35	100.4	35.5	68.40	1.47
35479	4	25	80	8	10	15	45.0	0.25	99.6	24.6	95.52	1.04
35478	4	60	80	10	10	15	100.0	0.25	218.5	54.6	96.74	2.26
35462	4	25	100	10	10	15	41.0	0.22	100.2	22.4	108.15	0.93
35477	4	50	100	10	10	15	82.0	0.22	200.3	44.8	108.15	1.85

IAC X-Pinch CPRS: to do list

Almost all designs satisfy condition > 1 kA/ns

Need to research how input current parameters such

1) peak current

2) time to peak

3) rise speed

will effect output X-Pinch pulse parameters such

1) time

2) width

3) power

4) etc.

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