

# Advanced Topologies: Opening Switch Transmission Line Modulator

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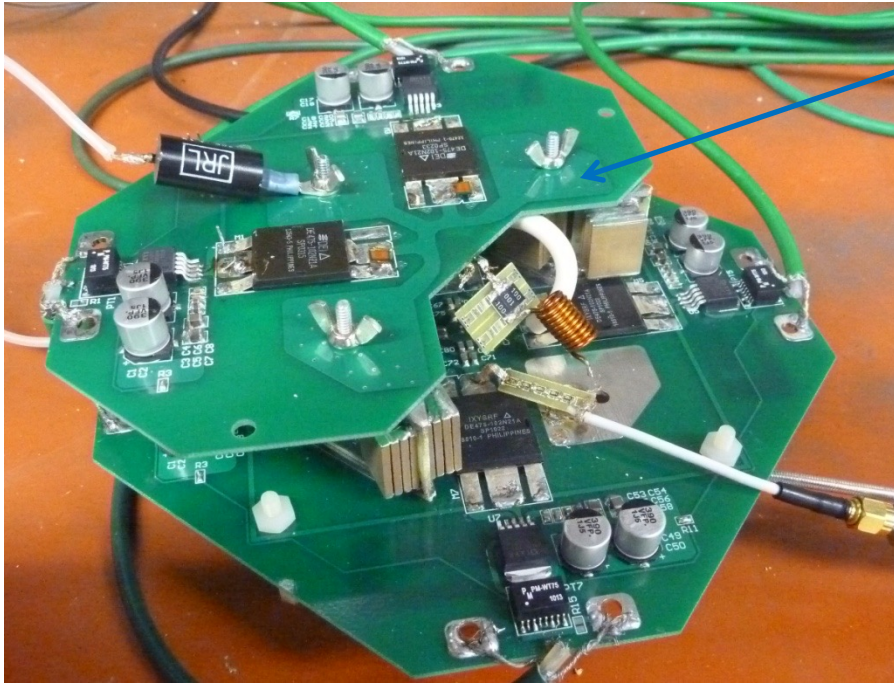
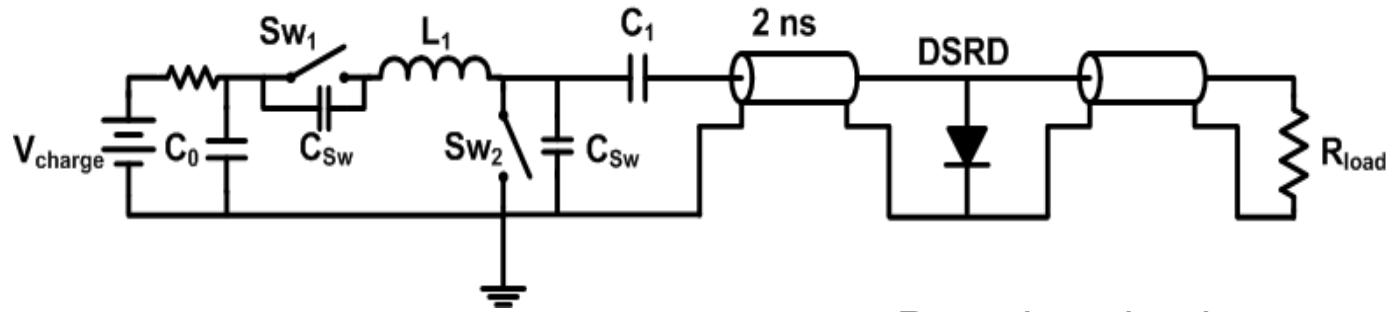


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# Opening Switch PFL: SLAC ILC Damping Ring Prototype



Pumping circuit

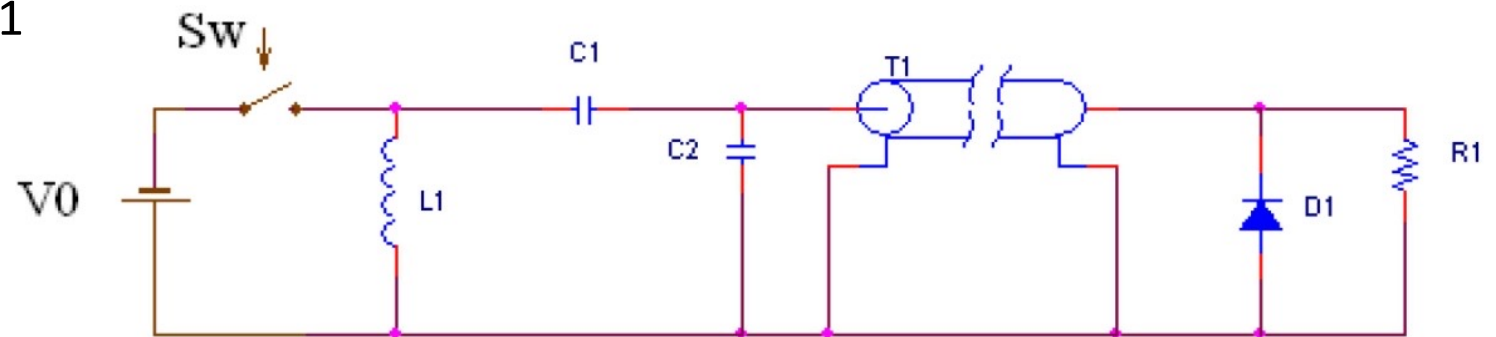
5 kV, 200A DSRD (*Ioffe Institute*)

ant (*for scale*)



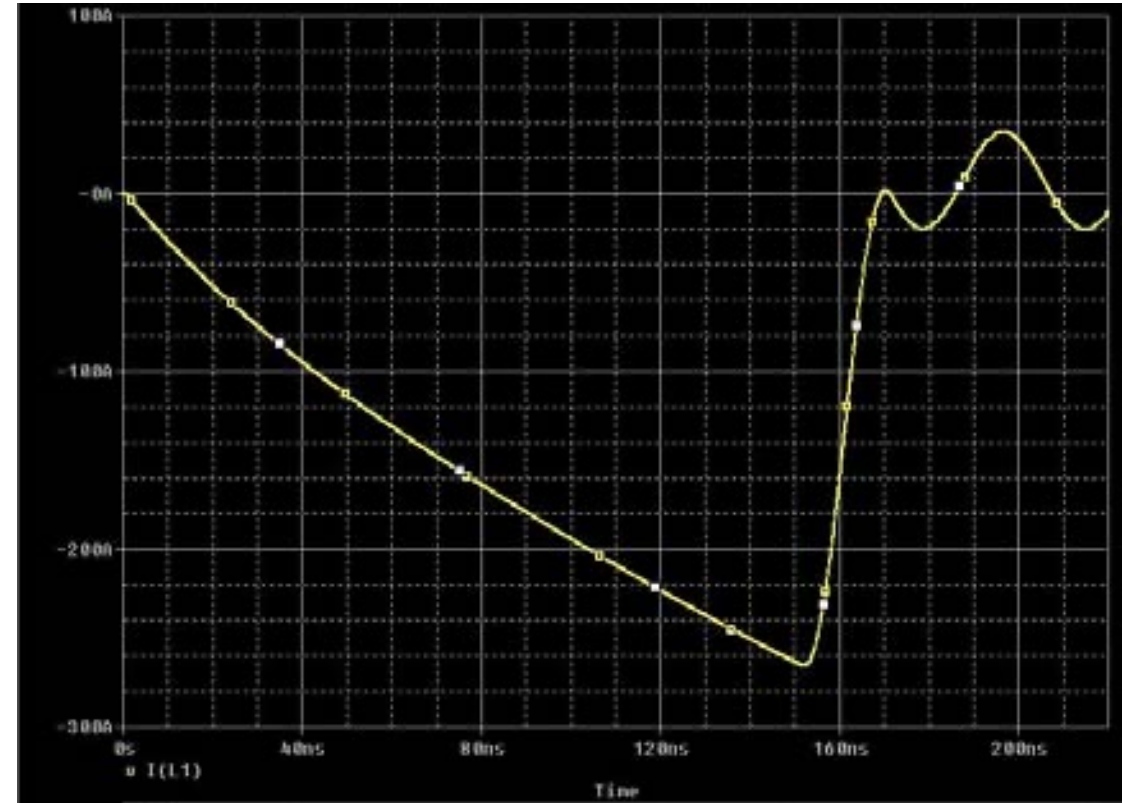
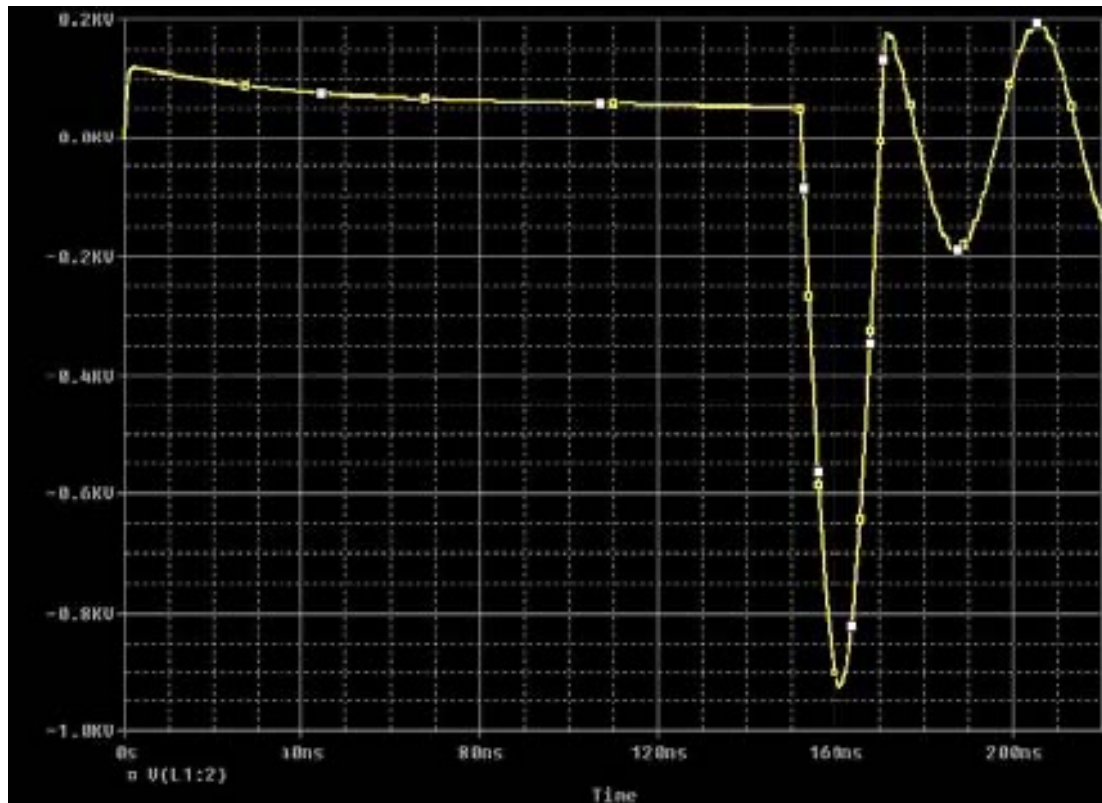
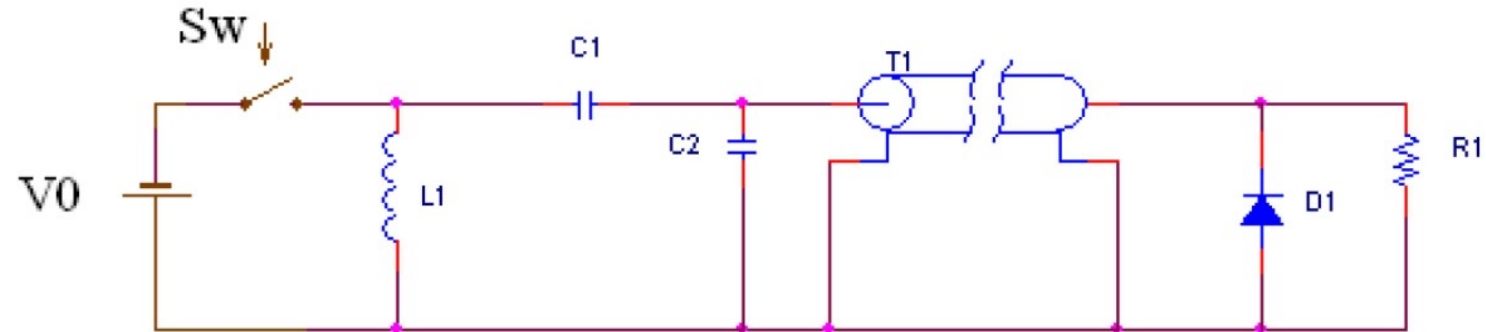
# Ultra-fast DSRD Switched TL Modulator

- DSRD as a sub-ns opening switch for a transmission line modulator for the ILC damping ring kickers
  - 5 kV into 50  $\Omega$
  - 4 ns flattop, <1 ns rise/fall (simulations for 2 ns pulse)
  - Bunch separation <10 ns
  - 3 (or 6) MHz burst at 5 Hz
- Switch, SW, is closed to charge L1, some parasitic component is transferred through C1/T1 for forward bias D1
- SW opens, L1 discharges into T1 via C1 (resonant transfer), D1 is still in conduction (reverse recovery charge), shorting T1 (current charging of T1 inductance)
- Energy transfer from L1 to T1 is completed as D1 opens
- T1 now connected to matched load, R1

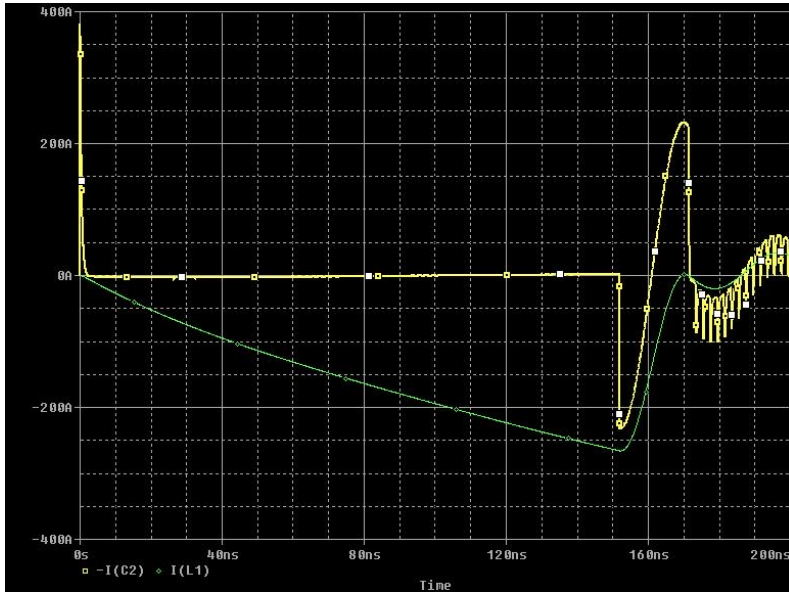


# DSRD Modulator Energy Transfer Sequence: Charging L1

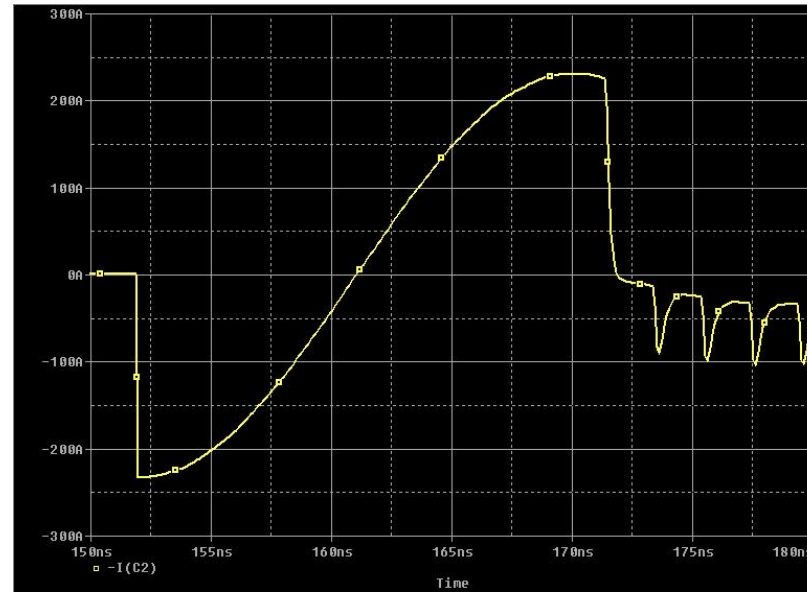
- Voltage (left) and current of L1 during charging period (SW closed)



# DSRD Modulator Energy Transfer Sequence: Charging T1



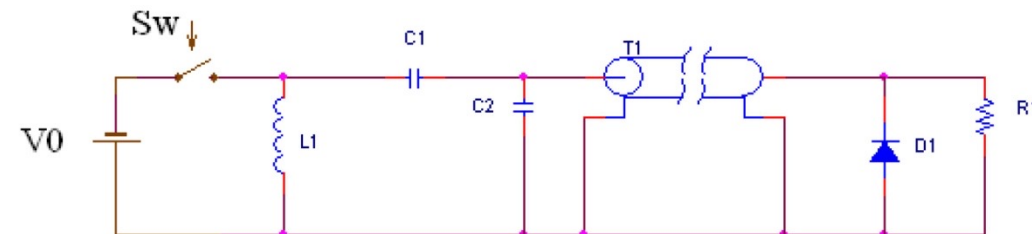
- Current in L1 (green) and C2 (yellow)
- $t < 154$  ns: charging of L1
- $154$  ns  $< t$ ,  $170.5$  ns: transfer to T1



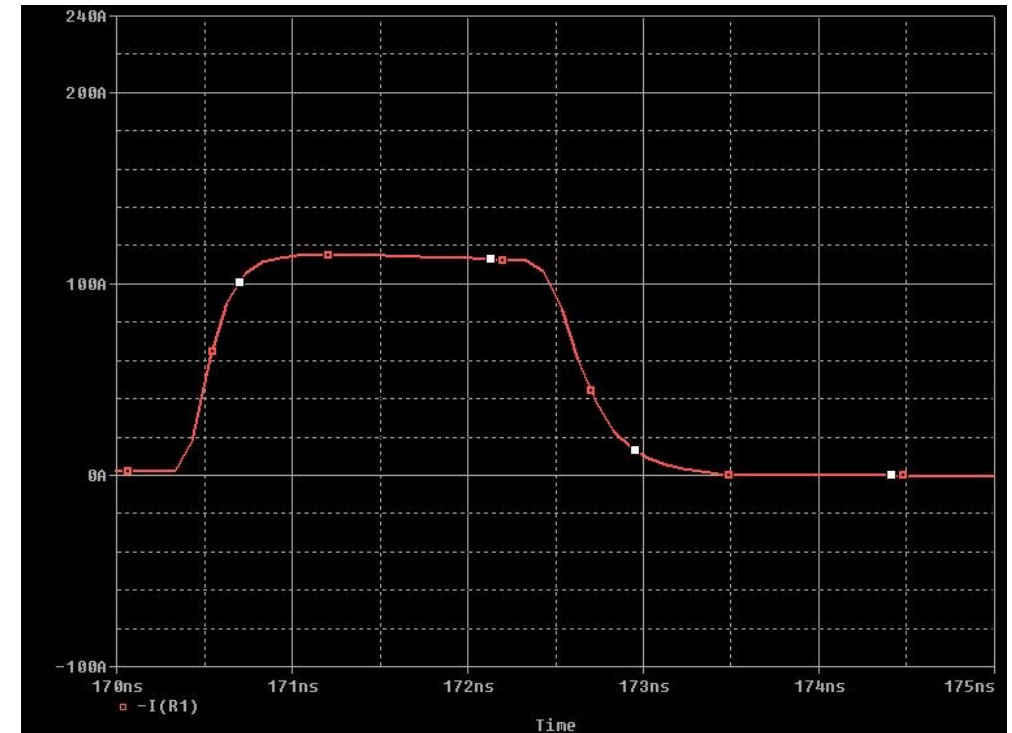
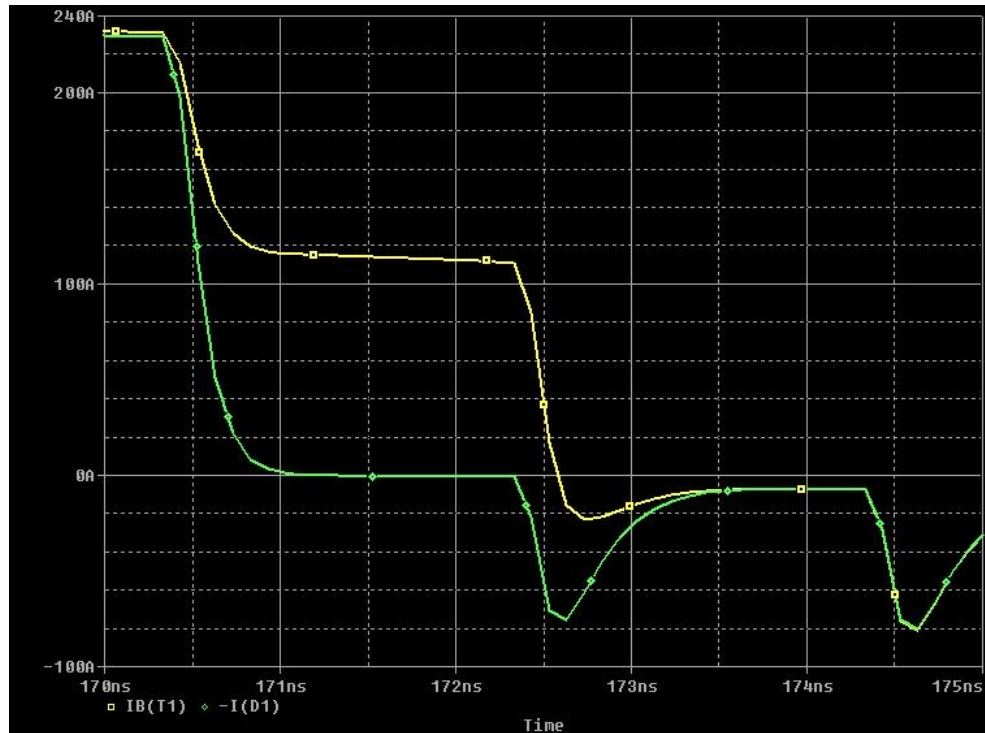
- Detail of current in C2
- $t < 170.5$  ns: energy transfer to T1
- $t > 170.5$  ns: discharge of T1 into R1 (C2 shorts LHS of T1)
- $t = 171.5$  ns: halfway through T1 discharge (end of LH wave)



- Current in D1 (green) and T1-load end, (yellow)
- $154$  ns  $< t$ ,  $170.5$  ns: charging T1
- $t = 170.5$  ns: D1 opens, T1 discharges into R1



# DSRD Modulator Energy Transfer Sequence: Transfer to Load (R1)



- Current in D1 (green) and T1-load end, (yellow)
- $\sim 170.5 \text{ ns} < t < \sim 172.5 \text{ ns}$ : T1 discharges into R1
- Challenges for opening-switched transmission-line modulator
  - Pre-pulse: finite DSRD turn-on time and forward-voltage (not visible in detail)
  - Post-pulse: residual energy (due to impedance mismatches) will “bounce around” and come out at later time
  - Optimum timing dependent on precise DSRD properties that are temperature dependent
- Current in R1 (red)
- $\sim 170.5 \text{ ns} < t < \sim 172.5 \text{ ns}$ : T1 discharges into R1