HVPS Upgrade for ALS Storage Ring RF System -Disconnect Switch Status

May 10th 2012

S.Kwiatkowski
LBNL ALS RF Group

Contributors
K.Baptiste, J. Julian

The new ALS storage ring RF system will use two 300kW THALES TH2161B klystrons to energize two single cell 500MHz ALS cavities. New system will require significant modification of the existing HV power supply (new power transformer, rectifier, choke and PLC based control). Also, classical ignitron based crow-bar system will be replaced with house made solid state disconnect switch which is undergoing final high power tests. We will keep existing voltage controlled unit based on 3-phase VVT which will regulate the DC voltage from 27kV to 54kV with precision better than +/- 0.5%.

Our existing HVPS is rated at 56kV and 12A.

Modify version will be rated at 54kV and 14.5A or 50kV and 16A (limited to 800kVA by VVT).

Does existing crowbar system is giving adequate protection for klystron(s)?

Philips YK1305 Requirements

Fast switch-off of the beam PS has to be provided in following situations:

1. Beam current increase rapidly.

2. Solenoid current deviates by more than +/- 5% from nominal value.

Proof protection: 28 gauge , 52cm long copper wire connected to the power supply instead of klystron should not be destroyed (approx. 60J -using I.M. Onderdonk Equation or 7.75kA for 10us pulse)

Thales TH2161B Requirements

Power supply must provide protection to limit energy discharge in the tube to 20J in case of arcing or too abrupt current surge.

During resent testing of the ALS crowbar unit it was found that the ignitrons conducting time period is unpredictable and changes from few dozen to several hundreds of millisecond. The biggest danger for the protected equipment exist when the ignitrons stop conducting before the AC power is disconnected (~ 30ms) what has happened on two occasions (out of several dozen crowbar actions). In these cases power supply tried to build up very high voltage in the crowbar cabinet what resulted in discharges in protecting spark gap at approximately 70kV. No other damage has been done.

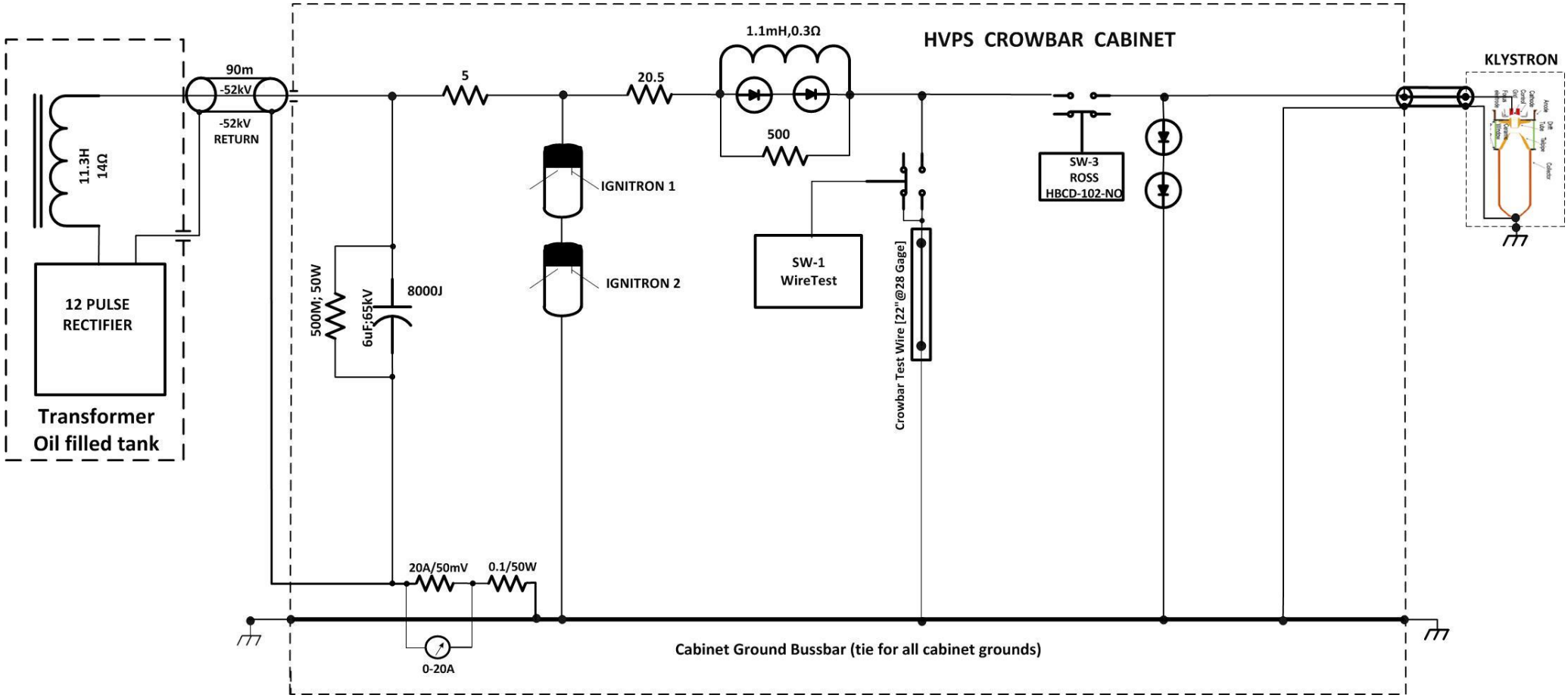


Figure 1

If the PS is OFF and 6uF filter capacitor is fully charged, the wire test will not damage the wire (only 30J).

PSpice model of the existing HVPS with disconnect switch

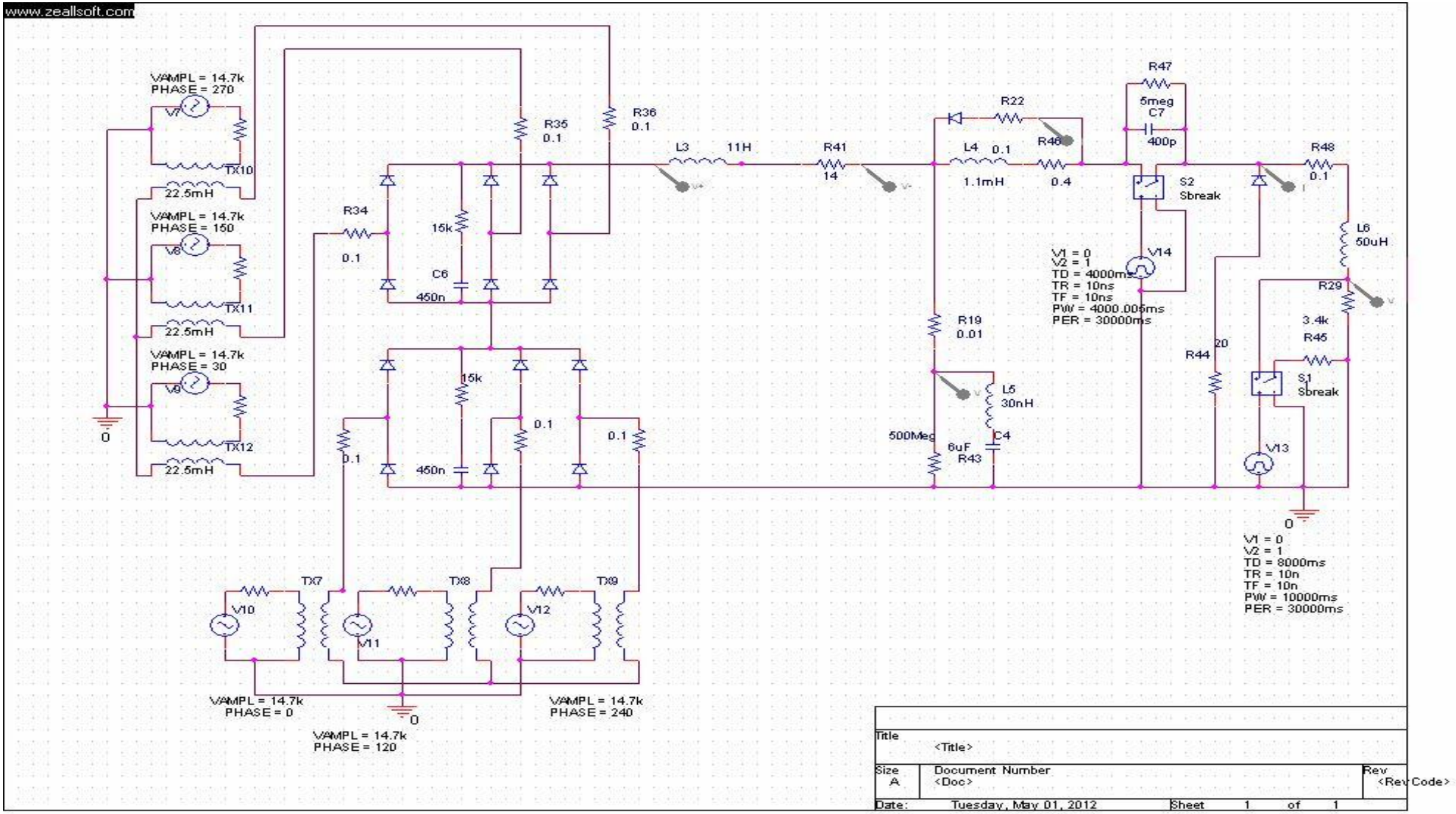


Figure 2

Voltage on the filter capacitor

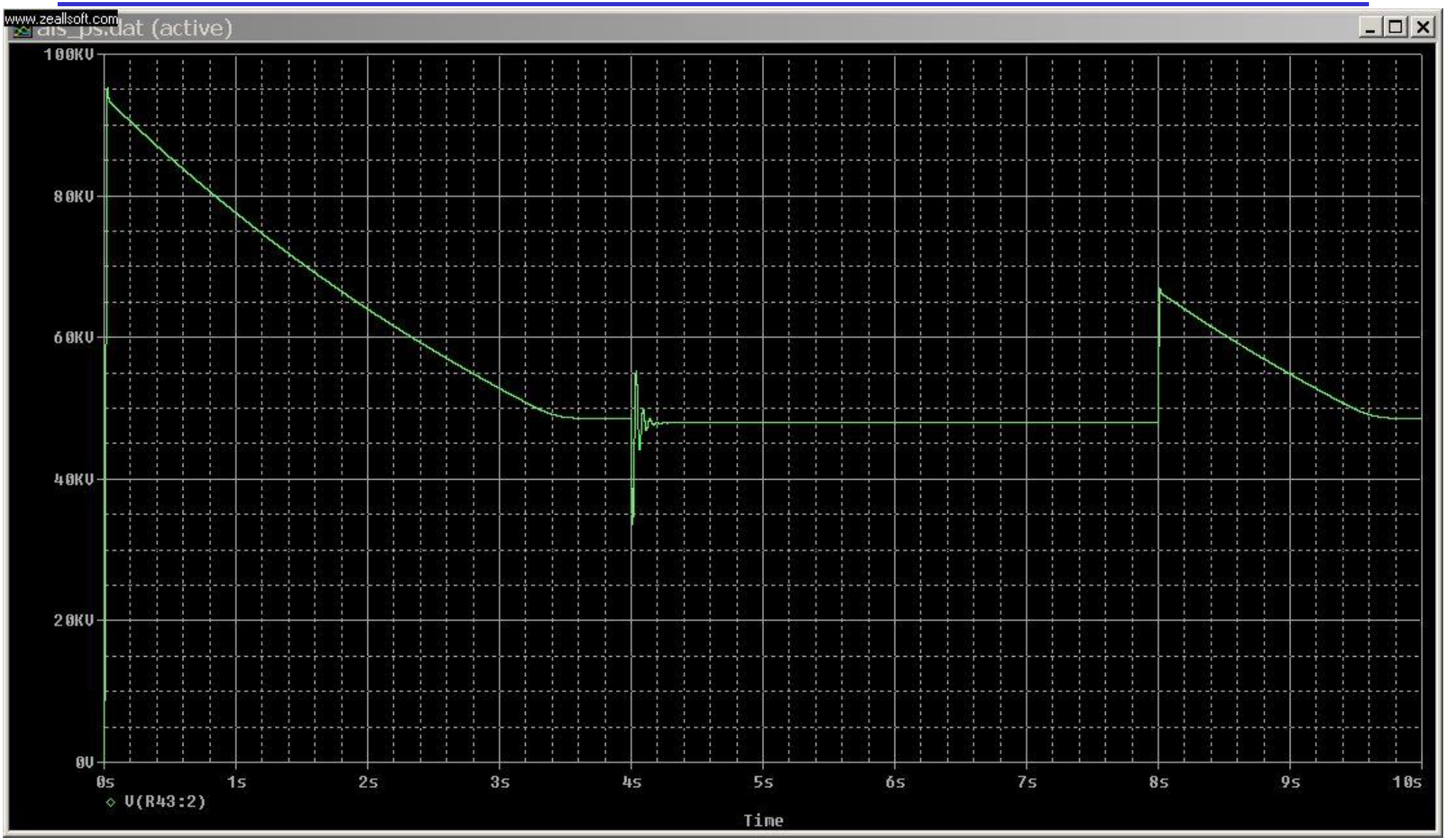


Figure 3

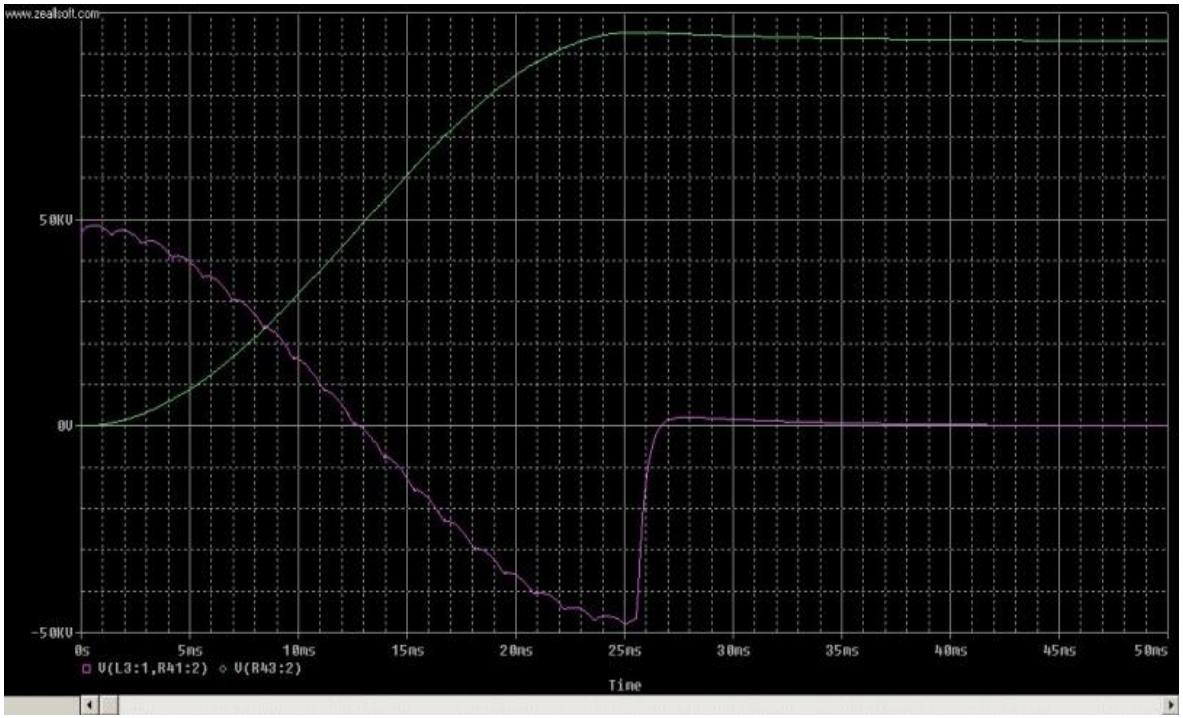


Figure 4

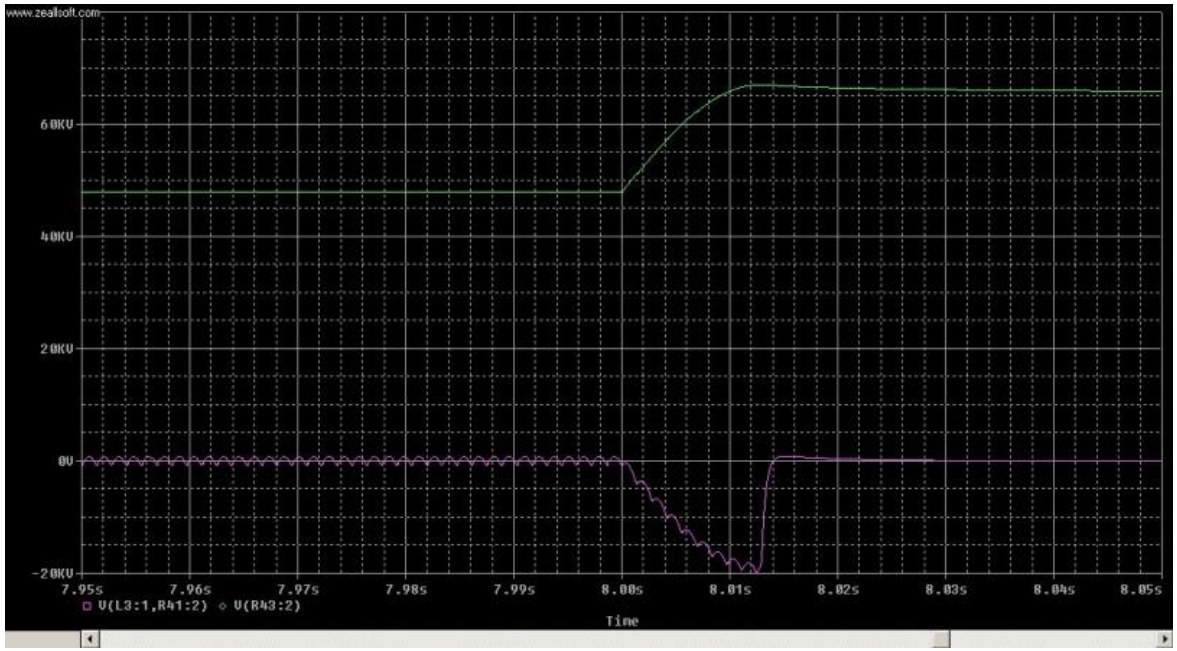


Figure 5

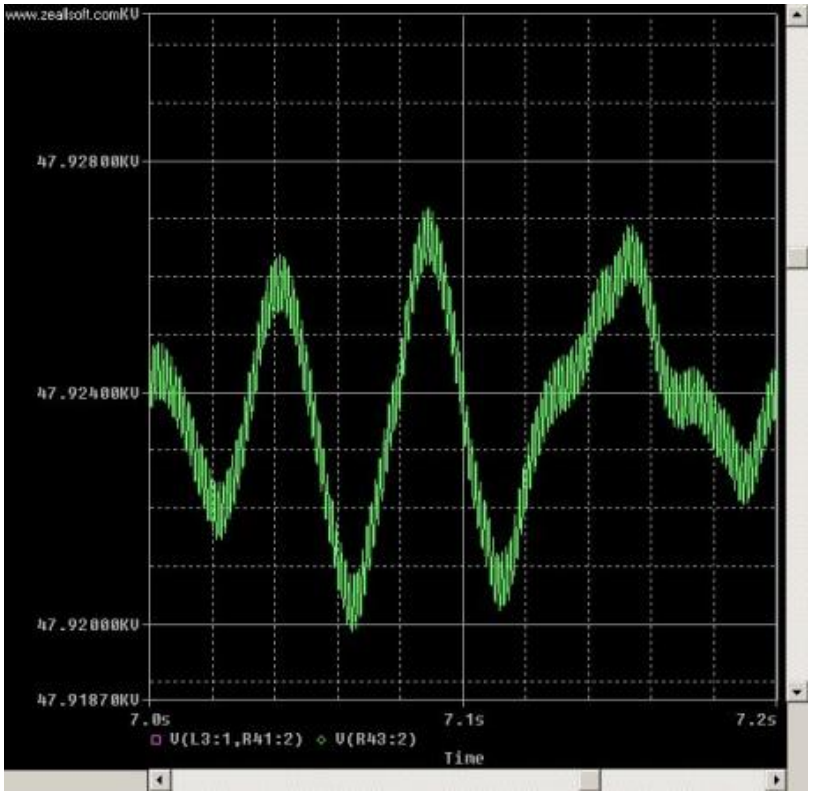


Figure 6

Fig. 4- represents the voltage on the filter capacitor(green) and filter choke(purple) during PS turn on.

Fig.5- same voltages after nominal load disconnect action by IGBT disconnect switch.

Fig.6- 19Hz and 720Hz ripples on the filter capacitor during PS operation on nominal load.

V720Hz ~1Vp-p

V19Hz ~7Vp-p

How to take care of the turn-on, turn-off transients?

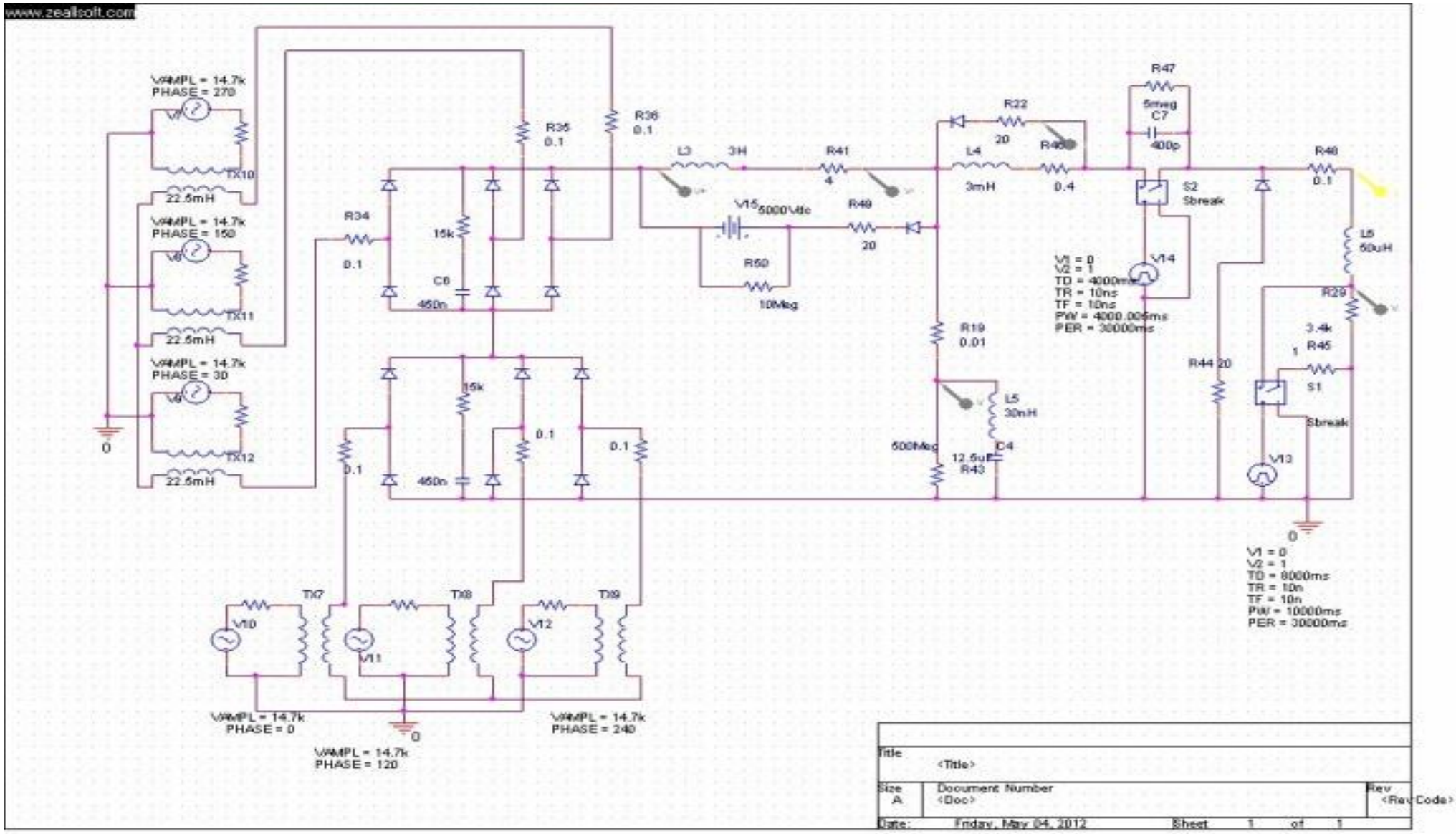


Figure 7

Voltage on the filter capacitor and choke

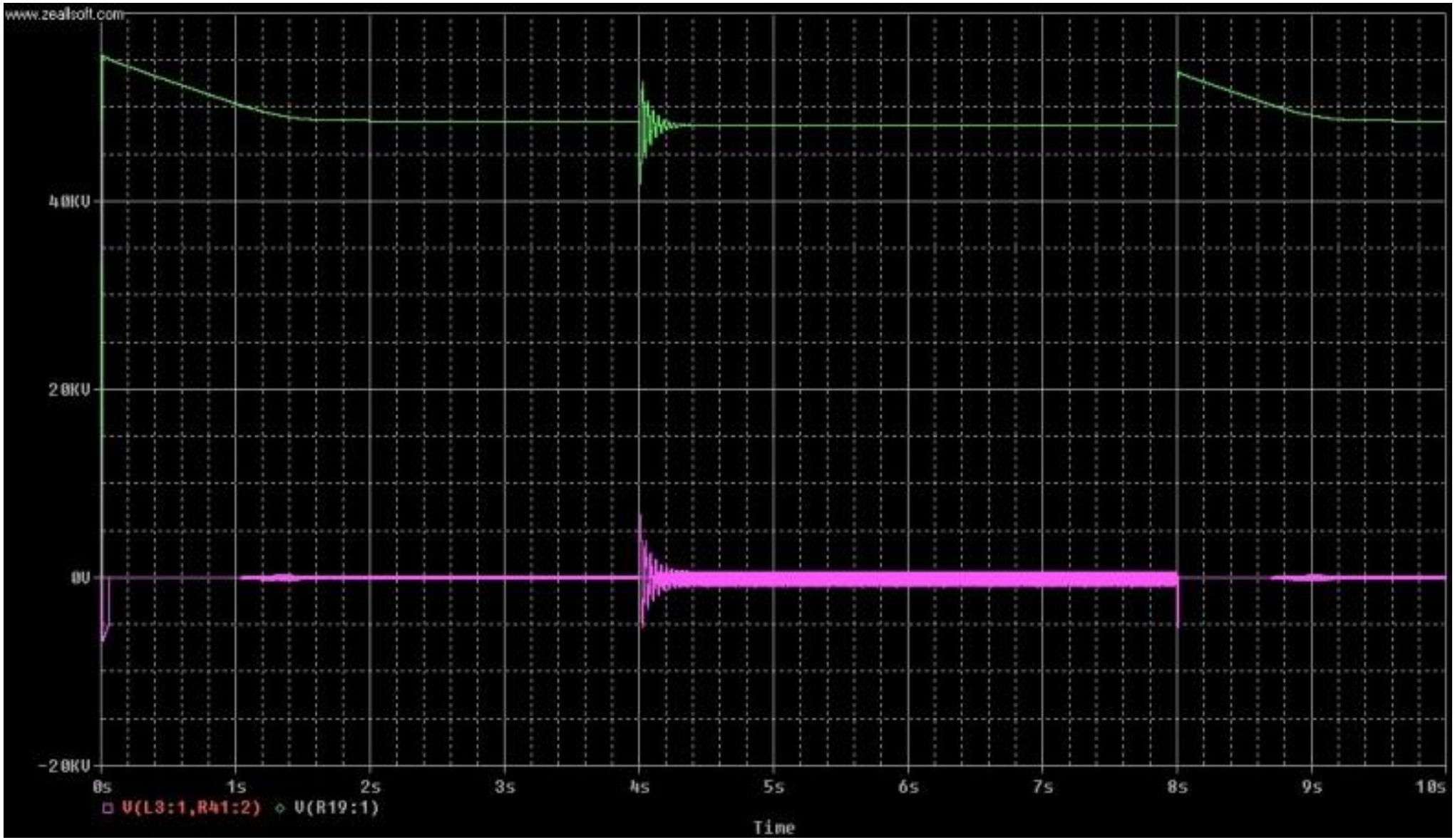


Figure 8

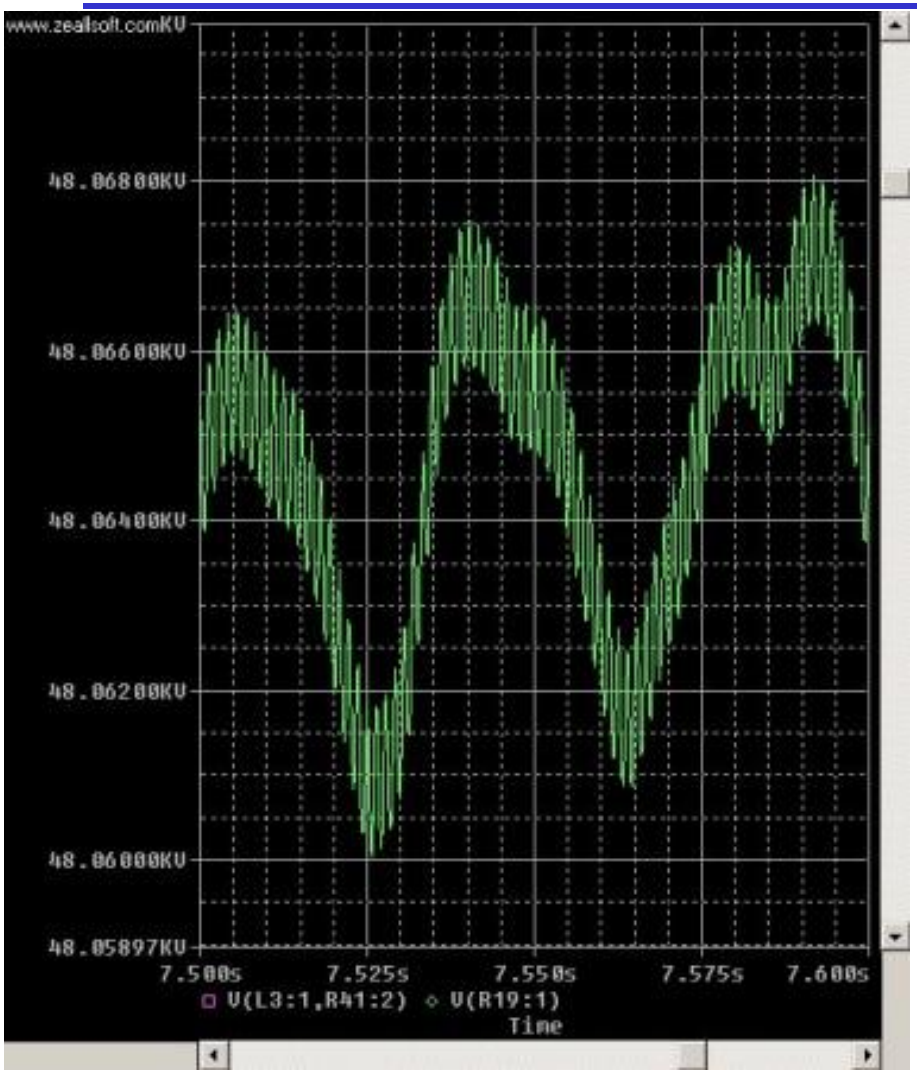


Fig.9 26Hz and 720Hz ripples on the filter capacitor during PS operation on nominal load.
V720Hz ~2Vp-p
V26Hz ~8Vp-p

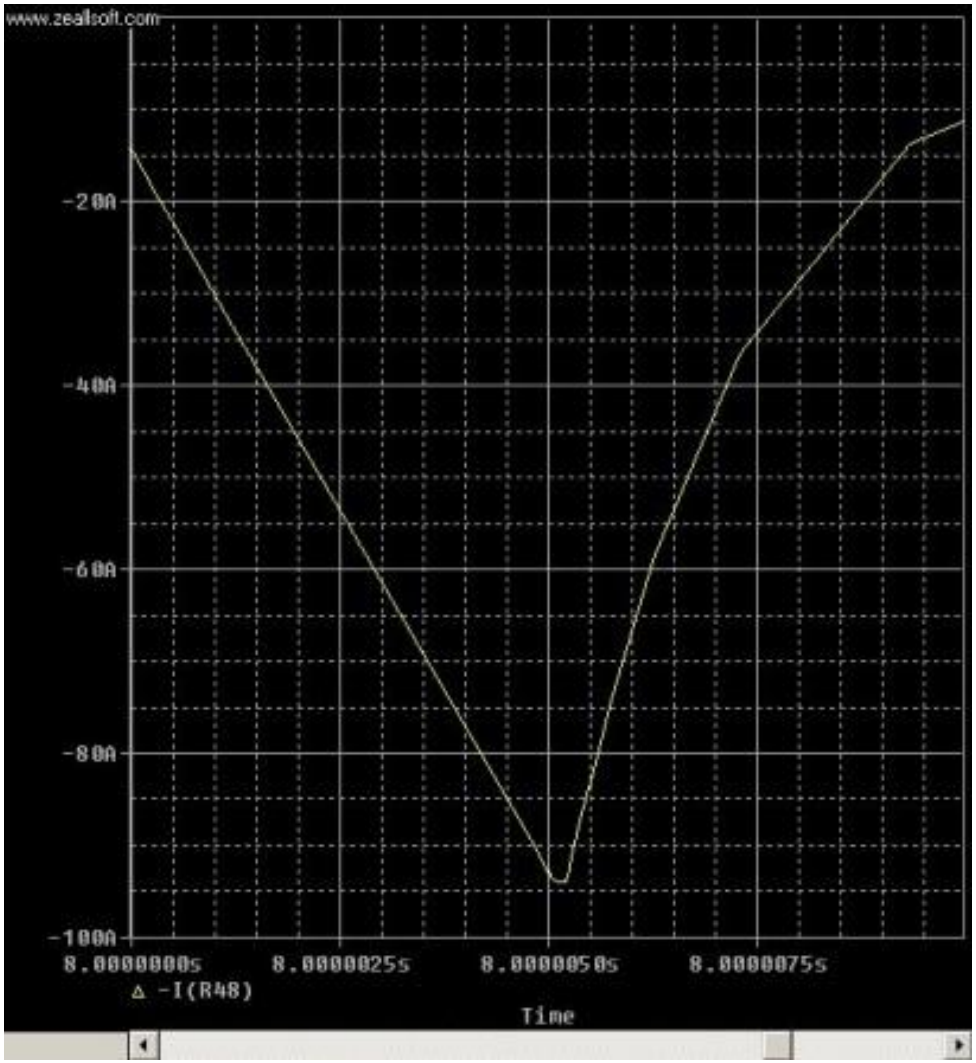


Fig.10 Current in the shorted load limited by 3mH inductor.

Why Disconnect Switch?

Generally, series switches have substantial advantages over the crowbars:

Faster action (typically <3us versus 8-10us for crowbars)
No stress on HV power supply elements.
HV can be turn back on within microseconds.
No series current limited resistors required.
Simpler control circuitry
No danger of mercury contamination.

There are few companies like: Diversified Electronic Inc, North Star Research Corp or Polarity Inc, which are using IGBT technology to build high voltage, high current disconnect switches/modulators. We decided to design and build our disconnect switch. The main reason for this decision was lower cost and fast service by our staff .

IGBT Choice

In order to decrease the overall cost of the switch and decrease the power dissipation within the switch itself, we were looking for the IGBT with the high voltage handling capabilities and the small dissipation factor (forward voltage drop to opening voltage ratio). The new IXYS IXEL40N400 4kV, 40A, IGBT with the dissipation factor<0.1% and the price below $100, was by far the best choice. The ALS disconnect switch contains 24 4kV IGBT modules connected in series with the total voltage handling capabilities up to 72kV . This large excess voltage capability will create a large redundancy factor and increase its operational reliability since the switch could continue to operate even with several faulty IGBT modules.

IGBT Data Sheet

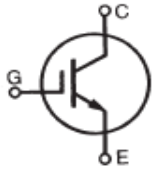
IXYS

Advance Technical Data

Very High Voltage IGBT

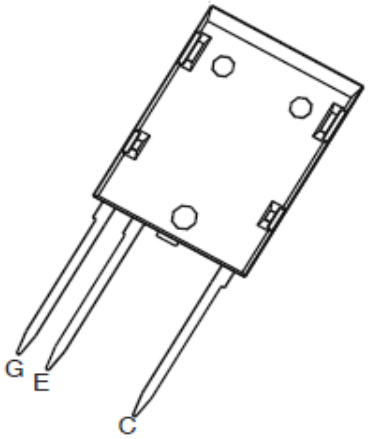
IXEL40N400

V_{CES}	=	4000	V
I_{C90}	=	40	A
$V_{CE(sat)}$	=	4.0	V
$t_{fi(typ)}$	=	450	ns



Symbol	Test Conditions	Maximum Ratings	
V_{CES}	T_J = 25°C to 125°C	4000	V
V_{GES}	Continuous	±20	V
I_{C90}	T_C = 90°C	40	A
I_{CM}	Limited by T_J	170	A
P_C	T_C = 25°C	380	W
T_J		-40 ... +125	°C
T_{JM}		125	°C
T_{stg}		-40 ... +125	°C
Maximum Lead temperature for soldering 1.6 mm (0.062 in.) from case for 10 s		300	°C
Maximum Tab temperature for soldering SMD devices for 10 s		260	°C
F_C	Mounting Force	30..170 / 7..36	N/lb
V_{ISOL}	I_{ISOL} < 1 mA, 50/60 Hz, t = 1 minute	2500	V~
Weight		10	g

ISOPLUS i5 (HV)



Features

- High current handling capability
- MOS Gate turn-on
  - drive simplicity
- Rugged NPT structure

Balancing IGBT's

The static voltage balancing can be easily achieved by connecting in parallel with each IGBT resistor with the value which will create the current flow significantly higher than the leakage current of the worst solid state device in the chain. The dynamic unbalance conditions are created by unequal switching characteristics of the solid state device or unequal delay in the drive chains. The dynamic balance has been achieved in our switch by connecting 10nF ceramic capacitors across each IGBT output, plus delay chips in each IGBT drive chain. Each module has also internal protection against sudden overvoltage transient.

It is accomplished by chain of 6 (500V) transient suppressors connected between collector and gate of each IGBT. Protection works very well for up to multi microsecond overvoltage transients.

Schematic Diagram of the 3kV IGBT Disconnect Switch Module

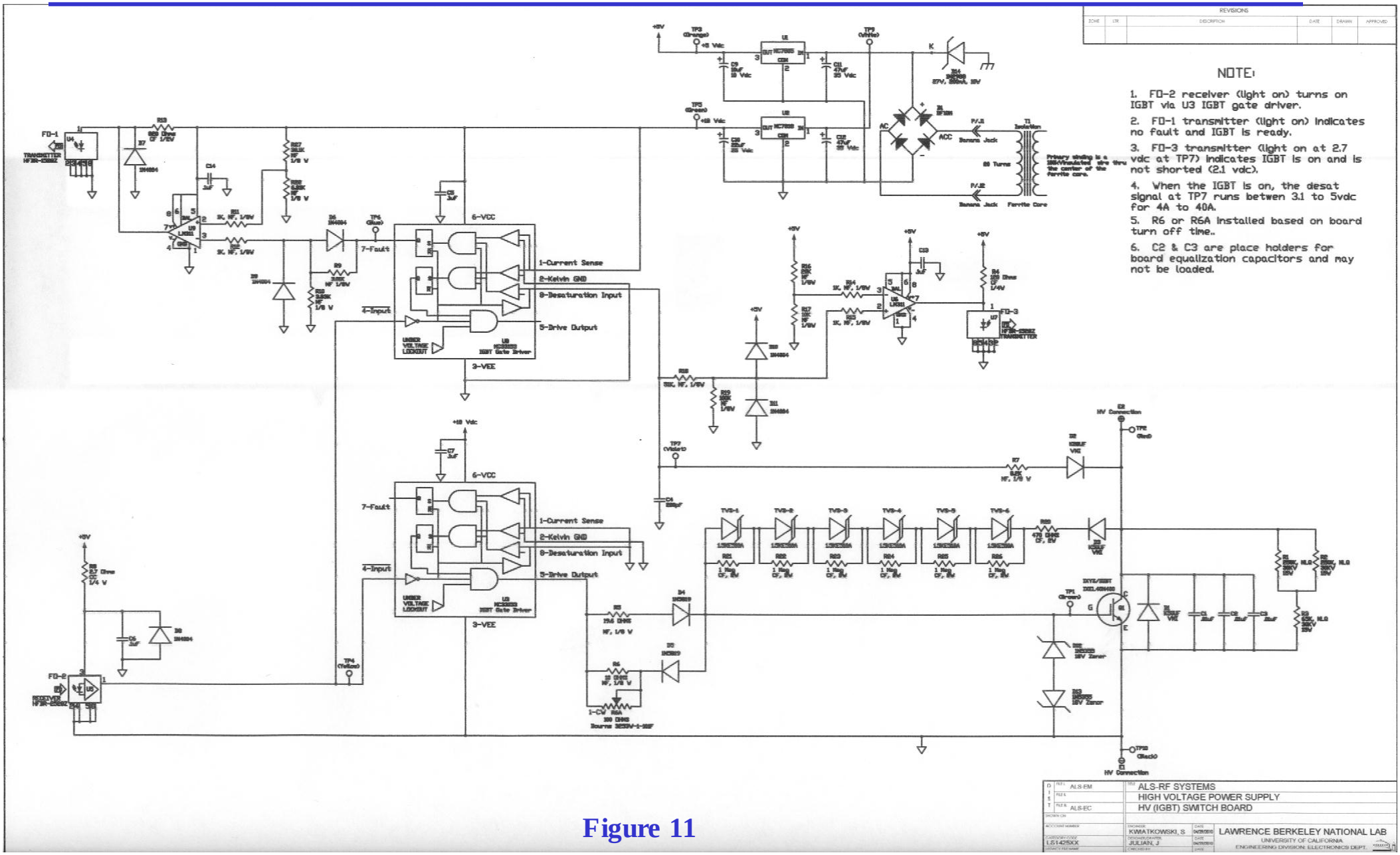


Figure 11

3kV IGBT Disconnect Switch Module

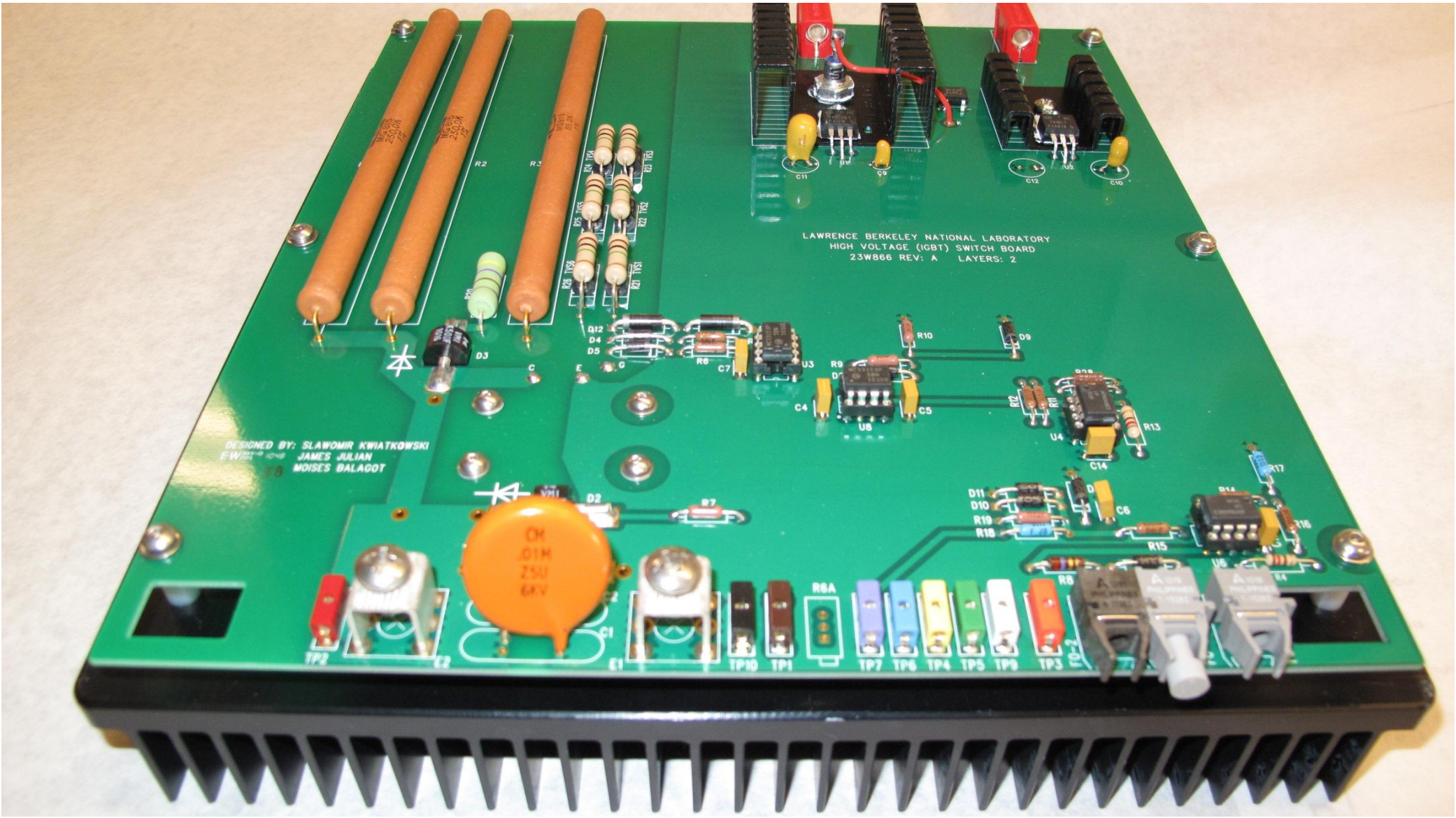
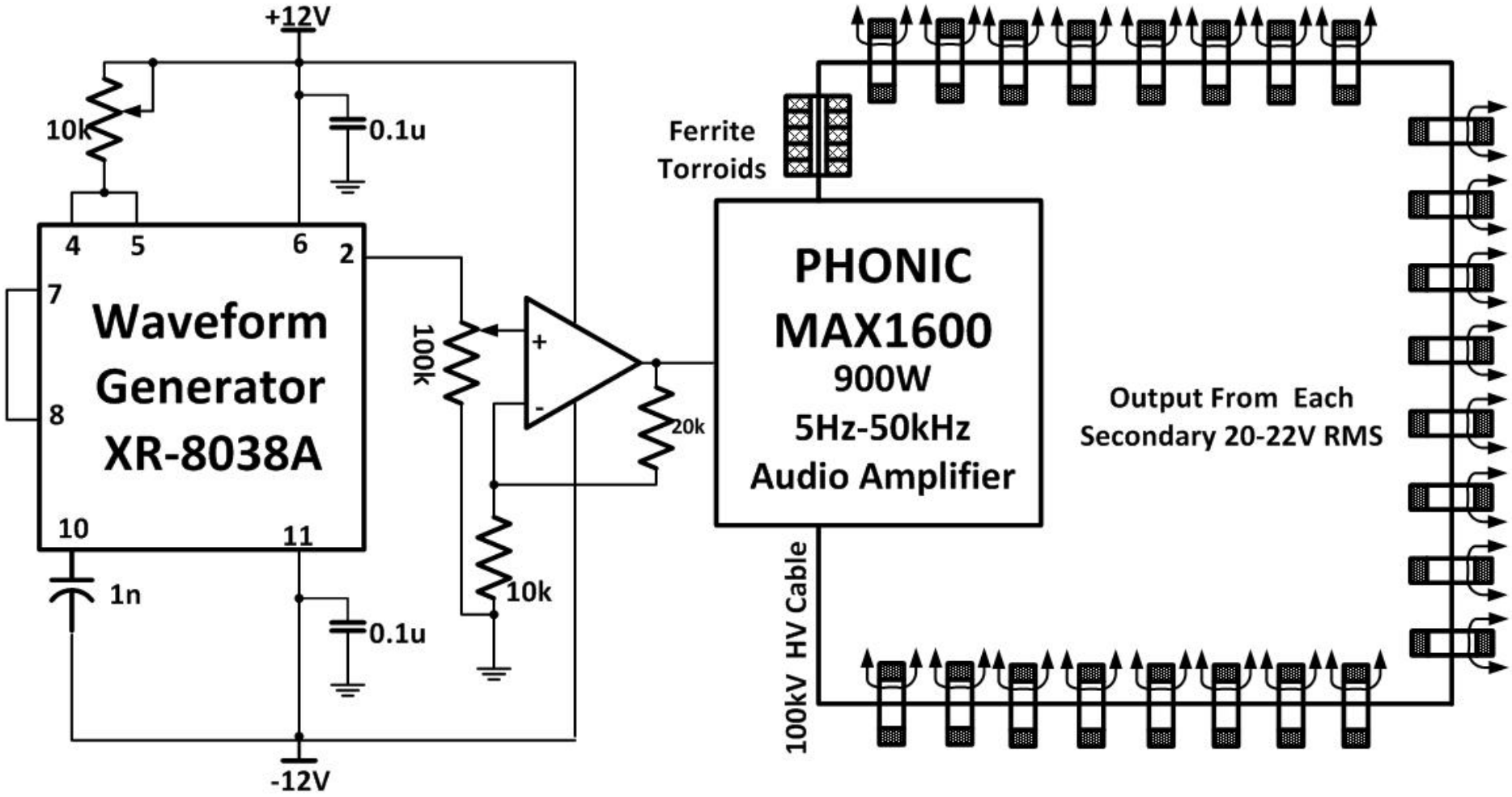


Figure 12



ALS Disconnect Switch Driver Power Supply Audio System

Figure 13

Disconnect switch view from front and back

Figure 14

Disconnect Switch Test Set-Up

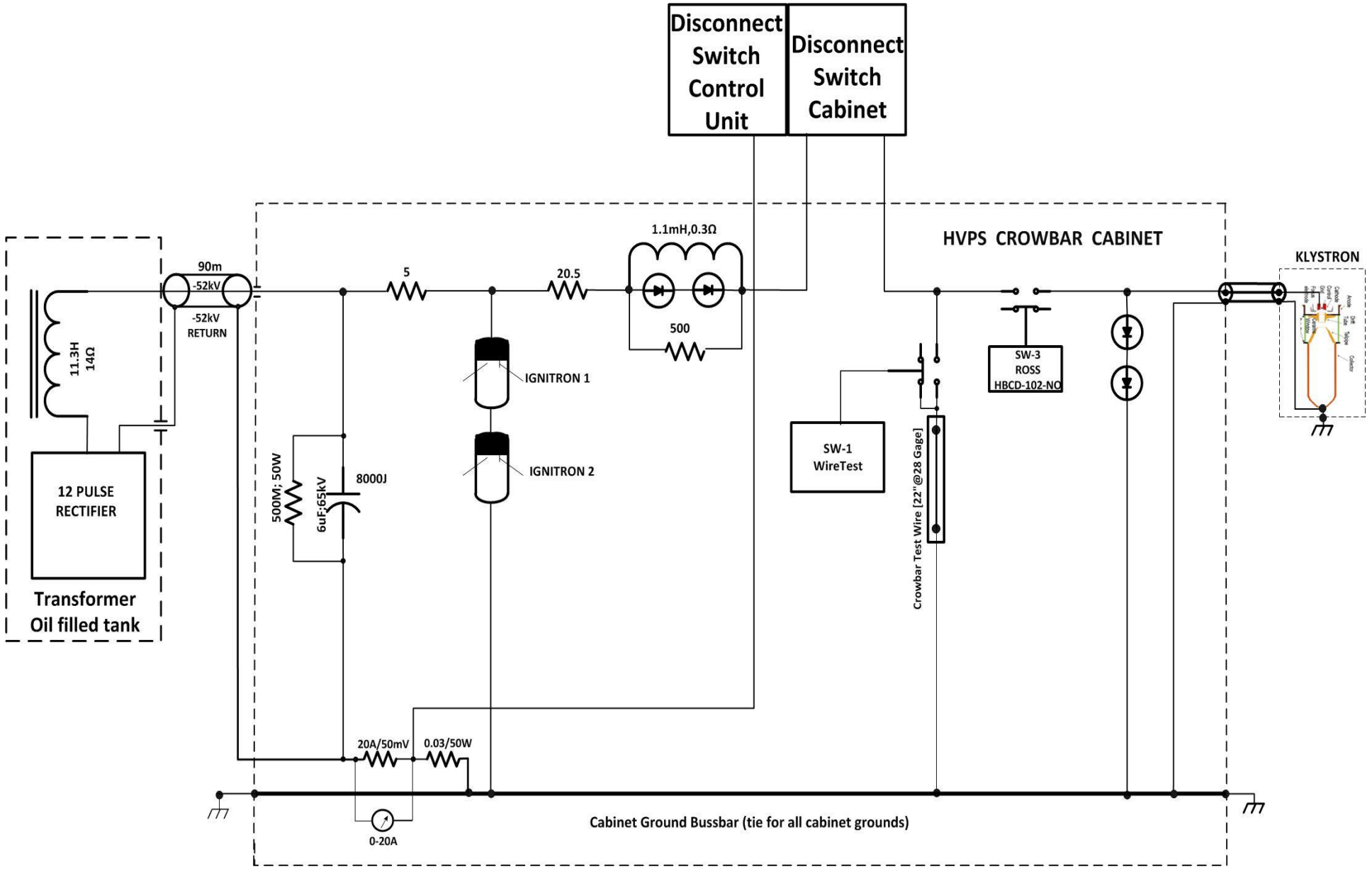


Figure 15

50kV-PS Turn-On Short (Disconnect Switch Closed)

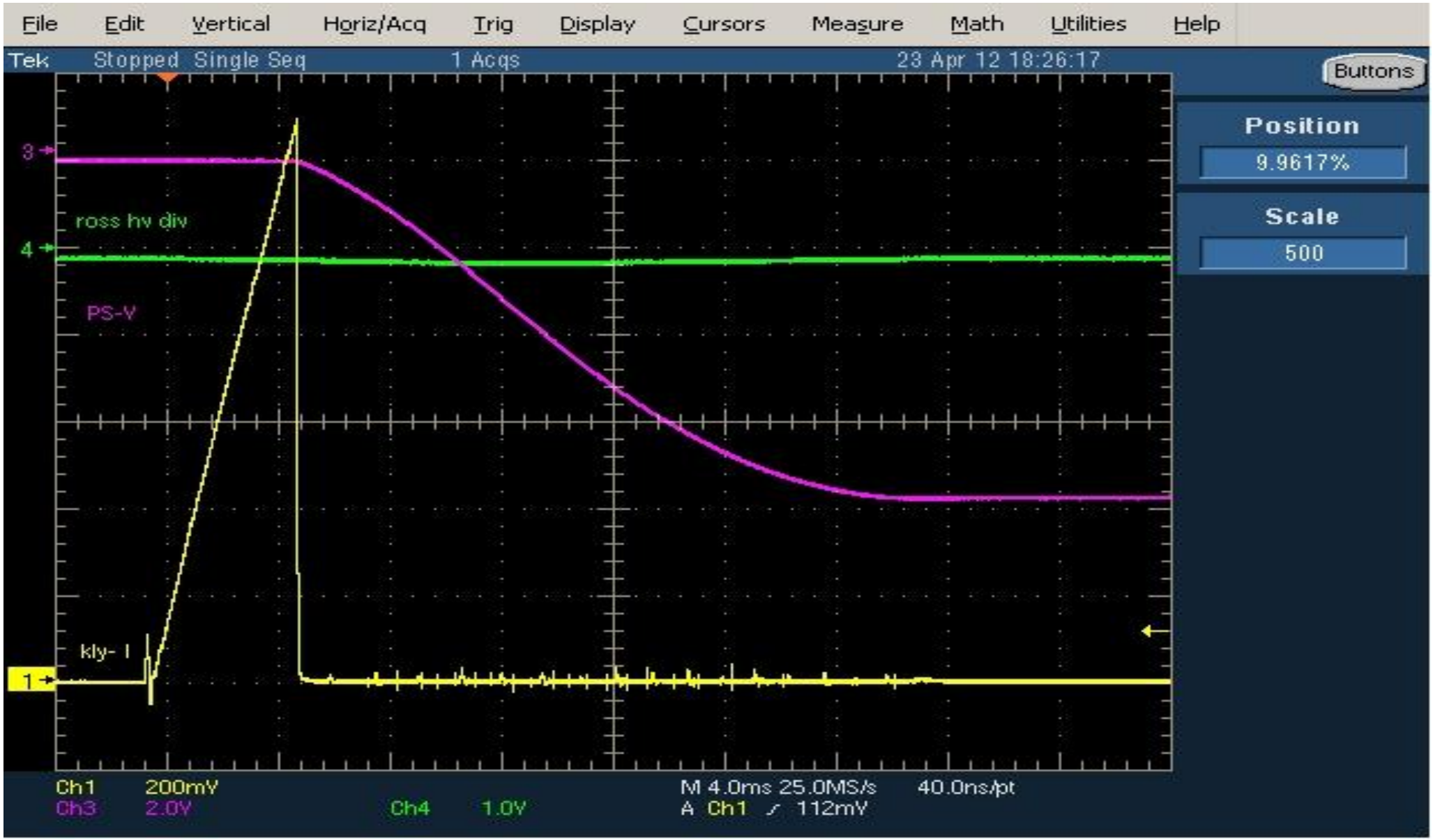


Figure 16

50kV-PS Turn-On Short (Disconnect Switch Closed)-Trailing Edge

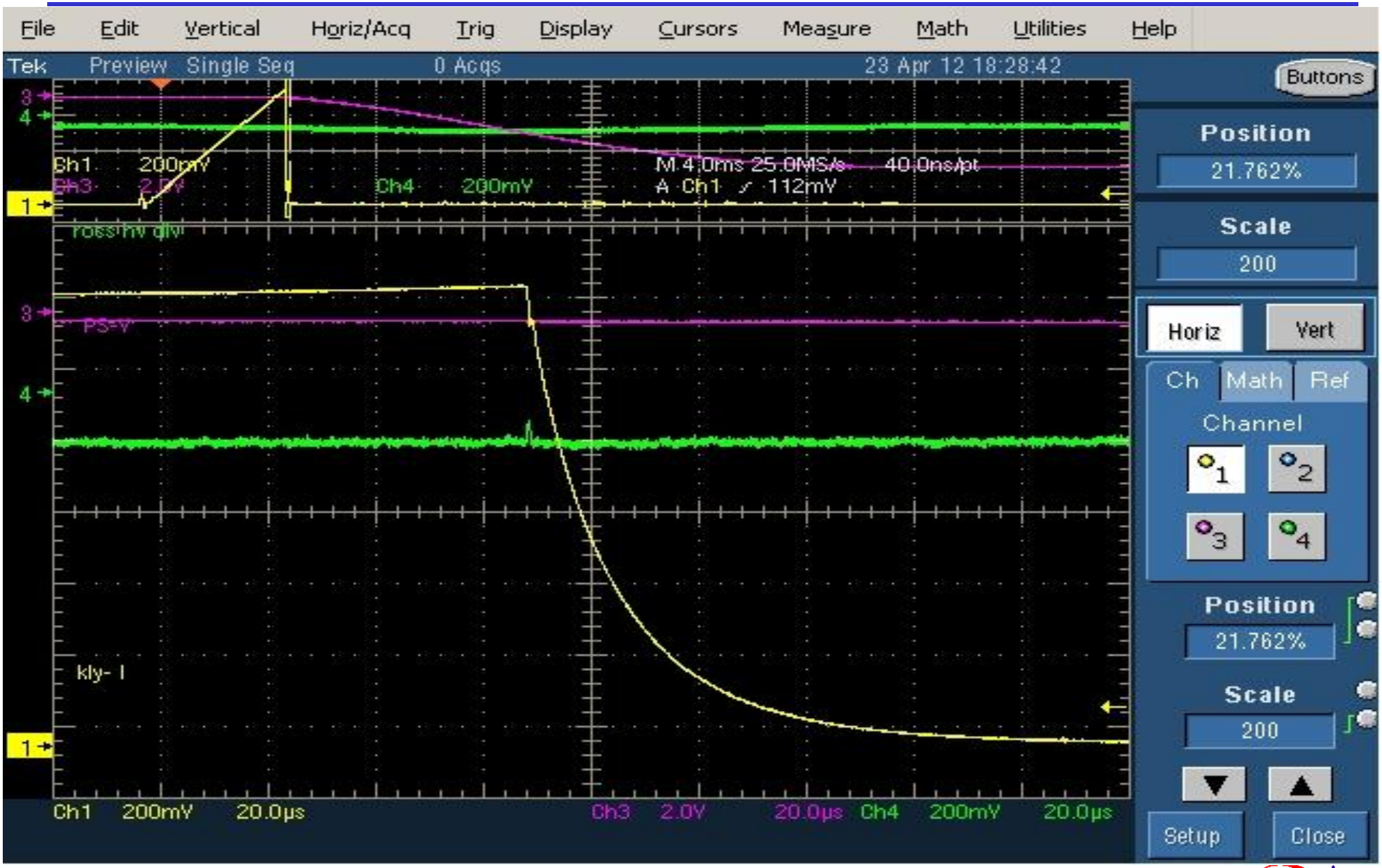


Figure 17

Wire Test- PS at 50kV when shorted by 28Gage Wire

Figure 18

Wire Test- PS at 50kV when shorted by 28Gage Wire-Front Edge Zoom

Figure 19

CONCLUSIONS:

So Far So Good

1.More Testing during two days shut-downs.

2. Plan-installation of the switch during second stage RF system upgrade (Early 2013) or even earlier to create ASAP better protection for THALES 2161B klystron.