MARS 2 IPB Short Circuit Protection

Update, Brenton Salmi, May 2024

LAST UPDATE = 7/12/2024

Applied Physics Laboratory
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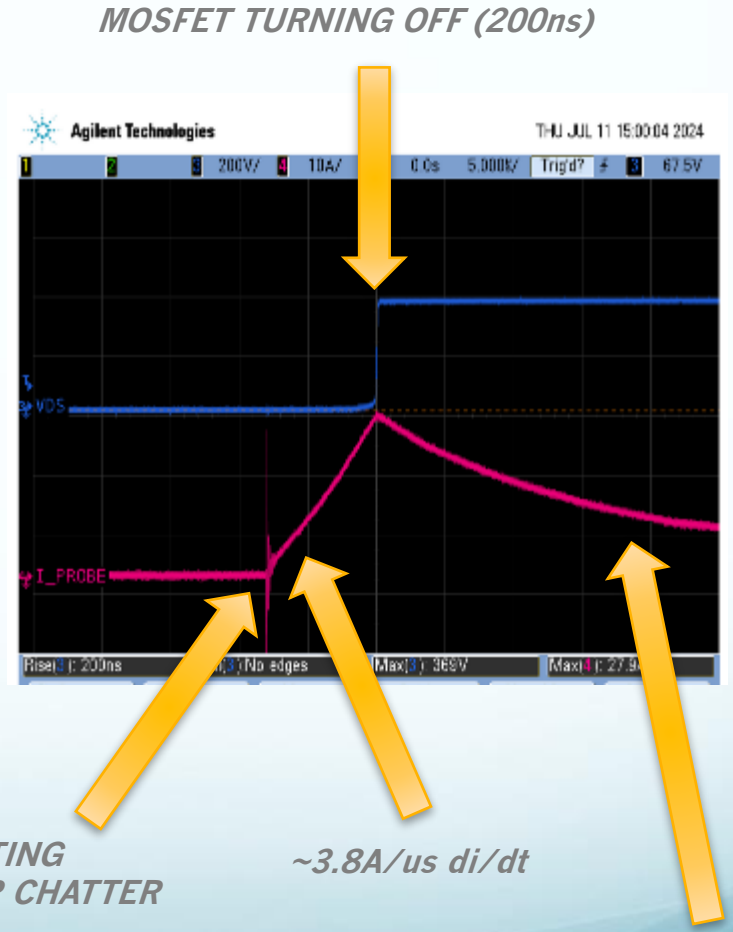
Test Setup

- Testing below was performed with a 375V 500mA power supply
  - This is sufficient due to the time scales involed and IGB / IPB input capacitance
  - Power supply sees almost no fault current
    - Fault timescale of <20us pulls all energy from capacitors
    - Small PSU looks like a large PSU on these timescales

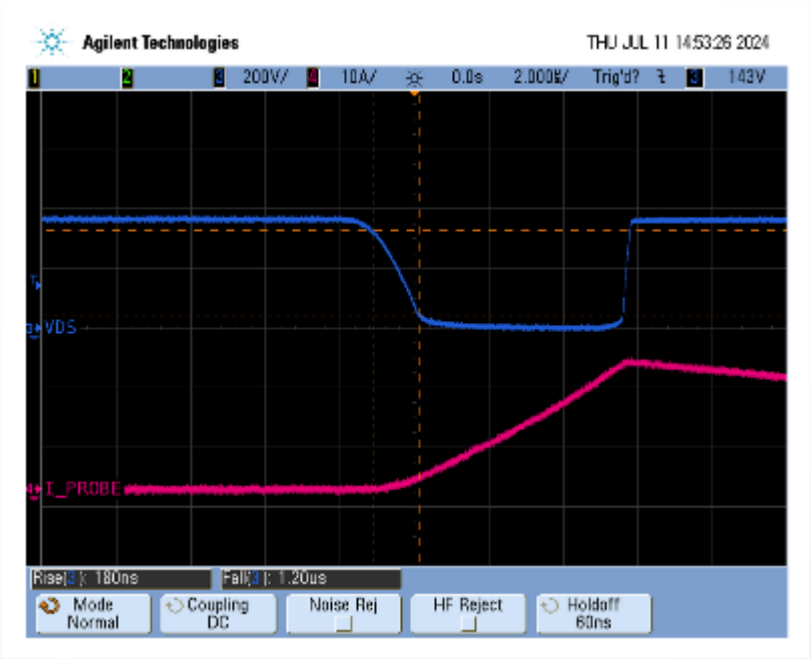
Short Circuit Protection!

- SETUP
  - 225mA Load
  - Shorting via contactor (800mOhm)
    - ~450A if not protected
  - ~18A Trip Current
- RESULTS
  - ~2us for circuit to react
    - 8A overshoot expected
  - 375V short successfully protected system
  - Current <30A limit (~50uH)



Enabling Channel Into SHORT

- Enabling channel into a short is not a problem
- Circuitry tuned for clean waveforms
  - Less EMI
  - Softer switching
  - More Reliable
- Vds snubber eliminated inductive flyback spikes
  - Well below 850V Vds(max)



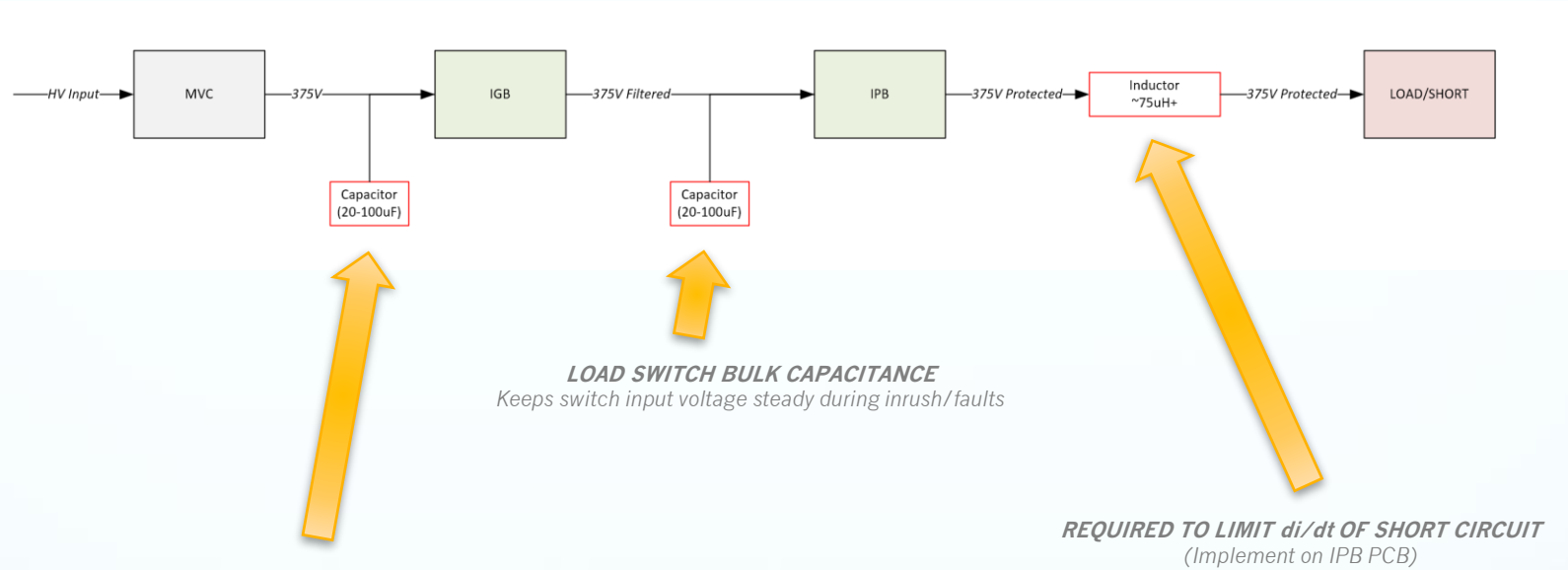
Capacitive Load (Inrush)

- Configuration
  - 1500 Ohm Load (~225mA)
  - 20uF 375V load capacitor
    - ~34 Ohms series resistance
    - ~11A max Inrush charge possible
- Results
  - Expect RC charge
    - 7.5A measured
  - Inrush was not a problem

Note: Current spike noise was tuned out after this waveform capture (gate resistor tuning)

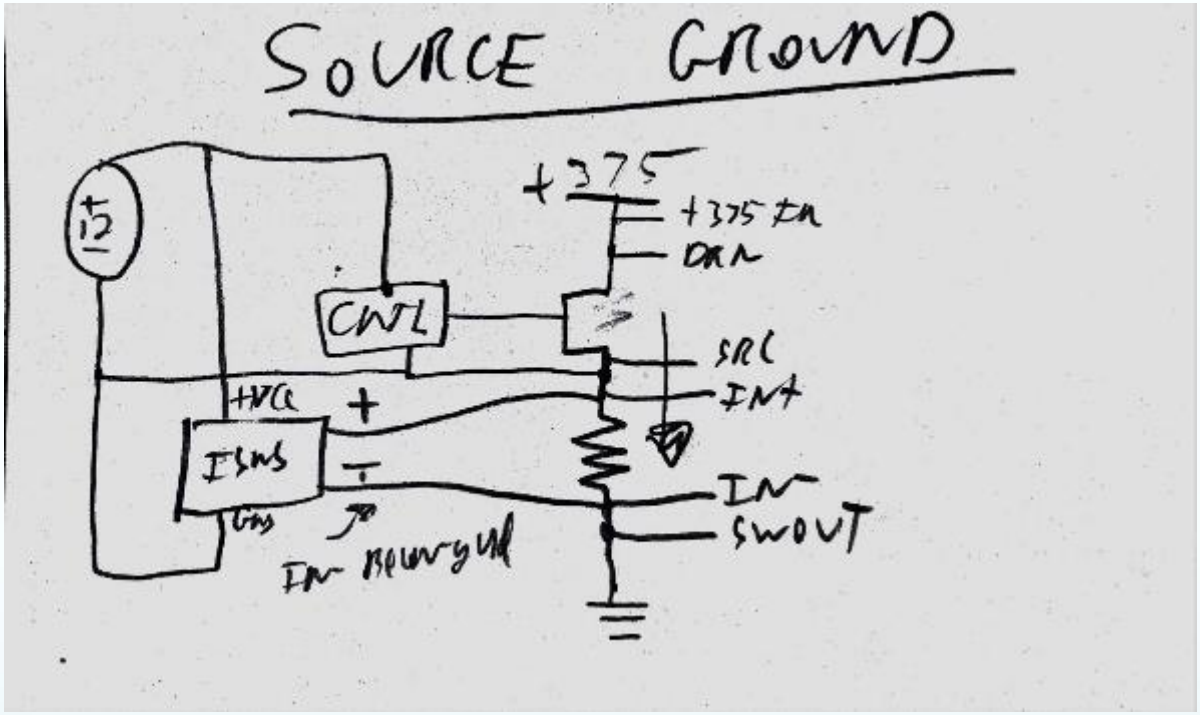
Final Design / Configuration

Significant lessons were learned at the system level during testing – Some system updates are needed.



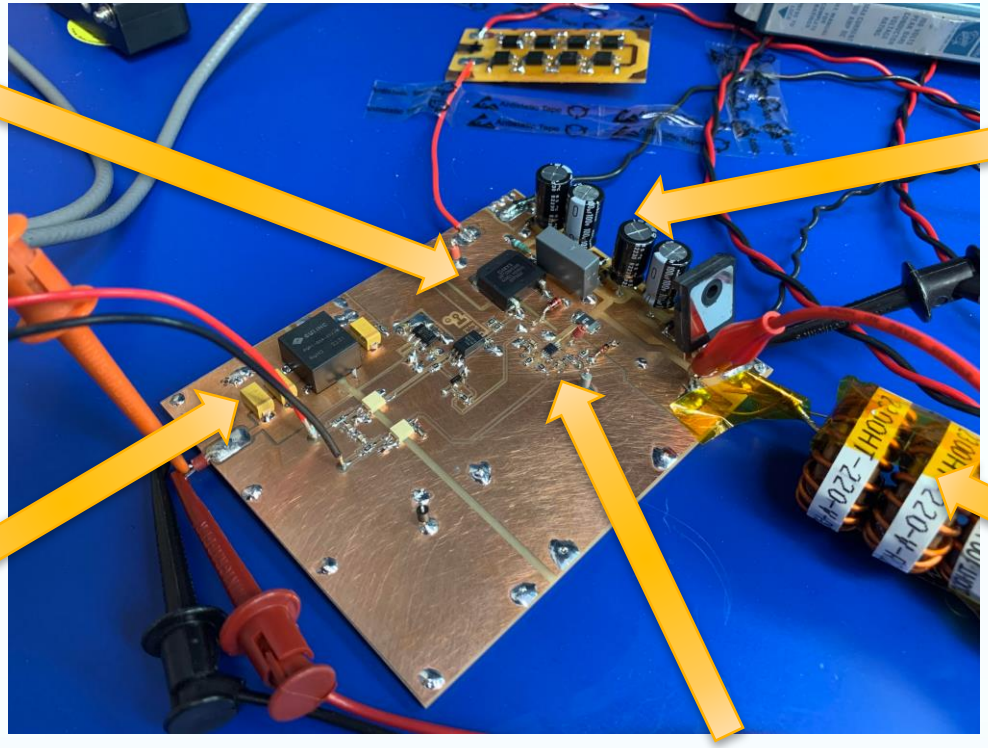
- ***Bulk capacitance needed to maintain voltages during inrush or fault currents***
  - *Voltage droops couple to other loads*
  - *Voltage droops affect load switch operation*
  - *PSU (MVC) may experience high speed feedback loop responses ("staircasing" observed)*
- ***Output channel inductor needed to limit rate of current increase during SHORT faults***
  - *This gives the short circuit protection circuits time to react (~2us needed)*
  - *IGB 220uH inductor is ineffective due to IPB input capacitance needed*

IPB Configuration



- Single 12V power for IPB channel
- Steering diode added to ISNS- input to protect from transients
  - -20V limit Vcm – normal operation is <-1V

Updated PCB Needed



- ***Original MVP PCB for short protection worked but suffered from induced EMI via drop down wires/standoffs***
  - *High dv/dt and currents in system above 200V caused poor fault detection*
  - *Single 12V HV power supply configuration!*
- ***PCB Mill 2-layer board created with entire IPB MOSFET switch and SHORT protection***
  - *No slow overcurrent or upstream logic implemented*
    - *INA310 SHORT detection latching / reset logic was utilized*
  - *Greatly eliminated loop areas – signals were clean and reliable*

Conclusion

- 375V SHORT circuit protection is design and tested
  - Took significantly more effort than original understood
  - Testing identified system level deficiencies
    - These were present prior to short detection inclusion
    - Would have been identified later at final testing with capacitive loads
  - A new “Test” PCB was needed implementing lessons from the first SHORT protection “MVP” PCB
- Up Next
  - IPB Updates have started!
    - Inclusion of all known prior clearance/issues found
  - Request from MBARI
    - Do you have detailed MVC output capacitance information/schematics?
    - If not – it may be beneficial to plan for adding output capacitance or test for the need

Relay

ABSMAX DC Current

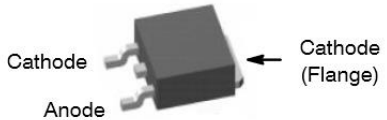
- 30A for non-switching application
- During high current pulse testing (40-90A observed) ***several relays are observed welded CLOSED***

DIODE

FFD08S60S-F085

ABSOLUTE MAXIMUM RATINGS (T_C = 25°C unless otherwise noted)

Symbol	Parameter	Ratings	Unit
V_{RRM}	Peak Repetitive Reverse Voltage	600	V
V_{RWM}	Working Peak Reverse Voltage	600	V
V_R	DC Blocking Voltage	600	V
$I_{F(AV)}$	Average Rectified Forward Current @ T_C = 115°C	8	A
I_{FSM}	Non−repetitive Peak Surge Current 60 Hz Single Half−Sine Wave	80	A
T_J, T_{STG}	Operating Junction and Storage Temperature	−65 to + 150	°C



DPAK3
CASE 369AS

- 80A half sine wave 60 Hz
- Use this as a rough guide – keep well below 80A

Existing IPB MOSFETS

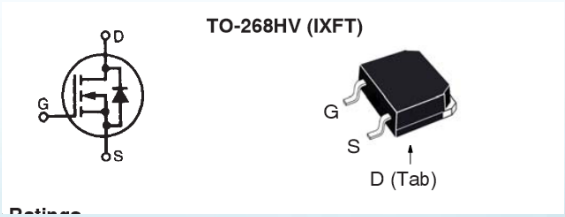
Existing IPB MOSFETS

- IXFN66N85X (Littlefuse) ($40/ea)
  - SOT-227 Package
  - Vds = 850V
  - Rds(on) = 65mOhms
    - 1.04W @ 4A
  - Gate Charge = 230nC
  - Id(max cont) = 65A

New MOSFET?

Same X-Class Family as IXFN66N85X

- IXFT50N85XHV (Littlefuse) ($18/ea)
  - TO-268HV Package (SMT!)
  - Vds = 850V
  - Rds(on) = 105mOhms
    - ~1.68W @ 4A
  - Gate Charge = 152nC
  - Id(max cont) = 50A



- ***We should seriously consider a NEW MOSFET***
  - *Labor $ to install SOT-227 is > New MOSFETS*
  - *Large, screws = FOD*
  - *Heating is not much of a concern at 4A cont. max…*

Extra