

Surviving Load Dumps on Military Vehicles

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Introduction

On 6 February 2009, the United Kingdom Ministry of Defence published Issue 6 of Defence Standard 61-5 part 6. The Issue 6 version of this specification was a substantial change over the issue 5 version. One of the key changes included the survival of electrical equipment when subjected to a DIT08.B Load Dump.

Although compliance to this specification included operator intervention, to replace a fuse for instance, and/or temporary interruption of operation of the equipment powered from this rail, many electronic devices could lose valuable data and be subject to an extended reboot period that might not be acceptable in some environments. Therefore a means to gaining criteria A compliance i.e. ‘the equipment shall continue to operate as intended during and after each test. No degradation of performance or loss of function or unwanted operation is allowed, when the equipment is used as intended’ is required by some applications. Other criteria compliance methods are not dealt with in this paper.

Furthermore, in this applications note we will consider 24V systems only, primarily because they are more prevalent where high-end equipment is likely to be used, but also because the same circuits – with small modifications – can be used to meet the requirements of the 12V systems. Also the energy available is smaller, and hence compliance is easier.

Figure 1
DIT08.B
Typical Test Configuration

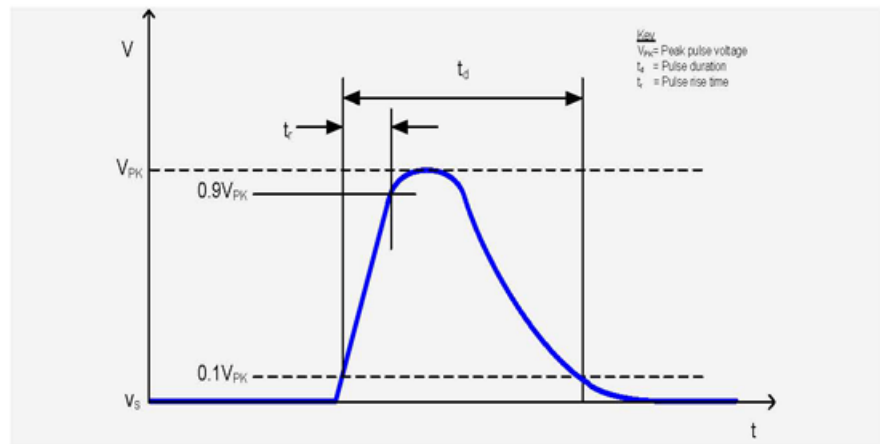


Figure 2
DIT08.B
Typical Test Configuration

Parameter	12V System	24V System
V_{PK}	87V	174V
t_d	400ms	350ms
t_r	10ms	
Transient Generator Output Impedance	0.5Ω	1Ω

Circuit Description

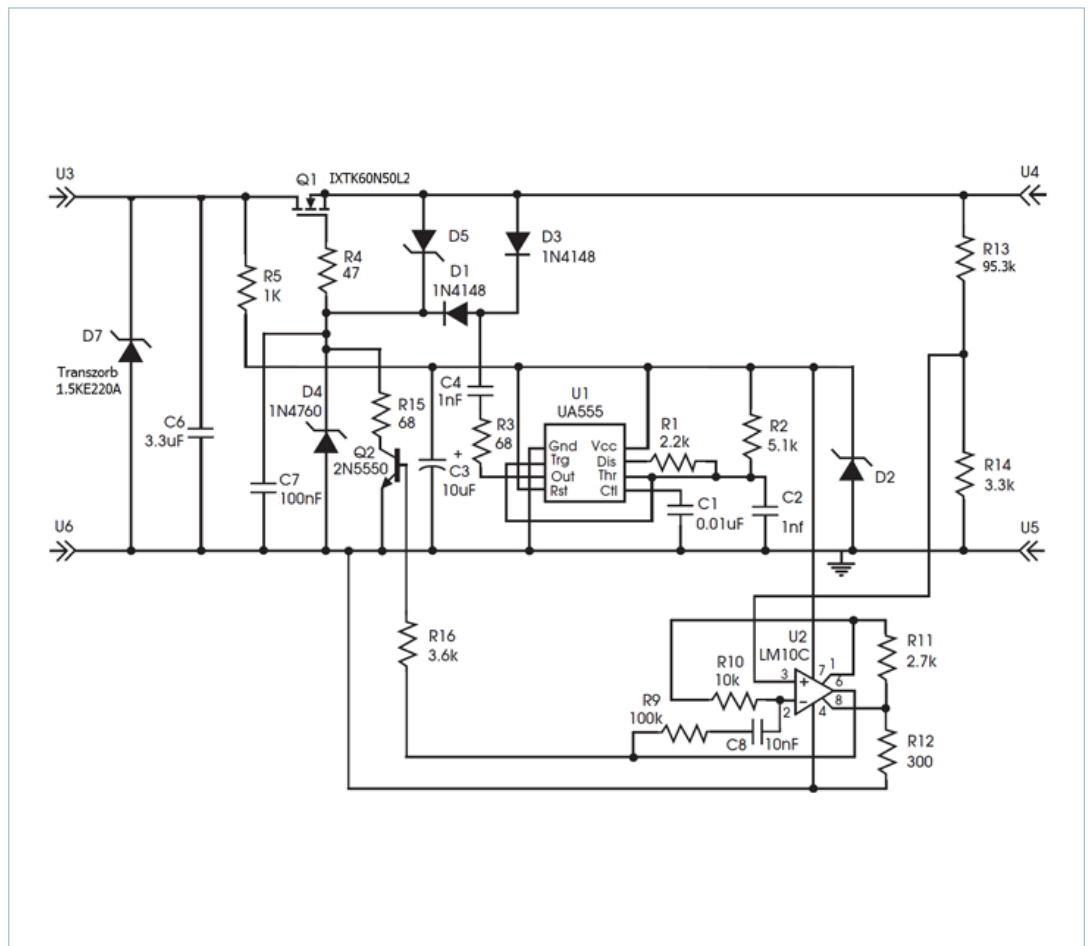
In a previous applications note, 'Meeting Transient Specifications for Electrical Systems in Military Vehicles', a simple protection circuit was described that allowed compliance to issue 5 of DEF STAN 61-5 part 6 and also MIL STD-1275 compliance. A modified version of this circuit can be used to meet the current DEF STAN 61-5 part 6 issue 6 and some of the DEF STAN 59-411 requirements, provided an appropriate transient protection and EMI filter module is placed after it. This also helps to reduce the stress on the main transient protection MOSFET, increasing overall surge energy handling so that higher operating temperatures can be achieved. Even so, a MOSFET with a large reliable SOA (safe operating area) is required. The IXYS IXTK60N50L2 (which uses an older MOSFET geometry, Q1) seems to meet these requirements. (Please note newer Trench FET devices are not likely to be suitable.)

High voltage, low energy spikes are absorbed by the capacitor and TransZorb across the input. All of the remaining circuitry addresses the problem of high-energy surges by performing two functions.

1. The output is clamped at 60V in the event that the input rises beyond that point.
2. If the overvoltage condition at the input persists for a period greater than about 350ms, the converter is shut down via the PC pin.

A charge pump provides full enhancement gate bias to the MOSFET (Q1) during normal operation. This function is accomplished by U1, an ICM7555 timer, which generates a rectangular waveform at 109kHz, that is peak detected and level shifted by R3, C4, D1 & D3. Capacitor C7 limits the rate of rise of the voltage across the output to less than 80V/ms, which in turn limits the inrush current to the filter module. The filter modules also provide inrush current limiting in accordance with the datasheets. If the input voltage exceeds 60V_{DC}, this circuit performs as a series pass linear regulator. The output voltage is compared with the LM10's reference voltage (1.95V). The error signal at the output of the LM10 is used to control transistor Q2 (2N5550), causing FET Q1 (IXTK60N50L2) to act as a voltage regulator. Capacitor C6 is the main spike removal device (the TransZorbs are only for added protection). C6 can also help reduce any high frequency ringing that may be applied to the circuit, although a small damping resistor in series with this capacitor may be required if the TransZorbs are not to be relied upon. D4 is added to limit the maximum voltage on C7.

Figure 3



The below circuit was then built and tested in conjunction with Figures 4 & 5.

A timing circuit was also used to protect the MOSFET by turning off the DC-DC converter, reducing the dissipation in Q1. An opto-coupler is used to ensure that the return current through the common-mode EMI filter components inside the M-FIAM9 are not short-circuited, which could affect the EMC performance of the device.

Please note: D9 needs to be a 36V zener diode (e.g. BZX84C36). D5 a 15V zener diode (e.g. 1N5245) and D7 (in Figure 3) a 1500W surge rated TransZorb (e.g. 1.5KE220A). A BZT03C12 can be used for D2.

Figure 4

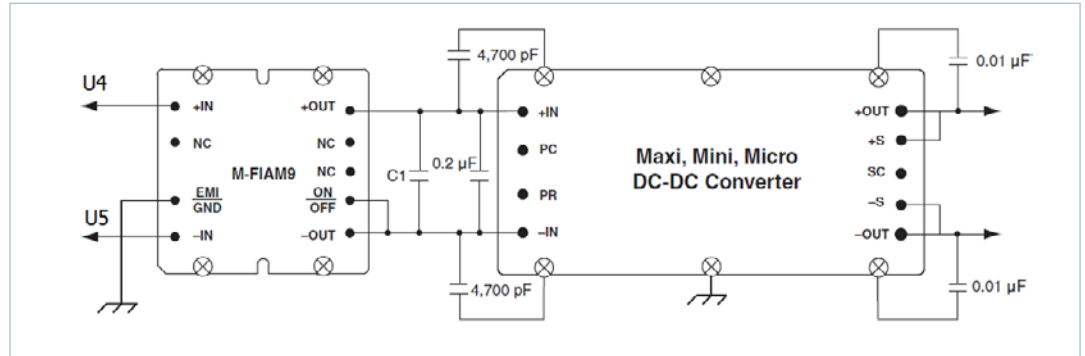
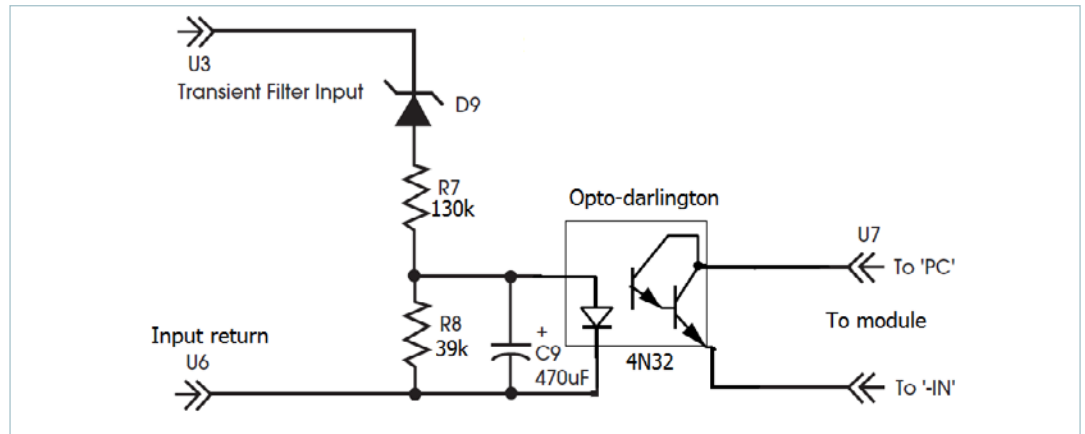


Figure 5



Surge Testing and Results with 24V range Micro Modules

Please see the following oscillograms that shows the performance with a 24V input range 5V output module when loaded at 20A. There is a short duration current spike through the MOSFET at the start of the surge that was measured separately at about 38A peak and had a 160 μ s duration. The first oscillogram (Figure 6) shows the timer circuit (Figure 5) switching off the PSU because the pulse duration exceeded the 350ms limit. Shorter duration surges are managed without affecting the performance of the DC-DC converter. Please see Figure 7. C1 was 780 μ F for these tests.

Trace 1 (yellow) is the input voltage to the circuit.

Trace 2 (blue) is the current through the Q1 mosfet.

Trace 3 (purple) is the output voltage of this circuit.

Trace 4 (green) is the PC pin voltage of the module.

Figure 6

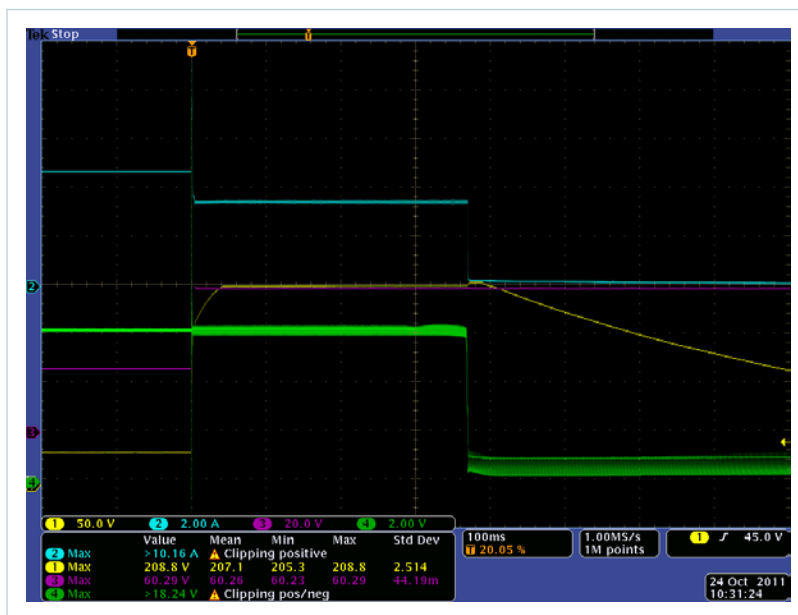


Figure 7

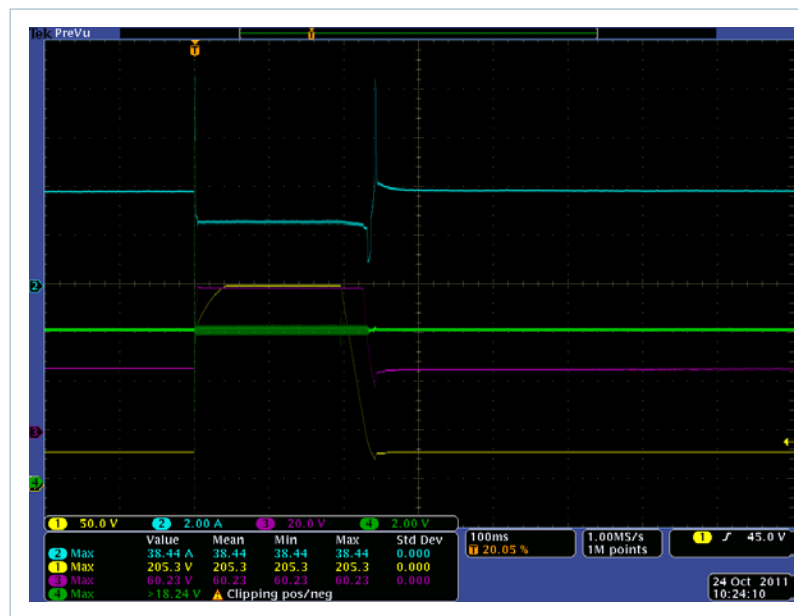


Figure 8



Figure 8 shows the voltage on the input to DC-DC converter with ride-through and shows the magnitude of the initial surge 40A surge and its duration.

Reviewing the SOA data for this part indicates, for this duration, that the transient thermal resistance is virtually identical to the steady state RthJC (thermal resistance junction to case) value of 0.13°C/W.

Therefore the transient temperature rise of the junction temperature will be:

$$\Delta T = 0.13^{\circ}\text{C/W} \cdot 3.4\text{A} \cdot (202 - 60)\text{V} = 63^{\circ}\text{C}$$

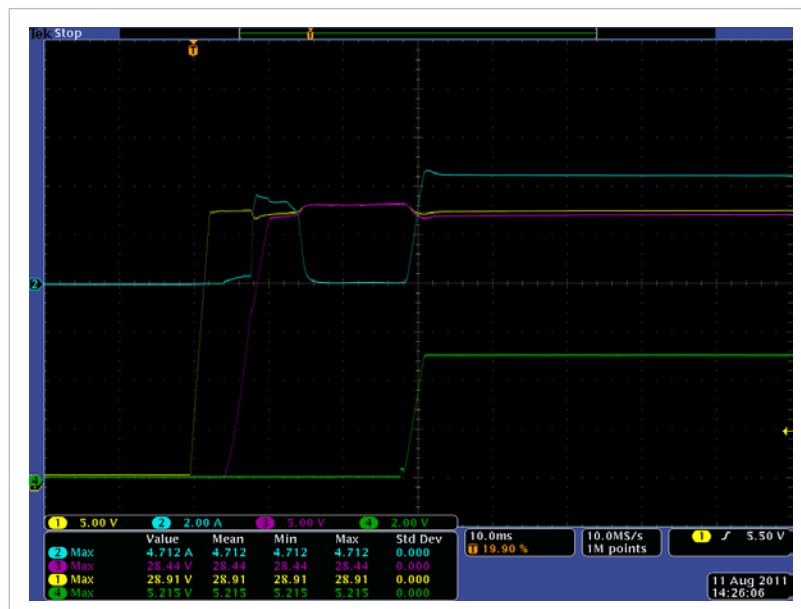
A further 5°C should be added to the above temperature to allow for the energy dissipated in the short duration current spike at the beginning of the surge. Since the maximum operating junction temperature for the device is 150°C this mean that this transistor is suitable for use provided its junction temperature prior to the surge is less than about 75°C allowing for a small safety margin.

Most of these UK Defence applications also require some level of DEF STAN 59-411 compliance. Normally a relatively small EMI filter prior to this transient protection circuit should enable compliance to land class A with a good layout, because the M-FIAM9 will accomplish the majority of the DC-DC converter module filtering.

The start-up performance with inrush current is shown for this arrangement in Figure 9. The loading is still 5V at 20A.

Please note that Trace 4 (green) now shows the output voltage of the module and not the PC pin voltage or module input voltage.

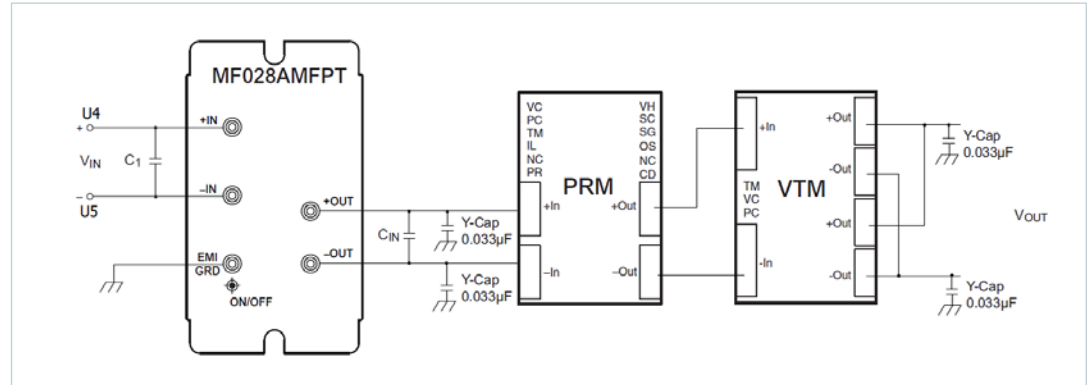
Figure 9



VI Bricks® (& VI Chips®)

This same circuit can be used with VI Chips and/or VI Brick products, replacing the M-FIAM9 filter with the MF028AMFPT filter. Because the shutdown timing circuit for this filter with 60V applied provides the correct timing shutdown period, timing circuit Figure 5 is not required. Therefore in the following oscillograms, circuit Figure 3 was placed before the standard circuit in Figure 10 shown below. Where $C_{IN} = 1000\mu\text{F}$ and $C_1 = 10\mu\text{F}$.

Figure 10



A 12V output VTM was loaded to 9.4A (i.e. the MPRM was loaded to its maximum 120W rating.) Figure 11 shows shutdown with a long duration surge. Figure 12 shows ride-through with a surge less than 350ms and Figure 13 shows start-up. The circuit suggested in Figure 5 was not used during these tests.

Trace 1 (yellow) is the input voltage to the circuit.

Trace 2 (blue) is the current through the Q1 mosfet.

Trace 3 (purple) is the output voltage of this circuit.

Trace 4 (green) is the output voltage of the VTM.

Figure 11

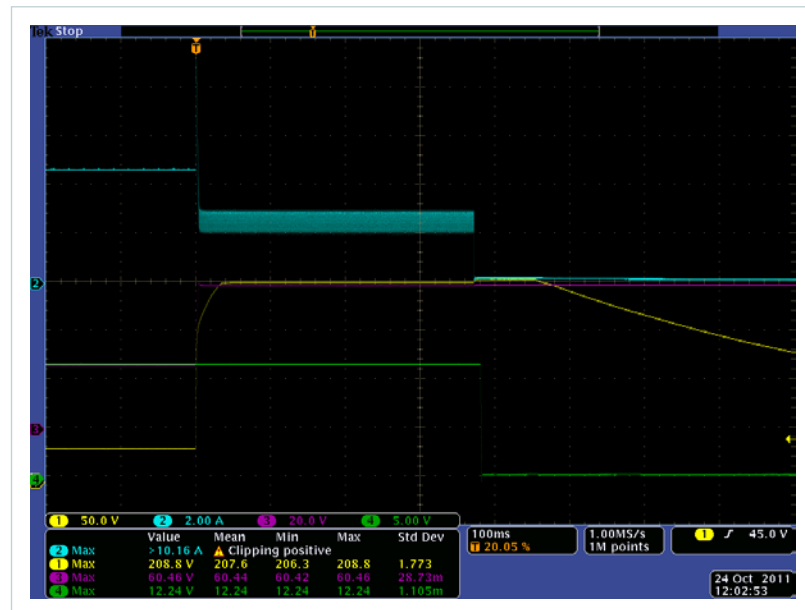


Figure 12

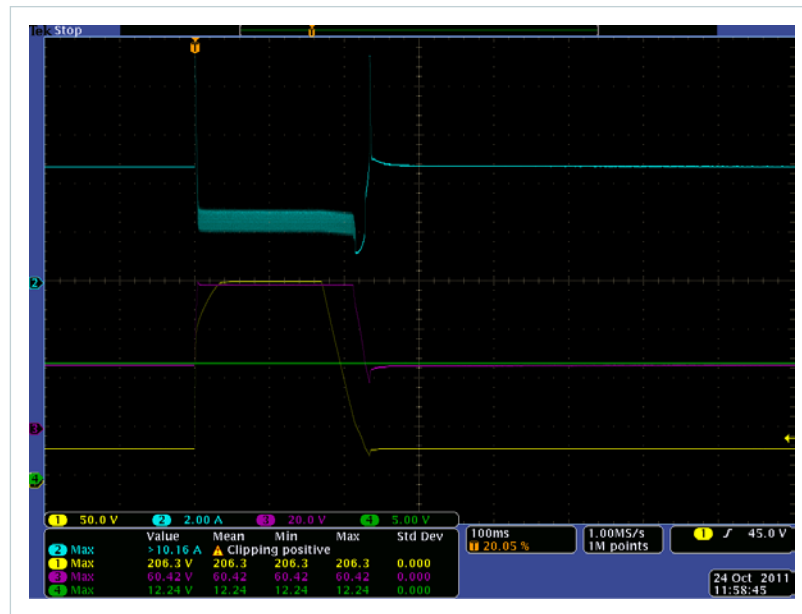
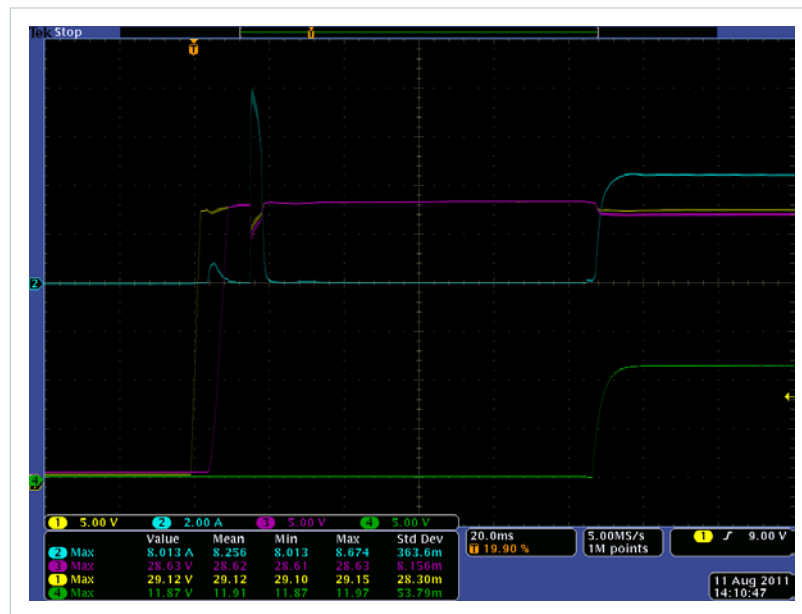


Figure 13



A similar review of the SOA for Q1, as carried previously for the M-FIAM9 and Brick module arrangement, indicates that under this mode of operation this circuit can be used with starting MOSFET temperatures up to 90°C.

Conclusion

The circuit recommended in Figure 3 is suitable for use with Vicor filter modules for DEF STAN 61-5 part 6 Issue 6 compliance criteria A applications, for up to 100W loads using 24V series modules and up to 110W loads when using MIL-COTS VI Chips® or VI Bricks®. A modest filter prior to the surge protection filter in conjunction with a layout to best engineering practices will enable compliance to DEF STAN 59-411 land class A, for conducted noise.

References

1. Are Trench FETs Too Fragile for Linear Applications? By Jeffrey A. Ely
2. Meeting Transient Specifications for Electrical Systems in Military Vehicles.

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