Use High Voltage Energy Storage Technique To Reduce Size and Cost of Transient Holdup Circuitry on ATCA Boards

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ABSTRACT

This application note presents a method for storing energy at high voltage (−72 V) to significantly reduce size and cost. Holdup energy in telecom systems is normally stored at −48 V. The high voltage energy storage technique is especially applicable to ATCA systems where up to 2.0 Joules of stored, available energy is required on each board.

1 Why Store Energy and Why at High Voltage?

Most telecomm equipment specs require full system operation despite 0-V transients at the system power input. The specified transient duration can be as short as 3 ms and as long as 16 ms. Many deployed systems satisfy holdup requirements with a large capacitor bank at the shelf or frame level. That solution will not suffice in ATCA systems since ATCA requires each board to store sufficient energy to keep the board running during a 5-ms short on the input. When the ATCA specified slew rates and UV levels are taken into account the hold up time is really about 9 ms. Further, input voltage magnitude may be as low as 43 V at the start of the transient and the board must still maintain full operation.

Assuming a −38-V undervoltage lockout level and a 20% capacitor tolerance the required onboard capacitance is:

$$C_{HOLDUP} = \frac{2E}{\left(V_1^{\,2} - V_2^{\,2}\right)(1 - K)} = \frac{2(1.8)}{\left(43^2 - 38^2\right)(1 - 0.2)} = 11,111\,\mu F$$

Where;

- E = required stored energy
- V1 = storage voltage = −43 V
- V2 = UVLO voltage = −38 V
- K = capacitor tolerance

11 mF of capacitance takes up a tremendous amount of space. It doesn't help that they must be rated to 100 V (unless otherwise protected upstream) and must be under the 21.33 mm height limit of ATCA boards.

By storing the energy at −72 V the amount of capacitance is drastically reduced while keeping the stored energy voltage within the input range of standard telco DC/DC converters. Substituting −72 for V1 in the equation above yields;

$$C_{HOLDUP} = \frac{2E}{\left(V_1^{\,2} - V_2^{\,2}\right)(1 - K)} = \frac{2(1.8)}{\left(72^2 - 38^2\right)(1 - 0.2)} = 1,203\ \mu F$$

This is almost a 90% reduction in the amount of required holdup capacitance. Figure 1 shows the capacitors required without HVES and Figure 2 shows the capacitors and circuitry required with HVES. Panasonic EEVFK2A331M 100-V, 330-µF capacitors are used. Using a doublesided board would further reduce the footprint of the HVES solution.

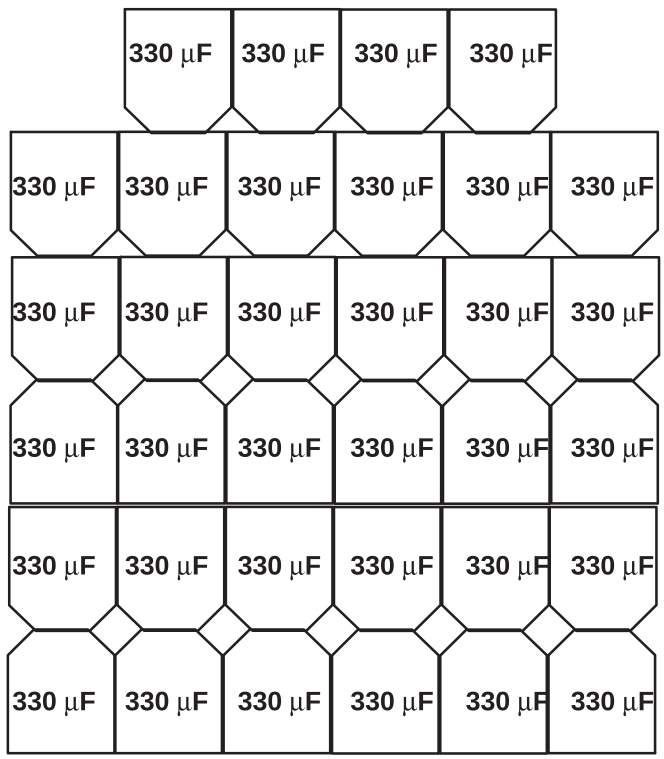

Figure 1. Energy Storage Capacitors Required for −43-V Storage Voltage 11,220 µF

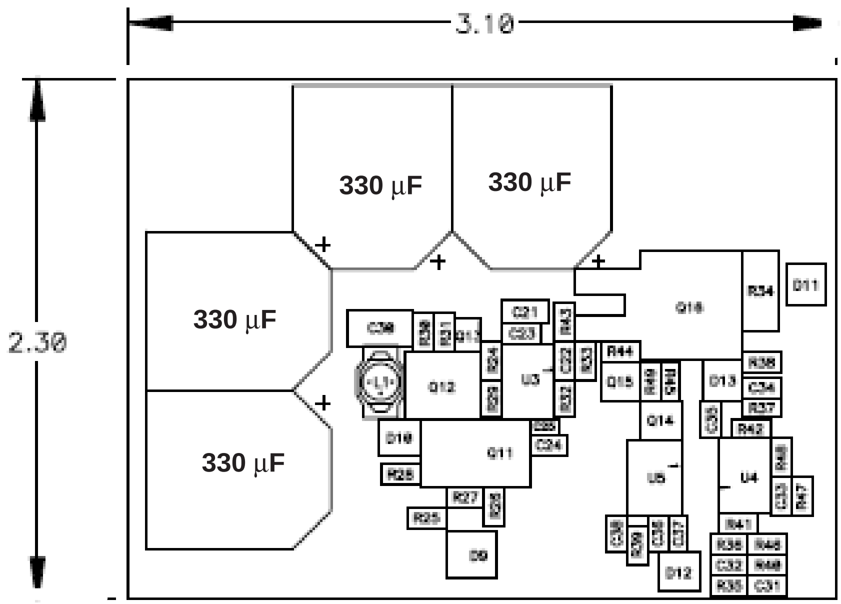

Figure 2. Energy Storage Capacitors and Circuitry Required for −72-V Storage Voltage 1,320 µF

1.1 Pump and Dump Circuitry

To store energy at high voltage two circuits are required. One circuit must boost the input voltage for storage and the other must dump the energy into the load during transient events. Although ATCA does not specify the minimum time between transient events it is generally assumed that quicker recharge times are better.

The circuit in Figure 3 uses a UC2572 negative boost converter to pump the input voltage to −80 V and stores it on four 330-µF capacitors. −80 V is an acceptable level because during a dump event Q16$R_{DS(on)}$ and trace impedance attenuate the input transient to less than 75-V magnitude. If longer holdup is required, the amount of capacitance can be increased to whatever amount is necessary.

The dump circuitry consists of two comparators, a one shot, and a FET switch. Comparator B enables the one shot when the stored voltage magnitude exceeds 61 V and disables the one shot if the stored voltage magnitude drops below 35 V. If the input voltage magnitude drops below 41 V (and the one shot is enabled) comparator A fires the one shot which turns on FET Q16 for a period of 10 ms. When Q16 turns on the HVES capacitors are shorted to the load and the energy dumps from the HVES capacitors into the load, and the load capacitors. If the transient still exists at the end of 10 ms when the one shot turns off it retriggers almost immediately as long as the HVES voltage magnitude is above 35 V.

In addition to the pump and dump circuitry there are 6 passive and 3 active components which create a −15-V reference. The −15-V reference is used by the UC2572, the comparators, and the 555 one shot as a supply voltage.

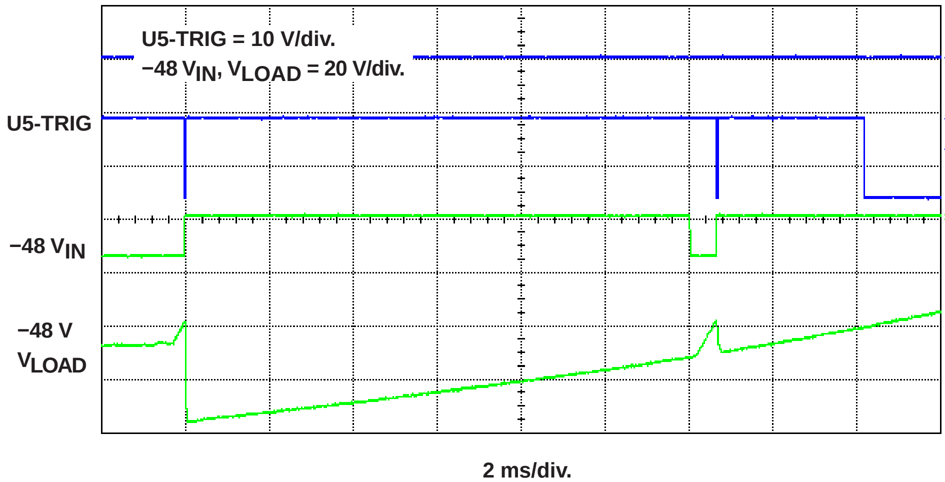

Figure 3. HVES Response to Loss of Input Power with 200-W Load

2 Summary

HVES is an effective method for reducing the cost and space required to comply with transient ride through requirements. This technique is appropriate for any high availability system which must continue to operate despite a short term loss of input power. A tested circuit and list of materials has been presented along with a description of circuit function.

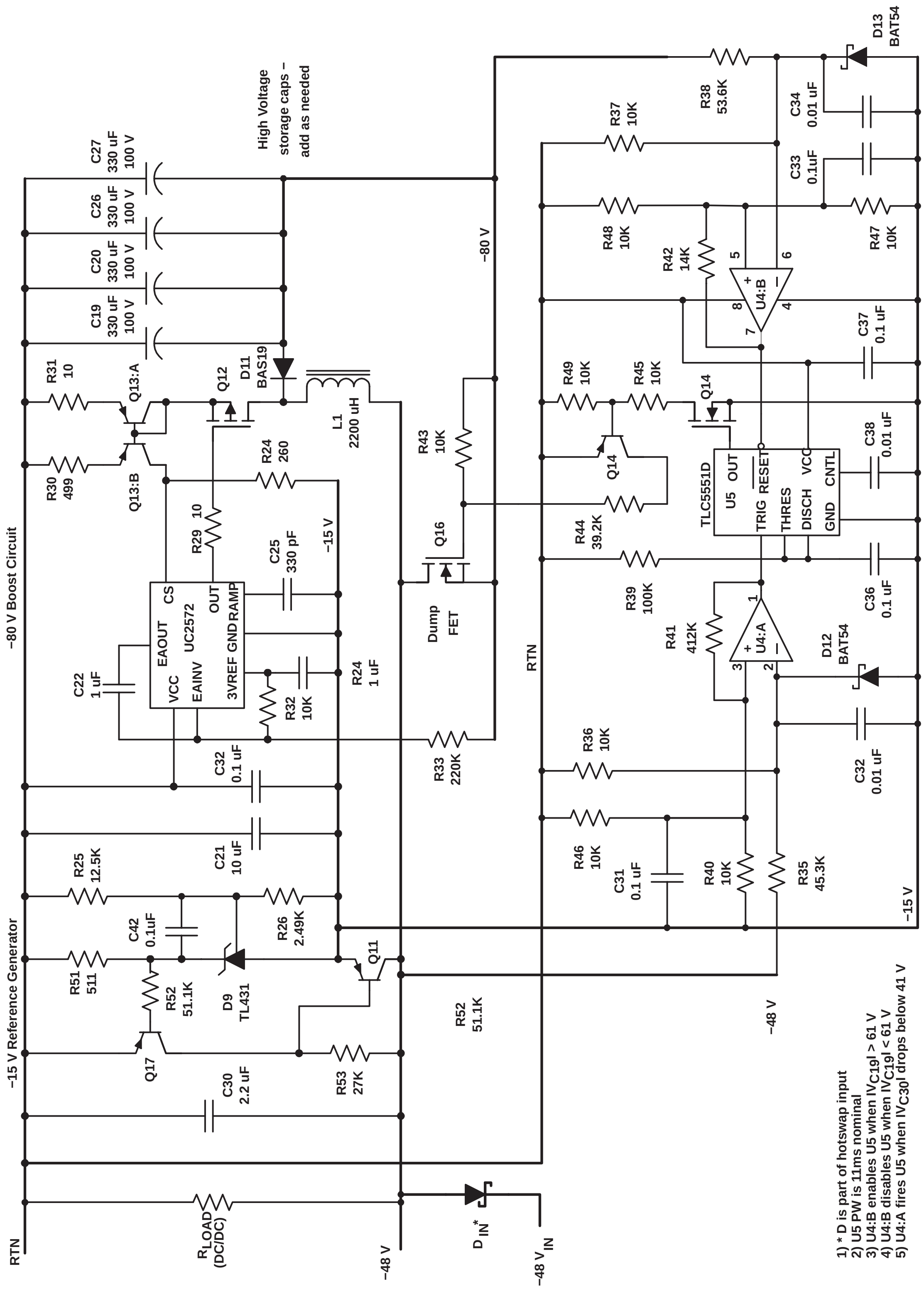

Figure 4. High Voltage Storage Circuit

Table 1. List of Materials for High Voltage Energy Storage Circuit

RefDes	QTY	DESCRIPTION	MFR	PART NUMBER
C19, C20, C26, C27	4	Capacitor, aluminum, sm, 330 µF, 100 V, 0.67 x 0.75	Panasonic	EEVFK2A331M
C21	1	Capacitor, ceramic, 10 µF, 25 V, X5R, 20%, 1206	Panasonic	ECJ−3YB1E106M
C22, C24	2	Capacitor, ceramic, 1 µF, 25 V, X7R, 10%, 0805	muRata	Std
C23	1	Capacitor, ceramic, 0.1 µF, 25 V, X7R, 10%, 0805	muRata	Std
C25	1	Capacitor, ceramic, 330−pF, 50 V, X7R, 10%, 0603	Std	Std
C30	1	Capacitor, ceramic, 2.2 µF, 100 V X7R 20% 1812	TDK	
C31, C33, C35, C36, C37	5	Capacitor, ceramic, 0.1 µF, 16 V, X7R, 10%, 0805	Vishay	Std
C32, C34, C38	3	Capacitor, ceramic, 0.01 µF, 16 V, X7R, 10%, 0805	Vishay	Std
C42	1	Capacitor, ceramic, 0.01 µF, 25 V, X7R, 10%, 0805	muRata	Std
D11	1	Diode, switching, 400 mA, 100 V, 250mW, SOT23	Diodes Inc.	BAS19
D12, D13	2	Diode, schottky, 200 mA, 30 V, SOT23	Vishay	BAT54
D9	1	IC, adjustable precision shunt regulator, SOT−89	TI	TL431CPKR
L1	1	Inductor, SMT, 2200 µH, 0.05 A, 19 Ω, 0.26x0.09	Coilcraft	DS1608BL−225
Q11	1	Transistor, power PNP, 100 V, 3 A, 15 W, DPAK	On Semi	MJD32CT
Q12	1	MOSFET, P-channel, 100 V, 1200 mA, 1.2 mΩ, SOT23	IR	IRFL9110
Q13	1	Transistor, NPN, dual, 150 V, 200 mA, SOT23	Diodes Inc.	MMDT5401
Q14	1	MOSFET, N-channel, 50 V, 0.17 A, 3.5 Ω, 14105	Zetex	BSS138
Q15	1	Bipolar, PNP, 150 V, 500 mA, SOT23	ON Semi	MMBT5401LT1
Q16	1	MOSFET, N-channel, 100 V, 120 A, 0.009 Ω, D2−PAK	ST Micro	STB120NF10
Q17	1	Transistor, PNP, −60 V, −600 mA, 225 W, SOT23	On Semi	MMBT2907ALT1
R24	1	Resistor, chip, 260 Ω, 1/10 W, 1%, 0805	Std	Std
R25	1	Resistor, chip, 12.5 kΩ, 1/10 W 1%, 0805	Std	Std
R26	1	Resistor, chip, 2.49 kΩ, 1/10 W, 1%, 0805	Std	Std
R29, R31	2	Resistor, chip, 10 Ω, 1/10 W, 1%, 0805	Std	Std
R30	1	Resistor, chip, 499 Ω, 1/10 W, 1%, 0805	Std	Std
R32	1	Resistor, chip, 10 kΩ, 1/10 W, 1%, 0805	Std	Std
R33	1	Resistor, chip, 220 kΩ, 1/10 W 1%, 0805	Std	Std
R35	1	Resistor, chip, 45.3 kΩ, 1/10 W, 1%, 0805	Std	Std
R36, R37, R40, R43, R45, R46, R47, R48, R49	9	Resistor, chip, 10 kΩ, 1/10 W, 1%, 0805	Std	Std
R38	1	Resistor, chip, 53.6 kΩ, 1/10 W, 1%, 0805	Std	Std
R39	1	Resistor, chip, 100 kΩ, 1/10 W, 1%, 0805	Std	Std
R41	1	Resistor, chip, 412 kΩ, 1/10 W, 1%, 0805	Std	Std
R42	1	Resistor, chip, 14 kΩ, 1/10 W, 1%, 0805	Std	Std
R44	1	Resistor, chip, 39.2 kΩ, 1/10 W, 1%, 0805	Std	Std
R51	1	Resistor, chip, 511 Ω, 1/10 W, 1%, 0805	Std	Std
R52	1	Resistor, chip, 51.1 kΩ, 1/10 W, 1%, 0805	Std	Std
R53	1	Resistor, chip, 27 kΩ, 1/10 W, 1%, 0805	Std	Std
RT1	1	Thermistor, PTC, 500 Ω, 0.197 DIA.	Vishay	2322 660 52893
U3	1	IC, Negative Output Flyback PWM, SO8	TI	UC2572D
U4	1	IC, Dual Micropower Comparator, SO8	TI	TLC3702ID
U5	1	IC, Timer, Low−Power CMOS, SO8	TI	TLC555ID

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