From Cold Crank to Load Dump: A Primer on Automotive Transients

MPS Webinar

October 2021

Webinar, Session 1 will begin at 7am ET-US | 1pm CEST - Europe | 8pm JST/KST – Japan/Korea

Webinar, Session 2 will begin at 8am PT-US | 11am ET-US | 5pm CEST – Europe

Material:

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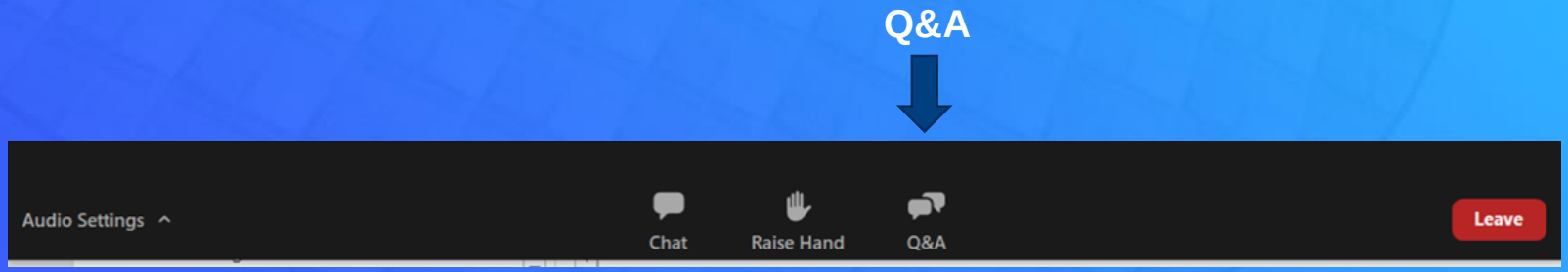
Presented By:

Todd Toporski

All webinar participants are muted.

At the end of webinar, there will be time for Q&A.

If you have a question, please ask only via the “Q&A” button,
and our team will reply live or by written response.



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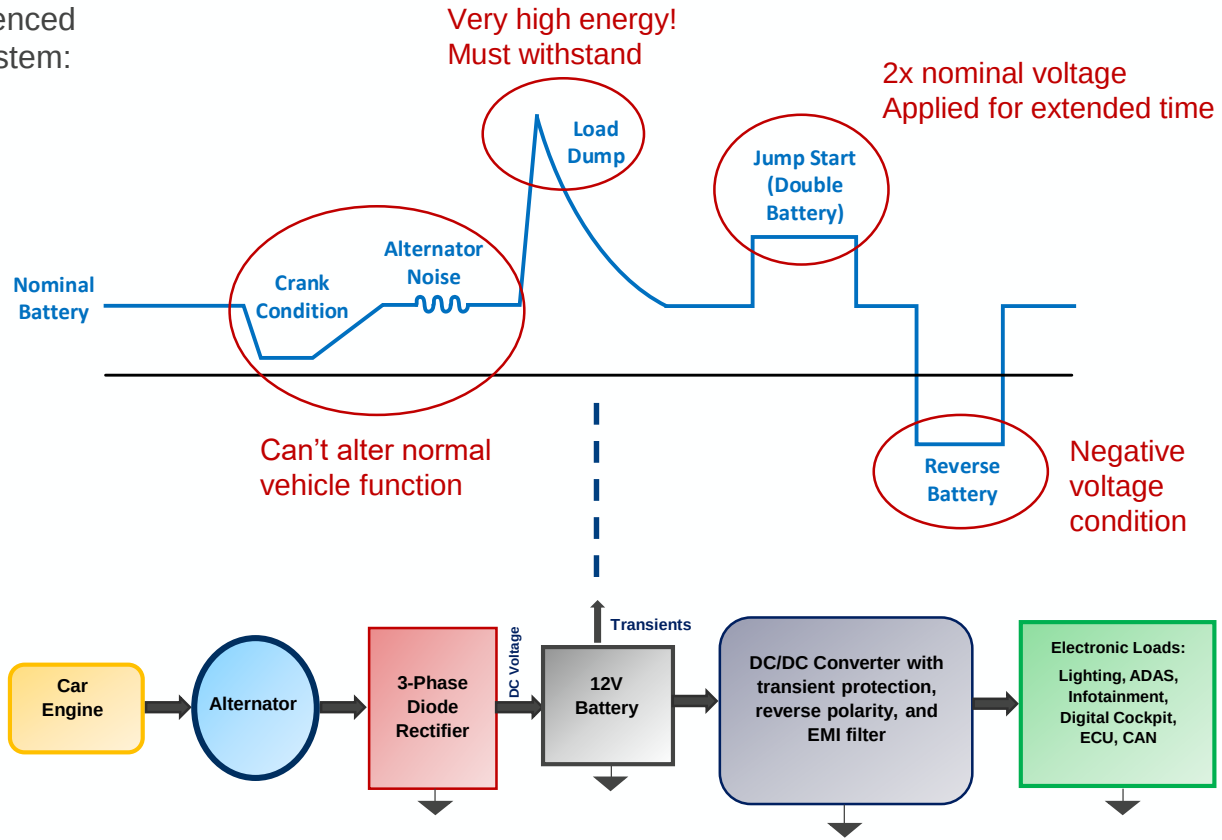
Transients experienced on 12V battery system:



Typical automotive transients

Typical automotive transients for 12V car systems

Transient Condition	Peak Voltage (V)	Peak Energy	Duration	Frequency of Occurrence
Load dump	120V	> 10J	40ms - 400ms	Not often
Double battery (jump start)	24V	--	Up to 5 minutes	Not often
Cold crank	-6V to -9V	--	1 to 10 seconds	Often
Warm crank	-6V to -7V	--	1 to 10 seconds	Very often
Reverse battery	-12V	Can be large	Up to 60 seconds	Not often
Ignition pulse (normal)	3-4V	< 1mJ	Few ms wide pulse	Continuous, f < 500Hz
Inductive loads switching	Up to 300V	< 1J	<300us	Very often

This is a subset of MANY transients that must be tested!!

Let’s look more closely at a few

Some that present significant design challenges for modern 12V vehicle electronics modules:

1) Cold crank & warm crank
2) Reverse battery
3) Load dump

For each of these transient conditions, let’s explore:

- How the transient condition occurs
- What the waveforms look like
- Design considerations the system designer must account for

Batteries, Temperature, & Crank Ratings

12V lead acid battery

- Lead acid chemistry is very sensitive to outdoor temperatures

- Battery test for Cold Crank Amps (CCA):
  - Occurs at 0ºF (-18ºC)
  - Load applied for 30 sec

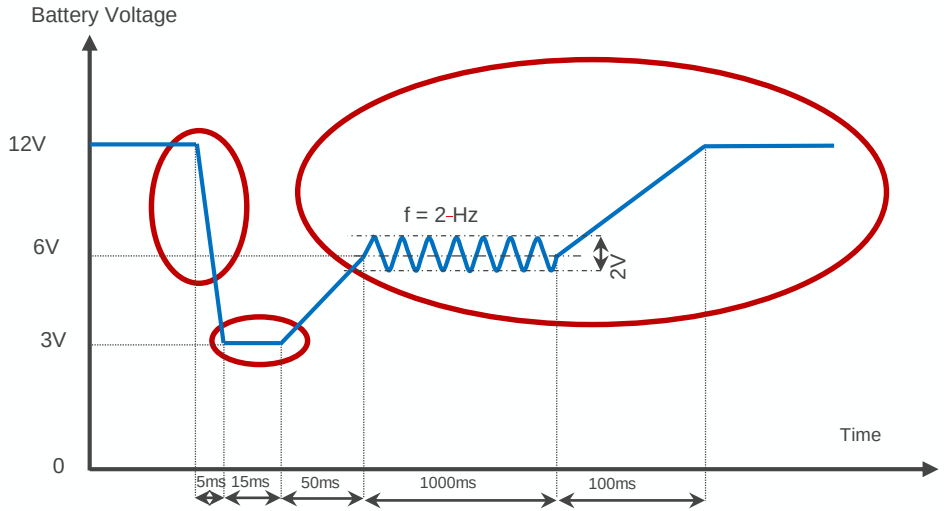
- Relative to room temperature power rating, lead acid battery has :
  - **~60% less power at 0ºF (-18ºC)**
  - **~75% less power at -20ºF (-29ºC)**

Also need to consider:

- Gas engine requires more power to start at cold temp (engine oil, mechanical parts impacted by temperature as well!)
- **Engine may require >200% more power to start at 0ºF (-18ºC) than it does at 70ºF (21ºC)!**

Cold crank

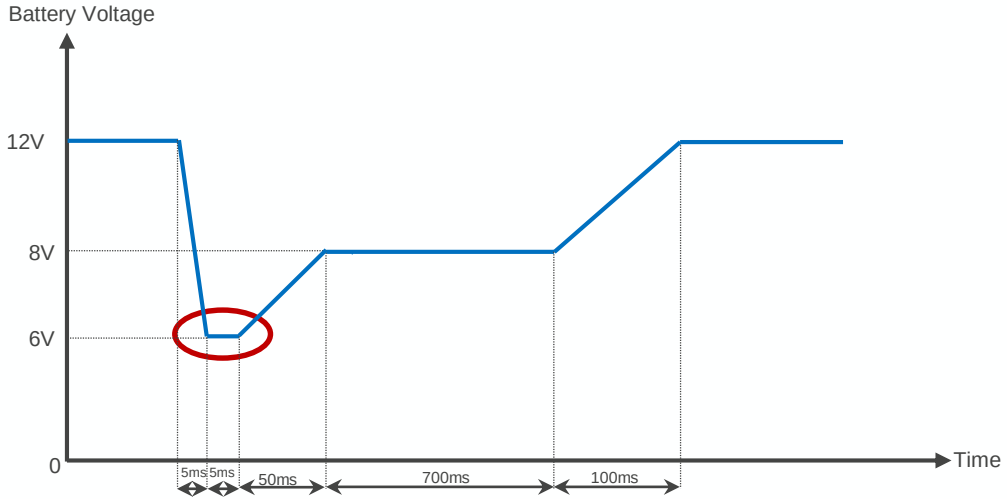
- **“Cold crank”** describes when a vehicle starts during cold conditions
- Vehicle battery and engine are both subjected to cold temperature
- In this condition, the starter draws a high current from the battery to start the engine, and the battery voltage drops very low.



Example of a cold crank waveform

Warm crank

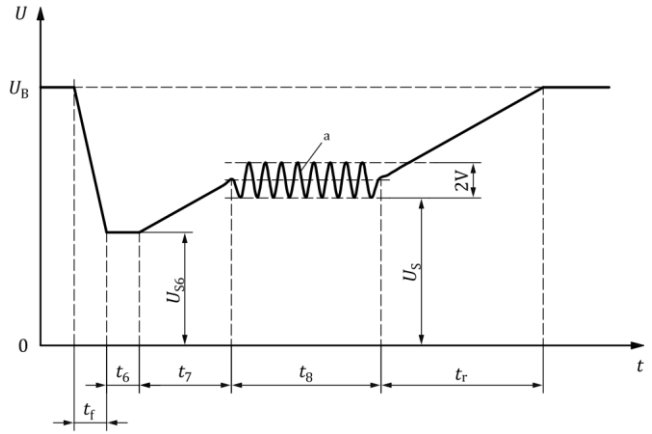
- **“Warm crank”** describes when a vehicle starts during warm conditions
- In this condition, the starter draws a current from the battery to start the engine, and the battery voltage drops
- Warm crank pulses typically not as severe as cold crank, voltage doesn’t drop as low



Example of a warm crank waveform

Standards for starting profiles

- **ISO 16750-2** and **ISO 7637-2** are two of the most commonly used specifications in the automotive industry.
- Both sets of standards define different starting profiles, for both 12V & 24V vehicle systems.
- Each starting profile contains specific voltage levels, pulse durations, and other timing information specific to common cold crank and warm crank waveforms.



ISO 16750-2 starting profile waveform

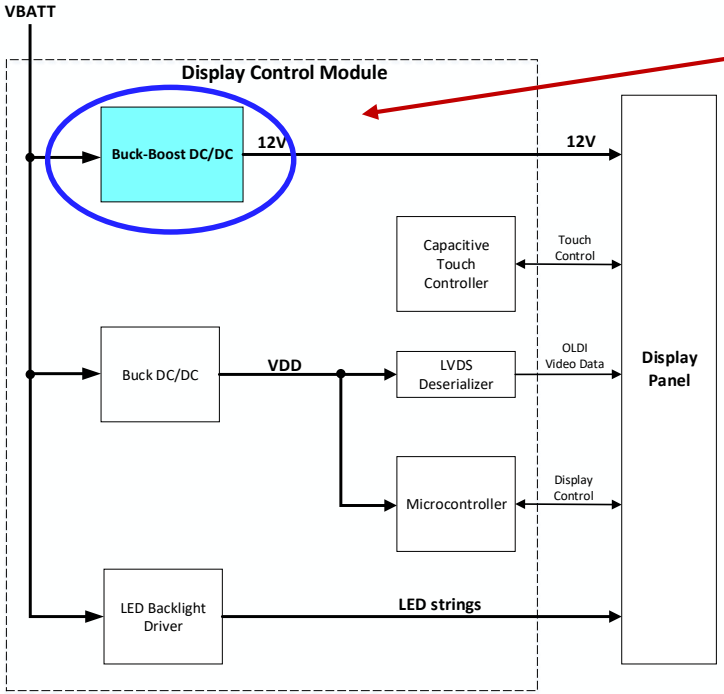
U_S, U_{S6}, t_f, t_6, t_7, t_8, & t_r are defined in ISO 16750-2 for specific start/crank waveforms.

- ISO 16750-2 includes injected sinusoid (ISO 7637-2 does not include sinusoid)

Many automotive OEM's use specifications that refer to one (or both) of these two ISO standards. They may also provide slight variations of these specs that pertain to their own unique requirements.

Starting profiles – system design considerations

- Many vehicles require that certain functions continue operating, even during various start conditions
- Common example: start/stop. When the engine shuts off and turns back on, specific modules must continue functioning normally.
- E.g. Displays, radio, and audio modules may not be allowed to temporarily shut off during start/stop



Example:

- Display Control Module must provide = 12V to Display Panel at all times
- Buck/boost DC/DC is used to maintain proper voltage
- Display flicker and video dropouts are avoided

- **Boost & buck/boost converters - excellent topologies to use in systems that must tolerate crank conditions**
- **These topologies offer high efficiency (>90%) for large load currents, low power dissipation**
- **Wide Vin converters are used, that can operate down to 3-4V on the input, and withstand voltages up to 36V or higher**

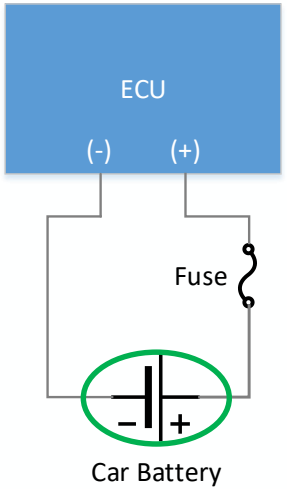
Reverse battery

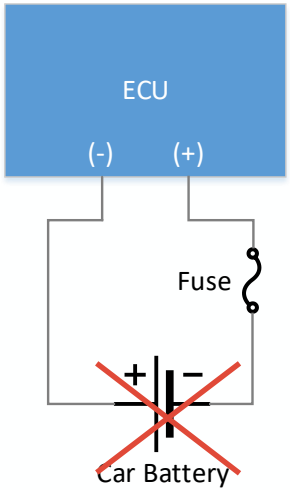
Reverse battery, or reverse voltage, describes a transient condition that occurs when the car battery is disconnected from the system and then reconnected with the battery polarity reversed.

This condition can accidentally occur during routine maintenance or service of the vehicle.

Reverse battery creates a **negative voltage (-12V) across the loads and circuits** that are typically supplied by the battery and alternator.

Correct!





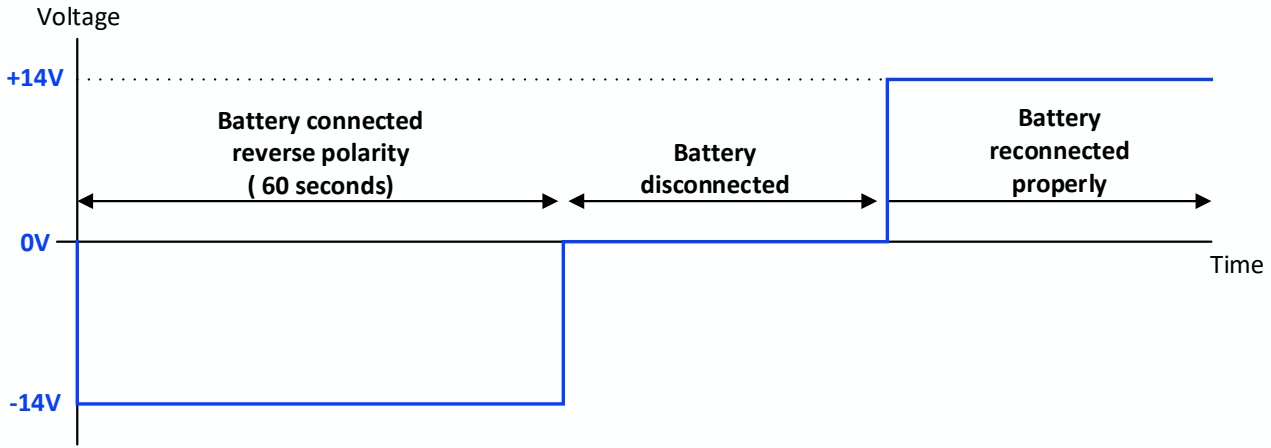
Not Correct!

Standards for reverse battery

ISO 16750-2, Section 4.7 describes a ‘Reverse voltage’ condition & test method

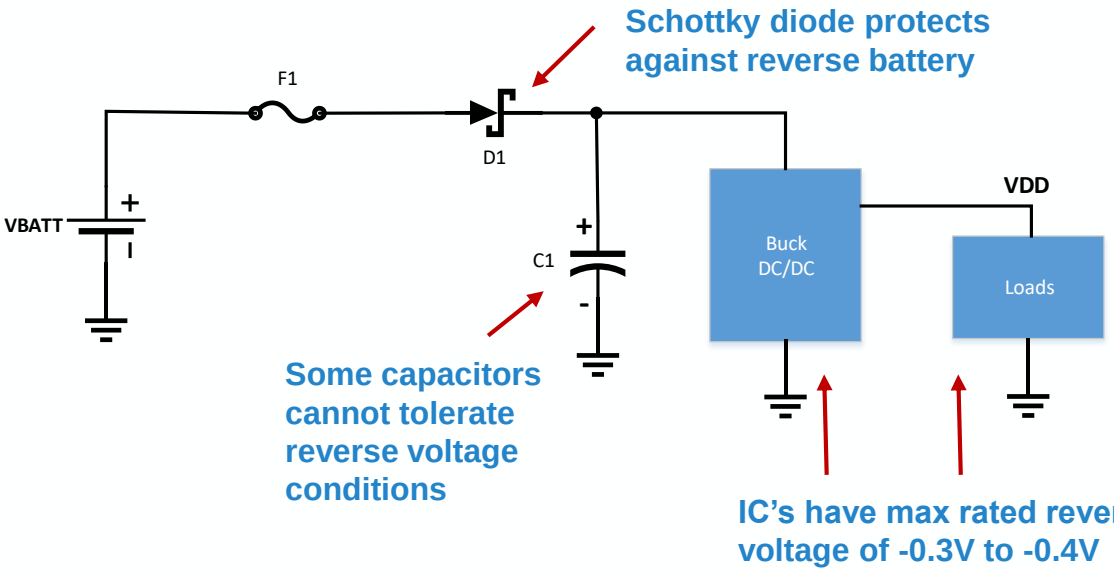
- The most common test case described applies -14V (for a nominal 12V system) for 60 seconds
- After the reverse test voltage is applied, the battery is disconnected, and system must then be re-tested with correct polarity (+14V) to ensure damage did not occur.

Reverse Battery Test:



Reverse battery – system design considerations

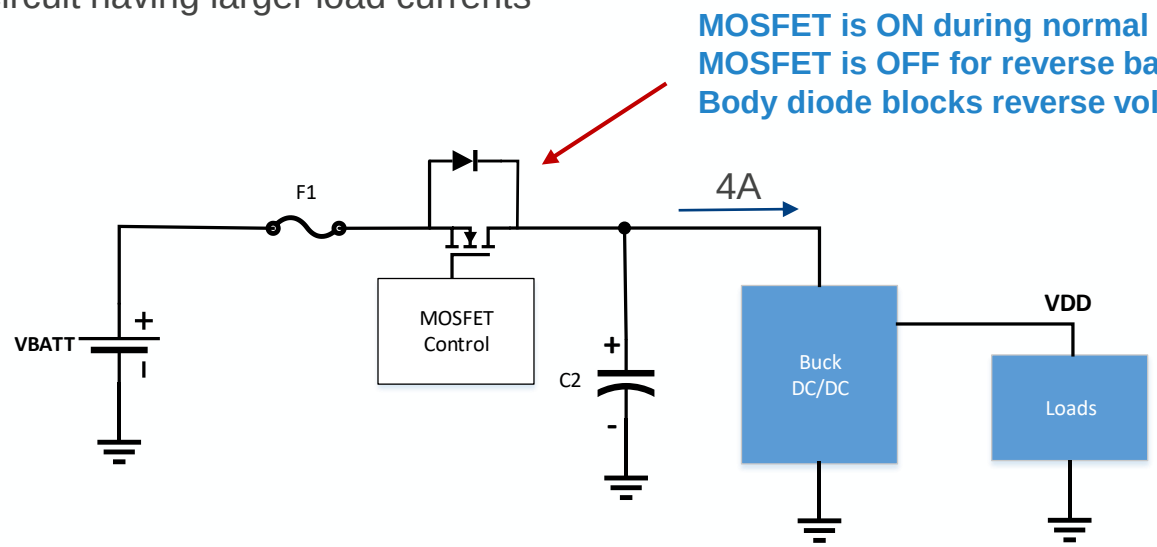
Consider a typical buck converter, stepping down from car battery to VDD



- Effective and low cost approach to provide reverse battery (reverse voltage) protection
- Good for low currents, ~2A-3A or less
- Forward voltage drop (VF) of diode becomes limiting factor at higher loads & temperature
  -> high power dissipation!!

Reverse battery – system design considerations (cont'd)

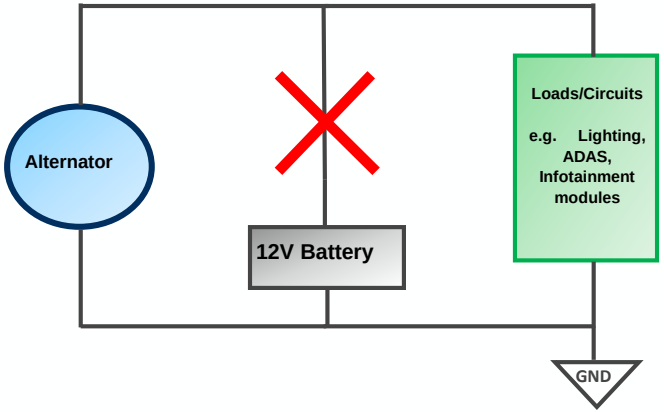
Similar circuit having larger load currents

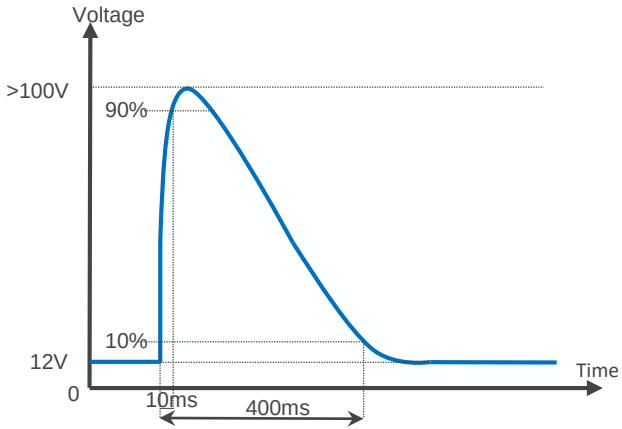


- Effective approach to provide reverse battery for larger load currents, e.g. > 3A
- Discrete or integrated circuit approaches to control MOSFET
- **Smart diode controller** is a very effective solution: **small, low cost, and very efficient!**

Load dump

Load dump describes a transient condition that occurs when the alternator is charging the battery, and the connection to battery is lost while other loads remain on the alternator.





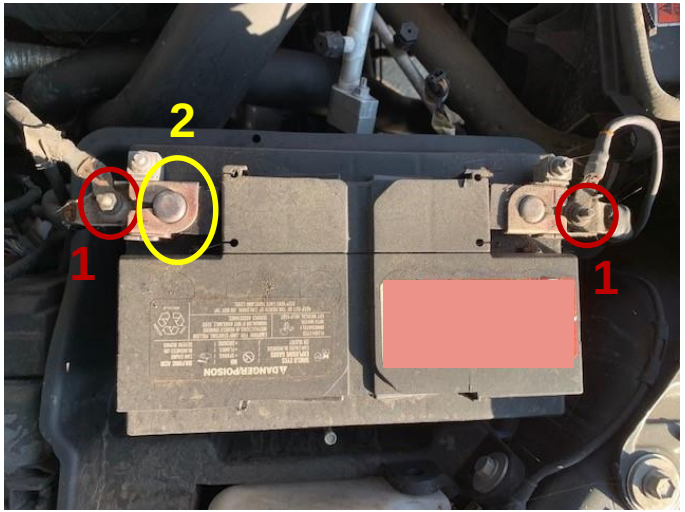
When battery connection is lost:

- Resulting large voltage surge can result in **>10J of energy!**
- Transient lasts for **nearly half a second!**
- All circuits and loads connected to alternator will be exposed to this transient.

How does load dump occur?

Conditions that could result in a load dump transient often involve problematic connections to the battery. Some of these include:

1. Loose connection to battery
2. Corroded battery terminals
3. Faulty or damaged cabling

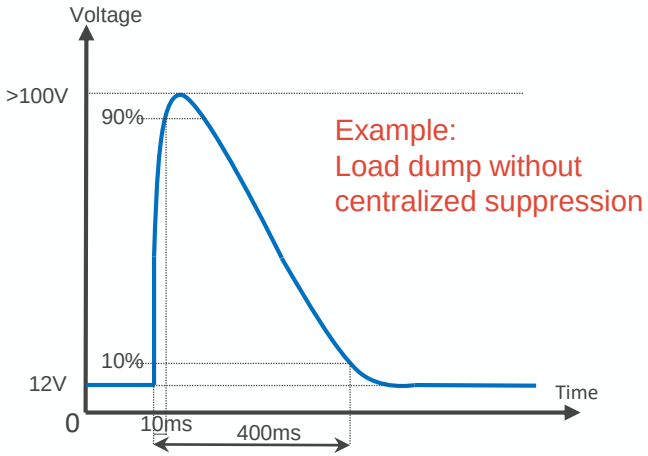


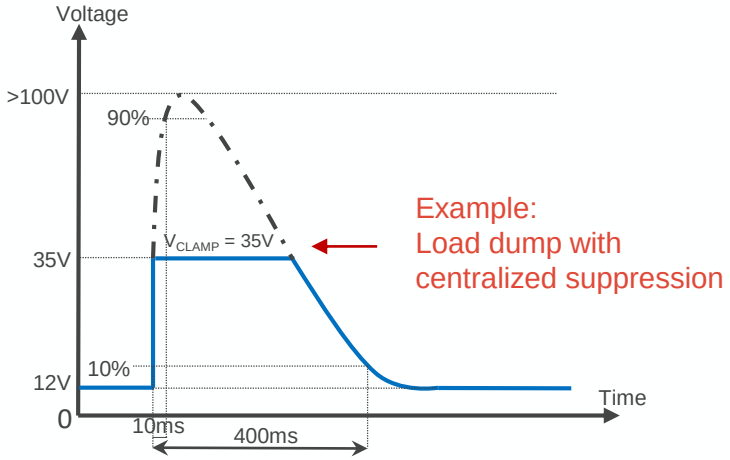
Standards for load dump

ISO 16750-2 and **ISO 7637-2** specify automotive load dump for 12V & 24V systems.

Both sets of standards define transient pulses for the cases of load dump:

a) **Without centralized suppression**
b) **With centralized suppression**

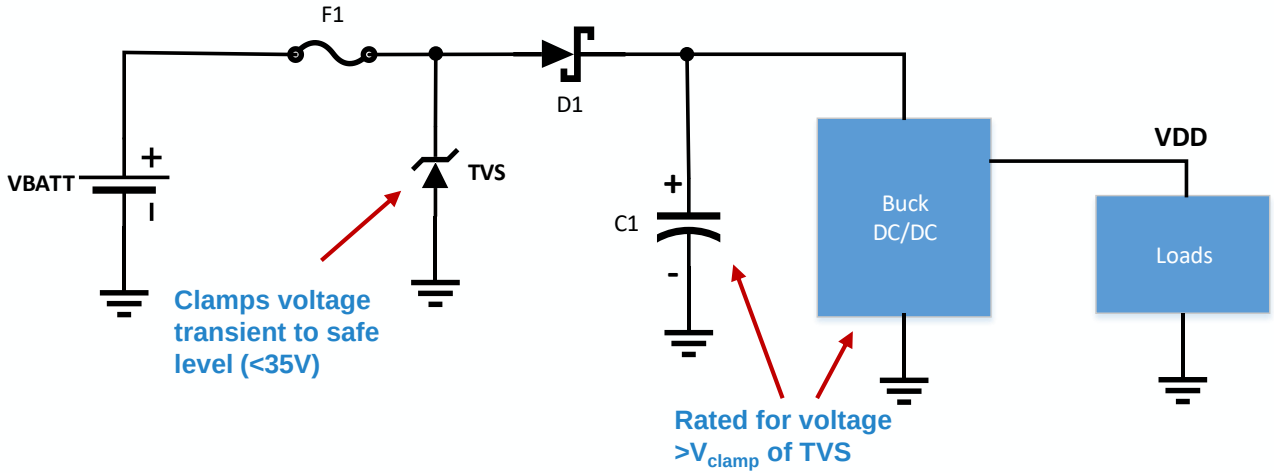




- Definitions for voltage levels, rise time, and pulse durations are provided in the ISO standards

System design considerations for load dump

For systems that must “ride through” load dump and continue working…



- Transient voltage suppressor (TVS) is one of most popular approaches
- Many different sizes, voltages, current and energy ratings
- Select TVS that starts to breakdown at a minimum desired $\mathbf{V_{BR}}$ (e.g. 24V)
- TVS maximum $\mathbf{V_{clamp}}$ is specified higher than $\mathbf{V_{BR}}$ (e.g. 35.5V)
- Voltage ratings of IC’s and components >$\mathbf{V_{clamp}}$ by some “safe” margin

Summary

This webinar provided background information on several critical automotive transients, including:

1) Starting profiles, such as “cold crank” & “warm crank”
2) Reverse battery
3) Load dump

Each transient was reviewed to understand how they occur, how their test waveforms are specified, and how automotive system designers must account for them in their designs.

Summary - continued

Details on MPS automotive power products can be found at:
https://www.monolithicpower.com/en/applications/automotive.html

Products that provide power during cold & warm crank conditions:

MPQ3910A-AEC1 - 35V, Boost PWM Controller
https://www.monolithicpower.com/en/mpq3910a-aec1.html

MPQ8875A-AEC1 - 36V, 4-switch, Synchronous Buck-Boost Converter
https://www.monolithicpower.com/en/mpq8875a-aec1.html

Products that can handle load dump input conditions:

https://www.monolithicpower.com/en/products/automotive-aecq-grade/switching-converters-and-controllers-aecq-grade.html

Products that help with reverse battery conditions:

MPQ5850-AEC1 Smart diode controller
Preliminary info, ask MPS Sales

THANK YOU!!

Q&A

Let us know your questions