FMC1278 Transient Sources

AEi Systems, LLC.

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Overview

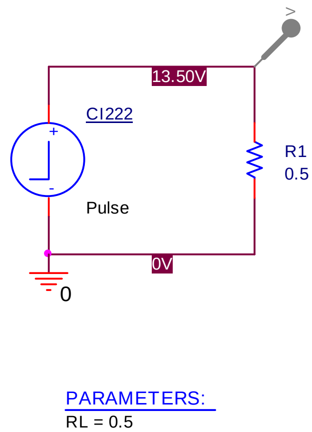
All EMC models are created in accordance with Ford's FMC1278 document (Electromagnetic Compatibility Specification for Electrical/Electronic Components and Subsystems, October 07, 2016) from Ford, as well as ISO 7637-2:2004(E) and related specifications.

The CI 220 source is somewhat unique. For CI 220 non-ISO pulses, although the physical FMC1278 test equipment can perform all the test types by selecting switch settings and connection locations, SPICE simulations are performed with specific SPICE models assigned to each of the pulse types. The loading the transient source sees is specific to the transient pulse type. For instance, the A2-1 (contact break arc) and C1 (contact make arc) pulse types are to be used with purely inductive loading. If a capacitive (shunt load capacitor) is in the circuit, this will alter the contact make/break characteristics of the SPICE model. In that case a different transient source is needed (A2-2 or C2, respectively). In real life the test equipment would adapt, but in the case of SPICE the sources do not know what they are connected to and therefore, the impedance must match what the model is expecting. In addition, low resistance loading (below a few hundred ohms) on the A2-1 and C1 transient source can significantly change the physics at the contacts where the arc voltage amplitudes are damped (no longer high in amplitude) and therefore, no longer applicable. The performance at higher currents is addressed by the other pulse types. It is up to the analyst to choose correct transient generator source to perform required tests.

For example, CI220_CHAT_C2_M3 can **only** be used to simulate Pulse C2 Mode 3 test condition. CI220_GEN_A1_M1_M2 can be used for both Pulse A1 Mode 1 and Pulse A2 Mode 2 simulations.

Please refer to "**Introduction to CI220 Non-Standard Transient Waveforms"** section on page 14 for more information about CI 220 pulses.

CI 220, 250, and 280 waveform outputs will change their shape depending on the load impedance that is connected to the circuit. Other pulses have a fixed 1mOhm output impedance. For the transients where the output load dictates the output voltage level (e.g. CI 222 Pulse 5a), a user defined passed parameter (with a default value) is added to emulate an appropriate output impedance (Ri).



Timestep has to be set below 1m
for the full resolution of the pulses to
be observed.
Simulation time can be reduced from
100s in order to speed up the
simulation.

In order for the model to work, a parameter
(not a resistor) called {RL} has to be added to
the circuit. If the circuit would be unloaded,
RL should be >= 1kOhm. If circuit has a
resistive load, RL should be equal to that
resistance.

Example: CI 222 Pulse 5B transient source with the user-specified passed parameter "RL" set below the 1kOhm resistance, thus setting Us and Us* values based on the resistive load Ri = RL=0.5 (See page 116 of the FMC1278 document).

Please refer to the "AutomotiveSources.opj" example project file to see how simulation circuits should be set up.

It should also be noted that time step control of the SPICE simulator is critically important. If the time step is allowed to become too large, aliasing will occur. The sources will **not** produce correct result if the maximum time step size (tmax) is not small enough to capture the full behavior of the waveforms. For most simulations, tmax must be as low as 30ns. Running preliminary simulations without applying any loading to the circuit can help confirm the correctness of the output waveforms.

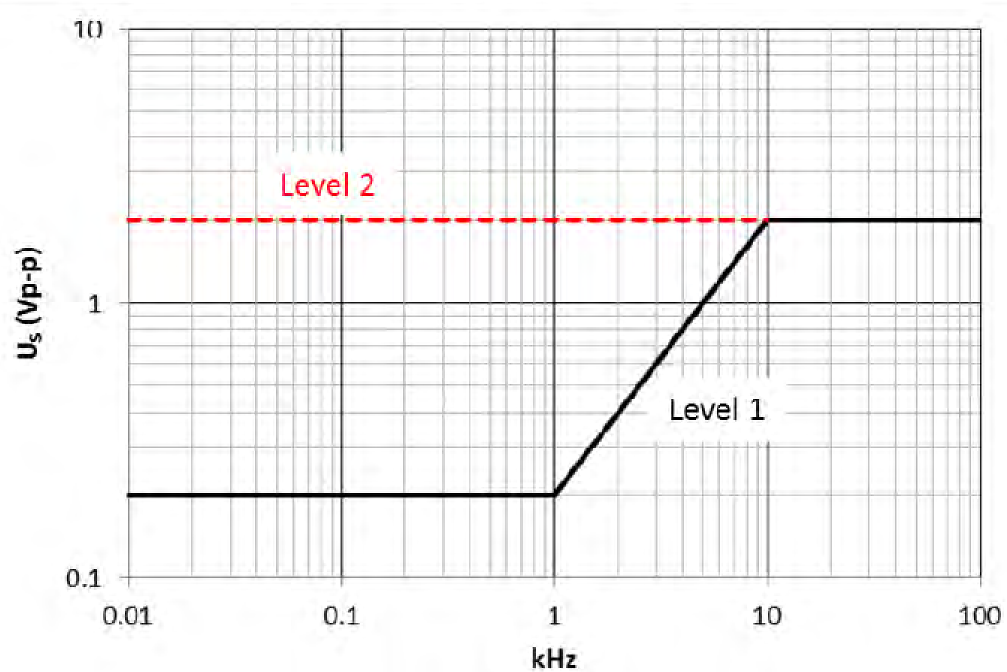
Given the long simulation time requirements and high burst counts, it is often required to use PSpice "schedule" option to set maximum step size values. In order to further improve convergence, the schedule option can be used for other simulation options as well, such as Reltol. If convergence issues persist, changing other simulation options such as GMIN, Abstol, Vntol, etc. can help. But be careful not to let these options become too large as the simulation fidelity may be compromised.

Before performing an EMC or ESD simulation, refer to the "Test Verification and Test Setup" section of each transient description, in the FMC1278 document, to make sure the circuit is set up correctly. Some simulations require the presence of additional components between the signal source and the DUT. For example, CI 260 Waveforms A, B, and C require placement a series fast recovery diode followed by a shunt resistor between the signal source and the DUT as noted in FMC1278.

CI 210 specification: Immunity from Continuous Power Line Disturbances

The function of the component/subsystem shall be immune from continuous disturbances that occur on the vehicle's power distribution system. The functional requirements are defined below. The two requirement levels shown below set the amplitude (Us) value of the transients.

Figure 16-1: CI 210 Requirements



Requirement Level	Frequency Range (kHz)	U_S (Vp-p)	Functional Performance Status		
			Class A	Class B	Class C
1	.01 - 1	0.2	I	I	I
	1 - 10	$0.2 \cdot f$			
	10 - 100	2.0			
2	.01 - 10	2.0	III	II	II

f = frequency in kHz

Figure 16-3: CI 210 AC Stress Level (U_S) Superimposed on DUT Supply Voltage (U_P)

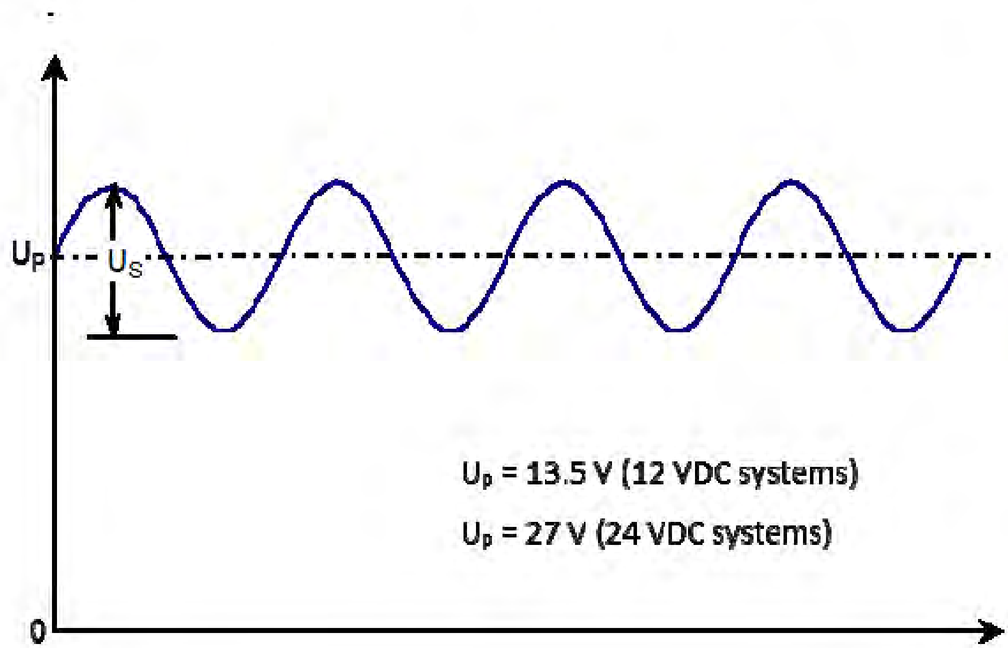


Table 16-1: CI 210 Test Frequency Requirements

Test Frequency Range (kHz)	Frequency Step (kHz)
0.01-0.05	0.01
0.05 - 1	0.05
> 1 - 10	0.5
> 10 - 100	5

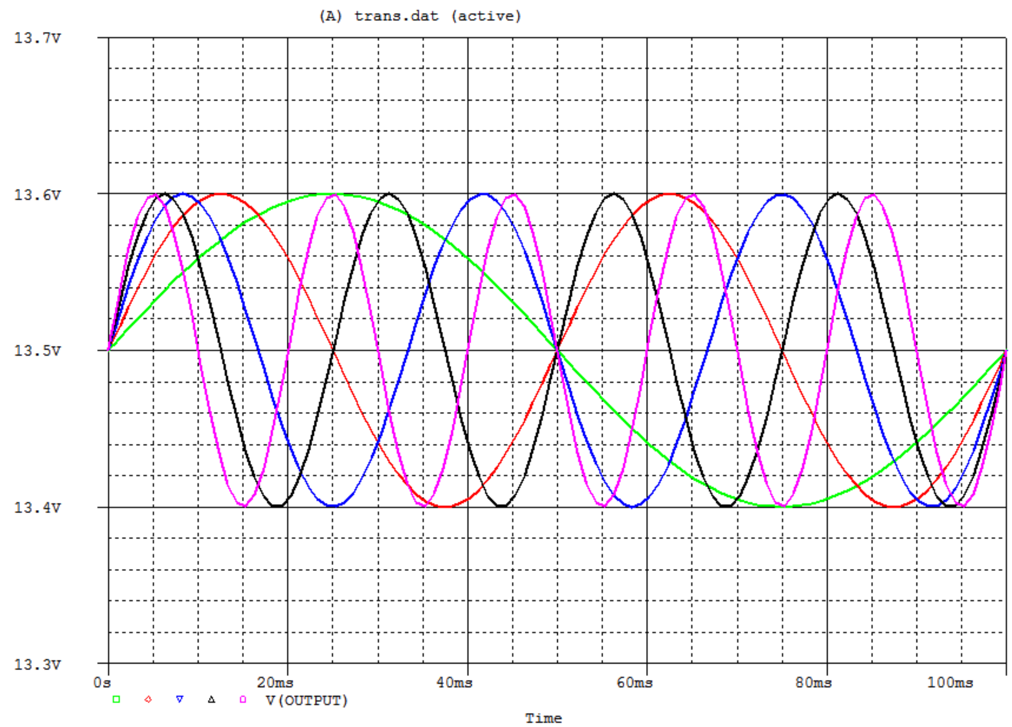


Figure: PSPICE simulation result for test frequency range of 0.01kHz - 0.05kHz with the frequency step of 1kHz. The peak-to-peak amplitude (US) stays constant at 0.2V as expected.

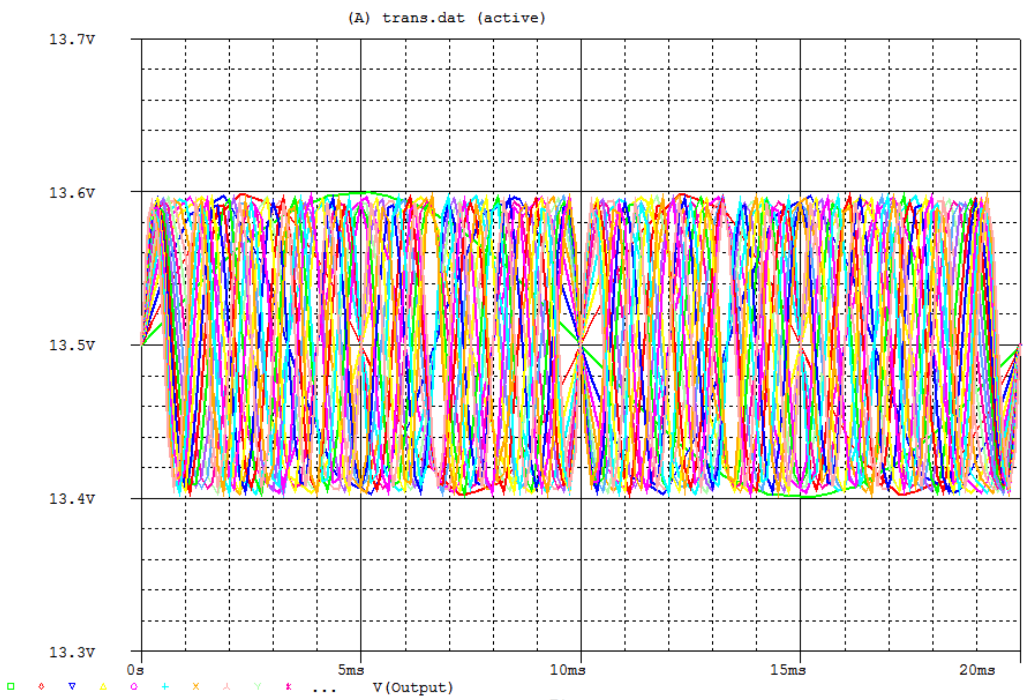


Figure: PSPICE simulation result for test frequency range of 0.05kHz - 1kHz with the frequency step of 1kHz. The peak-to-peak amplitude (US) stays constant at 0.2V as expected.

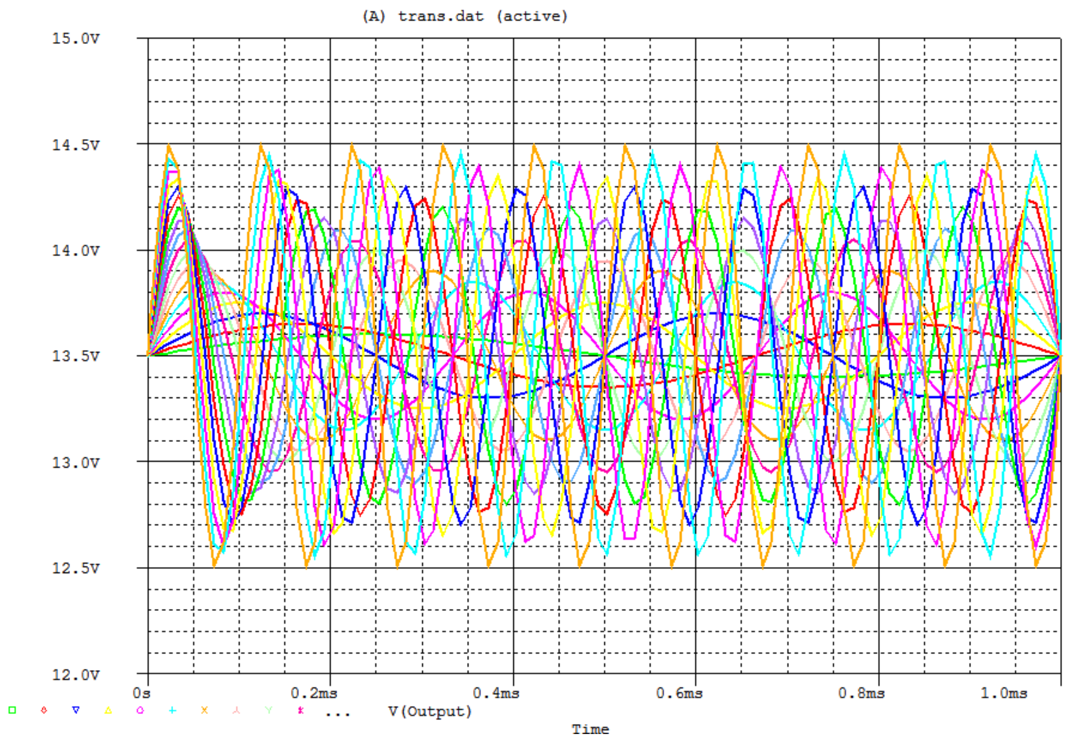


*Figure: PSPICE simulation result for test frequency range of 1kHz - 10kHz with the frequency step of 1kHz. The peak-to-peak amplitude (US) changes as frequency changes (US = 0.2V*freq), as expected.*

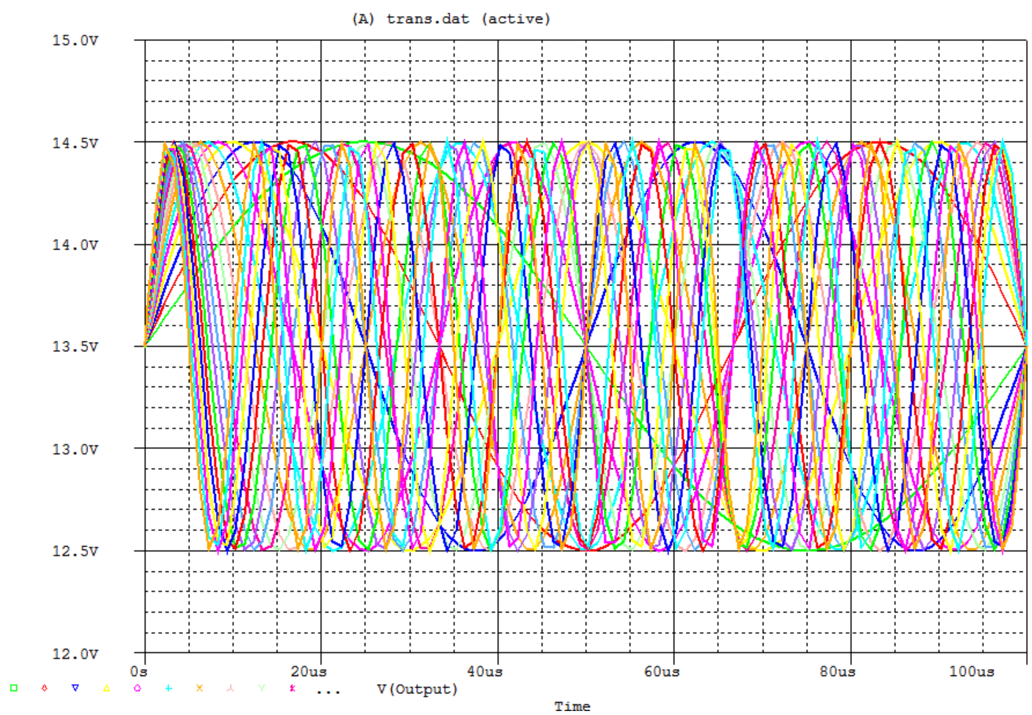


Figure: PSPICE simulation result for test frequency range of 10kHz - 100kHz with the frequency step of 1kHz. The peak-to-peak amplitude (US) stays constant at 2V as expected.

CI 220 specification: Immunity from Transient Disturbances

These requirements are related to immunity from conducted transients on 12 VDC power supply circuits in addition to control circuits connected directly to the vehicle's 12-VDC battery or indirectly connected by a switch or load.

<u>ISO Pulse 1</u>

Table 17-1: CI 220 Transient Immunity Requirements

Transient Pulse [1]	Application	Stress Level (Volts)		Transient Mode [1]	Minimum # of pulses or Test Duration	Functional Performance Status
		U_A	U_S			
ISO Pulse 1	Unswitched Power Supply Circuits	13.5	-100 [4]	n/a	5 [6, 7]	IV
ISO Pulse 1[5]	Switched Power Supply Circuits or Control Circuits ≥ 5 amperes	13.5	-100 [4]	n/a	24 pulses	II

Figure D-6: ISO Pulse 1 Characteristics

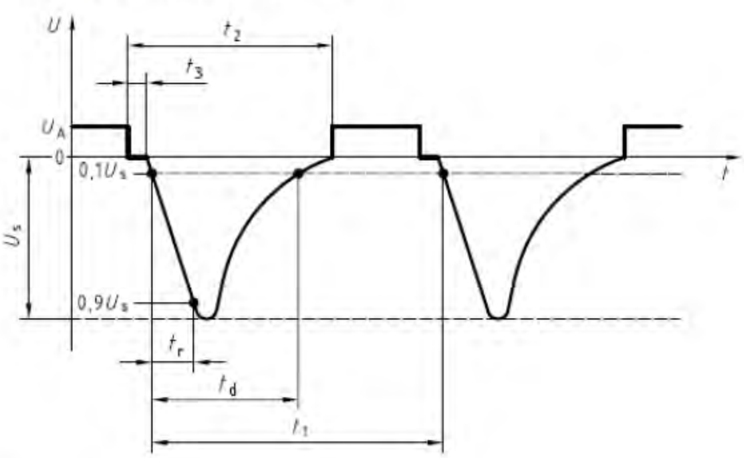
<u>Pulse 1 – Parameters</u>

U_A	13.5 VDC	27 VDC
U_s	See Tables 17-1 and 18-1	
R_i	10 Ω	50 Ω
t_d	2 ms	1 ms
t_r	1 (+0/ -0.5) us	3 (+0/-1.5) us
t_1	0.5 s (≥ 30 s)[1]	
t_2	200 ms	
t_3	≤ 100 us	

(1) See Table 17-1.

Waveform voltage begins and ends at U_A

Parameters listed are for open circuit conditions



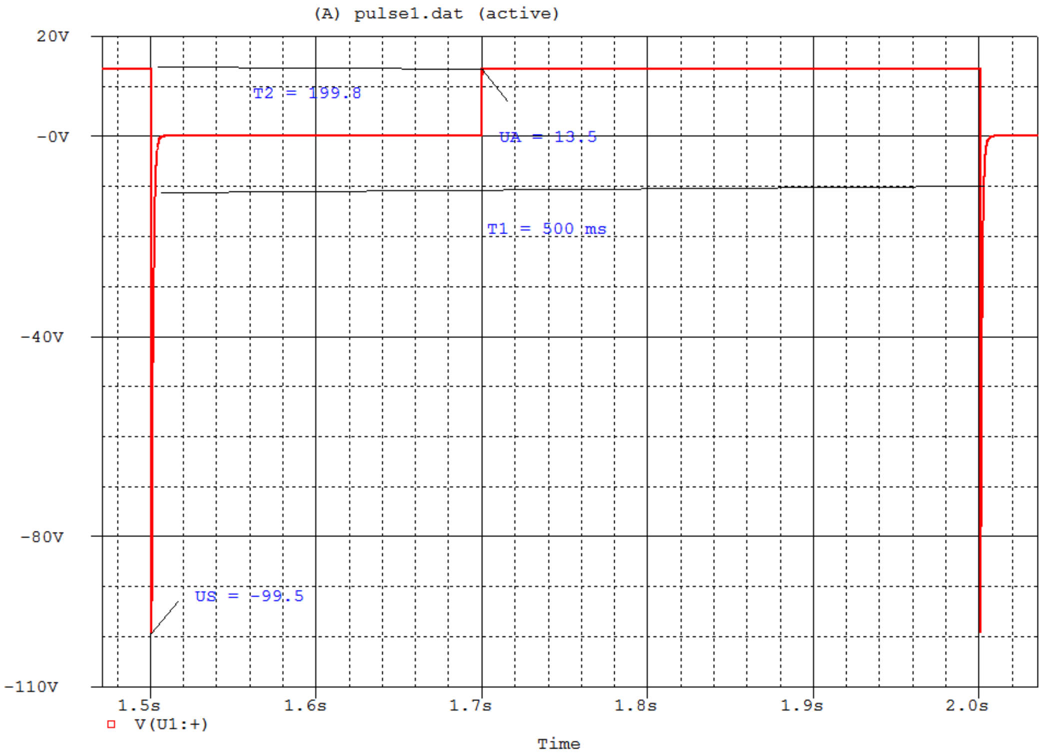


Figure: PSPICE simulation result for a single generated pulse 1 (12V)

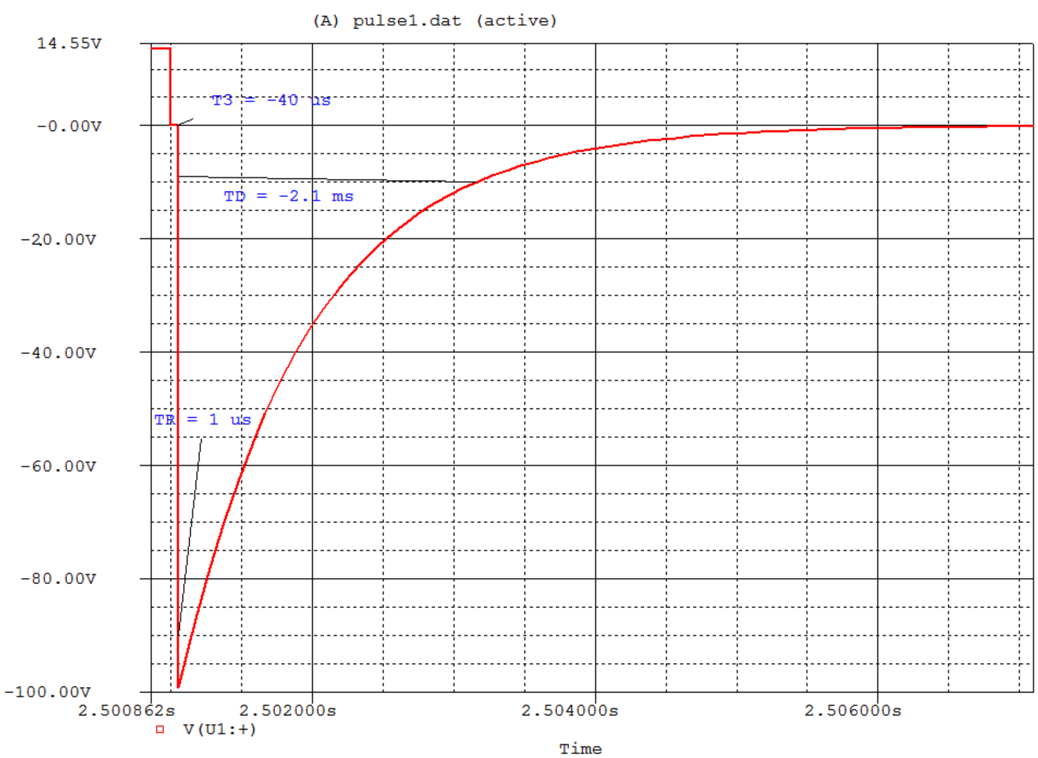


Figure: Zoomed-in PSPICE simulation result for a single generated pulse 1 (12V)

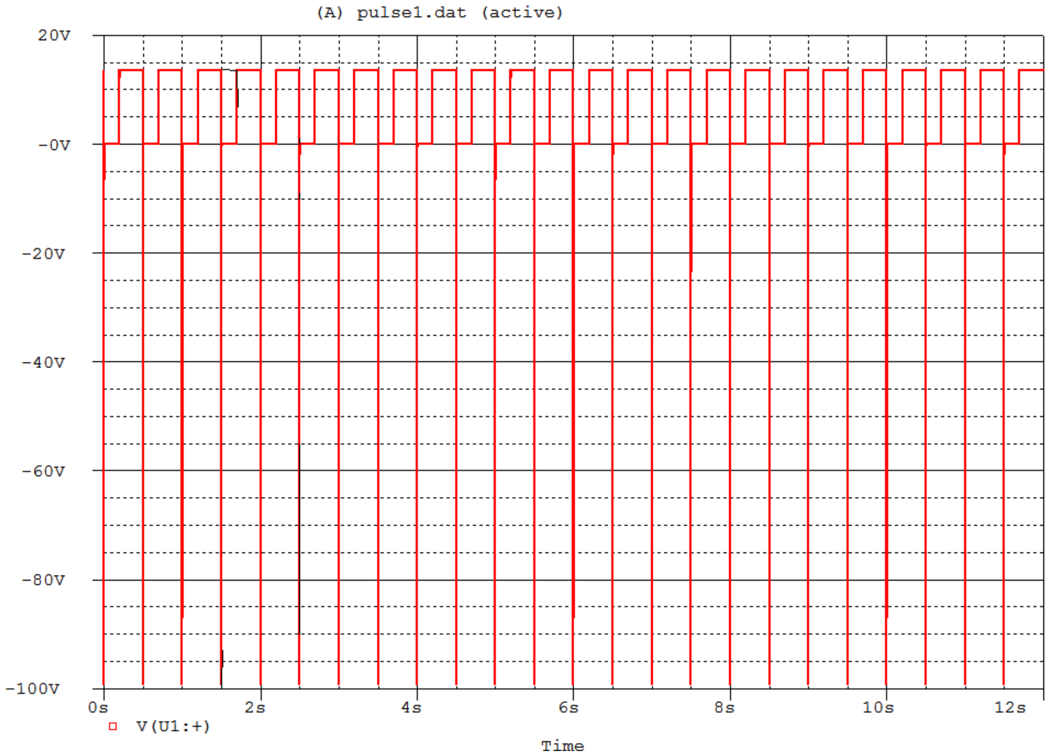


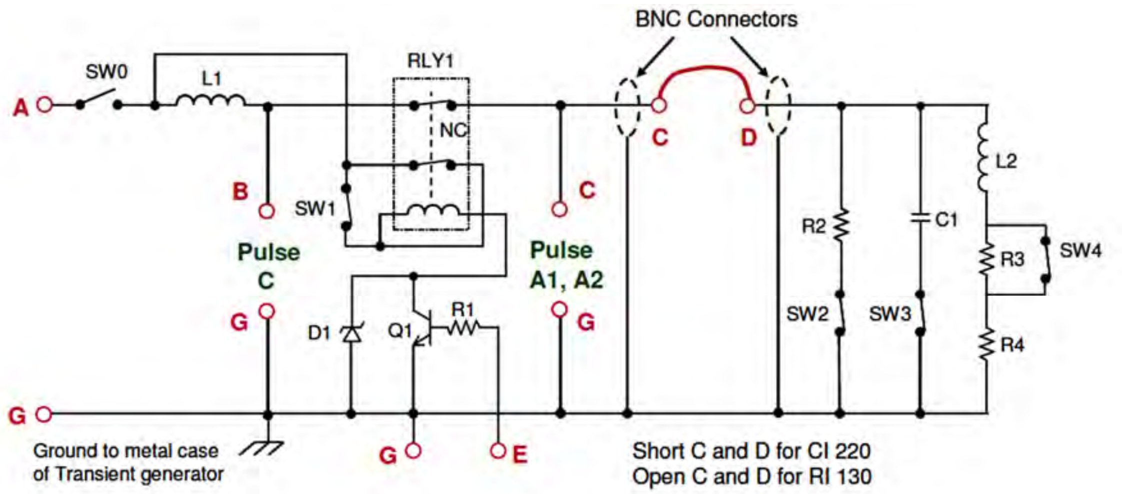
Figure: PSPICE simulation result of the generated pulse 1 (12V)

Transient Test Generator (Pulses A1, A2 and C)

Table E-1: CI 220 Transient Generator Switch Settings

Pulse	Mode *	SW1	SW2	SW3	SW4
A1	1, 2	Closed	Closed	Closed	Closed
A2-1	1, 2	Closed	Open	Open	Open
A2-2	1, 2	Closed	Open	Closed	Open
A2-1	3	Open	Open	Open	Open
A2-2	3	Open	Open	Closed	Open
C-1	2	Closed	Open	Open	Open
C-2	2	Closed	Open	Closed	Open
C-1	3	Open	Open	Open	Open
C-2	3	Open	Open	Closed	Open

* See Annex D for description of Mode operating conditions



Key

R1: 51 ohms, 0.25W	L2: 100 mH inductor *(Osborne Transformer Part Number 32416)**
R2: 220 ohms ± 5% , 2W	D1: Zener Diode, 39 V, 5W (*1N5366A*)
R3: 33 ohms ± 5% , 10W	Q1: NPN transistor (*TIP 41*)
R4: 6 ohms ± 5% , 50W	SW0 – SW4: Single Throw Switch (10 contact rating)
C1: 100 nF PETP polyester film capacitor, 400V (e.g. VISHAY Type 225 Orange Drop)	RLY1: 12 volt AC Relay** Use normally closed (NC) contacts *(Potter & Brumfield KUP-14A15-12)**
L1: 5 uH inductor (*Osborn Transformer Part Number 8745*) *	

L1 from Osborn shown as 5uH is actually closer to 7.3uH based on the waveforms show in FMC1278.

MODE Characteristics

Table D-1: CI 220 Mode 1 Characteristics

Transient Pulse	Pulse Repetition Rate (PRR)	Duration
A1	0.2 Hz, 10% duty cycle	120 sec
A2-1		
A2-2		

“Mode 1” pulses occur every 200ms with a duty cycle of 10%, resulting in a control pulse of “ON” for 20ms and “OFF” for 180ms and continued for 120 seconds. 120 seconds is not recommended for simulations, and if “Mode 1” is used, it should be limited to less than 3.2 seconds duration.

Figure D-13: CI 220 Mode 2 Characteristics

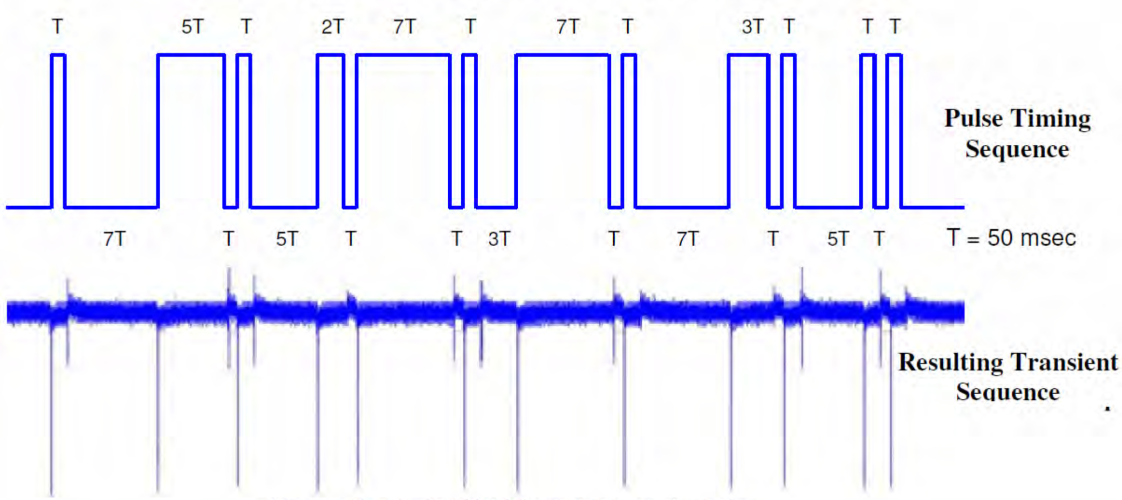
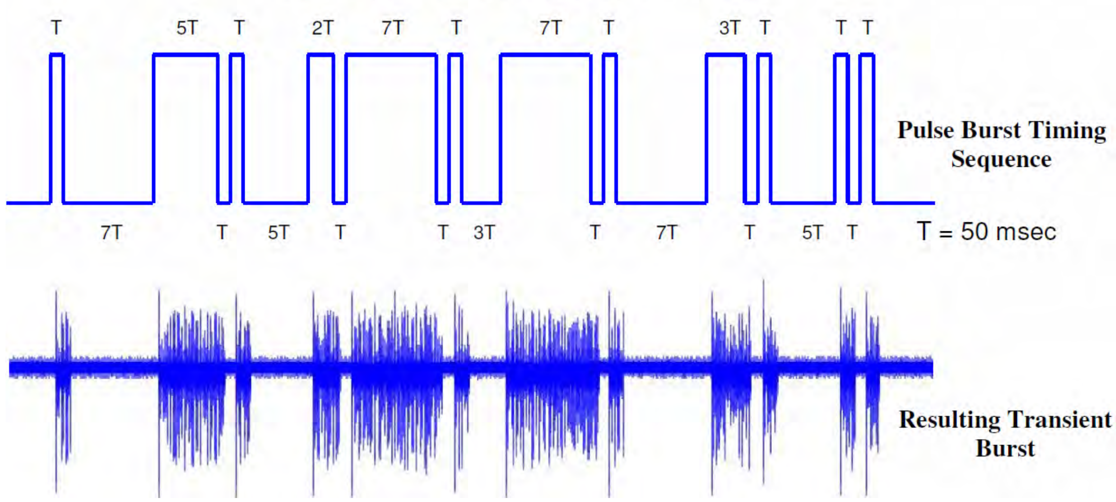


Figure D-14: CI 220 Mode 3 Characteristics



Introduction to CI220 Non-Standard Transient Waveforms

As per FMC1278 (Ref. 1), CI220 transient immunity testing consists of both standard pulses as delineated in ISO 7637-2 as well as **non-standard pulses including those produced by electromechanical switching of an inductive load.** These non-standard transient pulses are prevalent in the vehicle's electrical power distribution system. Non-standard transients created from this approach are highly affected by a number of factors including but not limited to resistive/capacitive loads sharing the same circuit as the inductive load. **Although consecutive transient events produced in this manner are often not repeatable** as compared to standard ISO test pulses, experience has shown that this random behavior can produce anomalies that are frequently missed when using only the standard repetitive ISO pulses.

All DUT loads consist of resistance, inductance, and capacitance forming RLC networks. Relay contacts making and breaking do not always produce a clean make or break. In addition, when contacts are closed, they usually bounce and arc. Therefore, the expected clean switching of the battery supply is far from perfect. In addition, some devices consume high amplitudes of current (inductive loads like starters, solenoids, motors) that create severe disturbances in the battery voltage supply. Since most loads are switched rapidly, sudden changes in current results in transient voltages and currents. In addition to the supply switching transients, the noise it creates is electrostatically and magnetically coupled into the adjacent cabling and ground structure of the automobile.

In order to reproduce the test waveforms in simulations, the actual conditions of their creation are required and duplicated where possible. In some cases, it is obvious while in others it is buried in the cluster of transients and requires awareness of what occurred prior to that specific waveshape in the related circuitry. Simply using a hard voltage or current source for the waveshapes may not meet the requirements of the test circuit.

The PSpice generated waveshapes are integrated as part of the test fixture and implemented in a manner to represent the required FMC1278 waveshapes under their defined conditions.

The chattering relay PSpice generated waveshapes (transient simulation models) present contact bounce and arcing in Mode 3 that are sustained between 50ms and 350ms as per FMC1278.

No clear numbers are provided for the contact bounce and arcing durations. From the available waveform images, assumptions are made for each of the durations for the appropriate defined transient generators. In additions, considerations for practical SPICE modeling limitations are applied.

Note that the FMC1278 waveforms are for the Transient Generator with NO LOADS APPLIED! When loads are applied, the waveforms may be completely different.

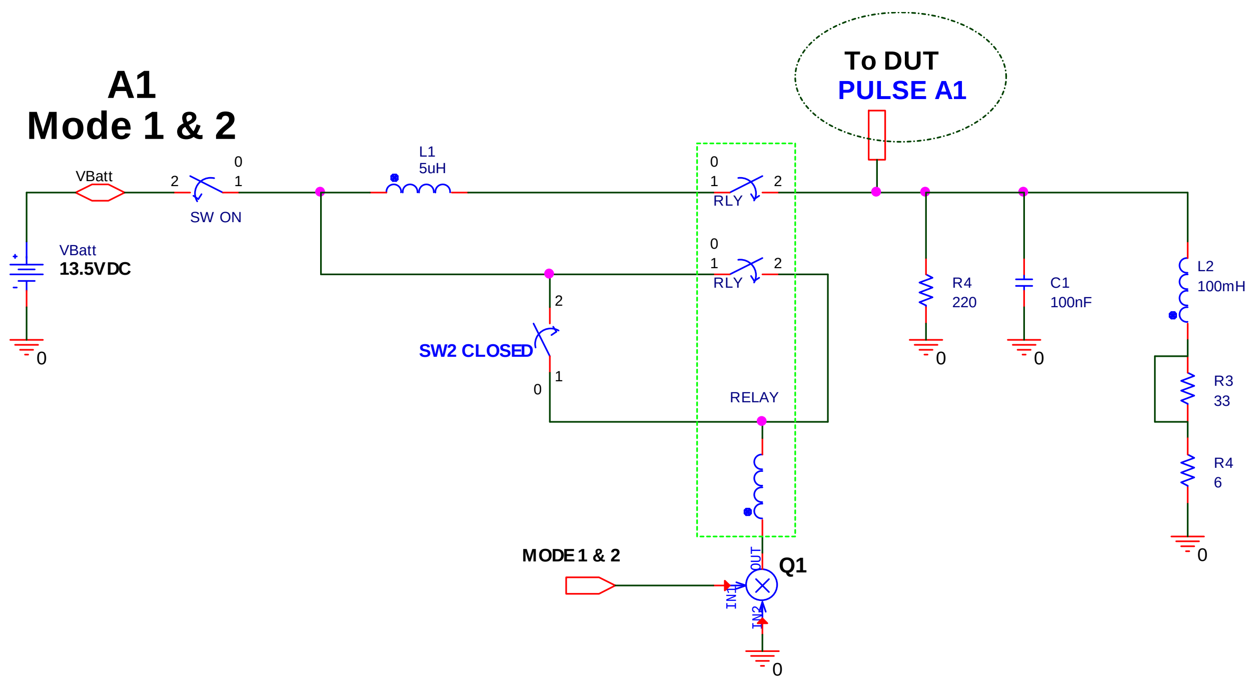
Pulse A1, Mode 1 and Mode 2

Pulse Module: *CI220_GEN_A1_M1_M2*

Test Pulse A1 represents the voltage transient produced during switching of higher current (1 – 5 ampere) inductive loads that share the same circuit with the DUT. "Z" represents the impedance of the other electrical loads sharing the same circuit with the DUT and the inductive load. The value of Z, which is set to 220Ω AND R4 at 6Ω, simulates minimally loaded circuits. Figure D-2 illustrates Pulse A1 using the configuration Table below. The peak pulse voltage levels will vary between –250 to –300 volts and occur during the MODE command edge when the relay contacts open. The transient is from L2 current being interrupted when the contacts open with NO arcing (clean switch).

Table E-1: CI 220 Transient Generator Switch Settings

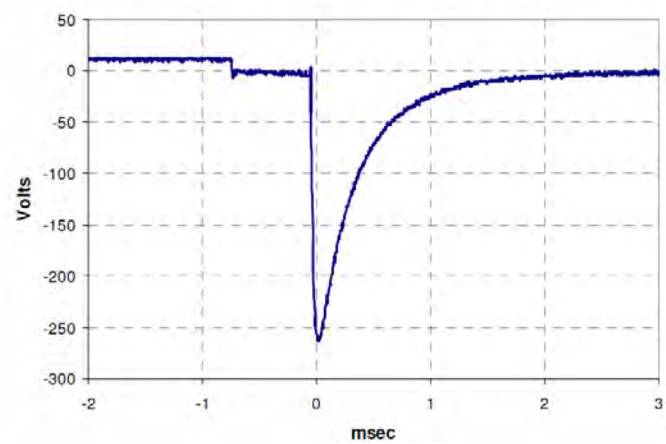
Pulse	Mode *	SW1	SW2	SW3	SW4
A1	1, 2	Closed	Closed	Closed	Closed



FMC1278 Test Generator A1 Basic Circuit Configuration

The DUT is in parallel with a vehicle load that is inductive shunted by a capacitor and resistive load. When the contacts open, a transient waveform occurs at the load. The amplitude and duration are related to the DUT capacitive and resistive loading. When the contacts close, a transient or oscillation voltage may occur on the DUT related to the capacitive and resistive loading.

Figure D-2: Pulse A1 Composite Waveform



Test circuit configuration for CI 220 Pulse A1 Mode 2 is shown below.

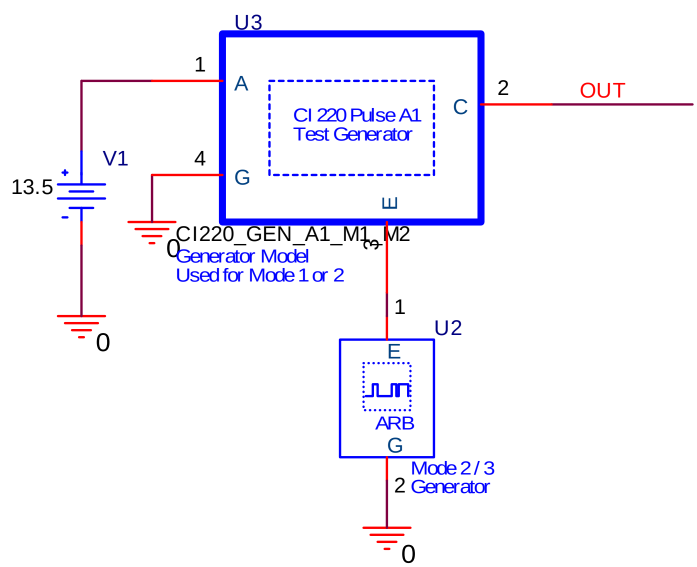


Figure: PSPICE Simulation test circuit for CI 220 Pulse A1 Mode 2

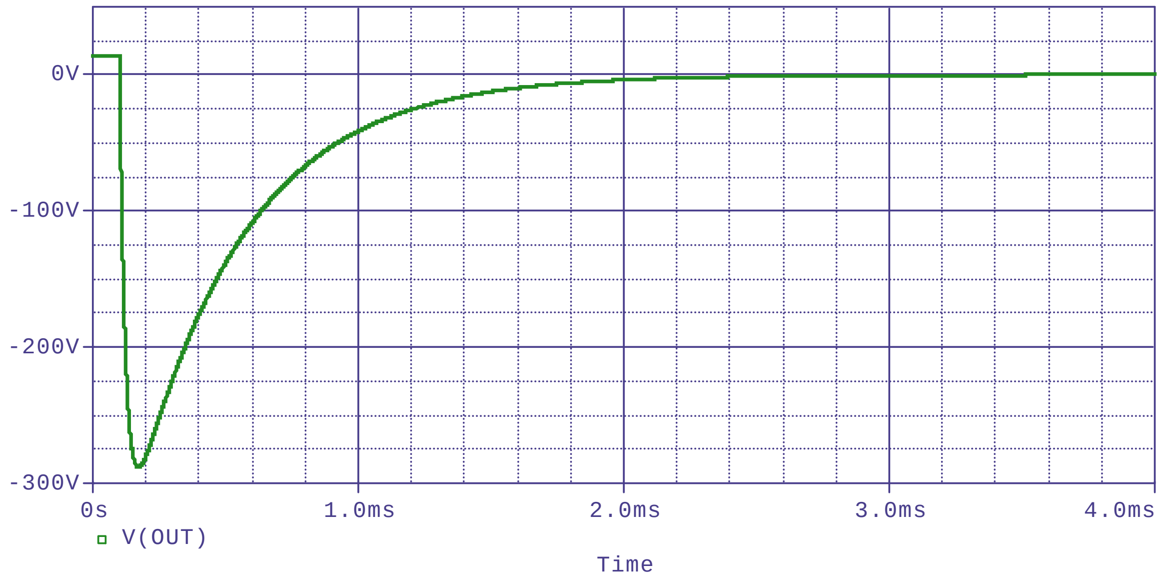


Figure: Simulation Waveform when relay contacts open

Pulse A2-1, Mode 1 and Mode 2 @ 1.67 MHz

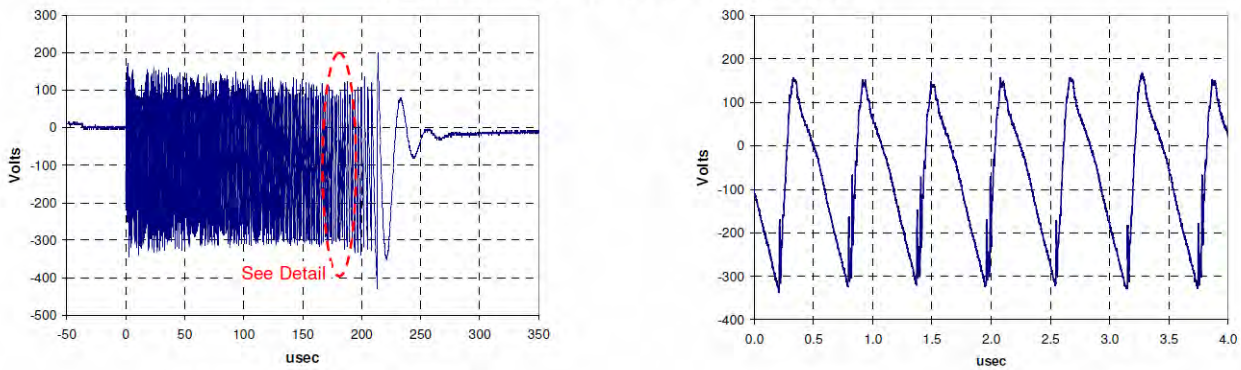
Pulse Module: ***CI220_GEN_A21_M1_M2***

Table E-1: CI 220 Transient Generator Switch Settings

Pulse	Mode *	SW1	SW2	SW3	SW4
A2-1	1, 2	Closed	Open	Open	Open

Pulse A2-1 occurs when the circuit consists only of the DUT and the switched inductive load.

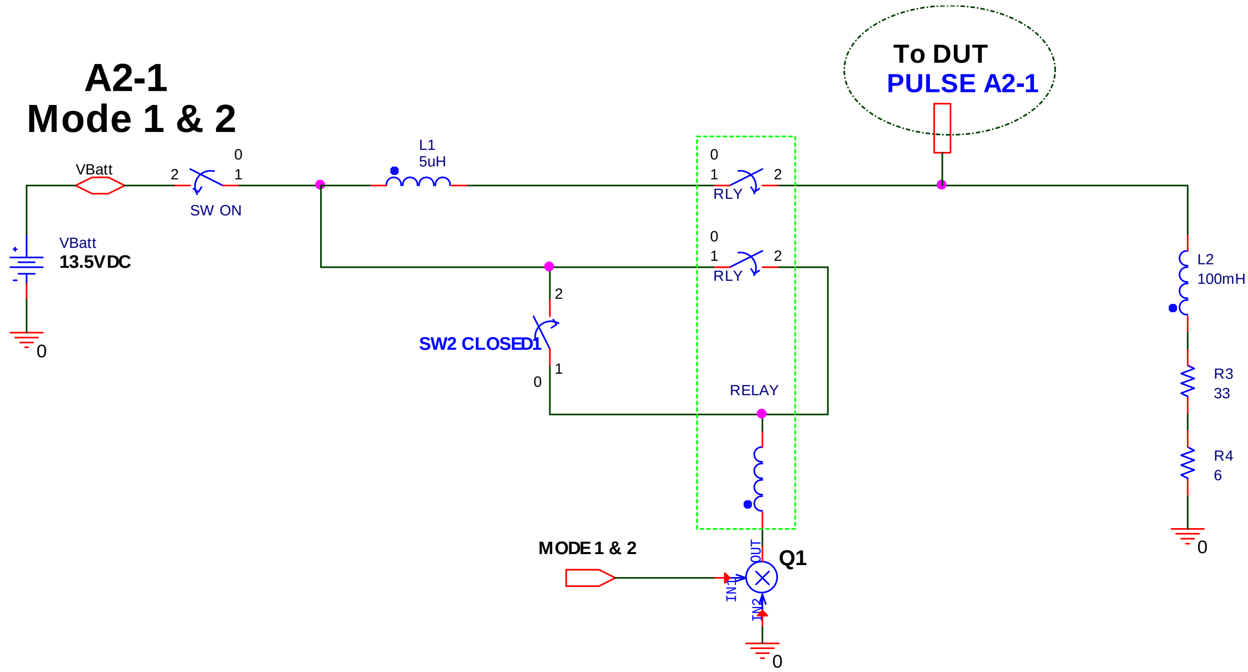
Figure D-3: Pulse A2-1 Pulse Characteristics



a) Contact Break and Bounce

b) Contact Break and Bounce (Detail)

This waveform occurs on contacts attempting to open and draw an arc. During this time period, there are high frequency oscillations before the arc extinguishes. These waveforms are related to current amplitude, relay contact materials, as well as, associated inductances and capacitances. This has nothing to do with contact bounce, however, this may also occur every time the contacts open and arc when the relay is being closed and bouncing. If the contacts open/close “clean” then a different waveform occurs (closer to A2-2). A problem may occur at the end of the arc train when the contacts open. When the L2 inductor current flow path is interrupted (contacts open) the inductor voltage across the contacts (arc) increases to maintain the inductor current flow. Current amplitude decays during the arc and ideally will be zero when the arc terminates (contacts truly open). However, if the arc extinguishes before the current reaches zero, a transient voltage will occur that is related to the current amplitude and open contact path resistances.



FMC1278 Test Generator A2-1 Basic Circuit Configuration

The A2-1 waveform occurs on contacts attempting to open and draw an arc. The arc is generated across the contacts by the induced voltages from the inductive loading. During this time period there are high frequency oscillations before the arc extinguishes. There is no damping or arc suppression components.

Note: If there is a capacitor in the DUT (at the output of the generator), the arcing may not occur and a different generator (A2-2) is required to be used. The test generator is not adaptive, meaning it cannot recognize if capacitive loading is present; therefore, the analysist must use the correct generator.

Therefore, the only loading that can be applied to this generator is resistive loading.

When there is capacitive loading in the circuit, the dv/dt required to create a high voltage to sustain arcing is usually too low. A2-2 is the circuit that represents testing with capacitive loads where there is no longer any arcing, therefore, A2-1 generator is not applicable. Conditions related to various types of relays (contact metals, spacing, high currents, etcetera) can result in sustained arcing, however, these tests are not used to evaluate those issues.

The figure below shows the test circuit configuration for CI 220 Pulse A2-1 Mode 1.

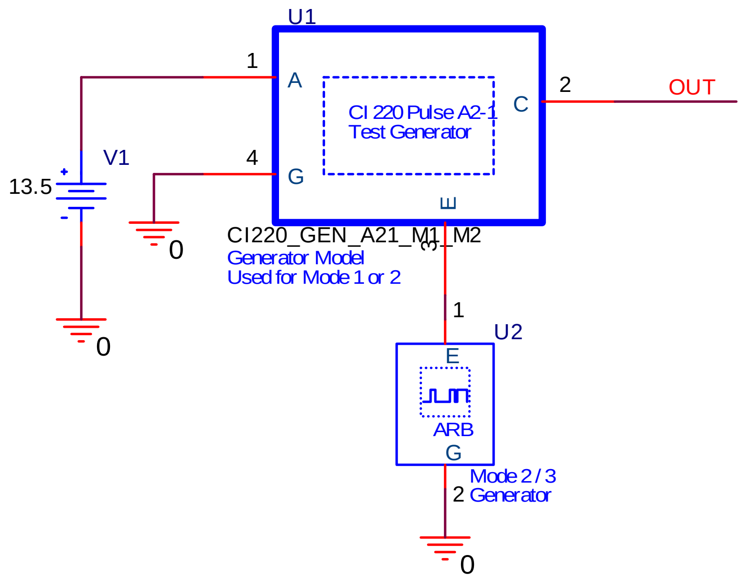
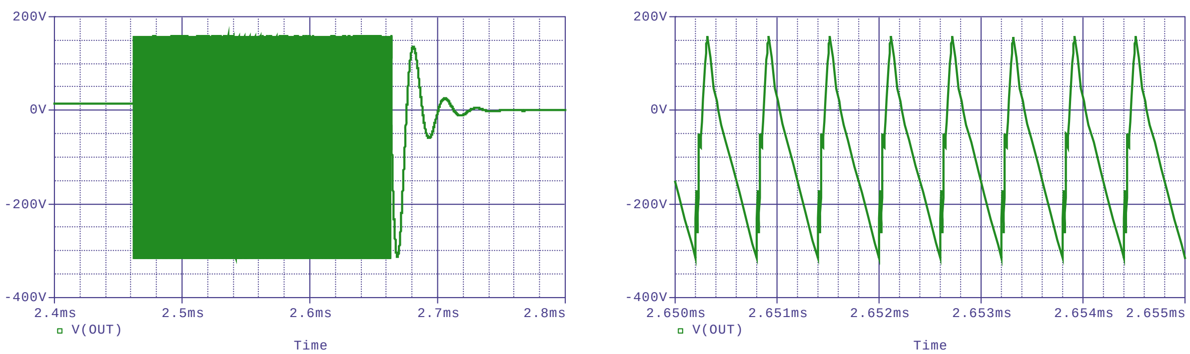


Figure: PSPICE Simulation test circuit for CI 220 Pulse A2-1 Mode 2



The duration of the arc is related to the current amplitude, inductance, and current path losses. In the simulation model, the current is approximately 200mA and decay is ~215us, which is the duration of the arc.

This waveform is for an arc occurring when the contacts open. On a HI on the Mode input, the contacts close and allow the current in L2 to build up. After ~2.5ms the contacts attempt to open creating an arc that lasts for ~215us where the contacts eventually are truly open. Each Mode input pulse lasts between 50ms to 350ms and is repeated multiple times. The arc occurs only once for each HI Mode pulse.

Pulse A2-1, Mode 3 Chattering Relay @ 1.67 MHz

Pulse Module: ***CI220_CHAT_A21_M3***

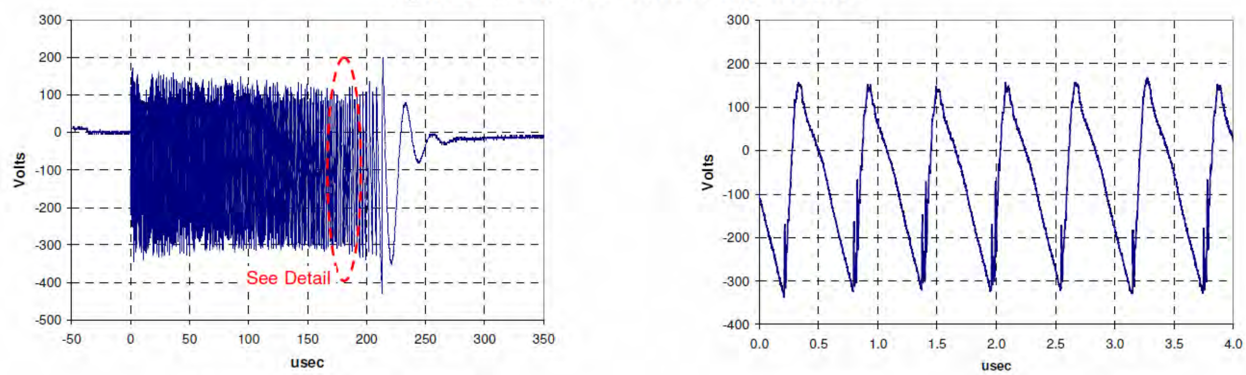
Table E-1: CI 220 Transient Generator Switch Settings

Pulse	Mode *	SW1	SW2	SW3	SW4
A2-1	3	Open	Open	Open	Open

Pulse A2-1 occurs when the circuit consists only of the DUT and a switched inductive load.

This waveform occurs on contacts attempting to open and draw an arc. During this time period, there are high frequency oscillations before the arc extinguishes. These waveforms are related to current amplitude, relay contact materials, as well as associated inductances and capacitances. This has nothing to do with contact bounce, however, this may also occur every time the contacts open and arc when the relay is being closed and bouncing. If the contacts open/close “clean” then a different waveform occurs (closer to A2-2). A problem may occur at the end of the arc train when the contacts open. When the L2 inductor current flow path is interrupted (contacts open) the inductor voltage across the contacts (arc) increases to maintain the inductor current flow. Current amplitude decays during the arc and ideally will be zero when the arc terminates (contacts truly open). However, if the arc extinguishes before the current reaches zero, a transient voltage will occur that is related to the current amplitude and open contact path resistances.

Figure D-3: Pulse A2-1 Pulse Characteristics



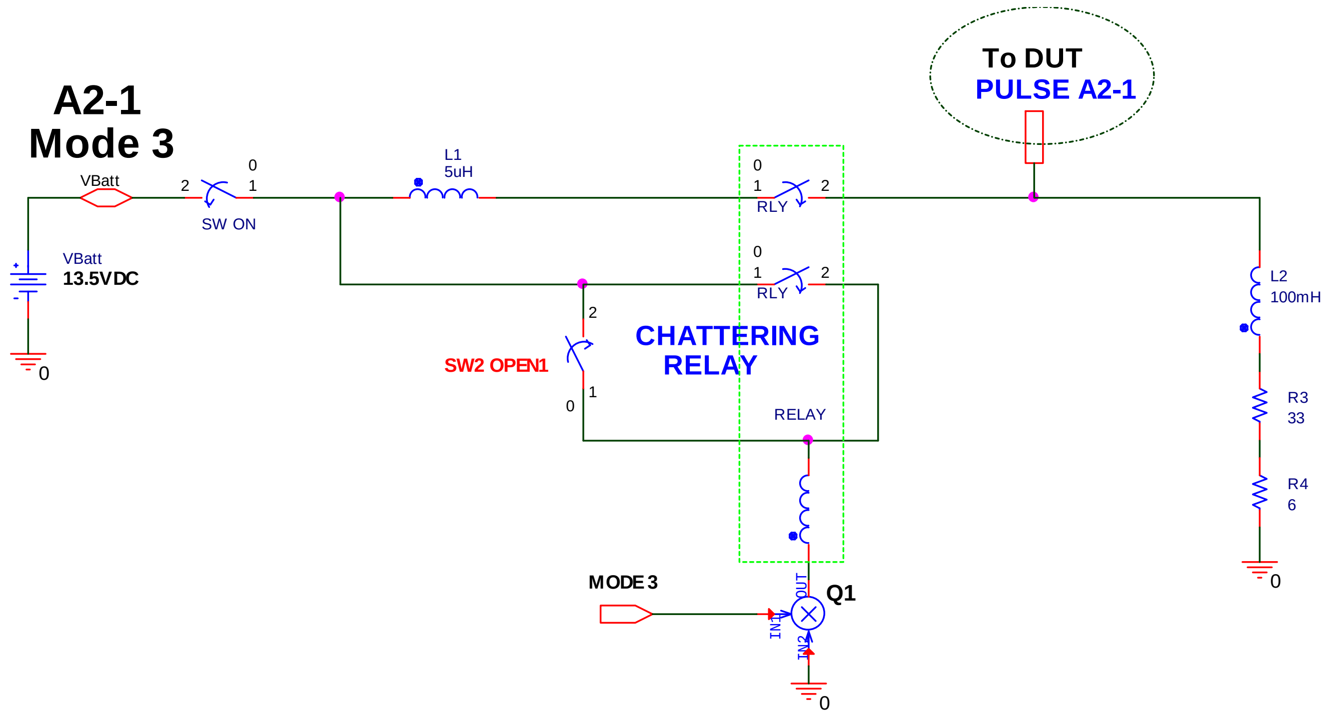
a) Contact Break and Bounce

b) Contact Break and Bounce (Detail)

This waveform is for an arc occurring when the contacts open. On a HI on the Mode input, the contacts close and allow the current in L2 to build up. After ~2.5ms the contacts attempt to open creating an arc that lasts for ~215us where the contacts eventually are truly open. The Mode input pulse lasts between 50ms to 350ms and is repeated multiple times. The arc occurs repetitively every 5ms for the duration of each HI Mode pulse.

5.00ms is selected to ensure that the simulations times for the Mode times are equally divisible by 5ms. This allows the generator internal model timing to complete internal functions and not create artifacts. This also allows the use of the PSpice schedule statement that reduces the step rate during the burst to 3.1ns.

Examine the waveforms to determine what the minimum step size should be use.



FMC1278 Test Generator A2-1 Basic Circuit Configuration

This simulation assumes repetitive relay operation as per MODE 3 with contact bounce.

The A2-1 waveform occurs on contacts attempting to open and draw an arc. The arc is generated across the contacts by the induced voltages from the inductive loading. During this time period there are high frequency oscillations before the arc extinguishes. There is no damping or arc suppression circuits.

Note: If there is a capacitor in the DUT, the arcing may not occur and a different generator (A2-2) is required to be used. The test generator is not adaptive, meaning it cannot recognize if capacitive loading is present; therefore, the analysist must use the correct generator depending on the circuit configuration (impedance presented to the source).

Therefore, the only loading that can be applied to this generator is resistive loading.

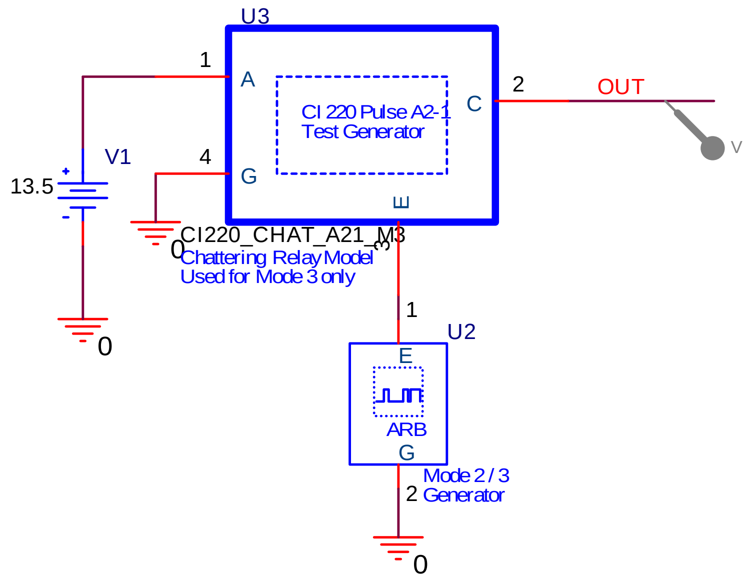


Figure: PSPICE Simulation test circuit for CI 220 Pulse A2-1 Mode 3

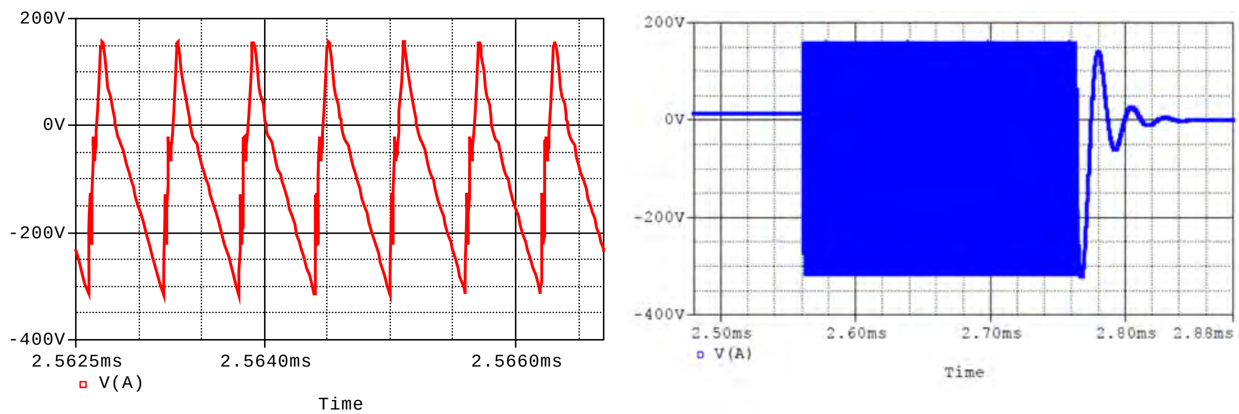


Figure: Simulation A2-1 Chattering Relay Contacts Voltage Waveforms

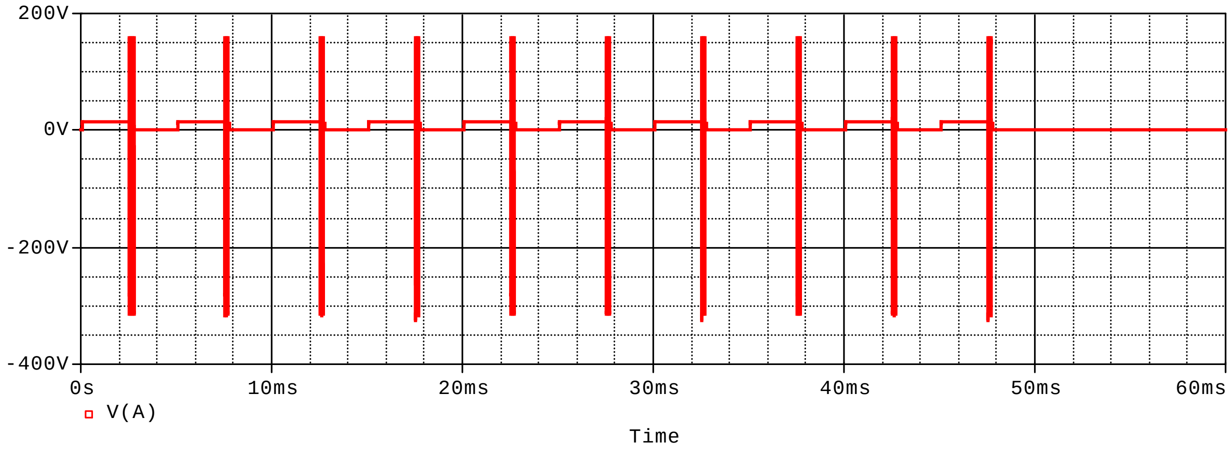


Figure: Simulation A2-1 Chattering Relay Contacts Voltage 50ms Mode Command

Pulse A2-2, Mode 1 and Mode 2 @ 180 kHz and 1.6 kHz

Pulse Module: *CI220_GEN_A22_M1_M2*

Table E-1: CI 220 Transient Generator Switch Settings

Pulse	Mode *	SW1	SW2	SW3	SW4
A2-2	1, 2	Closed	Open	Closed	Open

Pulse A2 represents the voltage transient produced during switching of a lower current (< 1 ampere) inductive loads that shares the same circuit with the DUT. The characteristics of Pulse A2 can vary significantly depending on the impedance of the other loads sharing the same circuit as the DUT. Given this dependency, two separated conditions exist for Pulse A2.

Pulse A2-2 occurs when the circuit includes other electrical loads that share the same circuit as the DUT and the switched inductive load. The other electrical loads are predominately capacitive (e.g. wiper motor filter capacitor).

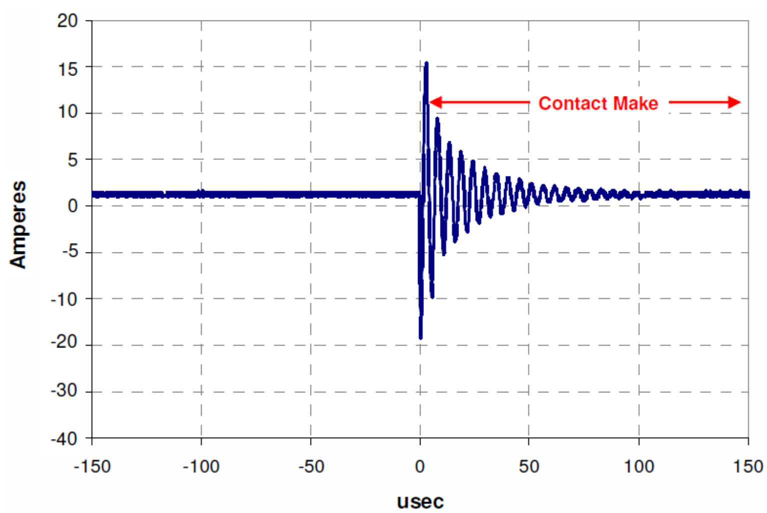
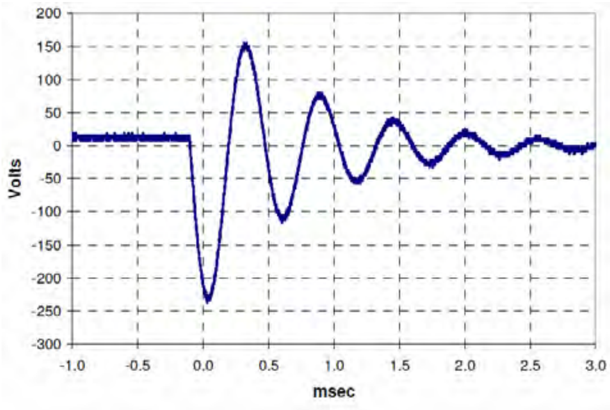


Figure: FMC1278 Contact Bounce Current



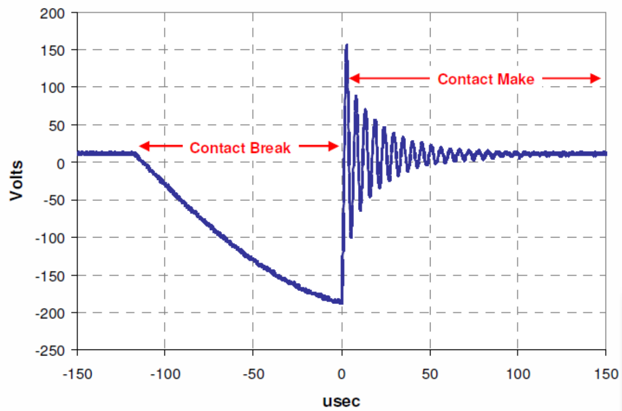
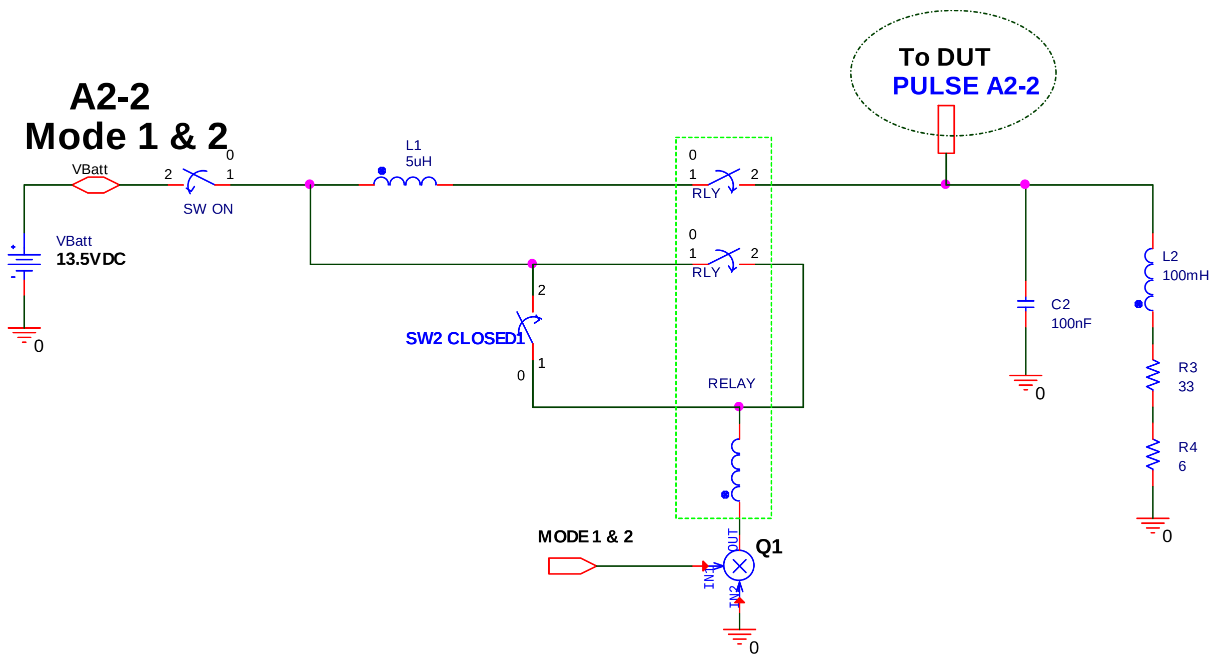


Figure: FMC1278 Contact Break Voltage & FMC1278 Contact Bounce Voltage



Pulse A2-2 occurs when the circuit includes other electrical loads that share the same circuit as the DUT and the switched inductive load. The other electrical loads are predominately capacitive (e.g. wiper motor filter capacitor). When the external circuit is predominately capacitive, the transient produced (Pulse A2-2) is significantly different than Pulse A2-1. When the switch contacts open, a damped sinusoidal transient (fres ~ 2 kHz) is produced. When the switch contacts bounce during closure a higher frequency, damped sinusoidal transient (fres ~180 kHz) is produced. During this phase, there is a corresponding current transient with a magnitude approximately 30 Ap-p. Therefore, this pulse Module generates two sets of pulses, one low frequency damped oscillation and ~three high frequency oscillations. There are also random variations in amplitudes.

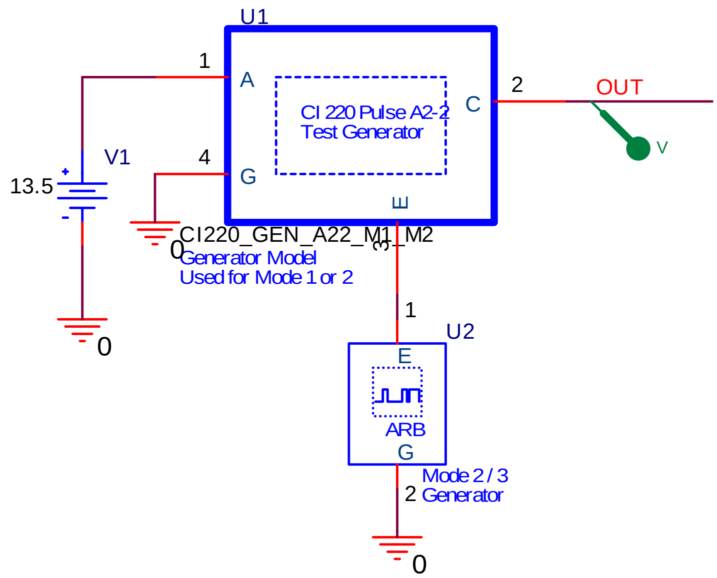


Figure: PSPICE Simulation test circuit for CI 220 Pulse A2-2 Mode 1

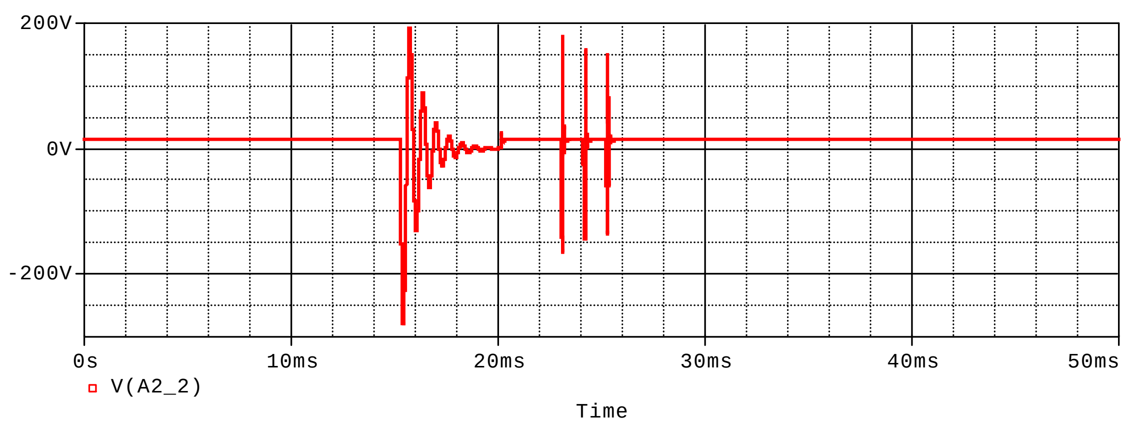


Figure: Simulation Single Contact Break Voltage and Contact Bounce Voltage Burst

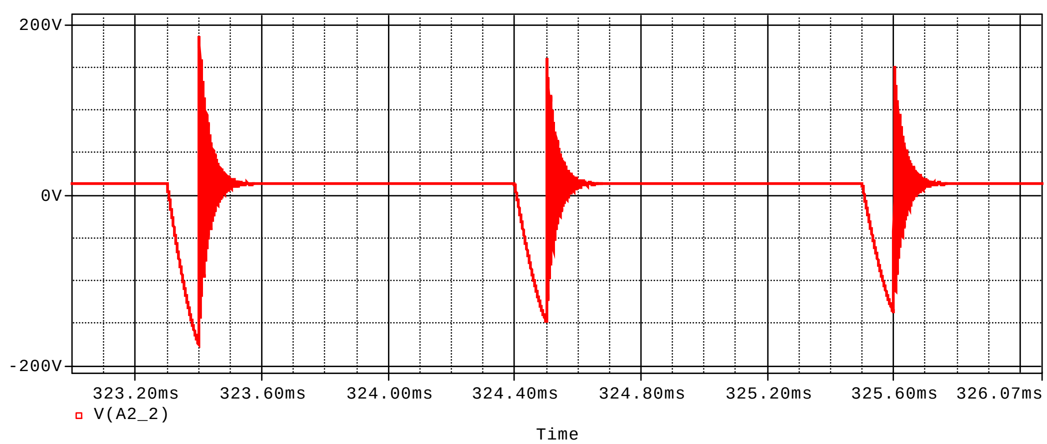


Figure: Simulation Contact Bounce Voltage

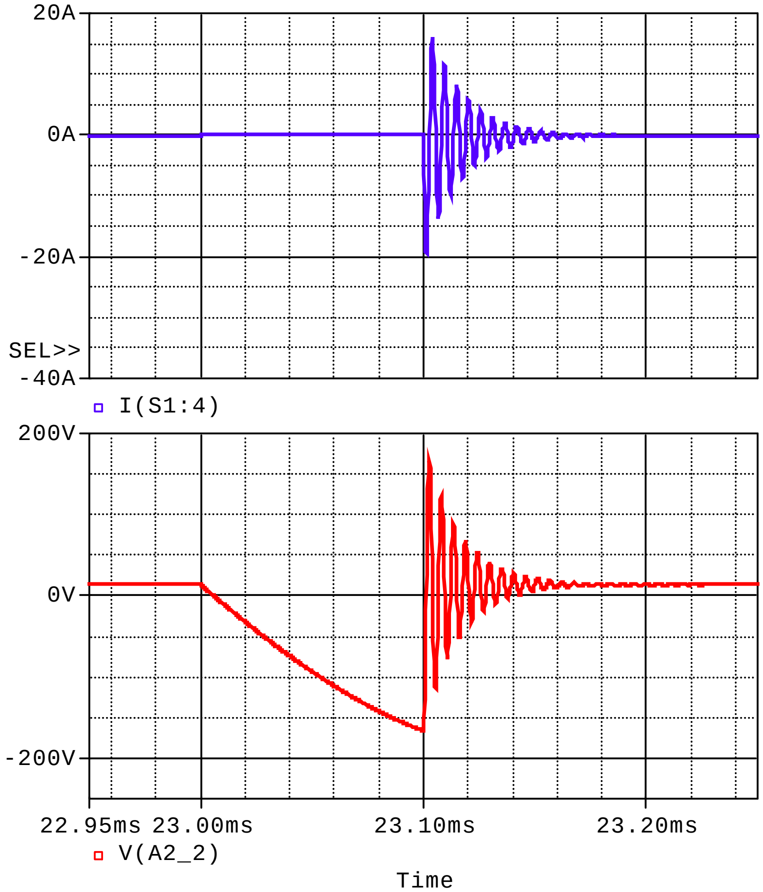


Figure: Simulation Contact Bounce Voltage & Current

On every positive going edge of the Mode Input pulse, the contacts make and break once providing the two required waveforms. The Mode pulse varies from 50ms to 350ms in duration and occurs multiple times. The two-waveform burst occurs only ONCE per Mode pulse.

Pulse A2-2, Mode 3 Chattering Relay @ 180 kHz and 1.6 kHz

Pulse Module: ***CI220_CHAT_A22_M3***

Table E-1: CI 220 Transient Generator Switch Settings

Pulse	Mode *	SW1	SW2	SW3	SW4
A2-2	3	Open	Open	Closed	Open

Pulse A2 represents the voltage transient produced during switching of a lower current (< 1 ampere) inductive loads that shares the same circuit with the DUT. The characteristics of Pulse A2 can vary significantly depending on the impedance of the other loads sharing the same circuit as the DUT. Given this dependency, two separated conditions exist for Pulse A2.

Pulse A2-2 occurs when the circuit includes other electrical loads that share the same circuit as the DUT and the switched inductive load. The other electrical loads are predominately capacitive (e.g. wiper motor filter capacitor)

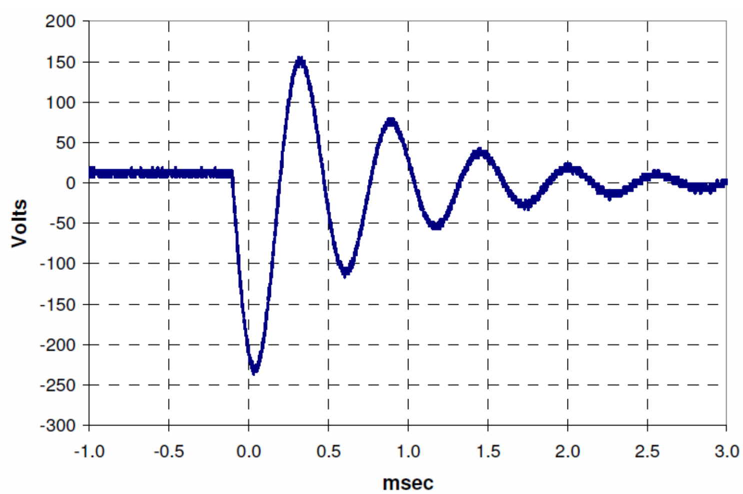
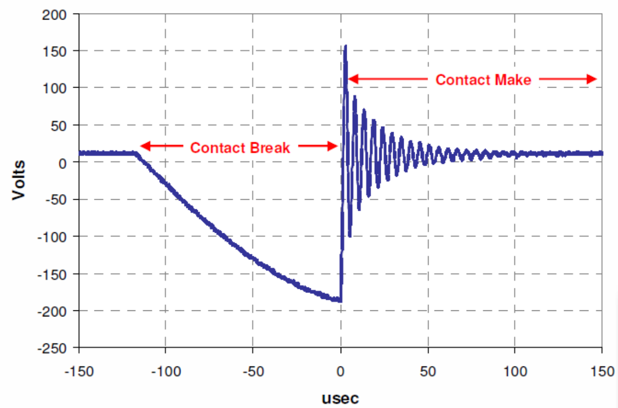


Figure: Contact Break Voltage



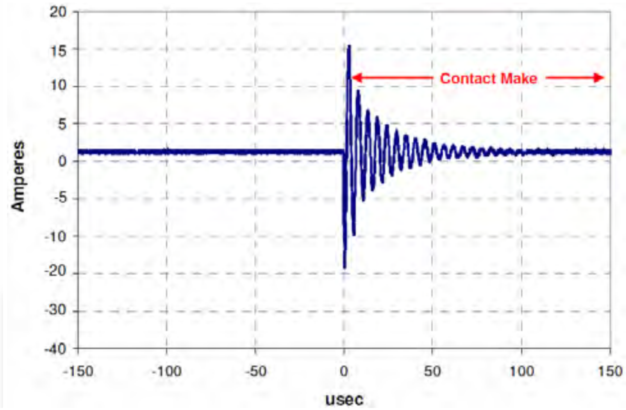


Figure: Contact Bounce Voltage & *Contact Bounce Current*

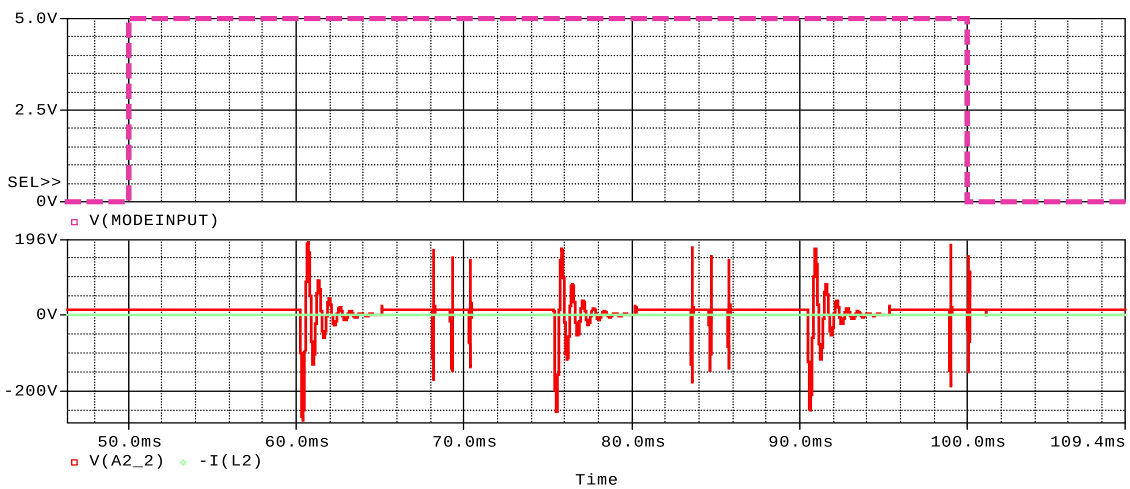
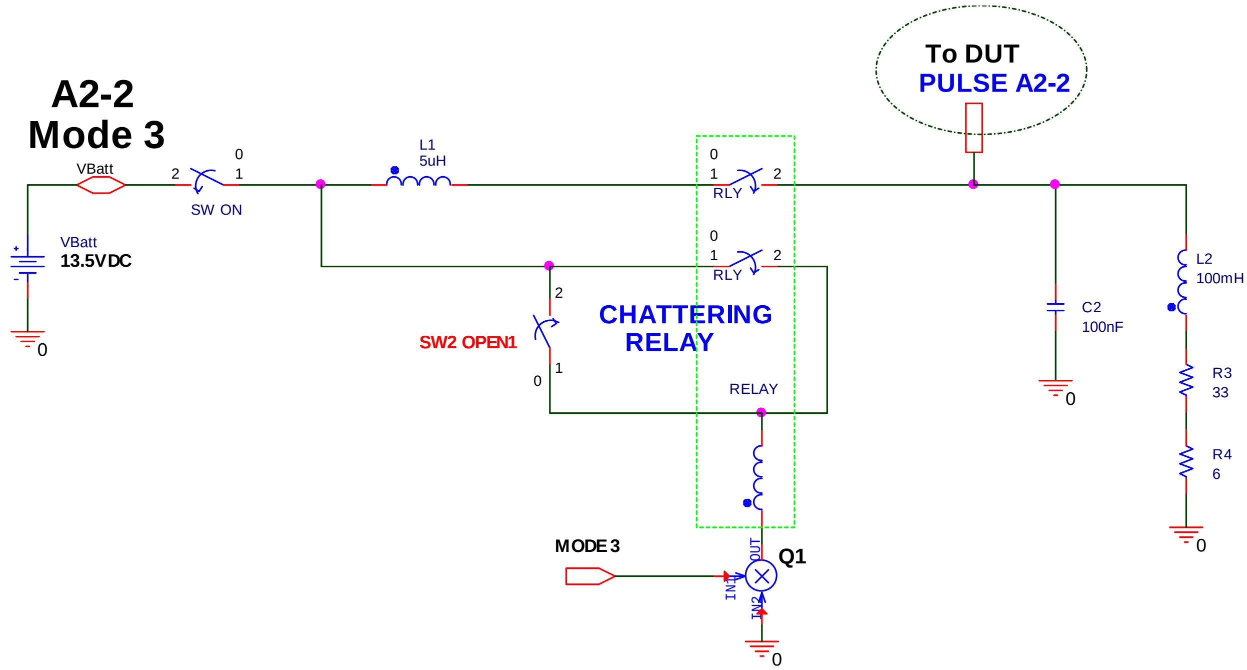


Figure: Simulation Waveforms during a 50ms ON Mode pulse window

The contact break has a low frequency damped waveform and the contact make has high frequency damped oscillation burst of two or three waveforms. There are approximately three sets occurring in 50ms.



FMC1278 Test Generator A2-2 Basic Circuit Configuration& Contact Bounce Voltage

This simulation assumes repetitive relay operation as per MODE 3 with contact bounce.

Pulse A2-2 occurs when the circuit includes other electrical loads that share the same circuit as the DUT and the switched inductive load. The other electrical loads are predominately capacitive (e.g. wiper motor filter capacitor). When the external circuit is predominately capacitive, the transient produced (Pulse A2-2) is significantly different than Pulse A2-1. When the switch contacts open, a damped sinusoidal transient (fres ~ 2 kHz) is produced. When the switch contacts bounce during closure a higher frequency, damped sinusoidal transient (fres ~180 kHz) is produced. During this phase, there is a corresponding current transient with a magnitude approximately 30 Ap-p. Therefore, this pulse Module generates two sets of pulses, one low frequency damped oscillation and ~three high frequency oscillations. There are also random variations in amplitudes.

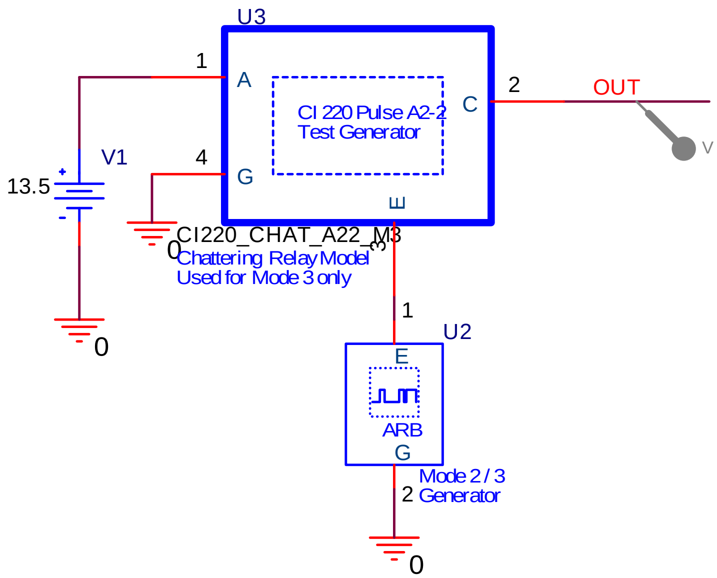
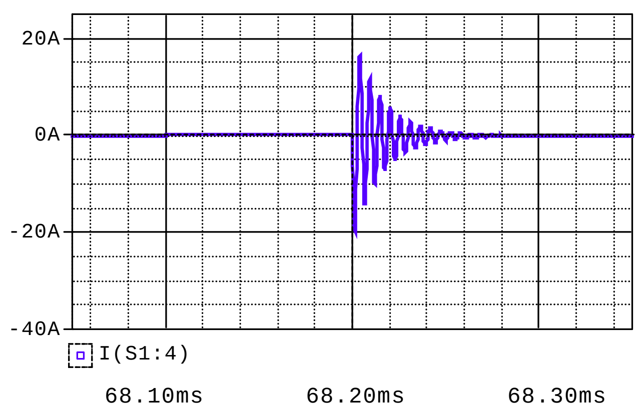


Figure: PSPICE Simulation test circuit for CI 220 Pulse A2-2 Mode 3



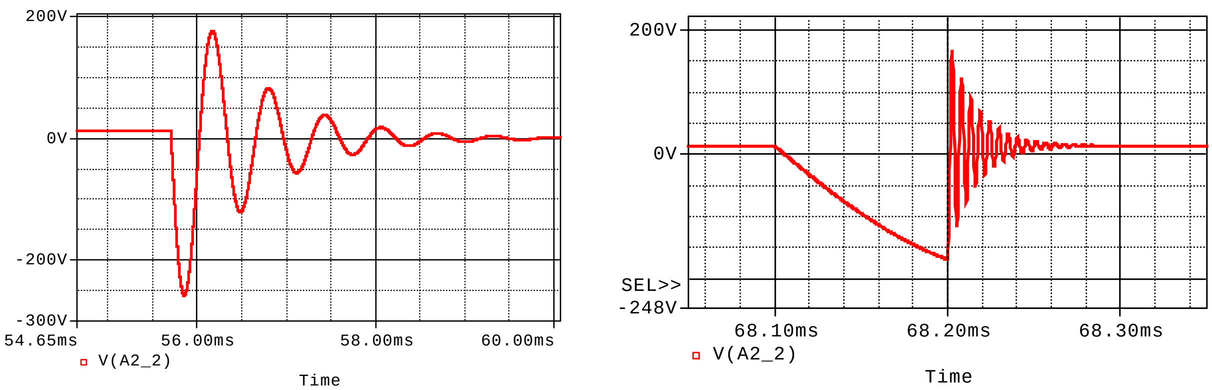


Figure: Simulation Waveforms

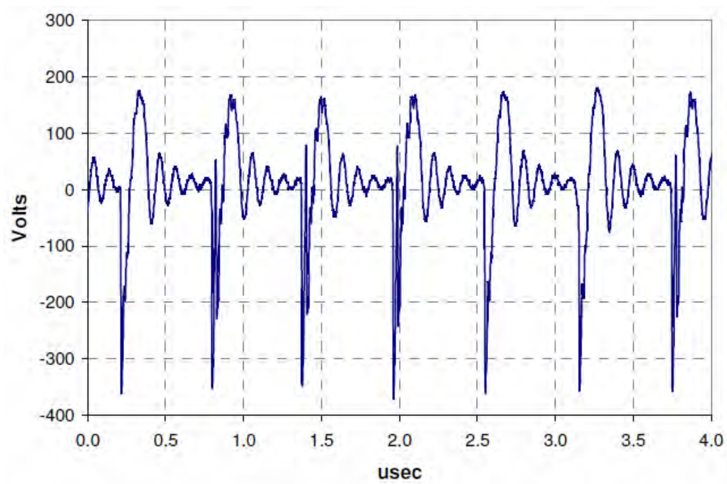
Pulse C1, Mode 1 and Mode 2 @ 10 MHz and 1.67 MHz

Pulse Module: ***CI220_GEN_C1_M1_M2***

Table E-1: CI 220 Transient Generator Switch Settings

Pulse	Mode *	SW1	SW2	SW3	SW4
C-1	2	Closed	Open	Open	Open

Pulse C-1 characteristics of this transient consist of a high frequency damped sinusoidal pulse (fres ~ 10 MHz) with the peak positive voltages levels between +150 to +250 volts and peak negative voltage levels are between –280 to –400volts. Pulse C-1 characteristics are illustrated in D-5b C-1 as shown below.



b) Pulse C-1

A current arc is not possible under a relay simulation with regular RLC & contacts. A SPICE generated signal mimicking the waveform C-1 is generated and injected in the relay contacts path in the test fixture. It is activated when the relay contacts are closed for the duration of 220us as shown in the waveforms.

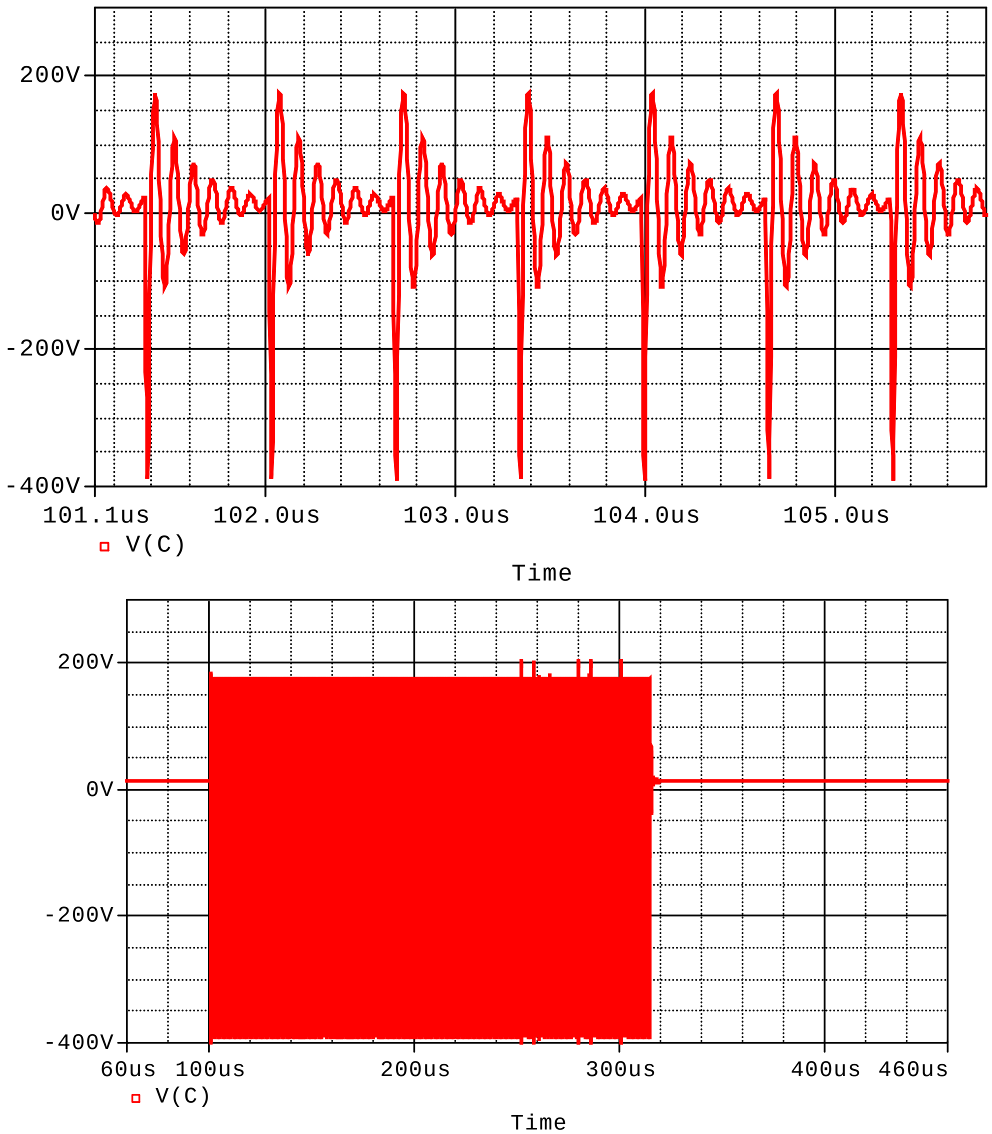
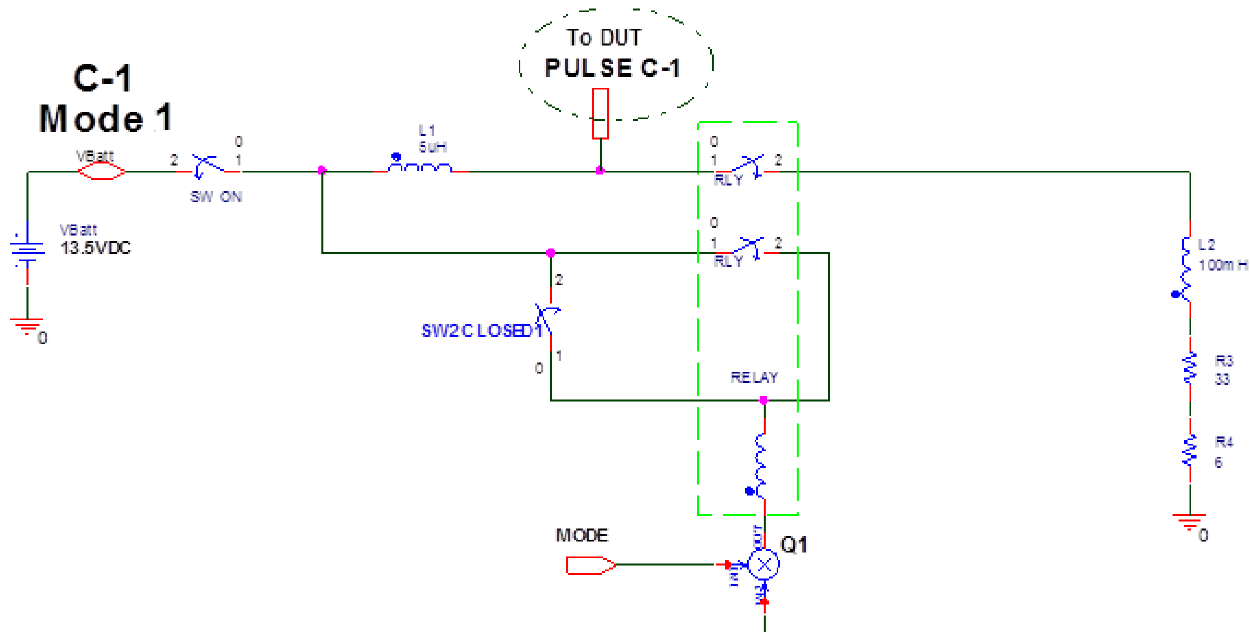


Figure: Simulation Waveforms Burst for ~215us



FMC1278 Test Generator C1 Basic Circuit Configuration

The C1 waveform occurs on contacts attempting to open and draw an arc. The arc is generated across the contacts by the induced voltages from the wiring inductance. During this time period, there are the very high frequency oscillations before the arc extinguishes. There is no damping or arc suppression circuits.

Note: If there is a capacitor, low resistance loading, or low voltage clamping in the DUT, the arcing may not occur and a different generator (C2) is required to be used. The test generator is not adaptive, meaning it cannot recognize if capacitive loading is present; therefore, the analyst must use the correct generator for the circuit being simulated.

The only loading that can be applied to this generator is light resistive load and high voltage clamping.

MODE pulses are 50ms to 350ms, with multiples of 50ms. This generator requires a small step size (TMAX) of **< 3.1ns** during the 225us burst. Since the burst is repeatable, a schedule statement is useful. For example, the regular step size can be < 311ns during the dead time portions and the fine step rate can be < 3.1ns during the bursts.

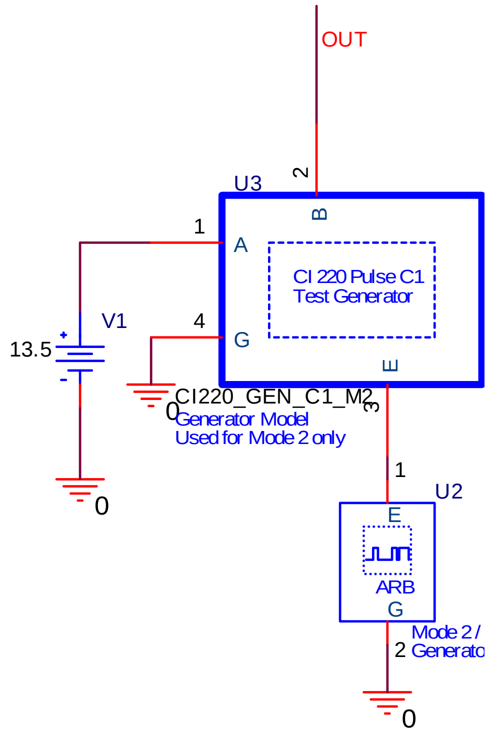


Figure: PSPICE Simulation test circuit for CI 220 Pulse C1 Mode 2

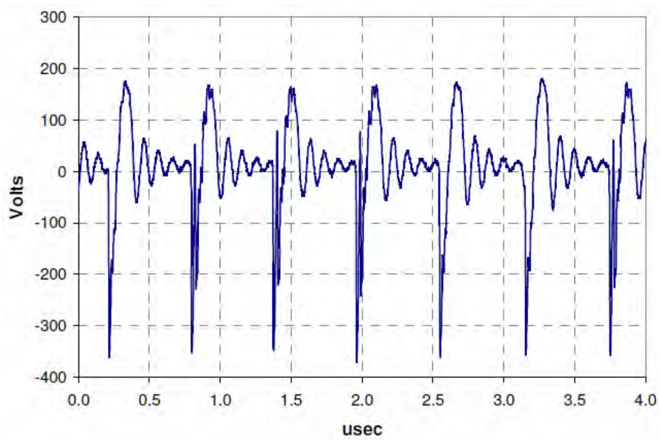
Pulse C1, Mode 3 Chattering Relay @ 10 MHz and 1.67 MHz

Pulse Module: ***CI220_CHAT_C1_M3***

Table E-1: CI 220 Transient Generator Switch Settings

Pulse	Mode *	SW1	SW2	SW3	SW4
C-1	3	Open	Open	Open	Open

Pulse C-1 characteristics of this transient consist of a high frequency damped sinusoidal pulse (fres ~ 10 MHz) with the peak positive voltages levels between +150 to +250 volts and peak negative voltage levels are between –280 to –400volts. Pulse C-1 characteristics are illustrated in D-5b C-1 as shown below.



b) Pulse C-1

A current arc is not possible under a relay simulation with regular RLC & contacts. A SPICE generated signal mimicking the waveform C-1 is generated and injected in the relay contacts path in the test fixture. It is activated when the relay contacts are closed during the ON commands of Mode 3.

Figure: Simulation C-1 Chattering Relay Contacts Voltage

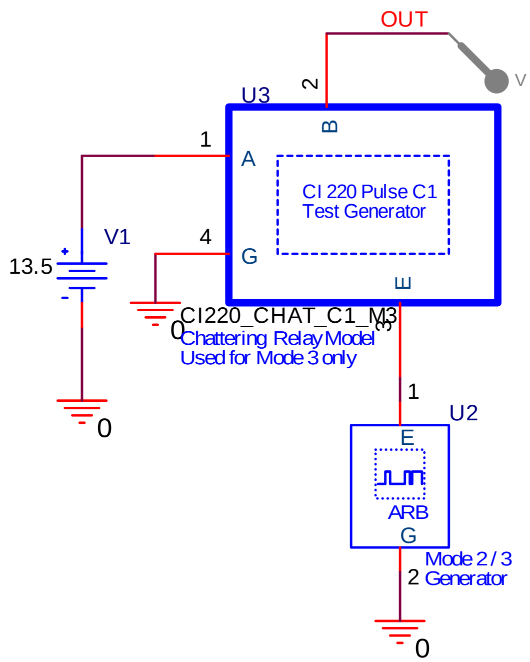


Figure: PSPICE Simulation test circuit for CI 220 Pulse C1 Mode 3

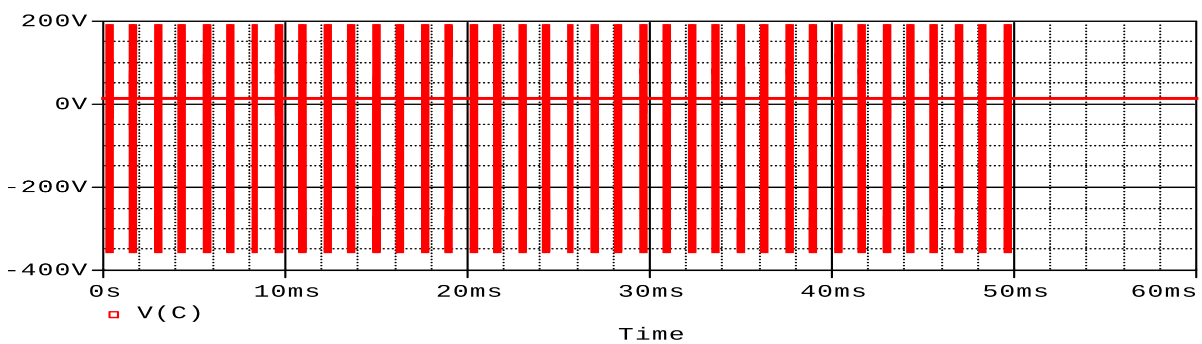


Figure: Simulation C-1 Chattering Relay Contacts Voltage 50ms

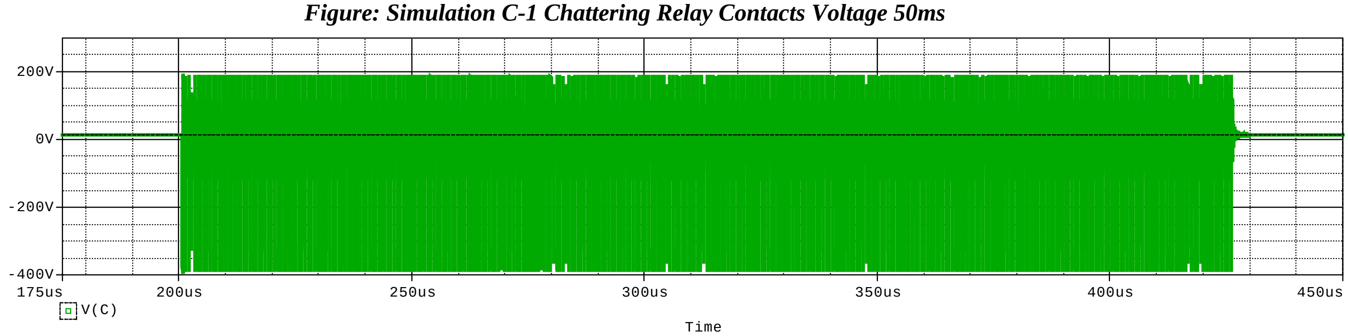


Figure: Simulation C-1 Chattering Relay Contacts Voltage 225us Burst

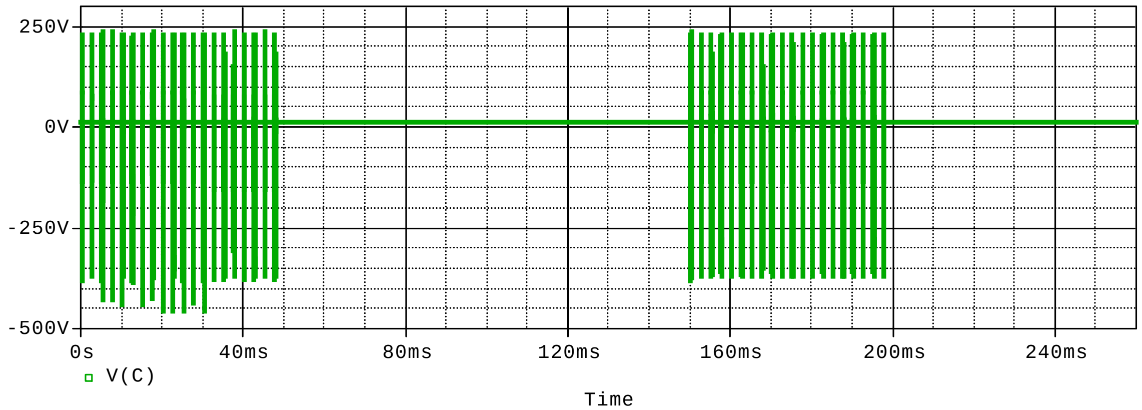
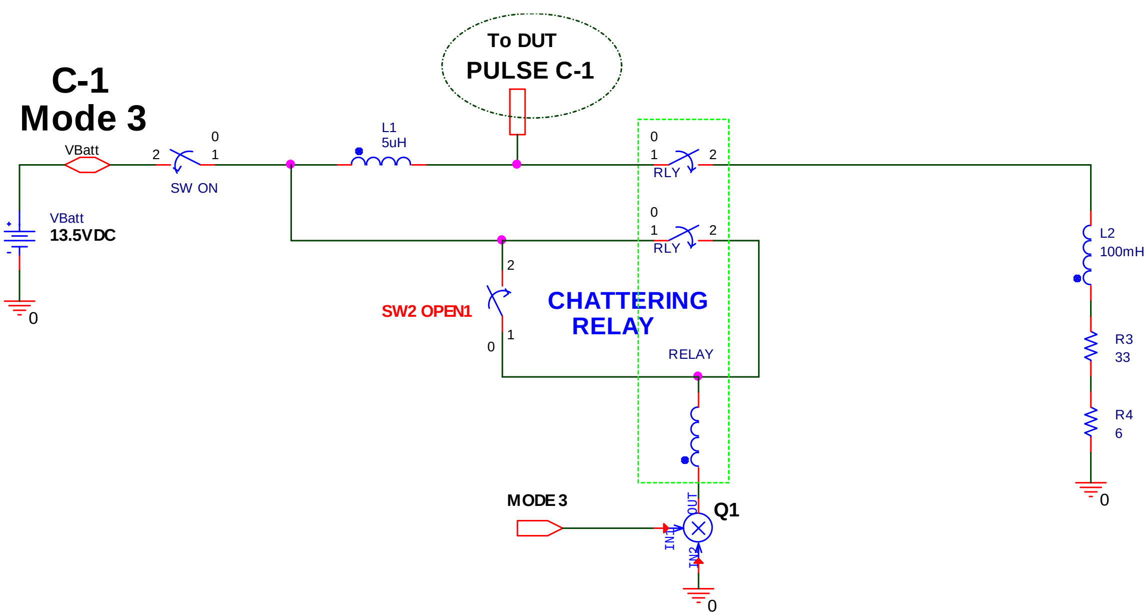


Figure: Simulation C-1 Chattering Relay Contacts Voltage 260ms Duration 331ns Step Size

MODE pulses are 50ms to 350ms, with multiples of 50ms. This generator requires a small step size (TMAX) of **< 3.1ns** during the 225us burst. Since the burst is repeatable, a schedule statement is useful. For example, the regular step size can be < 311ns during the dead time portions and the fine step rate can be < 3.1ns during the bursts.



FMC1278 Test Generator C1 Basic Circuit Configuration

This simulation assumes repetitive relay operation as per MODE 3 with contact bounce. The C1 waveform occurs on contacts attempting to open and draw an arc. The arc is generated across the contacts by the induced voltages from the wiring inductance. During this time period, there are the very high frequency oscillations before the arc extinguishes. There is no damping or arc suppression circuits.

Note: If there is a capacitor, low resistance loading, or low voltage clamping in the DUT, the arcing may not occur and a different generator (C2) is required to be used. The test generator is not adaptive, meaning it cannot recognize if capacitive loading is present; therefore, the analyst must use the correct generator.

The only loading that can be applied to this generator is light load resistive and high voltage clamping.

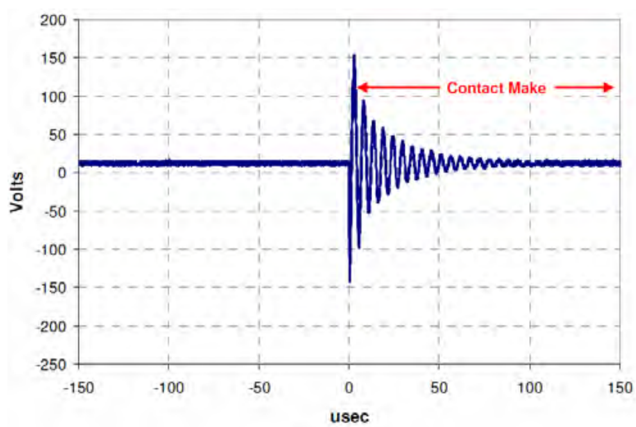
Pulse C2, Mode 1 and Mode 2 @ 180 kHz

Pulse Module: ***CI220_GEN_C2_M1_M2***

Table E-1: CI 220 Transient Generator Switch Settings

Pulse	Mode *	SW1	SW2	SW3	SW4
C-2	2	Closed	Open	Closed	Open

Pulse C-2 characteristics of this transient consist of a lower frequency damped sinusoidal pulse (fres ~ 180 kHz) with peak positive and negative voltages levels approximately ±150 volts when contacts close. Duration of the sinusoidal transient pulse is approximately 50µsec. Pulse C-2 characteristics are illustrated in D-5d.



d) Pulse C-2

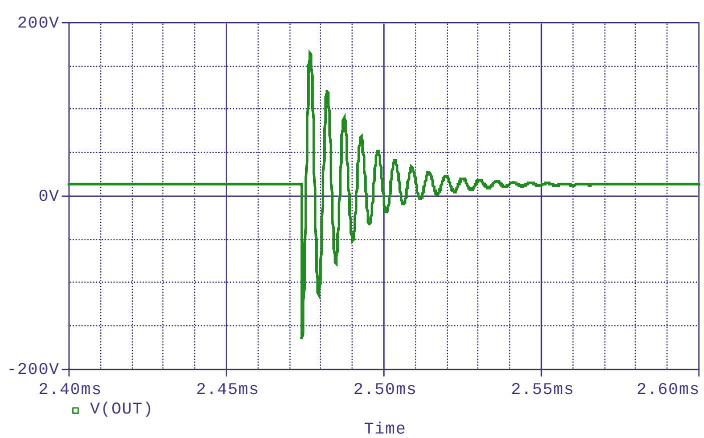


Figure: Simulation of Contacts "Make" (close during contact bouncing)

Although FMC calls out this single waveform, it is impossible to generate from the test fixture as this waveform only occurs during contact bounce (no arcing). Not only are multiple pulses required, they have to occur at specific contact current amplitude to get the correct amplitude.

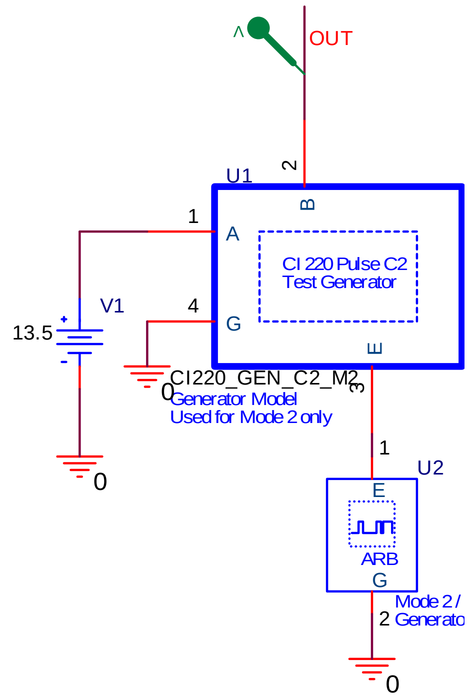


Figure: PSPICE Simulation test circuit for CI 220 Pulse C2 Mode 2

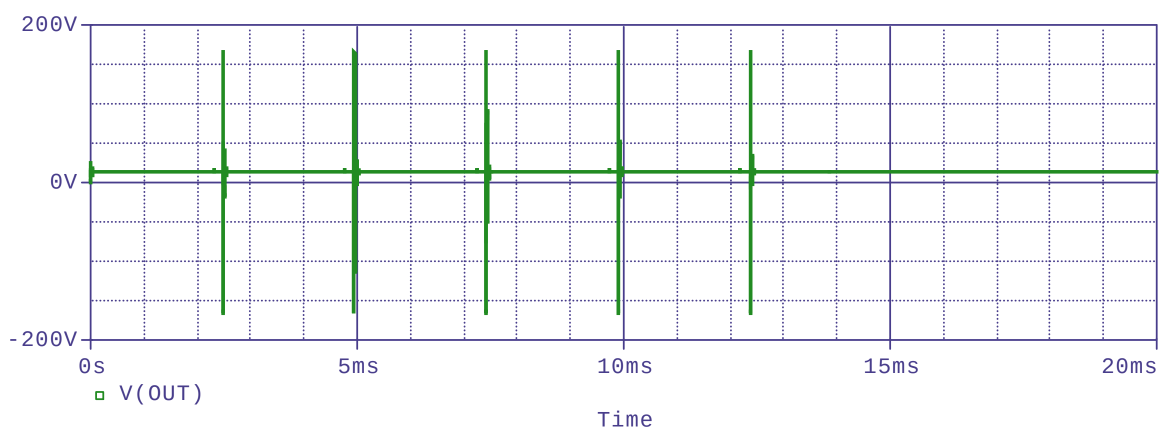
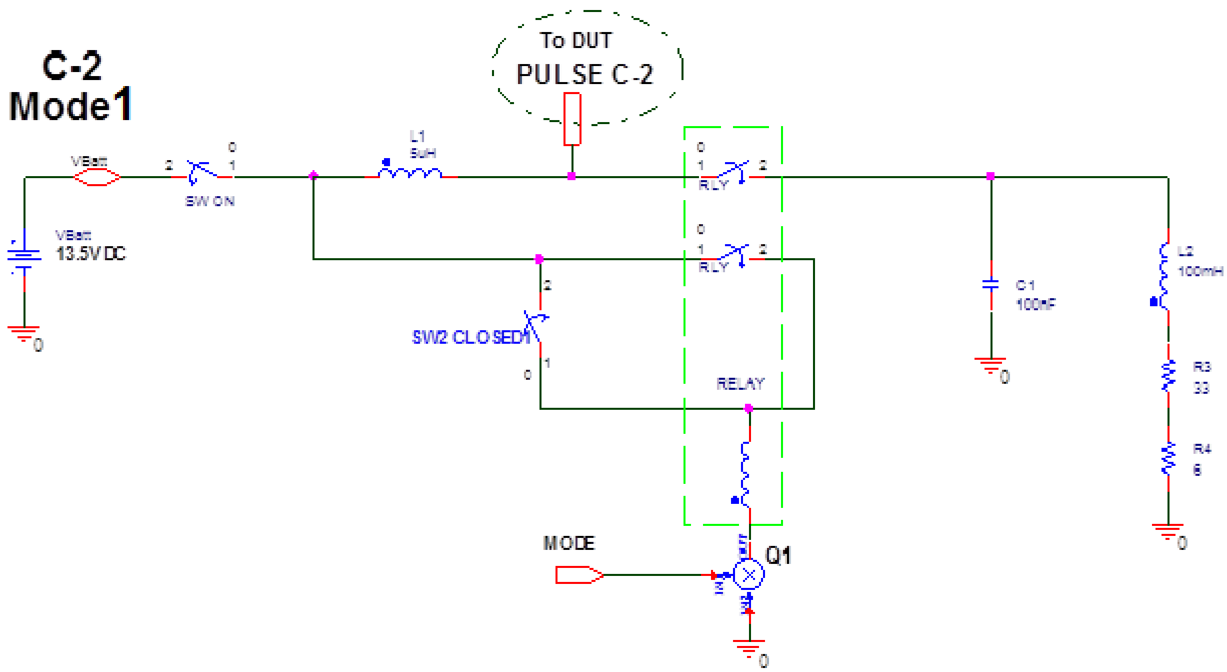


Figure: Burst for 13ms (contact bounce duration) shows Five Make and Break Bounces

On every positive going edge of the Mode Input pulse, the contacts bounce five times for 13ms providing the required waveforms on relay contacts closure. The Mode pulse varies from 50ms to 350ms in duration and occurs multiple times. The burst occurs only ONCE per Mode pulse.

Since there is also a contact break, the corresponding waveform may also be generated, but, it is not the primary waveform for use in this transient analysis. However, it is not to be ignored if there are unusual behaviors.

Pulse C-2 under Mode 1 has only one contact operation per Mode pulse. Pulse C-2 under Mode 3 has multiple contact closures resulting in bursts per Mode pulse due to chattering relay.



FMC1278 Test Generator C2 Basic Circuit Configuration

The C2 waveform occurs on contacts closing with no arcing resulting in damped oscillations due to the wiring inductance, C1, and DUT load capacitance. Although there is an inductive load (L2), its time constant is too long and does not contribute directly to the ringing. However, it does determine the repetition rate in the oscillations.

There is also a waveform occurring when the contacts open which is related to the capacitive and resistive DUT loading. However, since there is no arcing, the amplitudes are low.

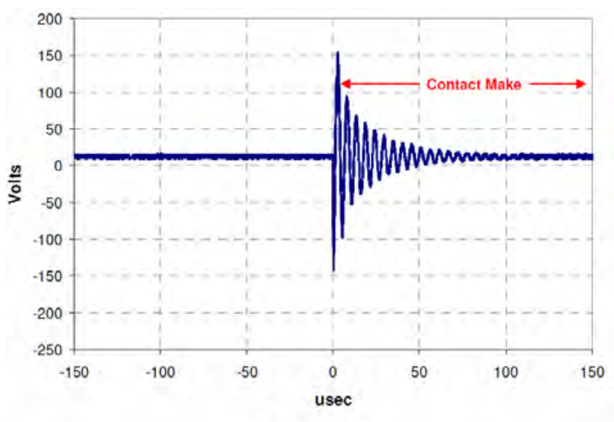
Pulse C2, Mode 3 Chattering Relay @ 180 kHz

Pulse Module: ***CI220_CHAT_C2_M3***

Table E-1: CI 220 Transient Generator Switch Settings

Pulse	Mode *	SW1	SW2	SW3	SW4
C-2	3	Open	Open	Closed	Open

Pulse C-2 characteristics of this transient consist of a lower frequency damped sinusoidal pulse (fres ~ 180 kHz) with peak positive and negative voltages levels approximately ±150 volts when contacts close. Duration of the sinusoidal transient pulse is approximately 50µsec. Pulse C-2 characteristics are illustrated in D-5d.



d) Pulse C-2

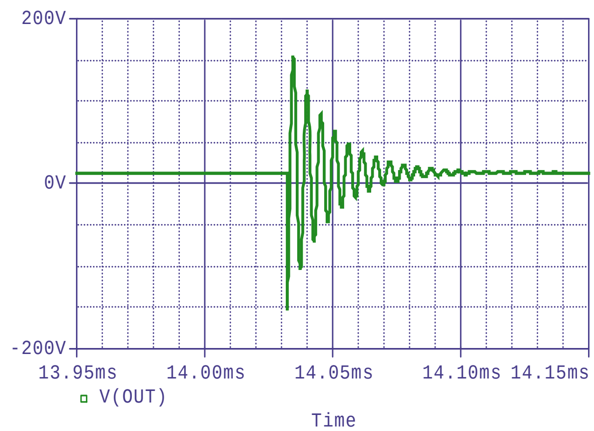


Figure: FMC1278 Pulse C-2 & Simulation C-2 Contact Bounce Voltage

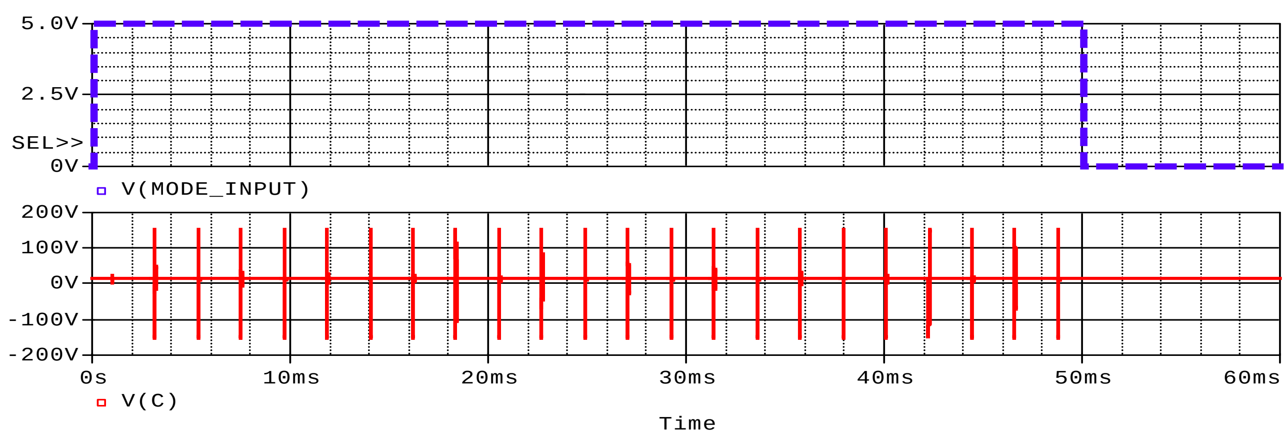
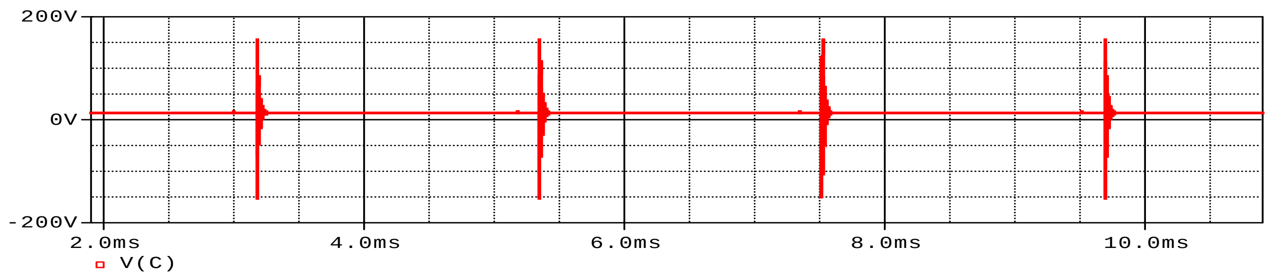


Figure: Simulation C-2 Chattering Relay Contacts Voltage 50ms Duration



Simulation C-2 Chattering Relay Contacts Voltage Three Bursts

On every ON voltage of the Mode Input, the contacts bounce continuously providing the required waveform on each Make. Since there is also a contact break, its waveform may also be generated, but, it is not intended for this analysis unless faulty conations result.

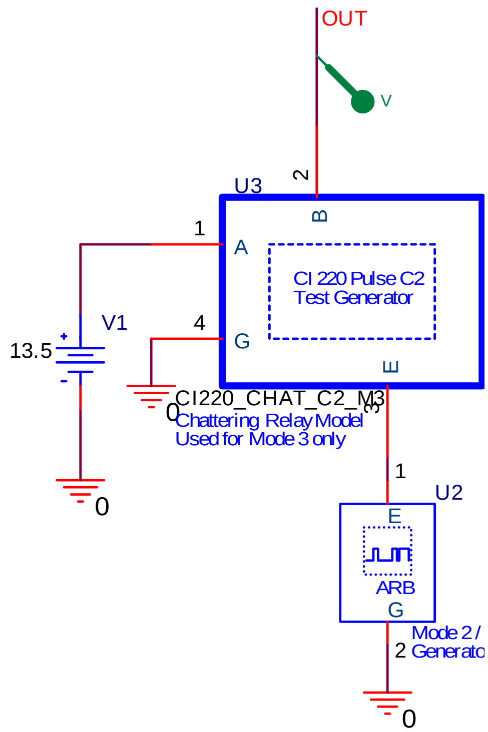
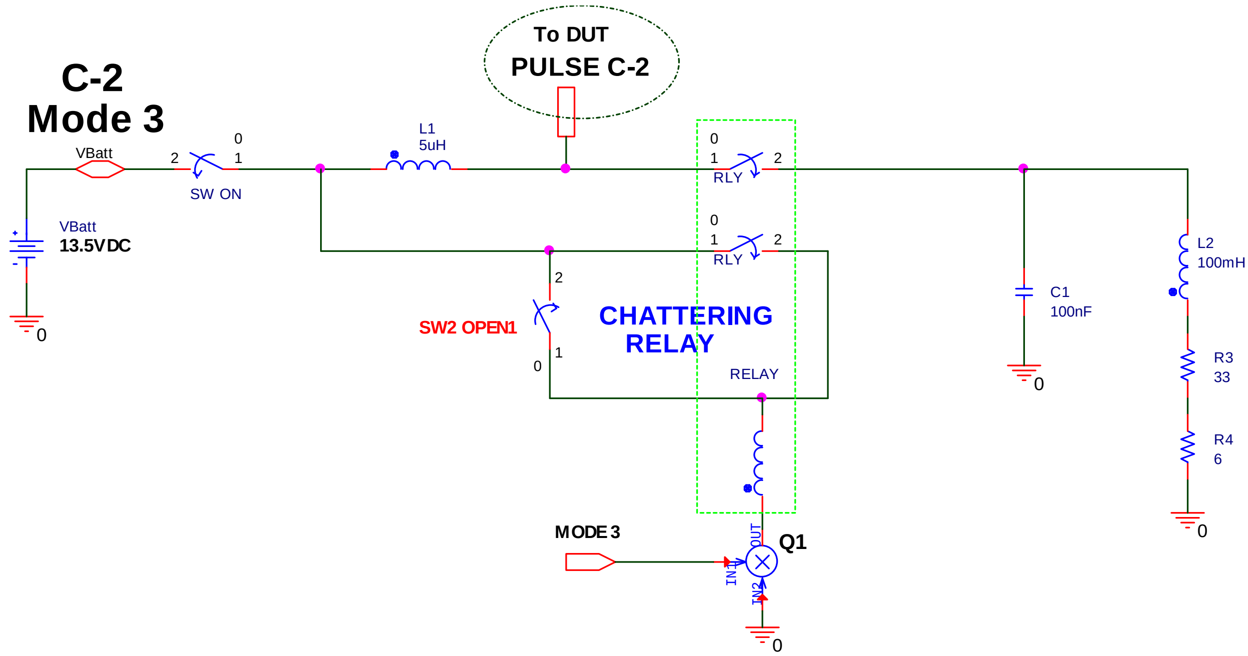


Figure: PSPICE Simulation test circuit for CI 220 Pulse C2 Mode 3



FMC1278 Test Generator C2 Basic Circuit Configuration

The C2 waveform occurs on contacts closing with no arcing resulting in damped oscillations due to the wiring inductance and C1, along with DUT resistance and capacitance. Although there is an inductive load (L2), its time constant is too long and does not contribute directly to the C2 ringing.

There is also a waveform occurring when the contacts open which is related to the capacitive and resistive DUT loading. However, since there is no arcing, the amplitudes are low.

CI 221 specification: Immunity from Transient Disturbances

These requirements are related to immunity from conducted transients occurring on both switched and unswitched power supply circuits of the component and/or subsystem. This requirement is applicable only to 24 VDC applications.

Table 18-1: CI 221 Transient Immunity Requirements

Test Pulse #	Application	Stress Level (Volts) (1,2		Minimum # of pulses or Test Duration	Repetition time	Functional Performance Status
		U_A	U_S			
1	Switched Power Supply Circuits	27	-450	5000 pulses	0.5 sec	II
2a	All Supply Circuit	27	+37	5000 pulses	0.2 sec	I
2b	Supply Circuits connected in parrallel with an electric motor	27	+20	10 pulses	0.5 sec	II
3a	All Supply Circuit	27	-150	1 hour	90 msec	I
3b	All Supply Circuit	27	+150	1 hour	90 msec	I

Pulse 1

This test is a simulation of transients due to supply disconnection from inductive loads. It is applicable to DUTs which, as used in the vehicle, remain connected directly in parallel with an inductive load.

Table 3 — Parameters for test pulse 1

Parameter	12 V system	24 V system
U_s	–75 V to – 100 V	– 450 V to – 600 V
R_i	10 Ω	50 Ω
t_d	2 ms	1 ms
t_r	$\left(1_{-0,5}^{\ 0}\right)$ µs	$\left(3_{-1,5}^{\ 0}\right)$ µs
t_1 [a]	0,5 s to 5 s	
t_2	200 ms	
t_3 [b]	< 100 µs	

[a] t_1 shall be chosen such that the DUT is correctly initialized before the application of the next pulse.

[b] t_3 is the smallest possible time necessary between the disconnection of the supply source and the application of the pulse.

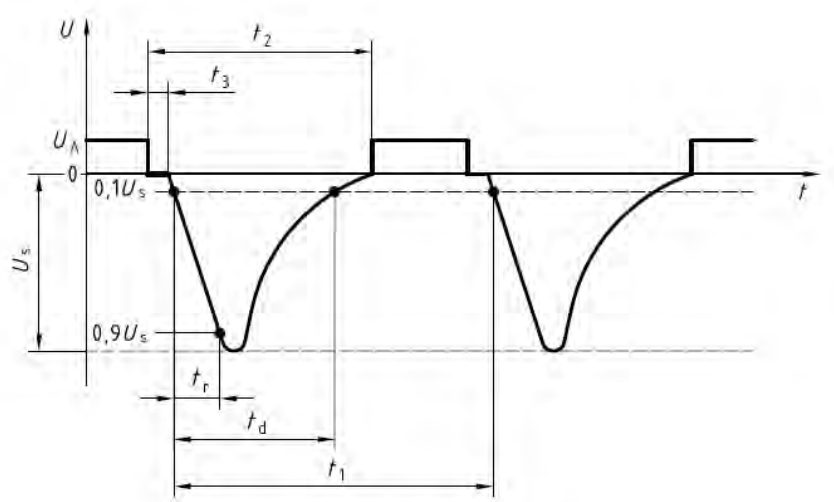


Figure 5 — Test pulse 1

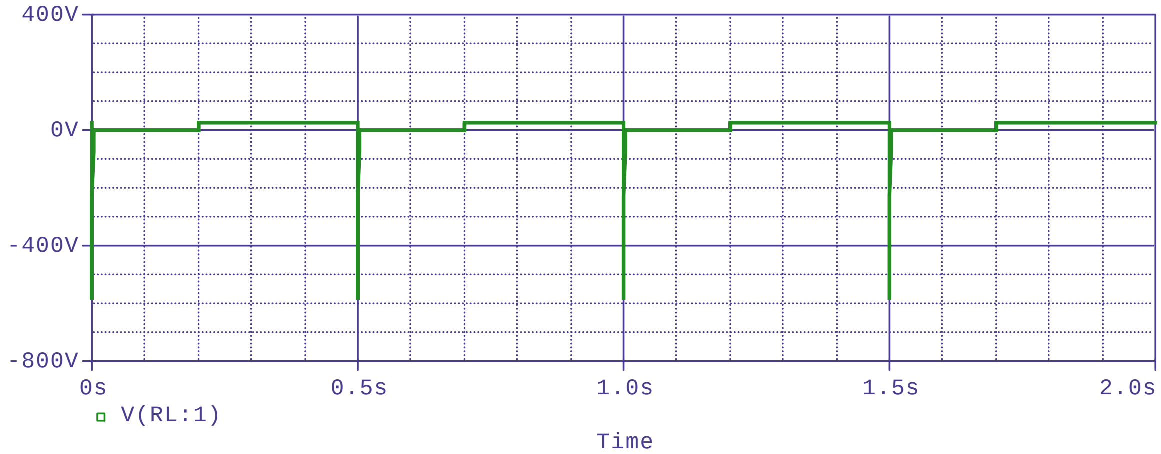


Figure: PSPICE simulation result for a single generated pulse 1

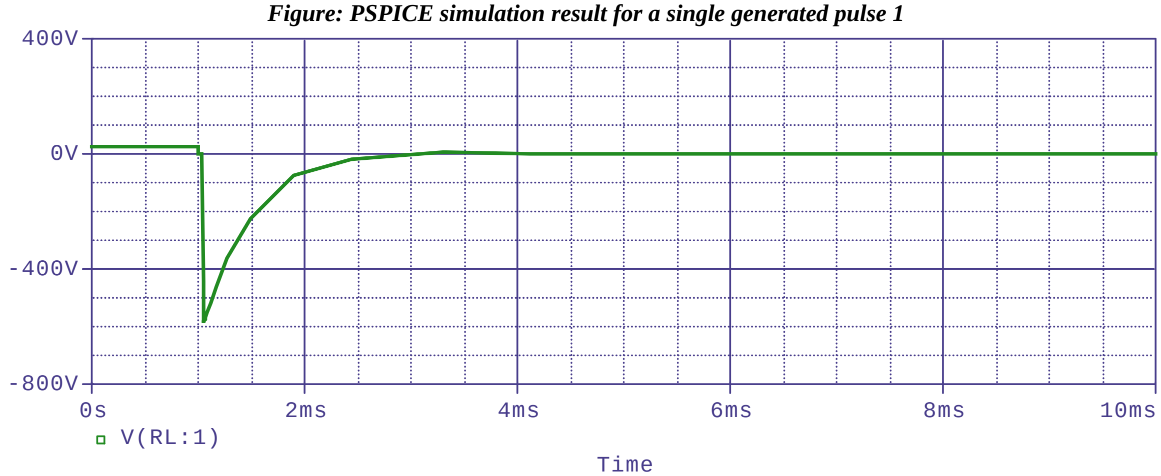


Figure: Zoomed-in PSPICE simulation result for a single generated pulse 1

Pulse 2a

Pulse 2a describes the situation where a positive voltage spike occurs due to current being interrupted to a circuit in parallel with the electronics being tested. Spikes occur in the wires when a device suddenly stops sinking current. The following transient waveforms describe such an event.

Table 4 — Parameters for test pulse 2a

Parameter	12 V system	24 V system
U_s	+ 37 V to + 50 V	
R_i	2 Ω	
t_d	0,05 ms	
t_r	$\left(1_{-0,5}^{\ 0}\right)$ µs	
t_1 [a]	0,2 s to 5 s	

[a] The repetition time t_1 can be short, depending on the switching. The use of a short repetition time reduces the test time.

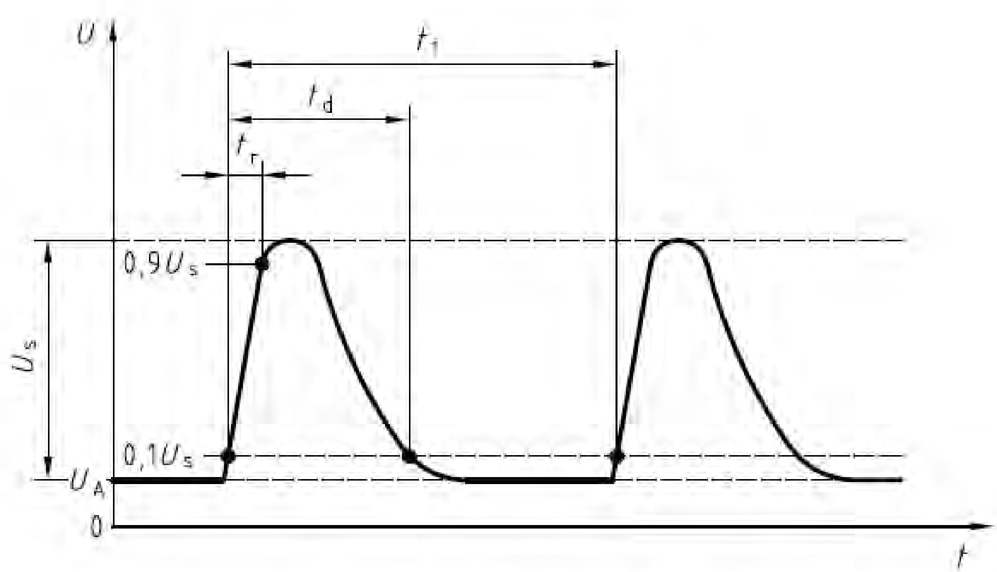


Figure 6 — Test pulse 2a

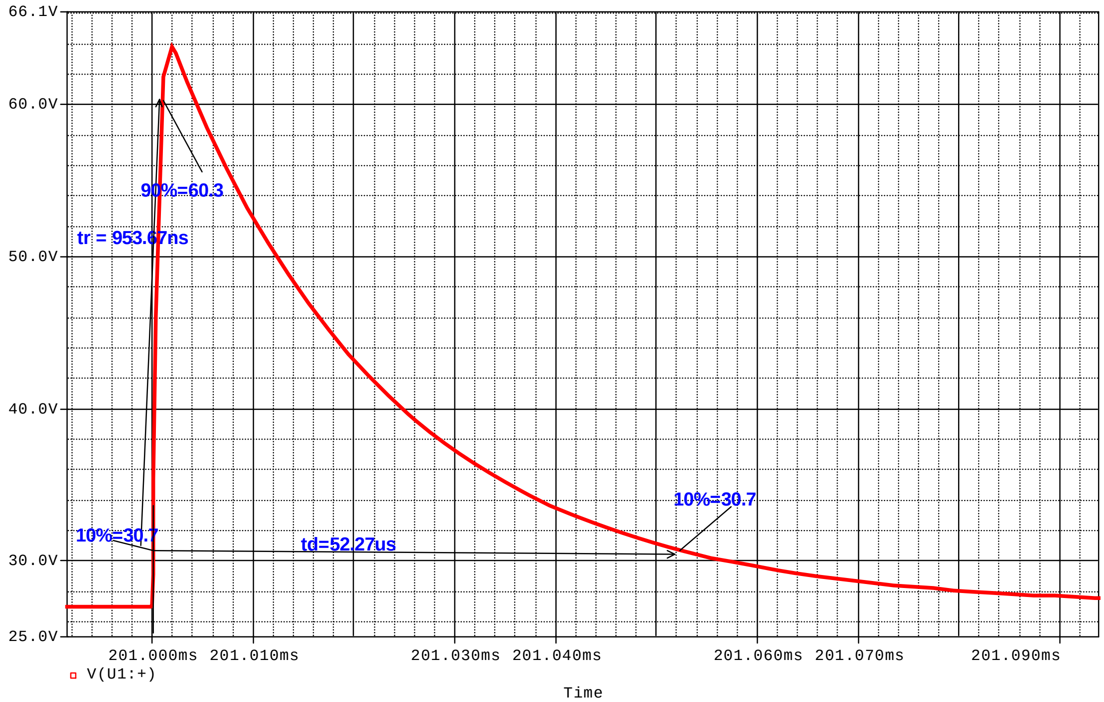


Figure: Zoomed-in PSPICE simulation result for a single generated pulse 2A

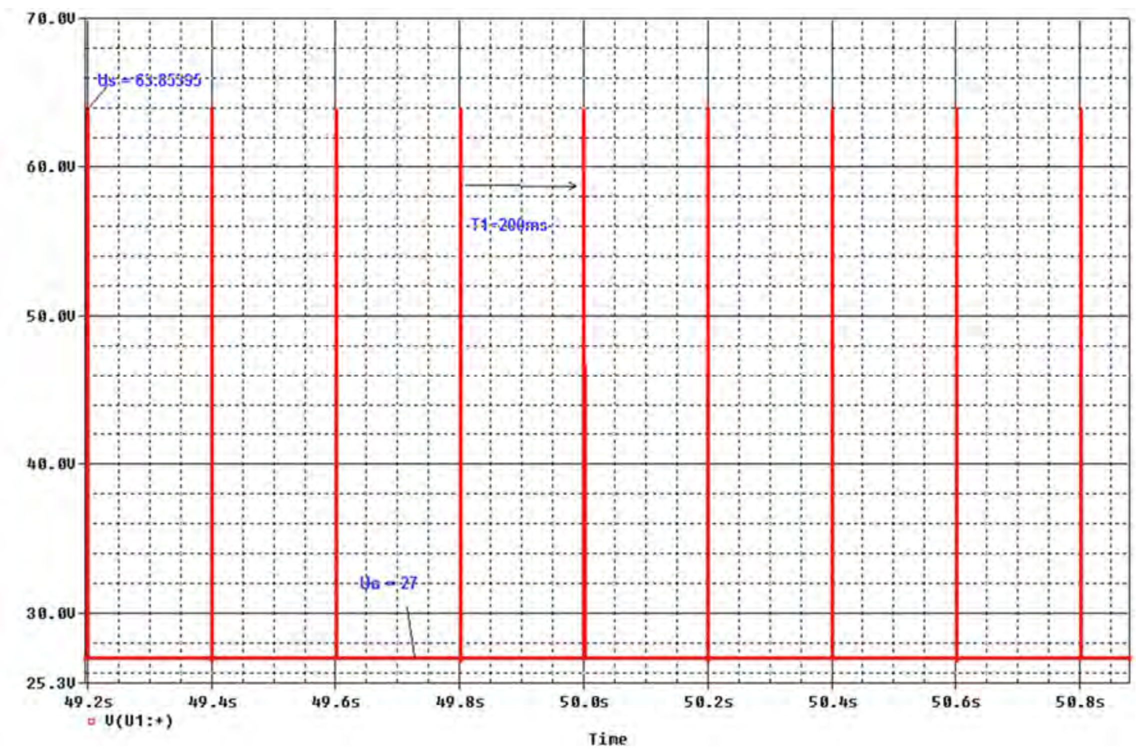


Figure: PSPICE simulation result of the generated pulse 2A

Pulse 2b

Pulse 2b defines a situation that occurs when the ignition is switched off and DC motors act as generators.

Table 5 — Parameters for test pulse 2b

Parameter	12 V system	24 V system
U_s	10 V	20 V
R_i	0 Ω to 0,05 Ω	
t_d	0,2 s to 2 s	
t_{12}	1 ms ± 0,5 ms	
t_r	1 ms ± 0,5 ms	
t_6	1 ms ± 0,5 ms	

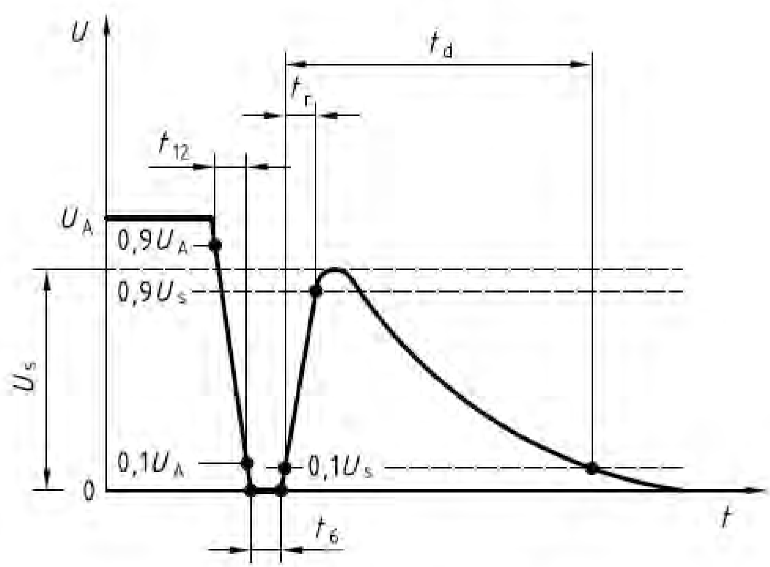


Figure 7 — Test pulse 2b

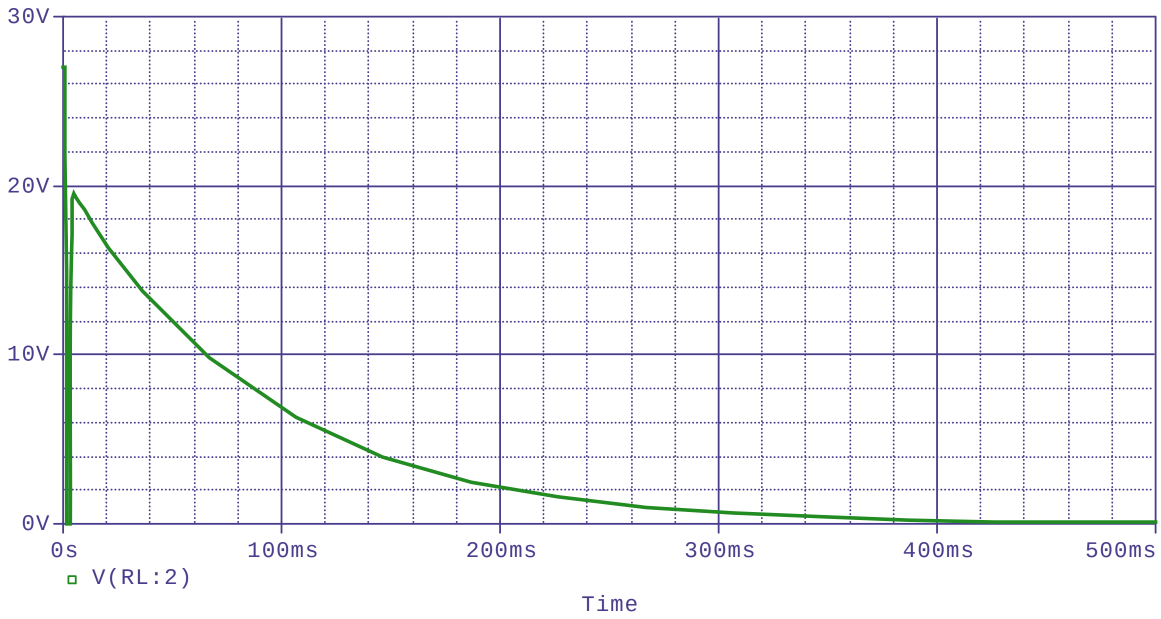


Figure: PSPICE simulation result for a single generated pulse 2B

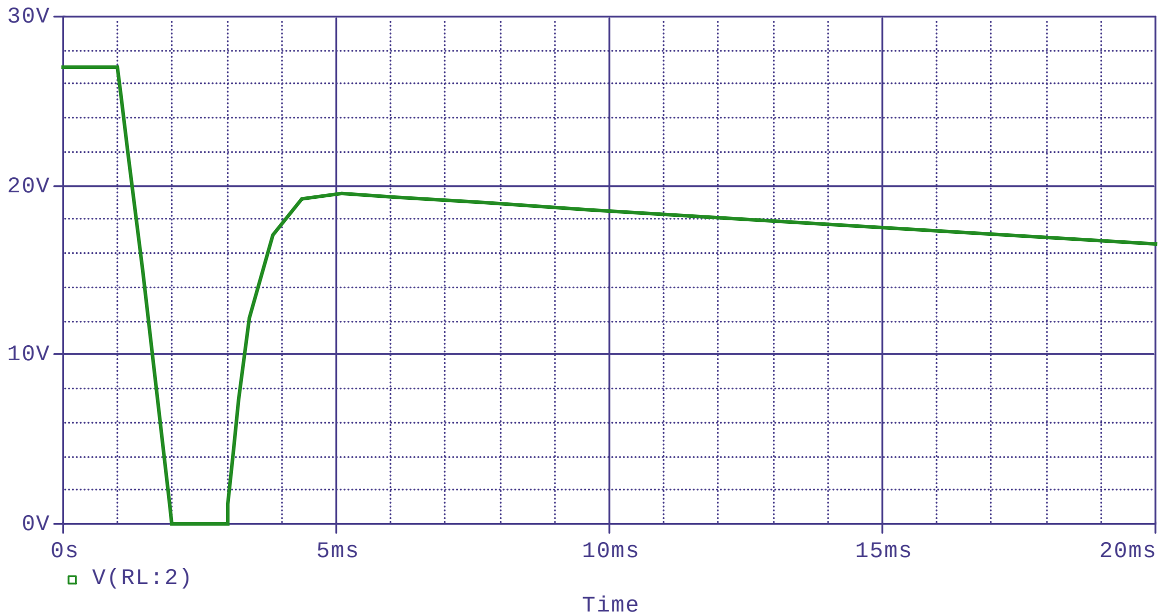


Figure: Zoomed-in PSPICE simulation result for a single generated pulse 2B

Pulse 3a

Pulse 3a describes the negative spikes that occur due to switching between processes. An example could be arcing across switches and relays.

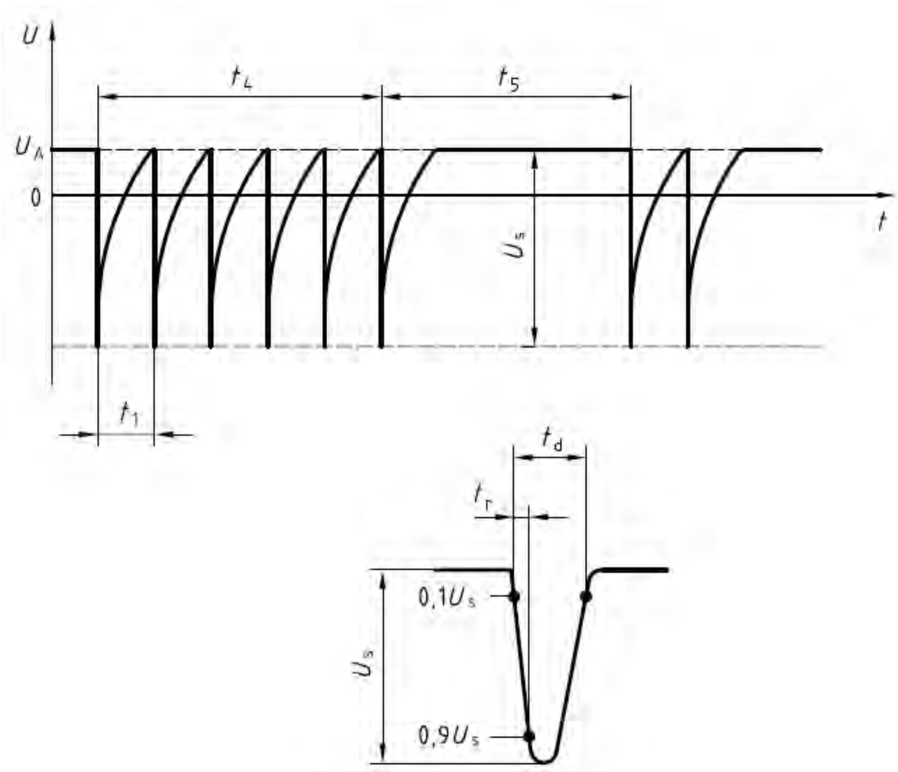


Figure 8 — Test pulse 3a

Table 6 — Parameters for test pulse 3a

Parameter	12 V system	24 V system
U_s	– 112 V to – 150 V	– 150 V to – 200 V
R_i	50 Ω	
t_d	$\left(0,1\,^{+0,1}_{\ \ 0}\right)$ µs	
t_r	5 ns ± 1,5 ns	
t_1	100 µs	
t_4	10 ms	
t_5	90 ms	

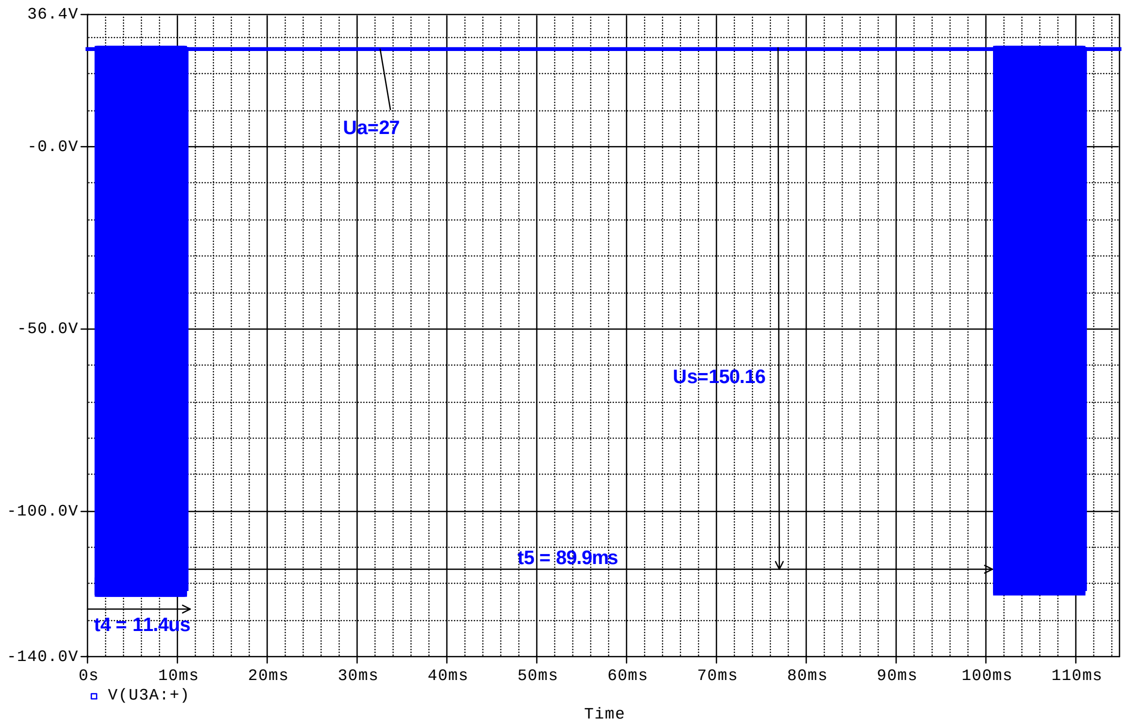


Figure: PSPICE simulation result of the generated pulse 3A

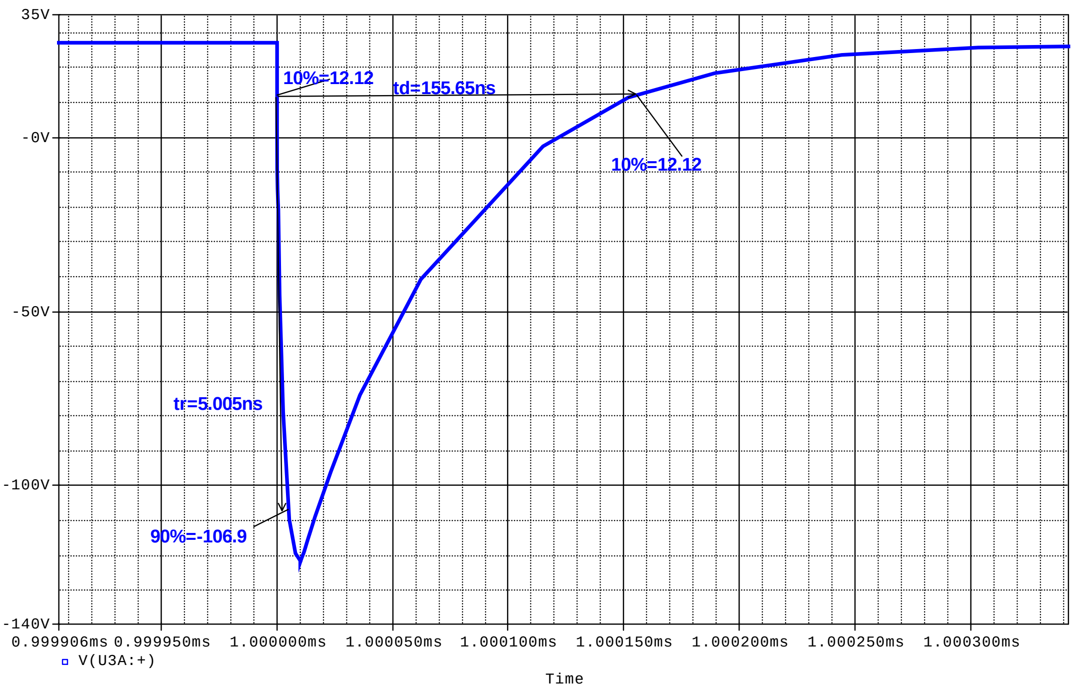


Figure: Zoomed-in PSPICE simulation result for a single generated pulse 3A

Pulse 3b

Pulse 3a describes the positive spikes that occur due to switching between processes including arcing across switches and relays.

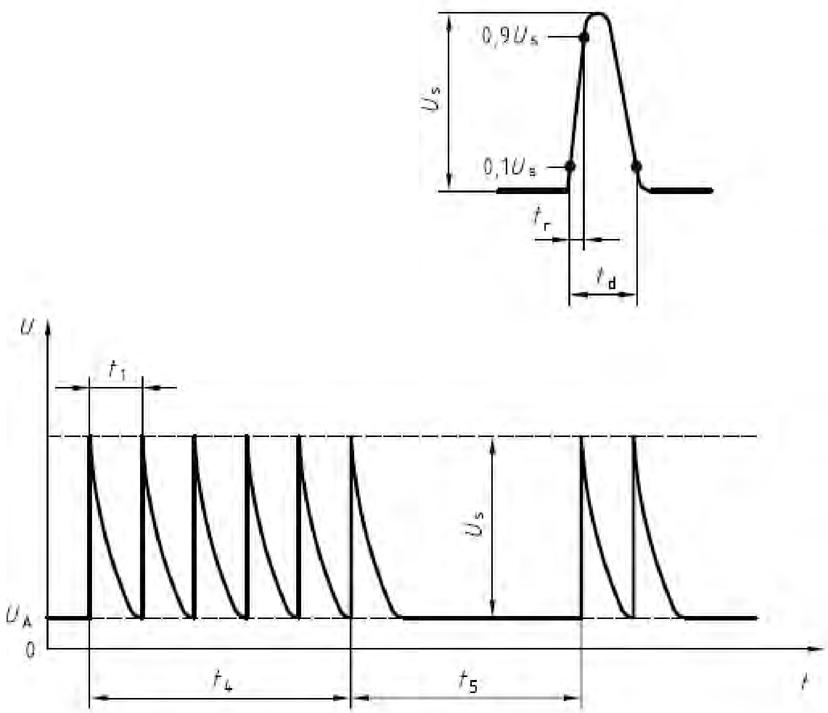


Figure 9 — Test pulse 3b

Table 7 — Parameters for test pulse 3b

Parameter	12 V system	24 V system
U_s	+ 75 V to + 100 V	+ 150 V to + 200 V
R_i	50 Ω	
t_d	$\left(0,1^{+0,1}_{0}\right)$ µs	
t_r	5 ns ± 1,5 ns	
t_1	100 µs	
t_4	10 ms	
t_5	90 ms	

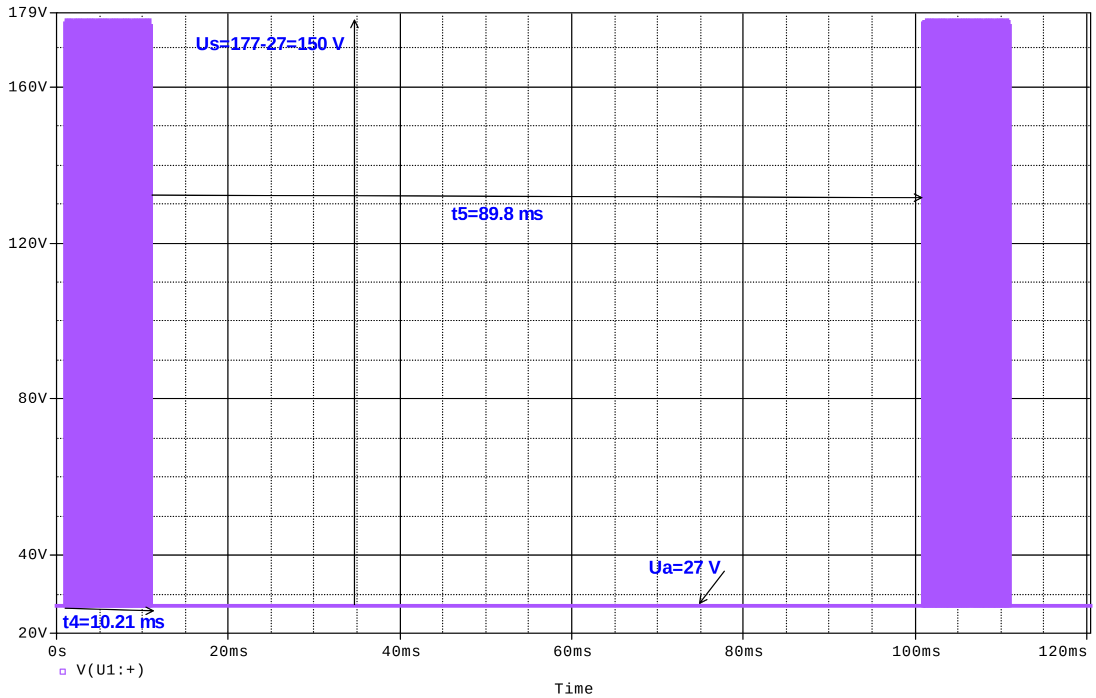


Figure: PSPICE simulation result of the generated pulse 3B

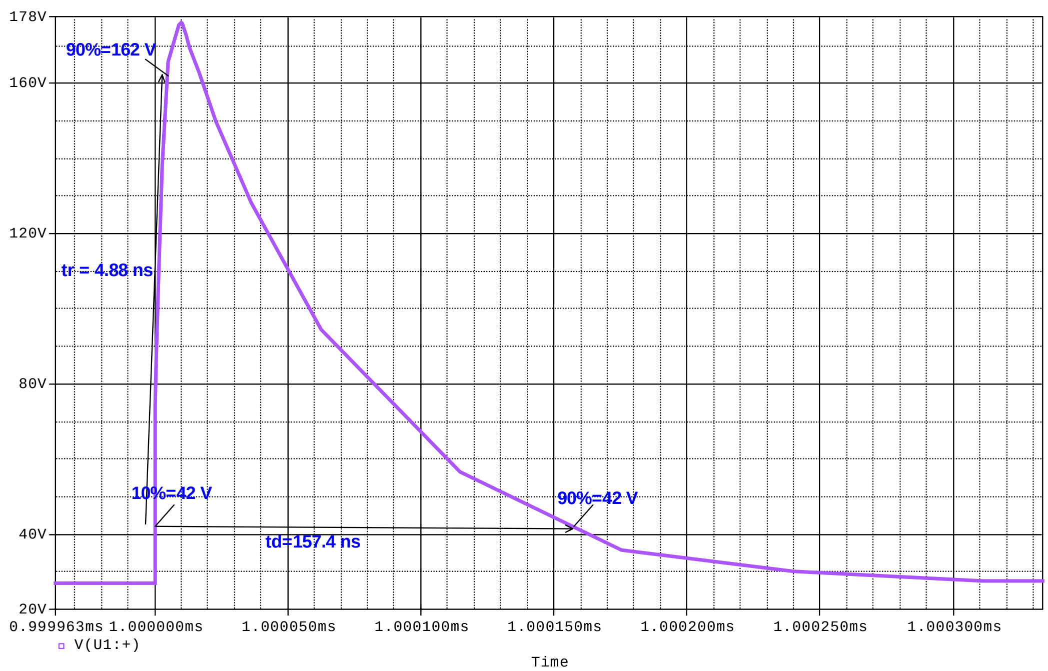


Figure: PSPICE simulation result for a single generated pulse 3B

CI 222 specification: Immunity from Load Dump

In the event of discharged battery disconnecting while the alternator is generating charging current with electrical loads still connected.

Table 19-1: CI 222 Load Dump Requirements

ISO Test Pulse	Application	Stress Level (Volts) 12 VDC System			24 VDC System		Minimum # of pulses	Repetition time	Functional Performance Status	
		U_A	U_S (2)	U_S * (2, 3)	U_A	U_S			Class A & B	Class C
5a (1)	All power supply circuits Control circuits	13.5	+60	n/a	27	+120 (2)	5	60 sec	III	II
5b (1)	All power supply circuits Control circuits	13.5	+30	+21.5 (-1/+0)	n/a		5	60 sec	III	II

Pulse 5A - 12VDC System

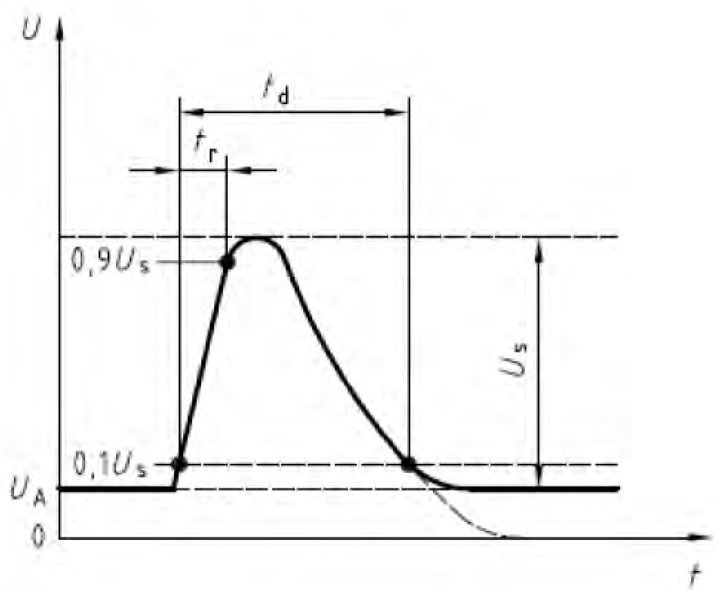
Figure D-11: ISO Pulse 5a Characteristics

Pulse 5a – Parameters(1)

Open Circuit Conditions (R_L = open)		
U_A	13.5 VDC	27 VDC
U_s	See Table 19-1	
R_i	0.5 Ω	1 Ω
t_d	300 ms +/-20%	
t_r	10 ms -5 /+0 ms	

Loaded Conditions (R_L = R_i)		
U_A	13.5 VDC	27 VDC
U_s	0.5*U_S (Open Circuit)	
R_i	0.5 Ω	1 Ω
t_d	150 mS +/-20%	
t_r	10 (-5 /+0) ms	

(1) All voltage values are with respect to 0 volts unless otherwise specified.



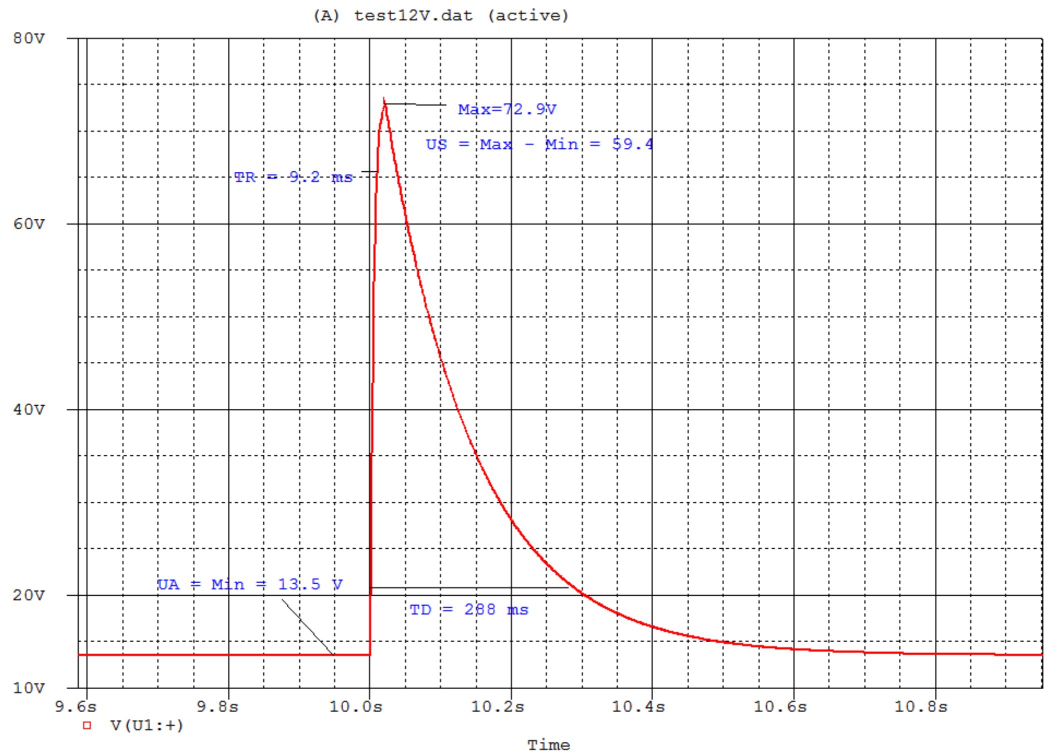


Figure: PSPICE simulation result for a single generated pulse 5A (open circuit)

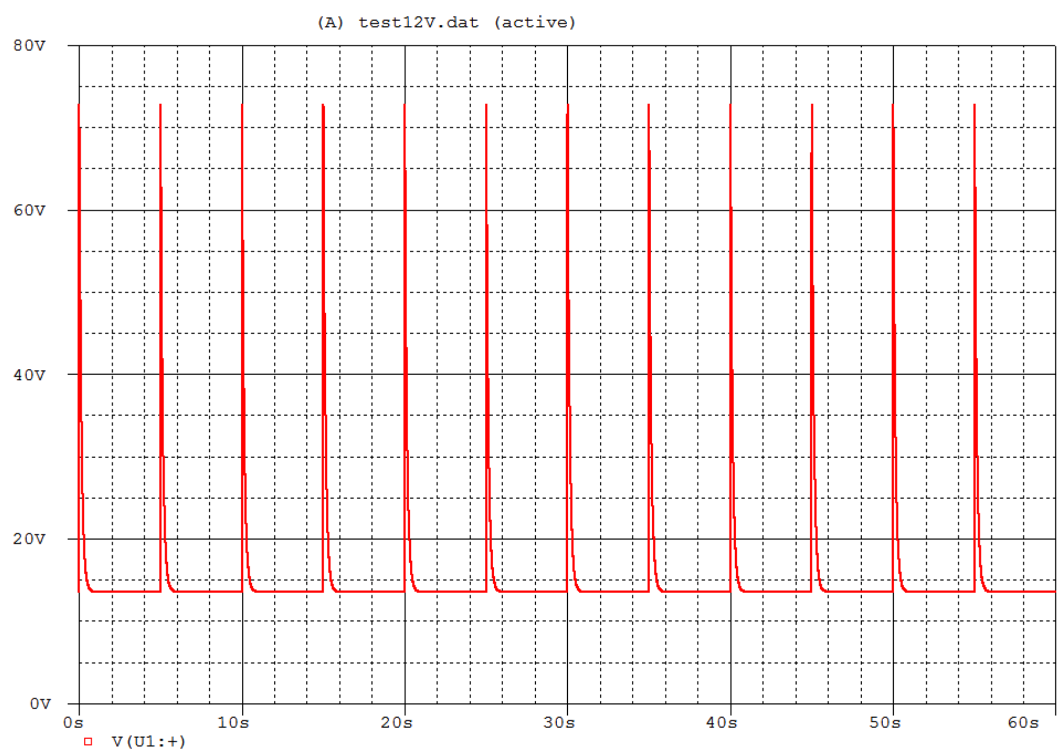


Figure: PSPICE simulation result of the generated pulse 5A (open circuit)

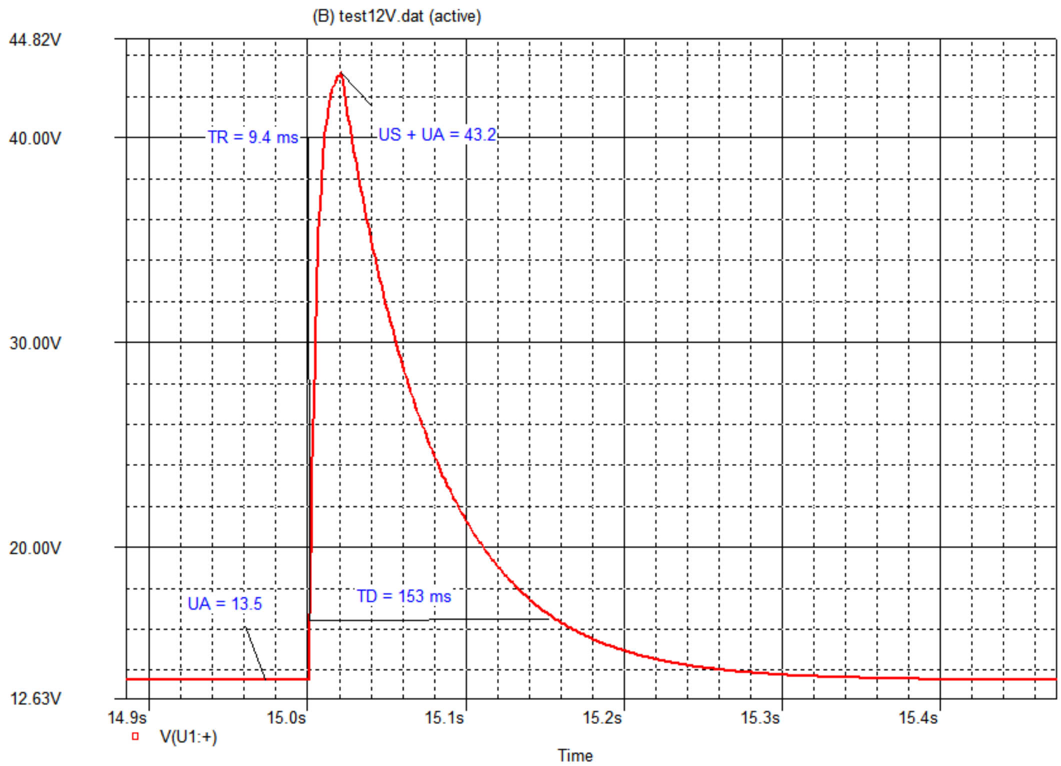


Figure: PSPICE simulation result for a single generated pulse 5A (0.5 Ohm load)

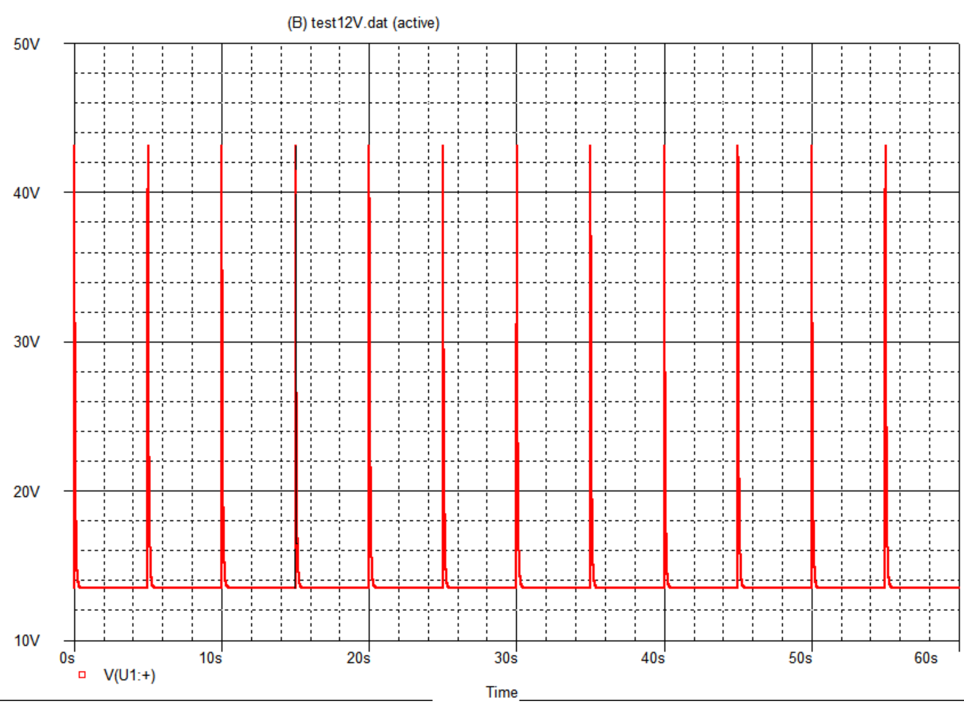


Figure: PSPICE simulation result of the generated pulse 5A (0.5 Ohm load)

Pulse 5B - 12VDC System

Figure D-12: ISO Pulse 5b Characteristics

Pulse 5b Parameters [1]

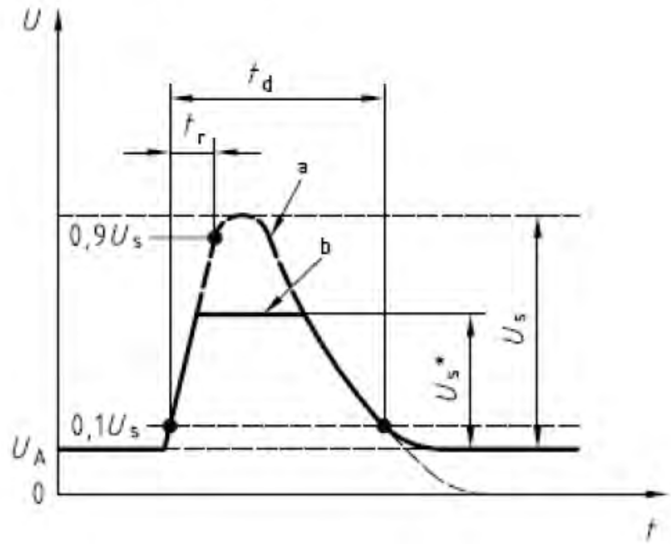
Parameter	Value
U_A	See Table 19-1.
U_s [2]	
U_s^{*} [2]	
R_i	0.5 Ohms
t_r	10 (-5 /+0) ms
t_d	150 mS +/-20%

(1) All voltage values are with respect to 0 volts unless otherwise specified.

(2) U_S and U_S^{*} based on 0.5 ohm resistive load ($R_L = R_i$).

a: Unsuppressed pulse

b: Suppressed pulse



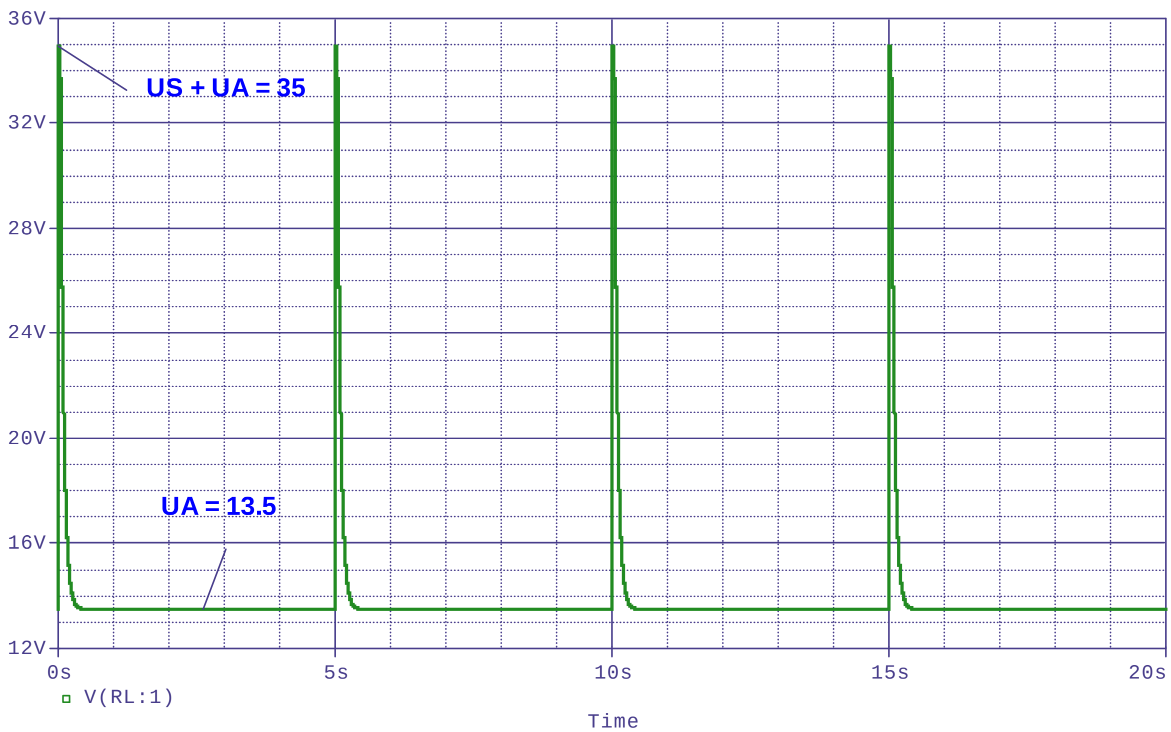


Figure: PSPICE simulation result of the generated pulse 5B

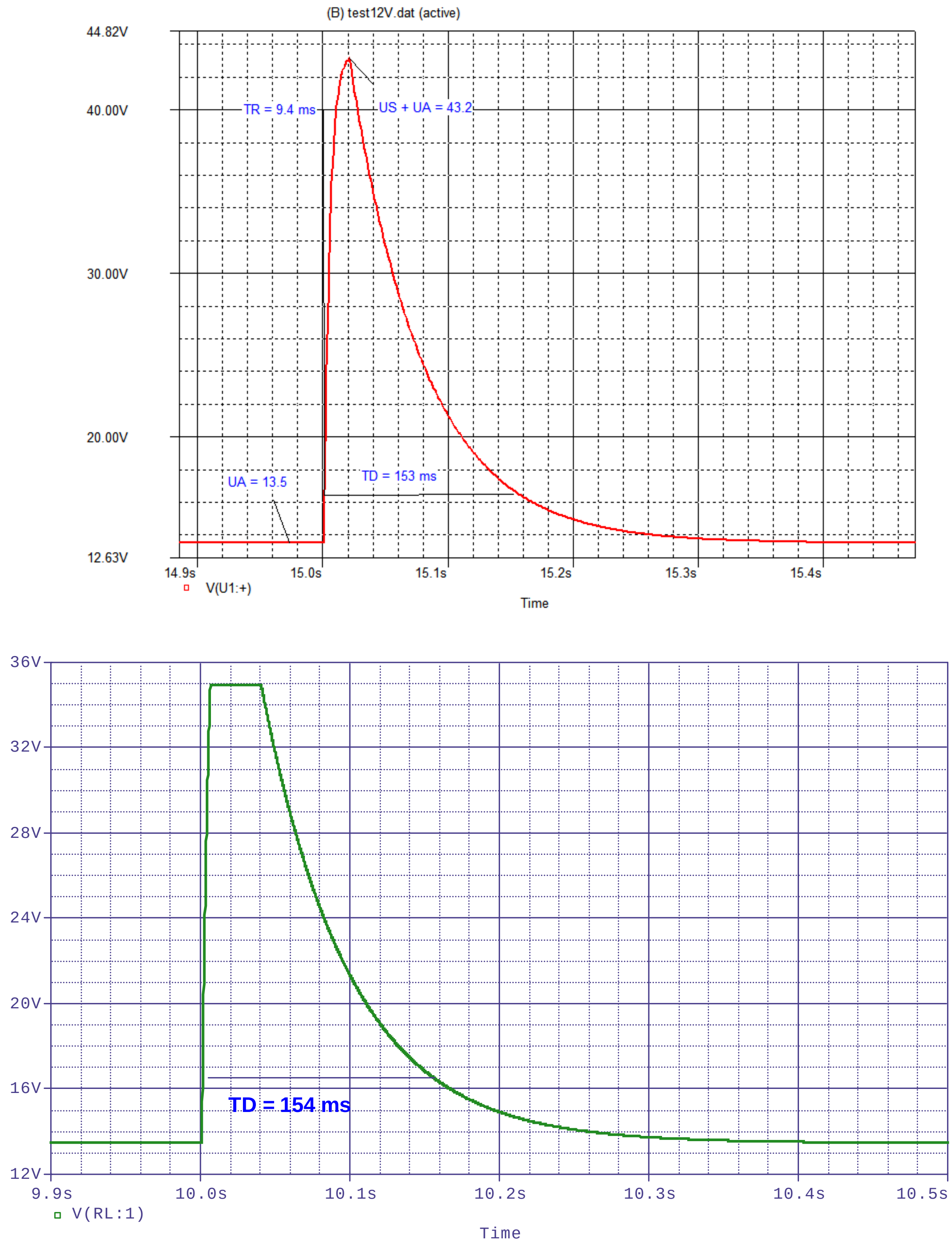


Figure: PSPICE simulation result for a single generated pulse 5A (top) and pulse 5B (bottom). Pulse 5B is the clamped version of pulse 5A.

CI 230 specification: Immunity from Power Cycling

DUT should be immune to input voltage fluctuations, during start of the vehicle under cold temperature, where engine is cold.

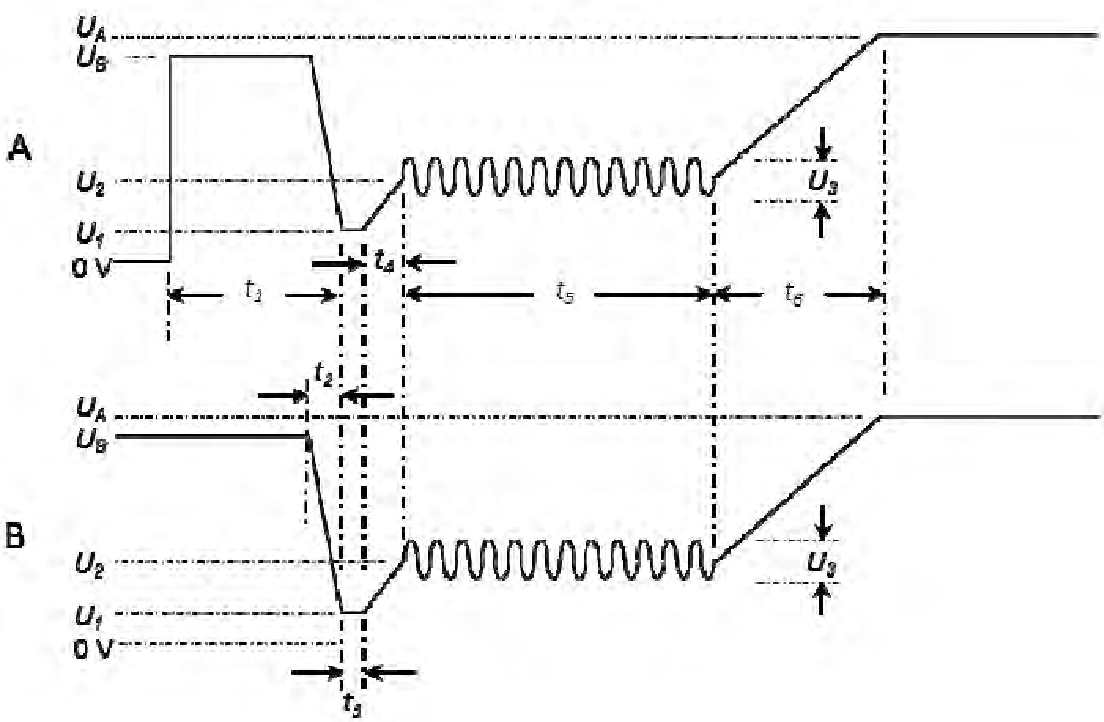
Table 20-1: CI 230 Power Cycling Requirements

Waveform [1]	Application	Duration	Functional Performance Status [2]
A	Switched Power & control circuits that are activated at initiation and duration of the start event	2 cycles separated by cooling period (see section 20.3)	II
B	Power circuits connected directly to Battery (i.e. unswitched)		II

1 Waveforms applied simultaneously to all power supply and control circuits.

2 Any degradation in performance shall not inhibit the ability of the vehicle to start.

Figure 20-1: CI 230 Power Cycling Waveforms and Timing Sequence



Key:

t_1 = 200 msec	t_5 = 10 sec	U_1 = 5 V
t_2 = 5 msec	t_6 = 500 msec	U_2 = 9 V
t_3 = 15 msec	U_A = 13.5 V	U_3 = 2 Vp-p @ 4 Hz
t_4 =50 msec	U_B = 12.5 V	

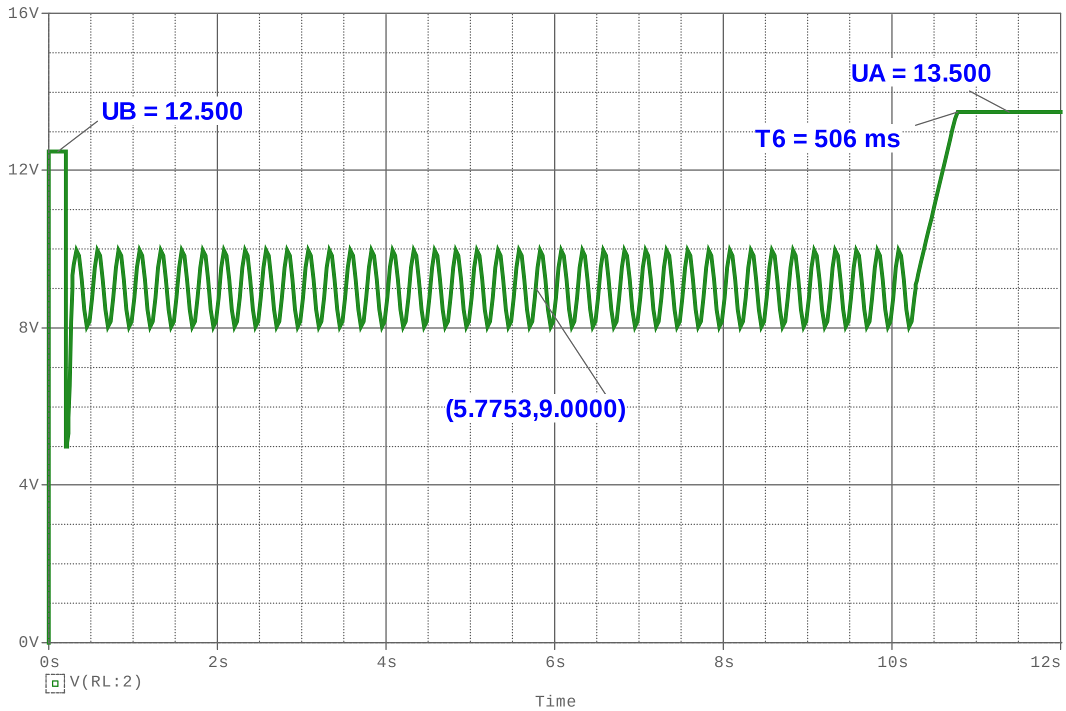


Figure: PSPICE simulation result of the generated CI 230 waveform A

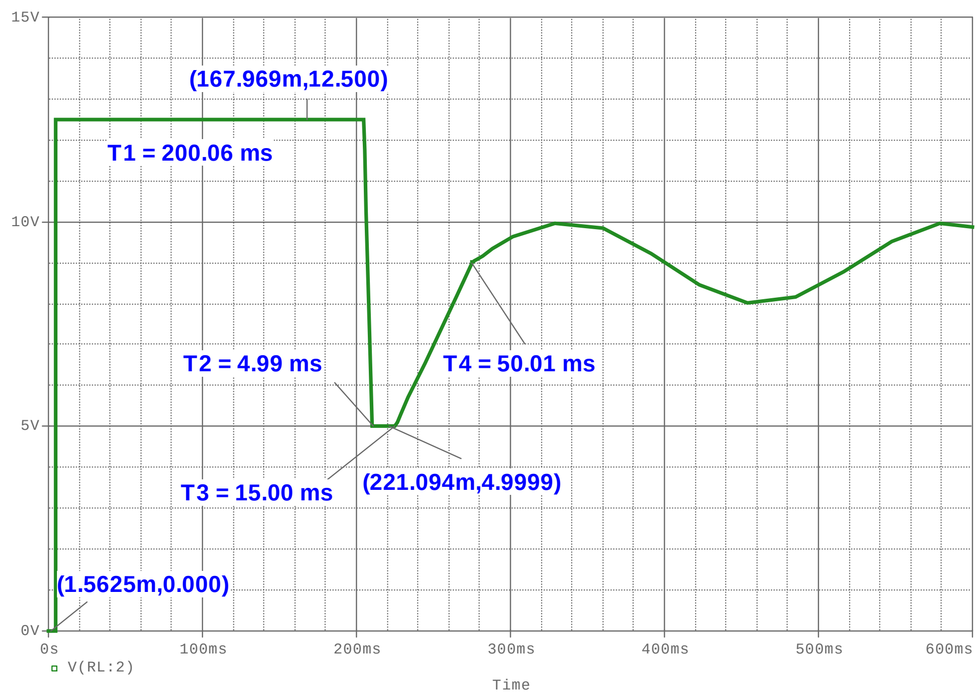


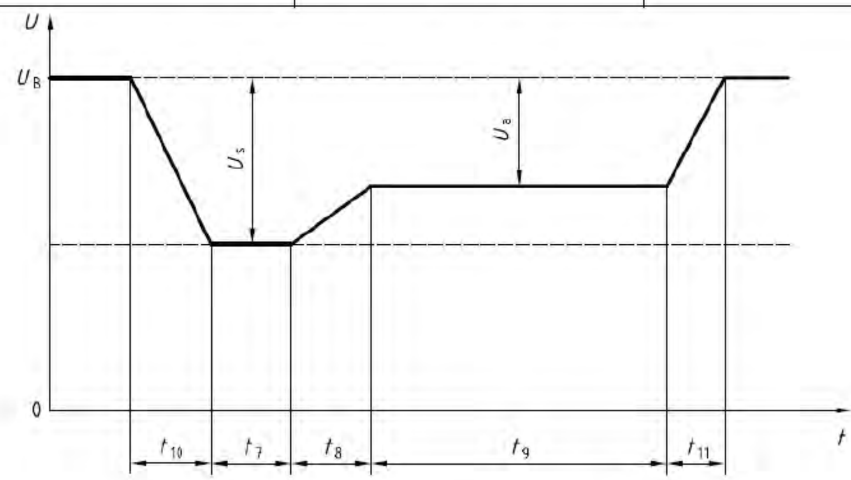
Figure: Zoomed in PSPICE simulation result of the generated CI 230 waveform A

CI 231 specification: Immunity from Power Cycling

This requirement is related to immunity from voltage fluctuation during starting of the vehicle's engine. This requirement is applicable only to 24 VDC applications.

Figure 21-1: CI 231 Power Cycling Requirements

Application	Duration	Functional Performance Status [1]
Switched & Unswitched Battery Circuits	2 cycles separated by 1 min [2]	II



Key:

U_B	U_S	U_a	R_i	t_7	t_8	t_9	t_{10}	t_{11}
24 V	-12V	-7	< 0.02Ω	50 msec	≤ 50 msec	10 sec	10 msec	100 msec

(1) Any degradation in performance shall not inhibit the ability of the vehicle to start.
(2) Duration must be long enough to evaluate DUT function after startup

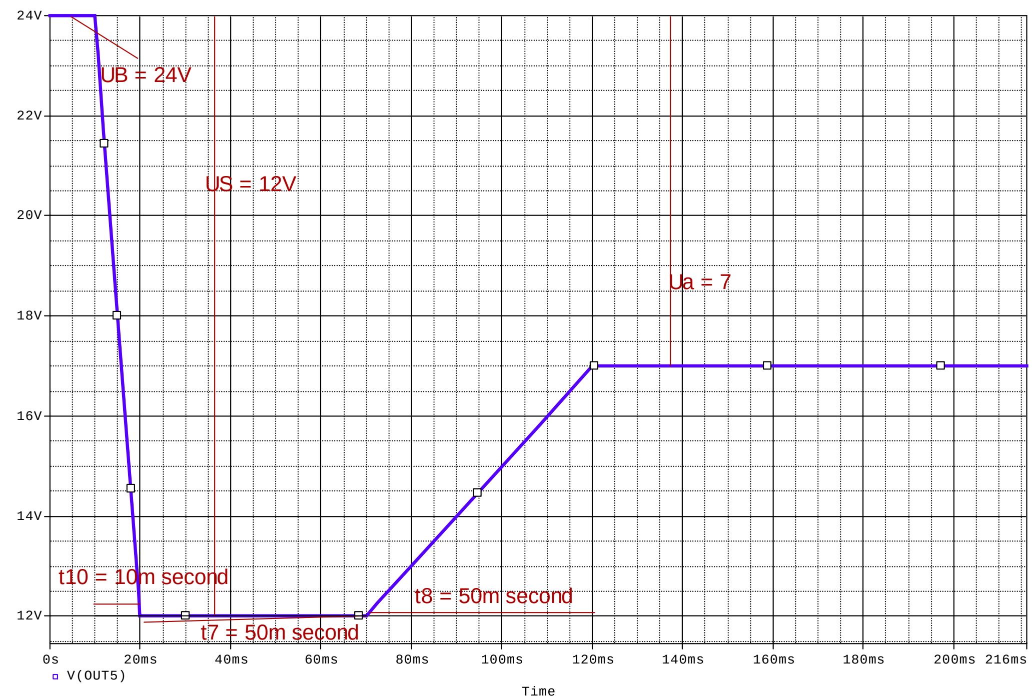


Figure: PSPICE simulation result for a single generated pulse 1 (24V)

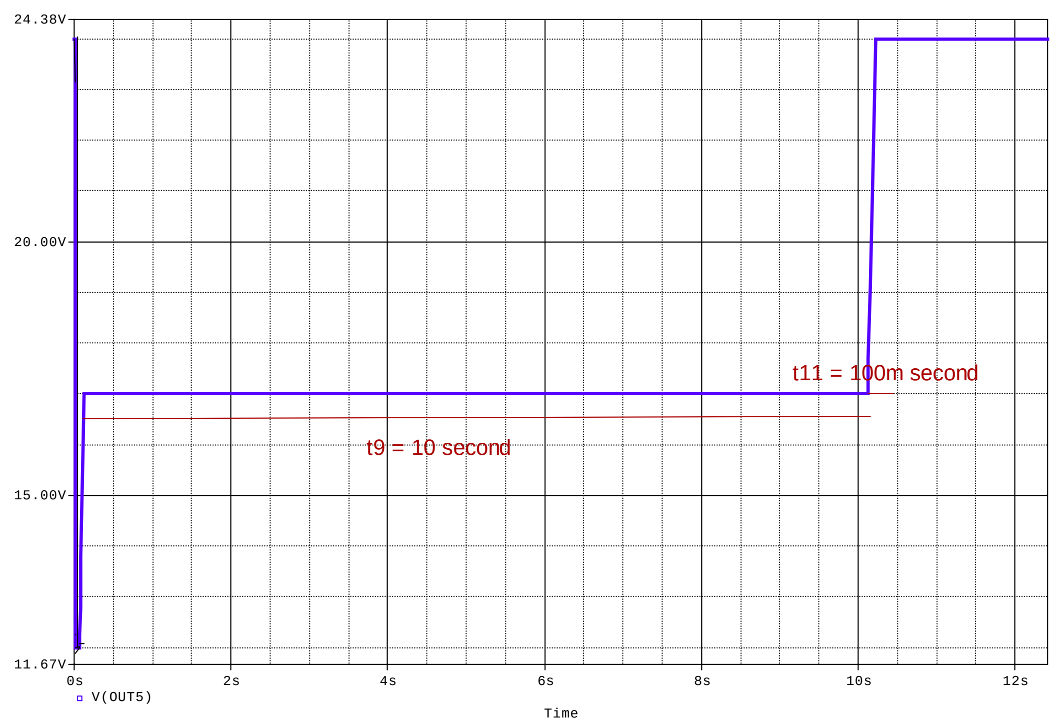


Figure: Zoomed-in PSPICE simulation result for a single generated pulse 1 (24V)

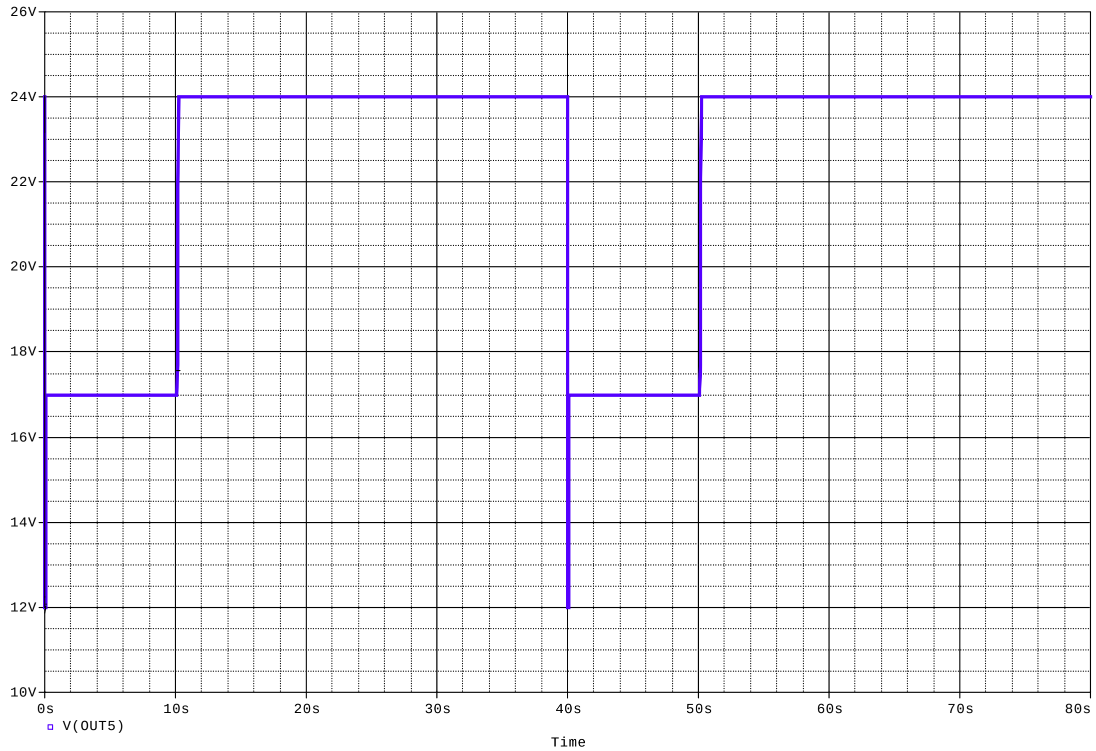
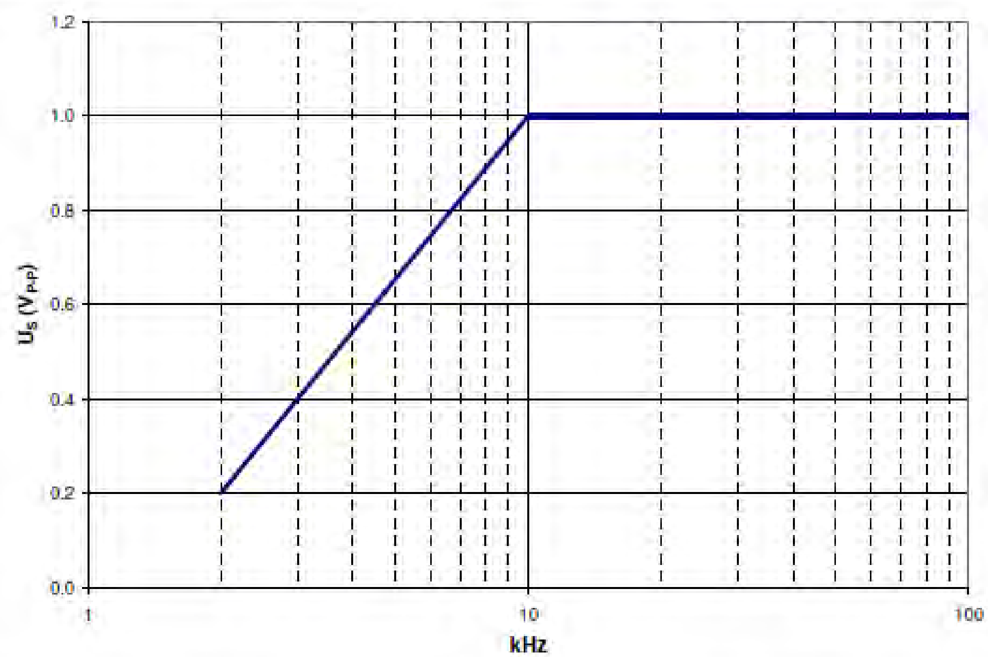


Figure: PSPICE simulation result of the generated pulse 1 (24V)

CI 250 specification: Immunity to Ground Voltage Offset

DUT should be immune from sinusoidal ground voltage offset, ranging from 2kHz to 100 kHz.

Figure 22-1: CI 250 Requirements (Continuous Disturbances)



Frequency Range (kHz)	U_S (V_{P-P})
2 – 10	$1.0+1.14\log\left(\frac{f}{10}\right)$
10 – 100	1.0

f = frequency in kHz

Figure 22-3: CI 250 Transient Pulse Delay Detail

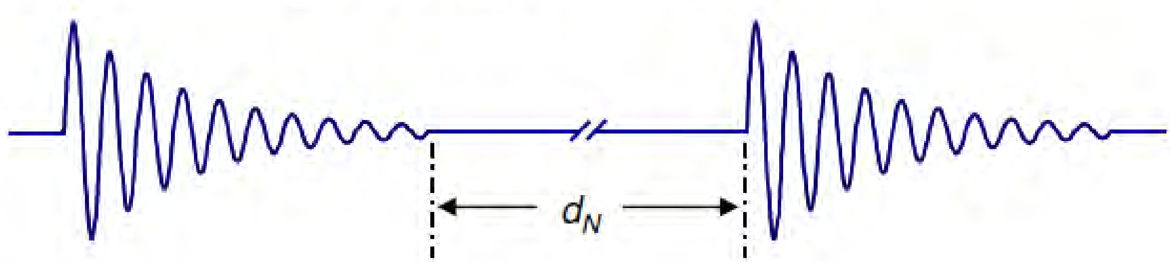
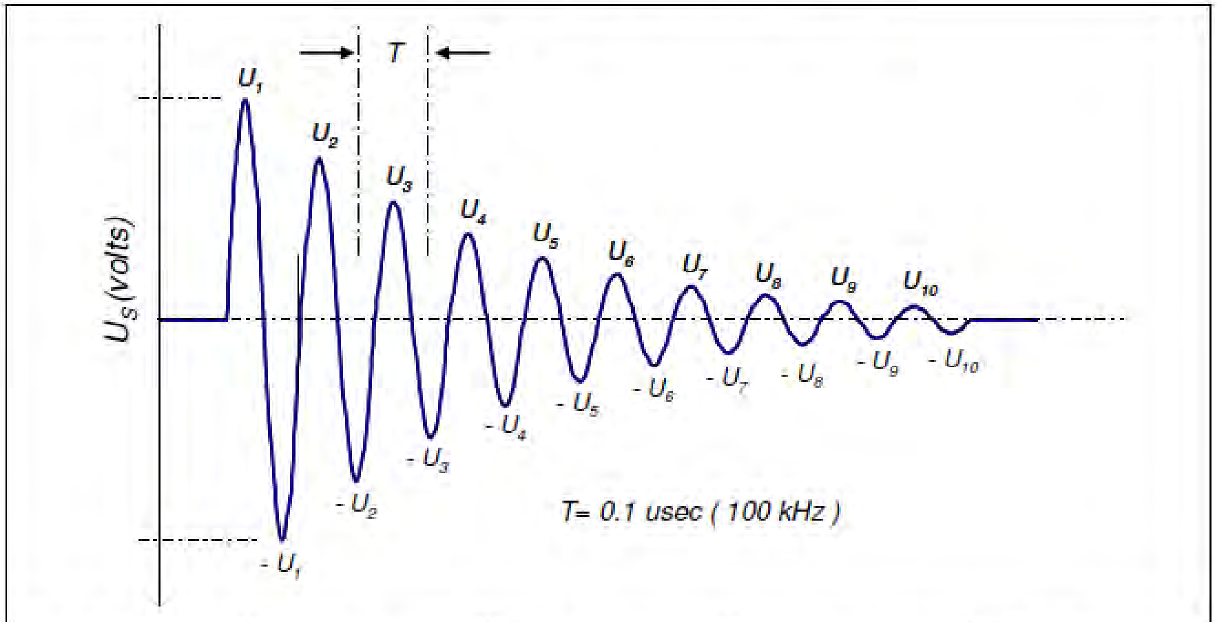


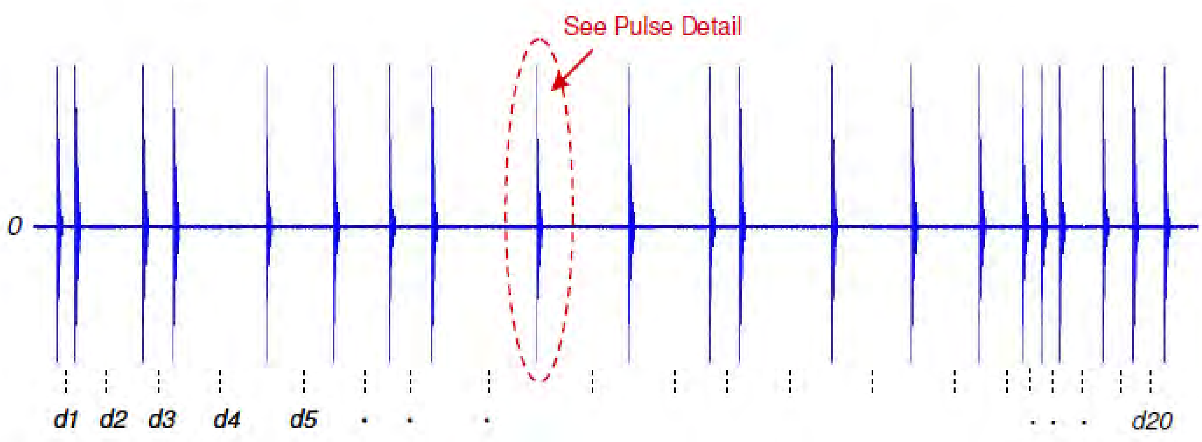
Figure 22-2: CI 250 Transient Pulse Detail



$U_1 = 5.00$	$U_3 = 2.67$	$U_5 = 1.42$	$U_7 = 0.76$	$U_9 = 0.41$
$U_2 = 3.65$	$U_4 = 1.95$	$U_6 = 1.04$	$U_8 = 0.55$	$U_{10} = 0.30$

$F(Hz) = 100x10^3 \; (100\,kHz)$

Figure 22-4: CI 250 Requirements (Transient Disturbance Sequence)



Sequence 1:

Sequence 1	d1	0.1 ms	d6	0.4 ms	d11	0.2 ms	d16	0.1 ms
	d2	0.5 ms	d7	0.3 ms	d12	0.3 ms	d17	0.1 ms
	d3	0.2 ms	d8	0.4 ms	d13	0.6 ms	d18	0.3 ms
	d4	0.7 ms	d9	0.6 ms	d14	0.5 ms	d19	0.4 ms
	d5	0.5 ms	d10	0.6 ms	d15	0.3 ms	d20	0.2 ms

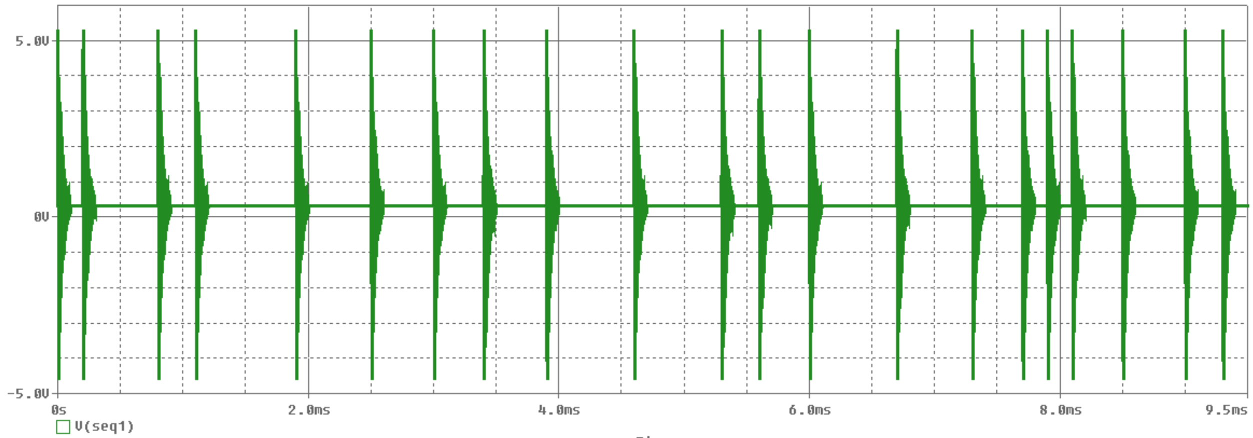


Figure: PSPICE simulation result of the generated CI 250, sequence 1 transient

Sequence 2:

Sequence 2	d1	0.2 ms	d6	0.8 ms	d11	0.4 ms	d16	0.2 ms
	d2	1.0 ms	d6	0.6 ms	d12	0.6 ms	d17	0.2 ms
	d3	0.4 ms	d8	0.8 ms	d13	1.2 ms	d18	0.6 ms
	d4	1.4 ms	d9	1.2 ms	d14	1.0 ms	d19	0.8 ms
	d5	1.0 ms	d10	1.2 ms	d15	0.6 ms	d20	0.4 ms

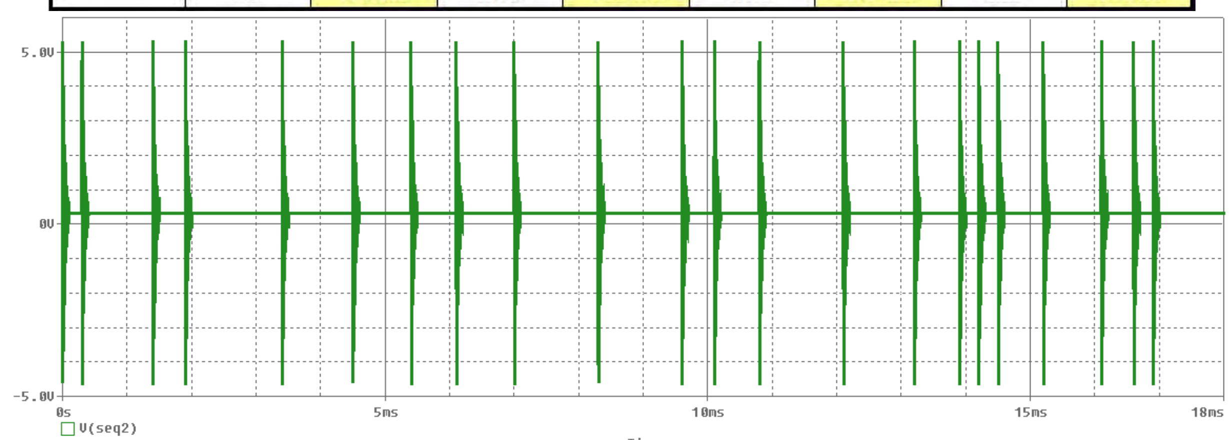


Figure: PSPICE simulation result of the generated CI 250, sequence2 transient

Sequence 3:

Sequence 3	d1	0.5 ms	d6	2.0 ms	d11	1.0 ms	d16	0.5 ms
	d2	2.5 ms	d6	1.5 ms	d12	1.5 ms	d17	0.5 ms
	d3	1.0 ms	d8	2.0 ms	d13	3.0 ms	d18	1.5 ms
	d4	3.5 ms	d9	3.0 ms	d14	2.5ms	d19	2.0 ms
	d5	2.5 ms	d10	3.0 ms	d15	1.5 ms	d20	1.0 ms

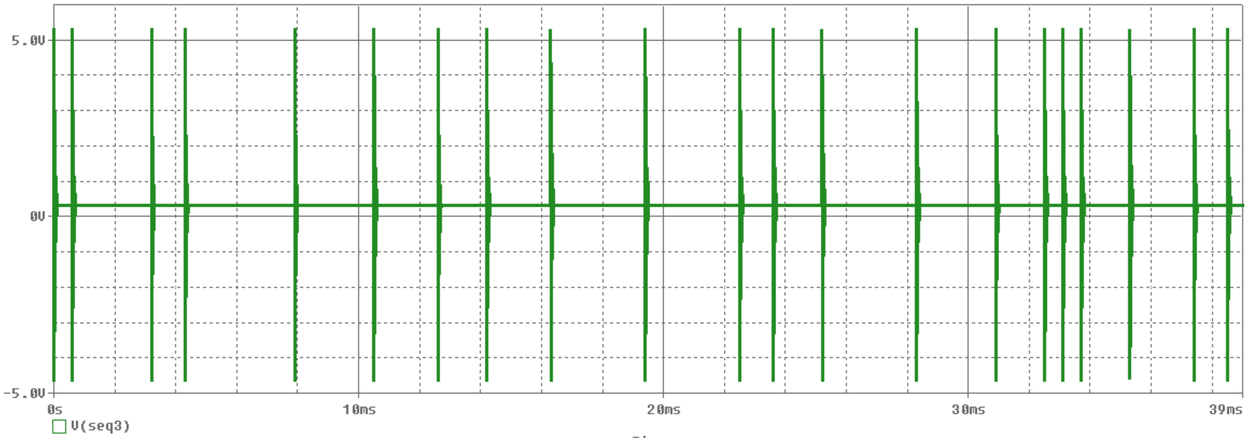


Figure: PSPICE simulation result of the generated CI 250, sequence 3 transient

Sequence 4:

Sequence 4	d1	1 ms	d6	4 ms	d11	2 ms	d16	1 ms
	d2	5 ms	d6	3 ms	d12	3 ms	d17	1 ms
	d3	2 ms	d8	4 ms	d13	6 ms	d18	3 ms
	d4	7 ms	d9	6 ms	d14	5 ms	d19	4 ms
	d5	5 ms	d10	6 ms	d15	3 ms	d20	2 ms

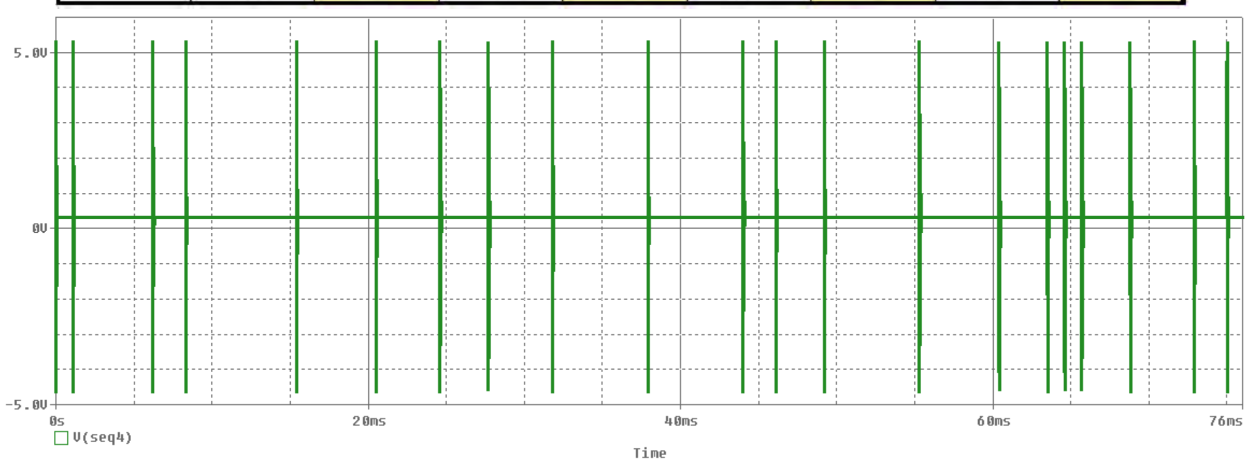


Figure: PSPICE simulation result of the generated CI 250, sequence 4 transient

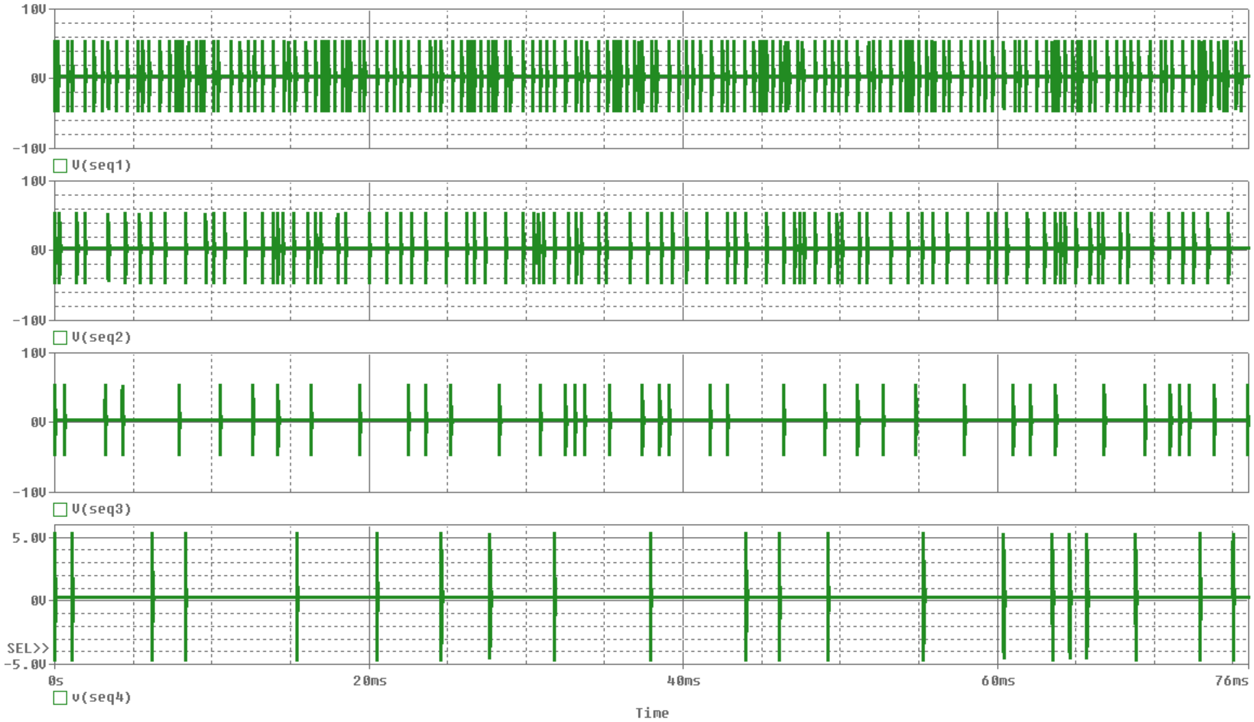


Figure: PSPICE simulation result of the generated CI 250 transients

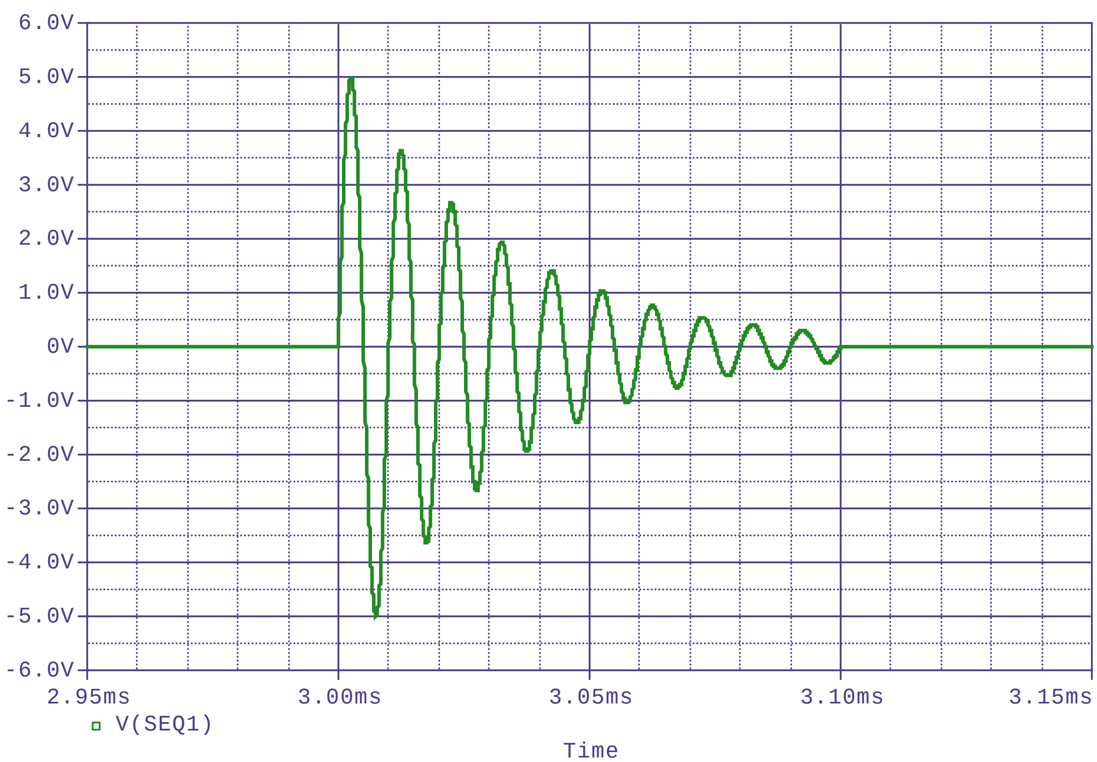


Figure: PSPICE simulation result of the generated single CI 250 transient

CI 260 requirement: Immunity to Voltage Dropout

DUT should be immune to momentary input voltage dropouts.

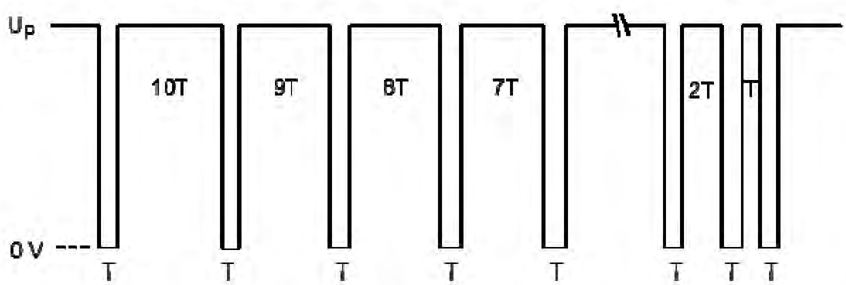
Table 23-1: CI 260 Voltage Dropout Requirements

Waveform	Application	Level	Duration	Functional Performance Status [1]		
				Class A	Class B	Class C
A Voltage Dropout: High	All Power Supply and Control Circuits	See Figure 23-1	3 cycles separated by 20 s	II	II	II
B Voltage Dropout: Low	All Power Supply and Control Circuits	See Figure 23-2	3 cycles separated by 20 s	II	II	II
C Single Voltage Dropout	All Power Supply and Control Circuits	See Figure 23-3	3 cycles separated by 20 s	I	I	I
D Voltage Dip	All Power Supply and Control Circuits	See Figure 23-4	10 cycles separated by 20 s	II	II	II

1 Performance Status checked after each waveform cycle (applies to Status II response only)

CI 260 Waveform A

Figure 23-1: CI 260 Waveform A (Voltage Dropout: High)



Key:

	Power from Vehicle Battery				Regulated Power from another Module			
U_p	13.5V, 27V [2]				Nominal Supply Voltage (e.g. 5 Vdc, 3 Vdc)			
T [1]	100 us	300 us	500 us	2 ms	100 us	300 us	500 us	2 ms
	5 ms	10 ms	30 ms	50 ms	5 ms	10 ms	30 ms	50 ms

(1) Waveform transition times are approximately 10 us

(2) Voltage selected dependent on use of 12 or 24 VDC systems

T = 100 us

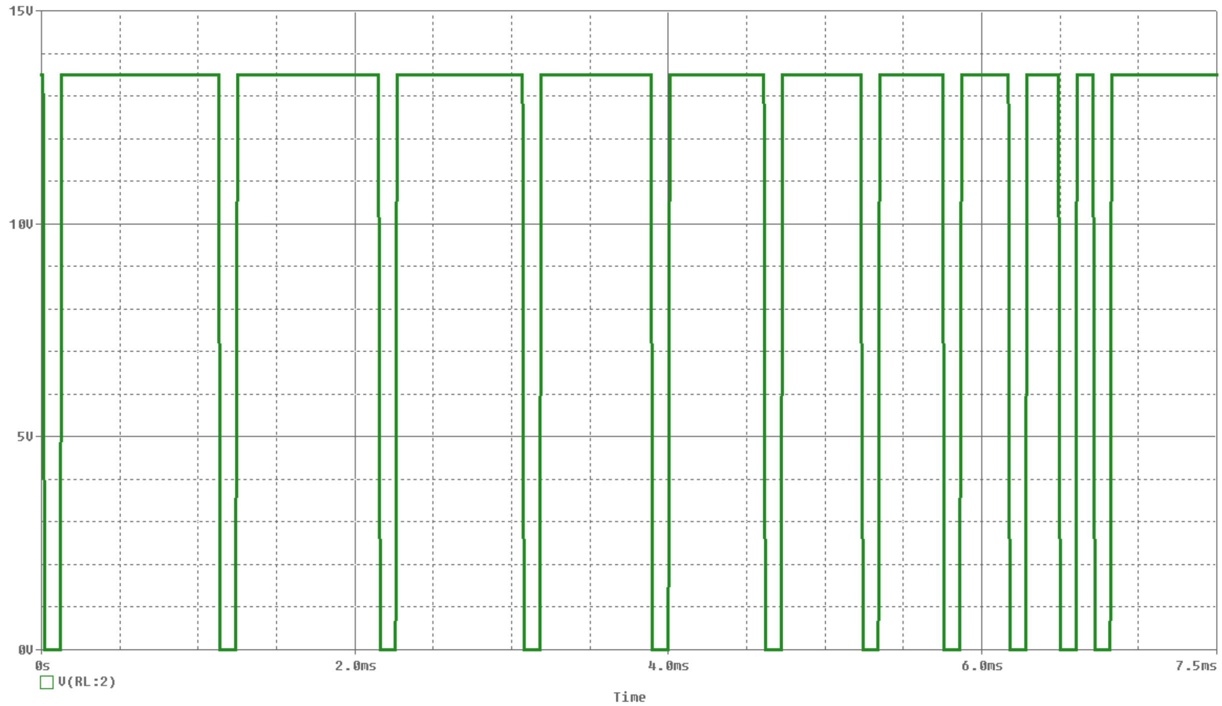


Figure: PSPICE simulation result of the generated CI 260 waveform A transient for T = 100us.

T = 300 us

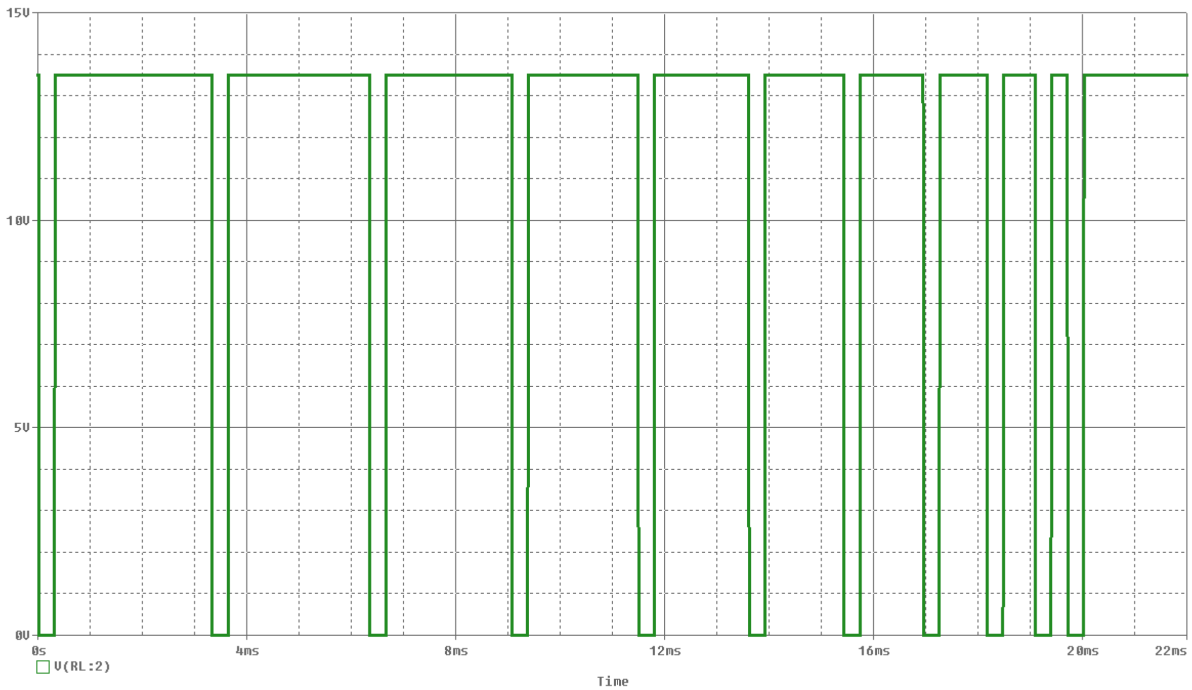


Figure: PSPICE simulation result of the generated CI 260 waveform A transient for T = 300us.

T = 500 us

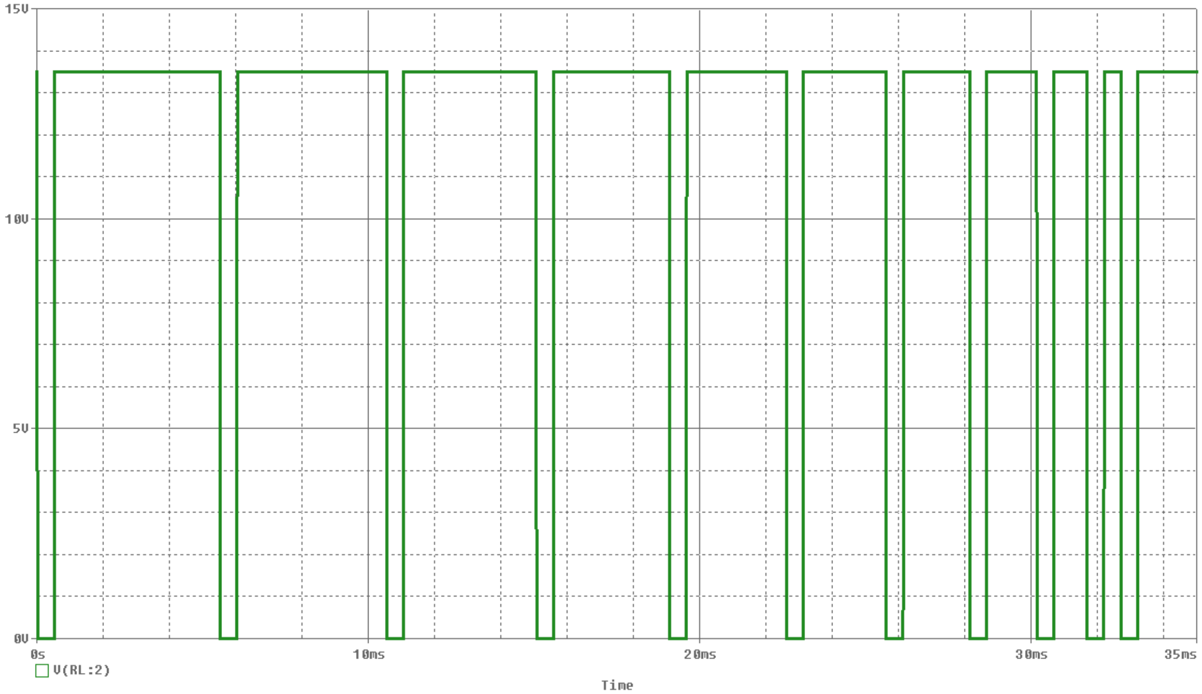


Figure: PSPICE simulation result of the generated CI 260 waveform A transient for T = 500us.

T = 2 ms

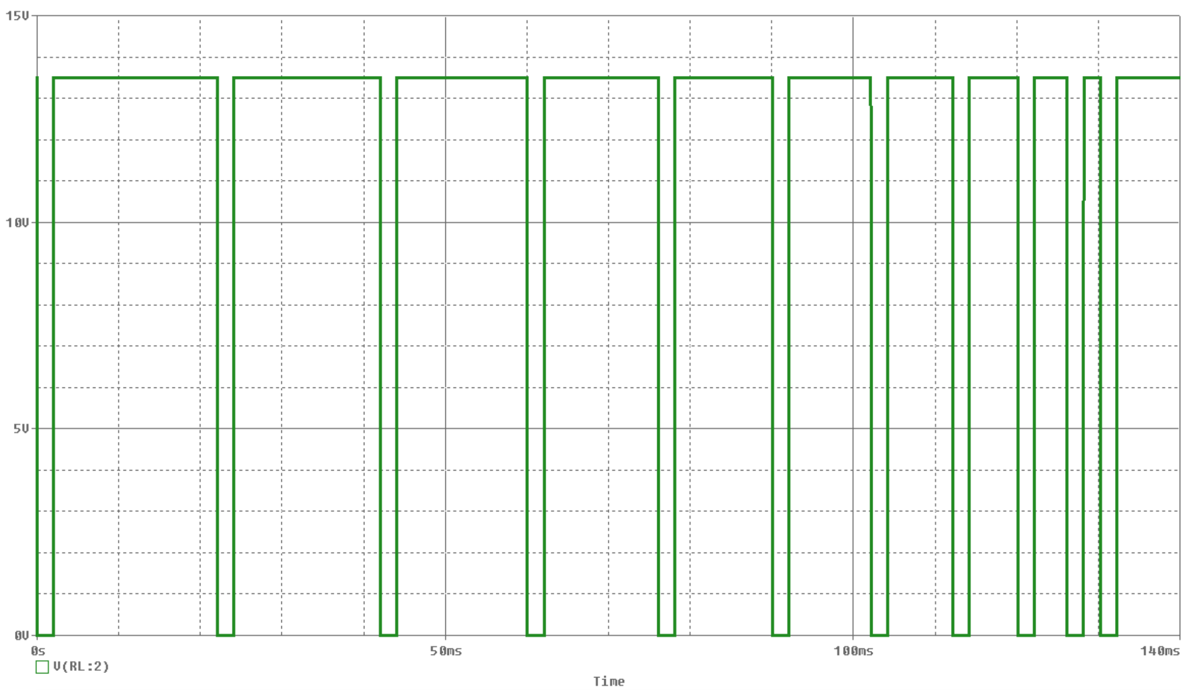


Figure: PSPICE simulation result of the generated CI 260 waveform A transient for T = 2ms.

T = 5 ms

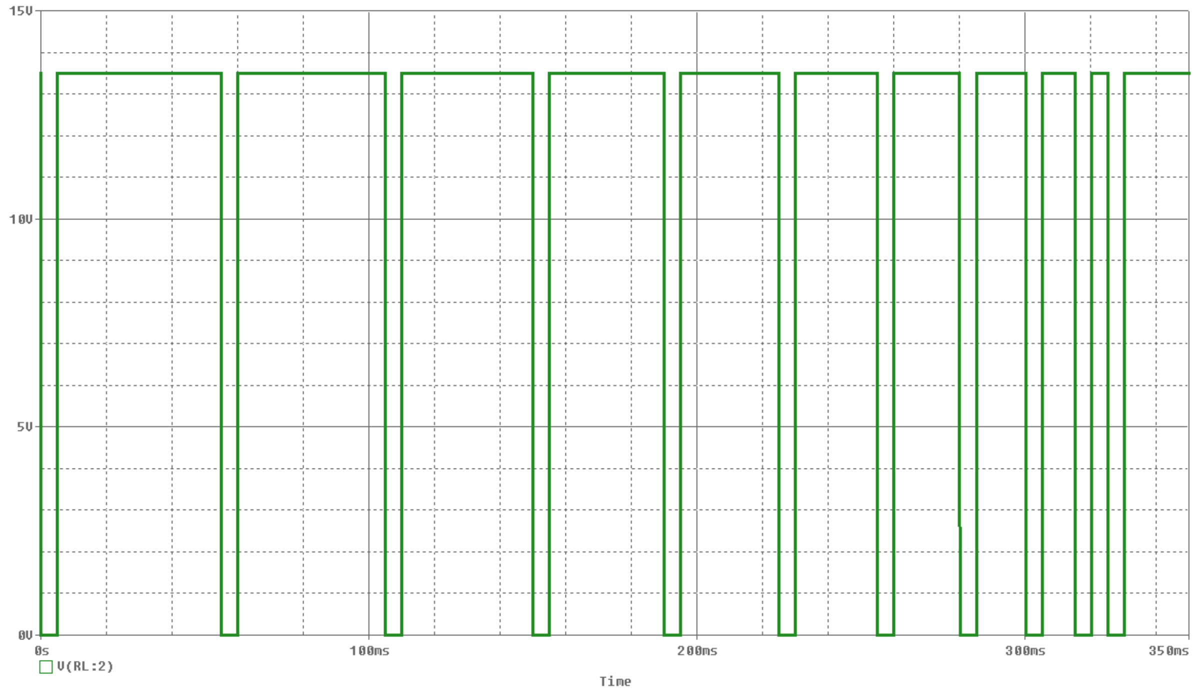


Figure: PSPICE simulation result of the generated CI 260 waveform A transient for T = 5ms.

T = 10 ms

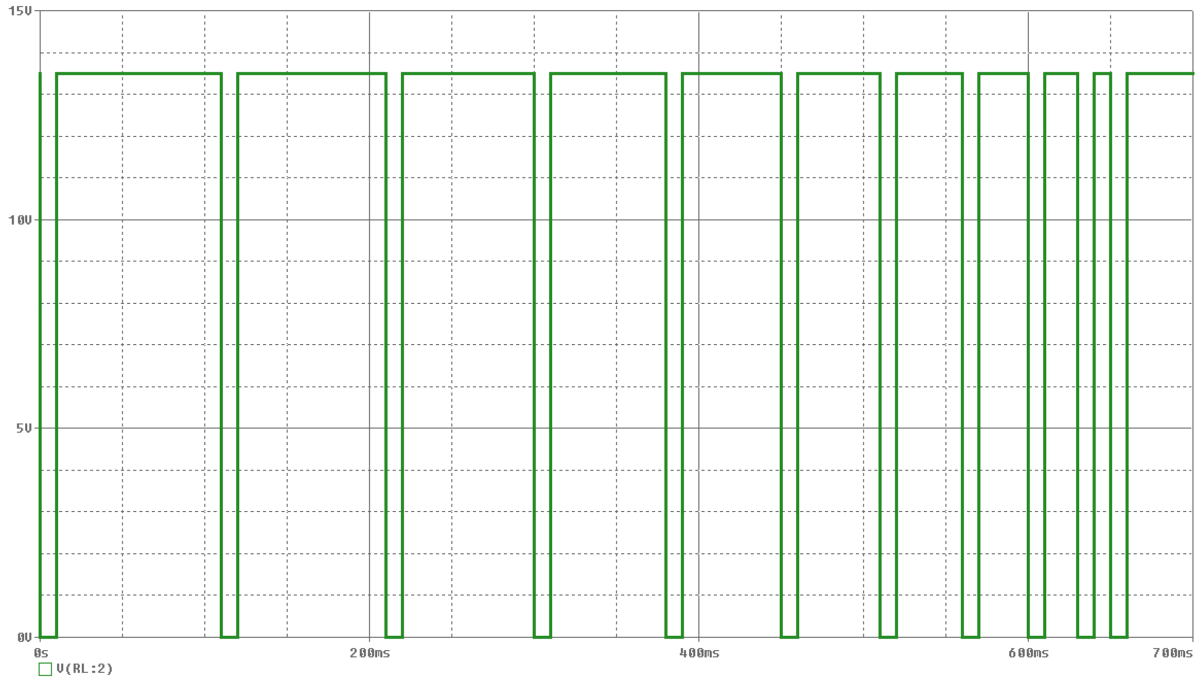


Figure: PSPICE simulation result of the generated CI 260 waveform A transient for T = 10ms.

T = 20 ms

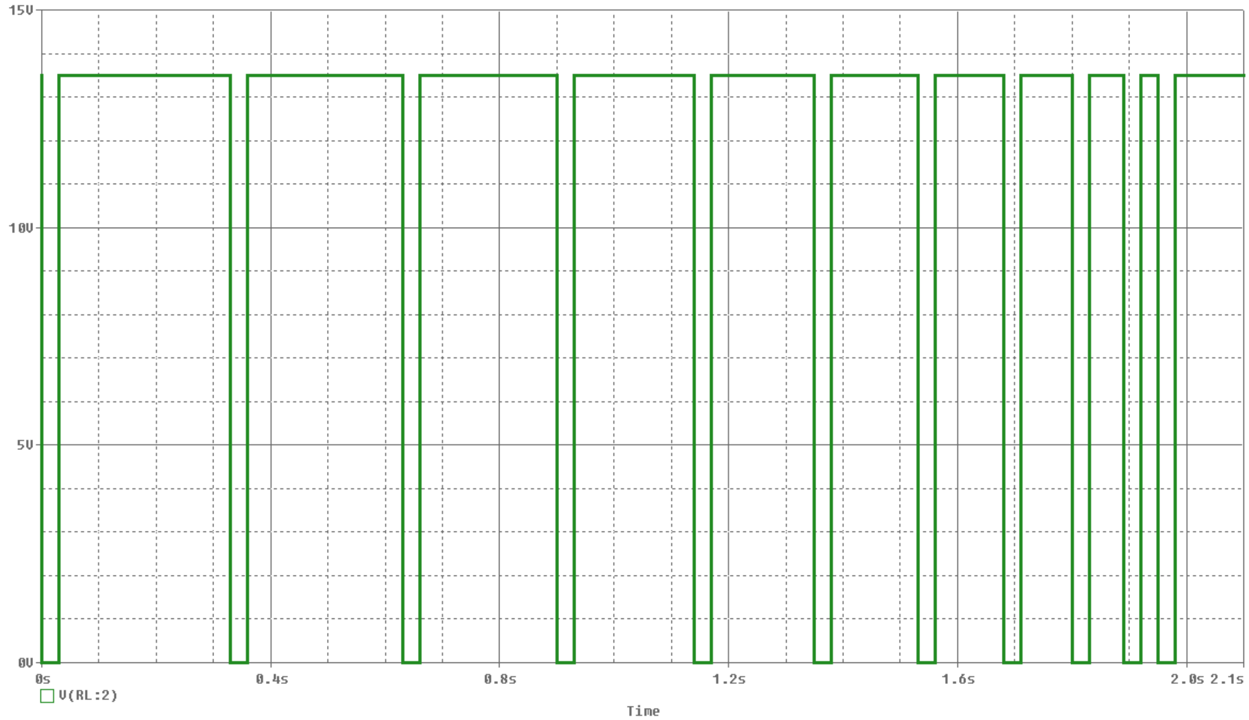


Figure: PSPICE simulation result of the generated CI 260 waveform A transient for T = 20ms.

T = 50 ms

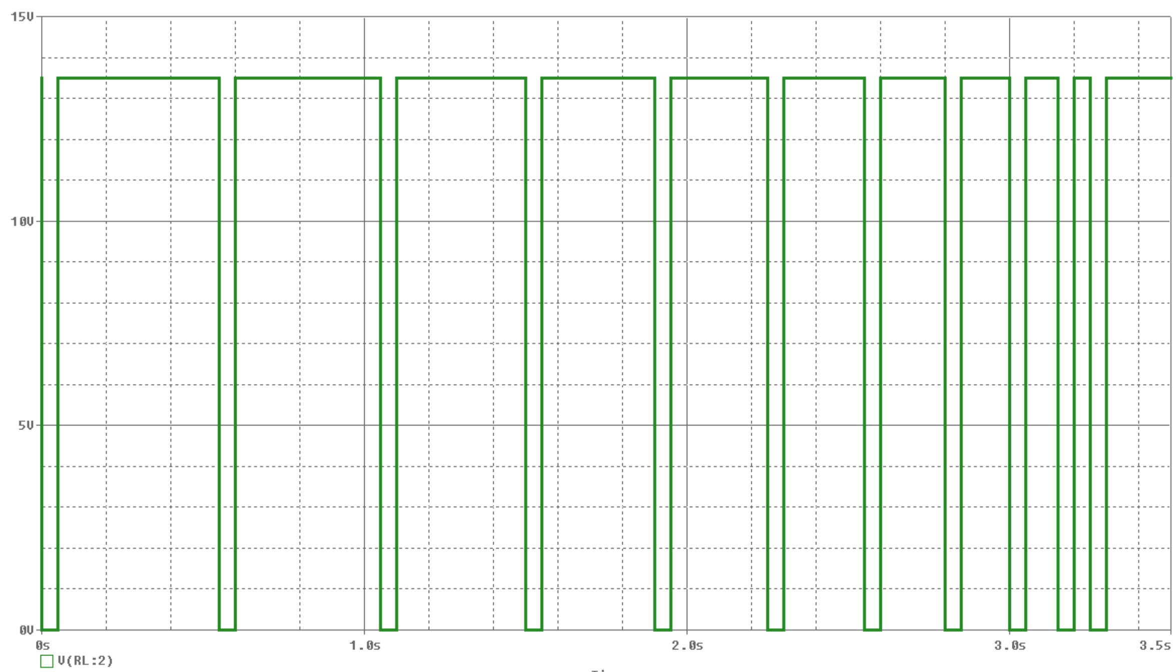
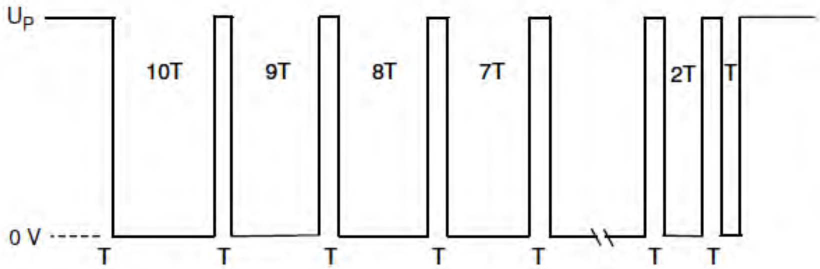


Figure: PSPICE simulation result of the generated CI 260 waveform A transient for T = 50ms

CI 260 Waveform B

Figure 23-2: CI 260 Waveform B (Voltage Dropout: Low)



Key:

	Power from Vehicle Battery				Regulated Power from another Module			
U_P	13.5V, 27V [2]				Nominal Supply Voltage (e.g. 5 Vdc, 3 Vdc)			
T [1]	100 us	300 us	500 us	2 ms	100 us	300 us	500 us	2 ms
	5 ms	10 ms	30 ms	50 ms	5 ms	10 ms	30 ms	50 ms

(1) Waveform transition times are approximately 10 us

(2) Voltage selected dependent on use of 12 or 24 VDC systems.

T = 100 us

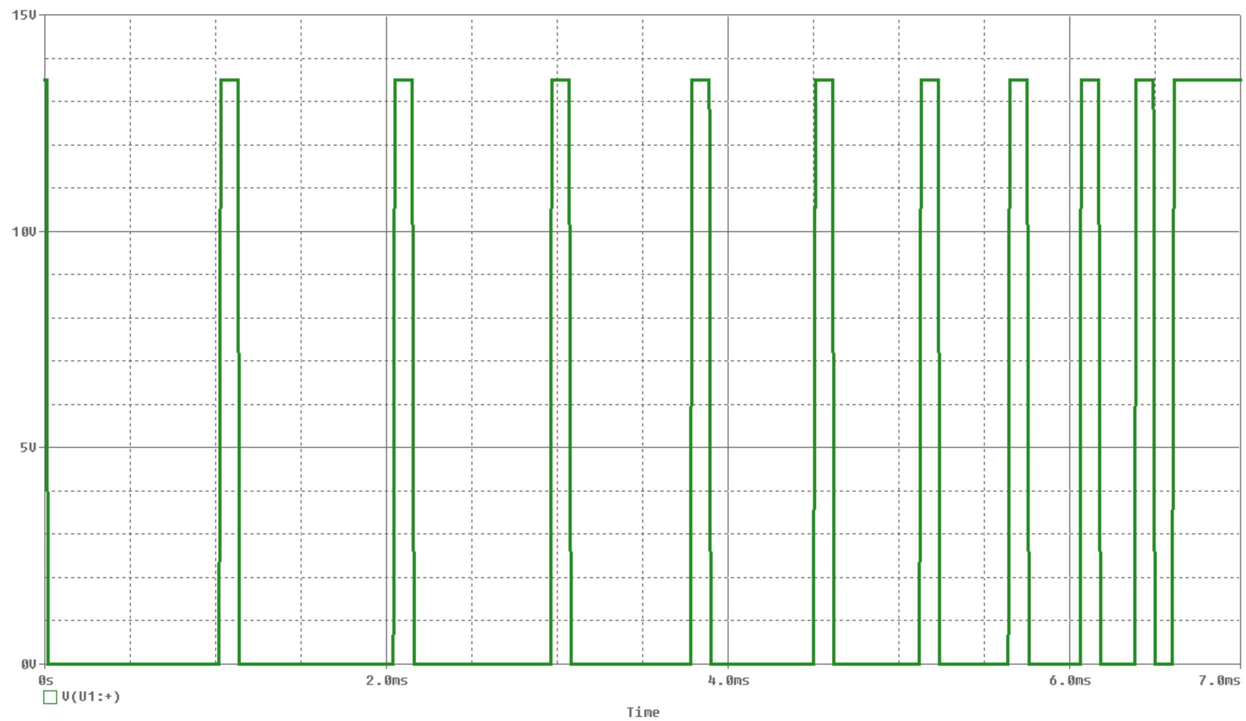


Figure: PSPICE simulation result of the generated CI 260 waveform B transient for T = 100us.

T = 300 us

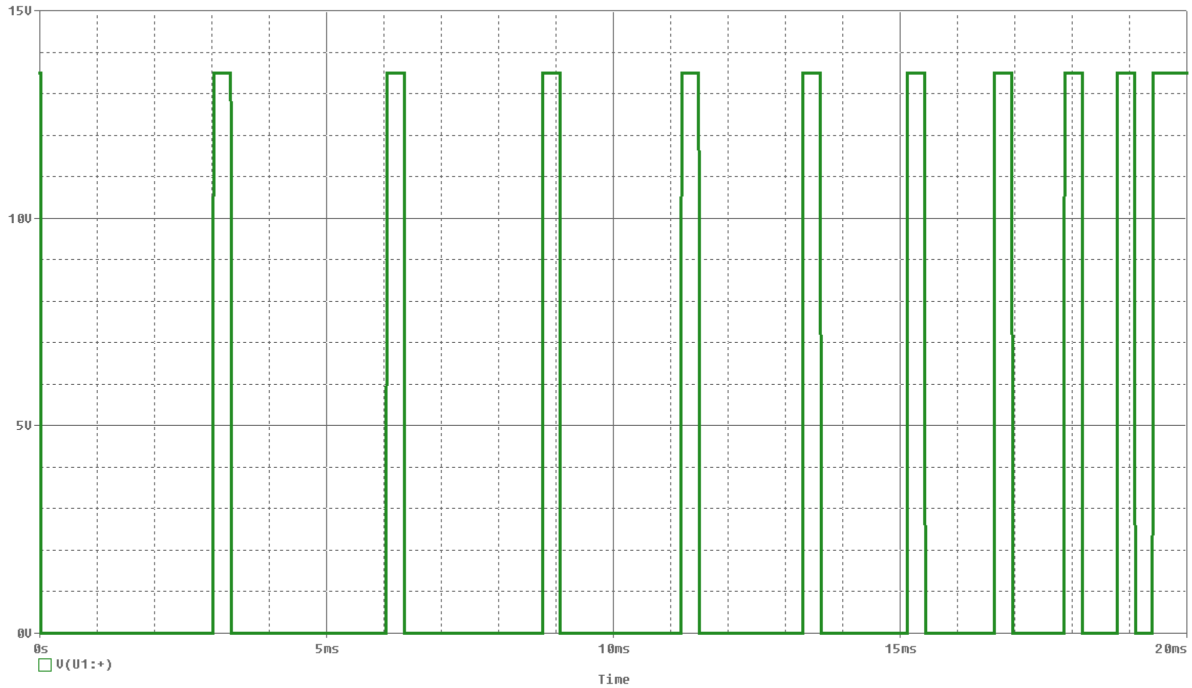


Figure: PSPICE simulation result of the generated CI 260 waveform B transient for T = 300us.

T = 500 us

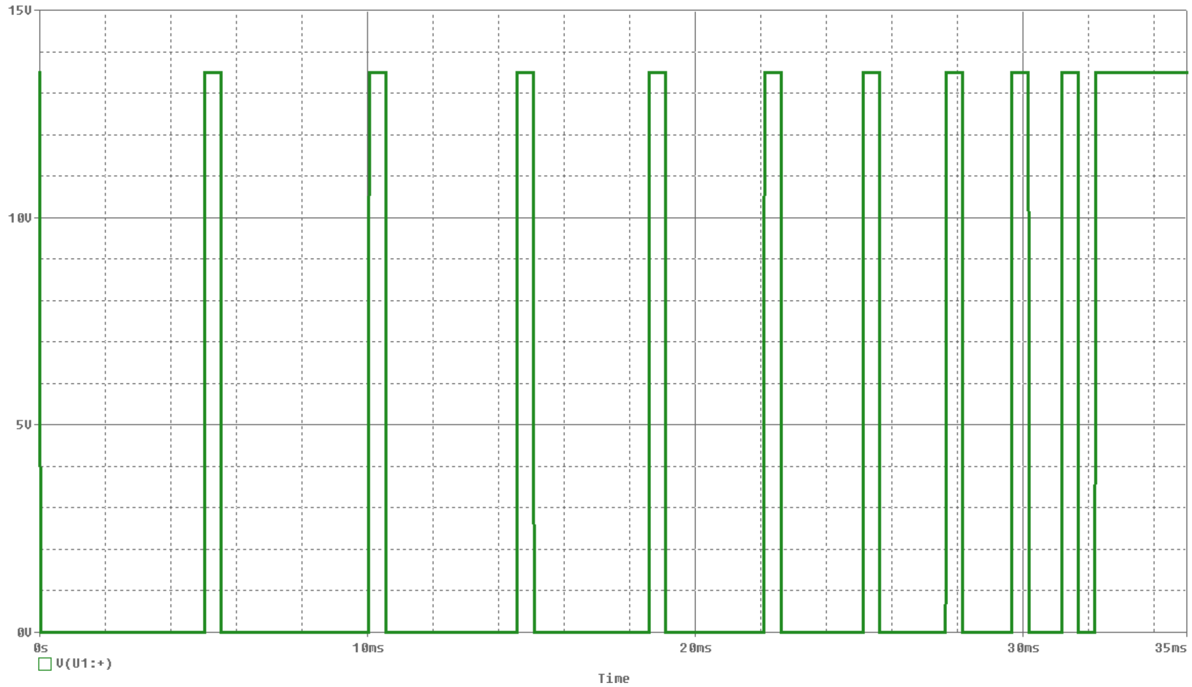


Figure: PSPICE simulation result of the generated CI 260 waveform B transient for T = 500us.

T = 2 ms

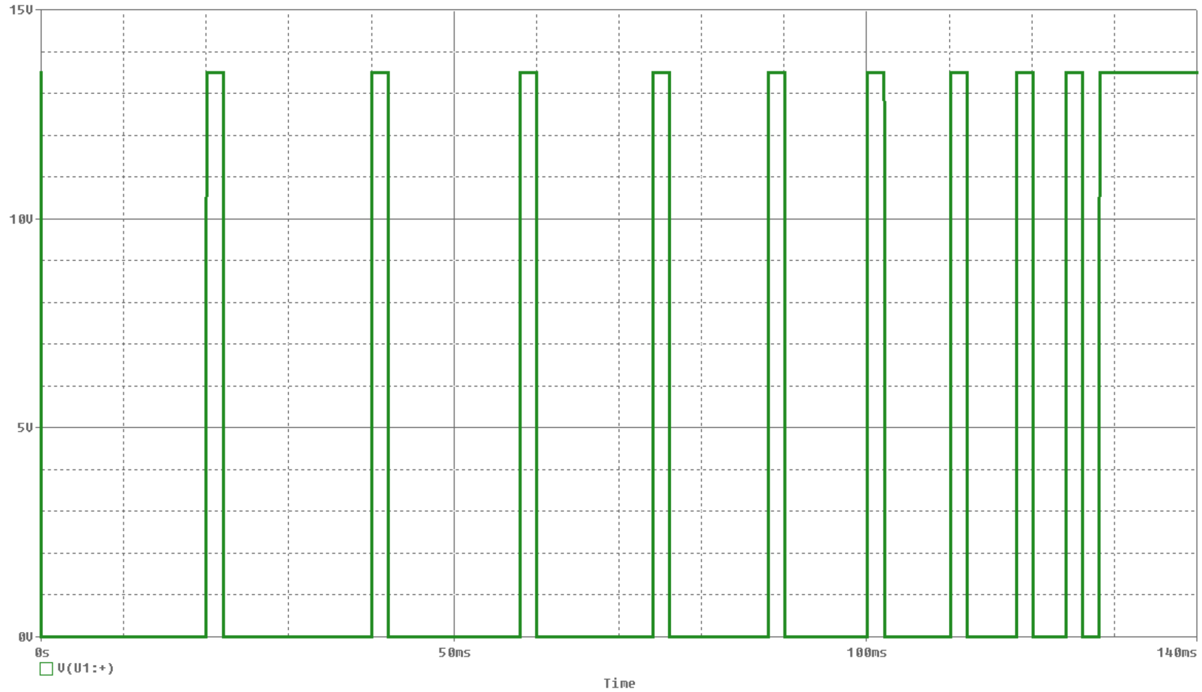


Figure: PSPICE simulation result of the generated CI 260 waveform B transient for T =2ms.

T = 5 ms

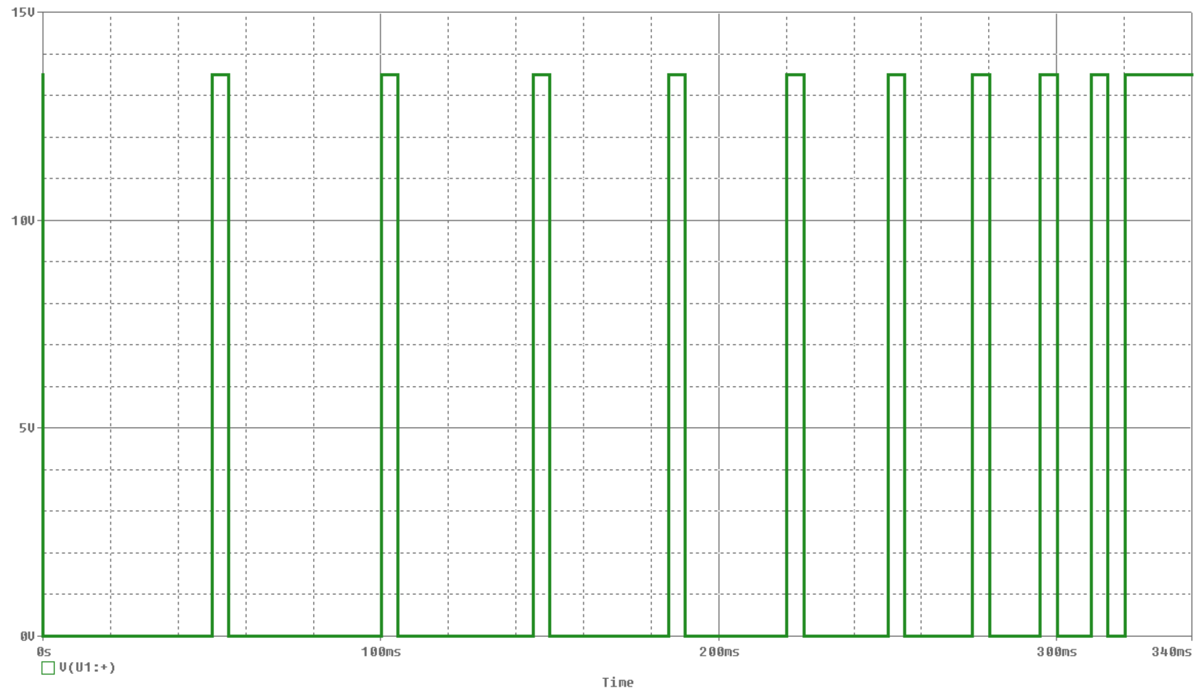


Figure: PSPICE simulation result of the generated CI 260 waveform B transient for T =5ms.

T = 10 ms

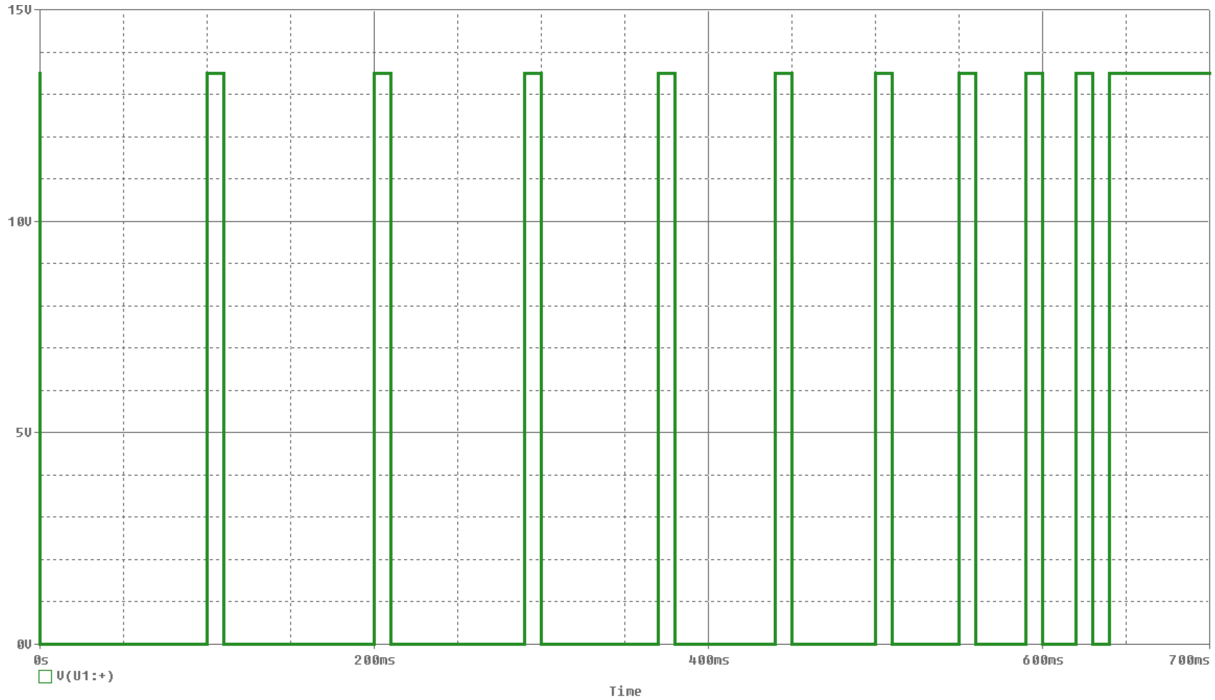


Figure: PSPICE simulation result of the generated CI 260 waveform B transient for T =10ms.

T = 30 ms

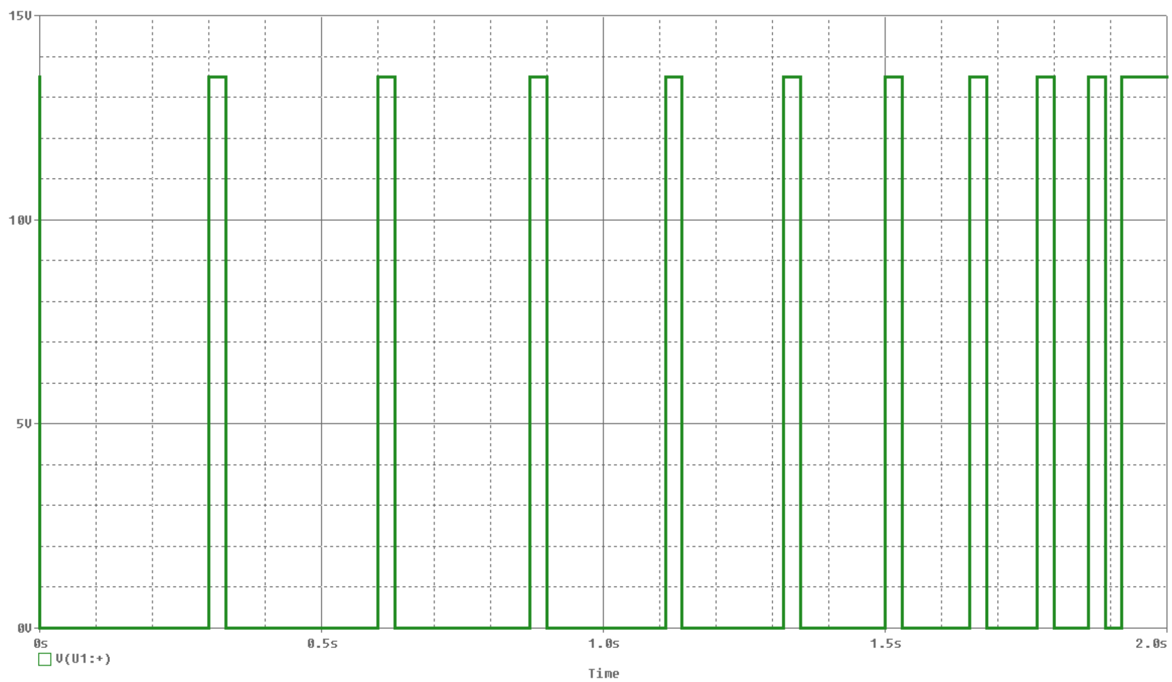


Figure: PSPICE simulation result of the generated CI 260 waveform B transient for T =30ms.

T = 50 ms

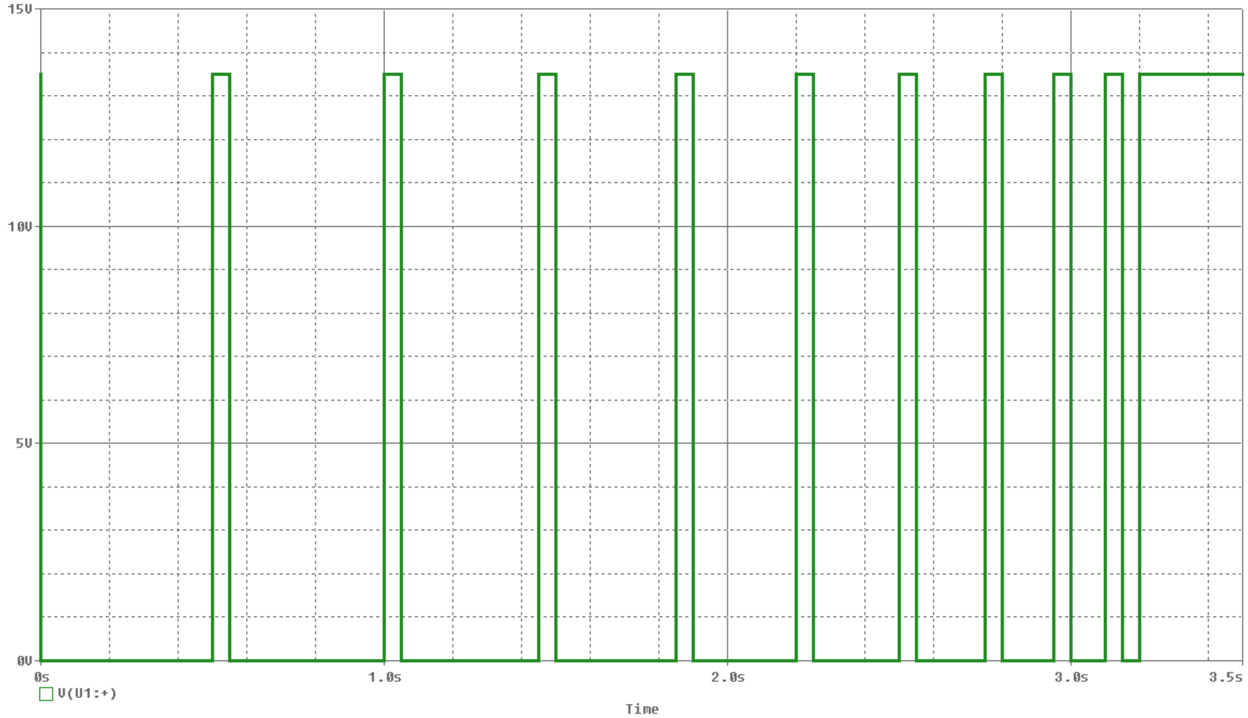
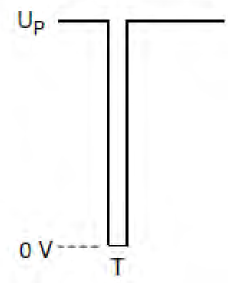


Figure: PSPICE simulation result of the generated CI 260 waveform B transient for T = 50ms

CI 260 Waveform C

Figure 23-3: CI 260 Waveform C (Single Voltage Dropout)



Key:

	Power from Vehicle Battery			Regulated Power from another Module		
U_P	13.5V, 27V (2)			Nominal Supply Voltage (e.g. 5 Vdc, 3 Vdc)		
T (1)	100 us	300 us	500 us	100 us	300 us	500 us

(1) Waveform transition times are approximately 10 us

(2) Voltage selected dependent on use of 12 or 24 VDC systems

T = 100 us

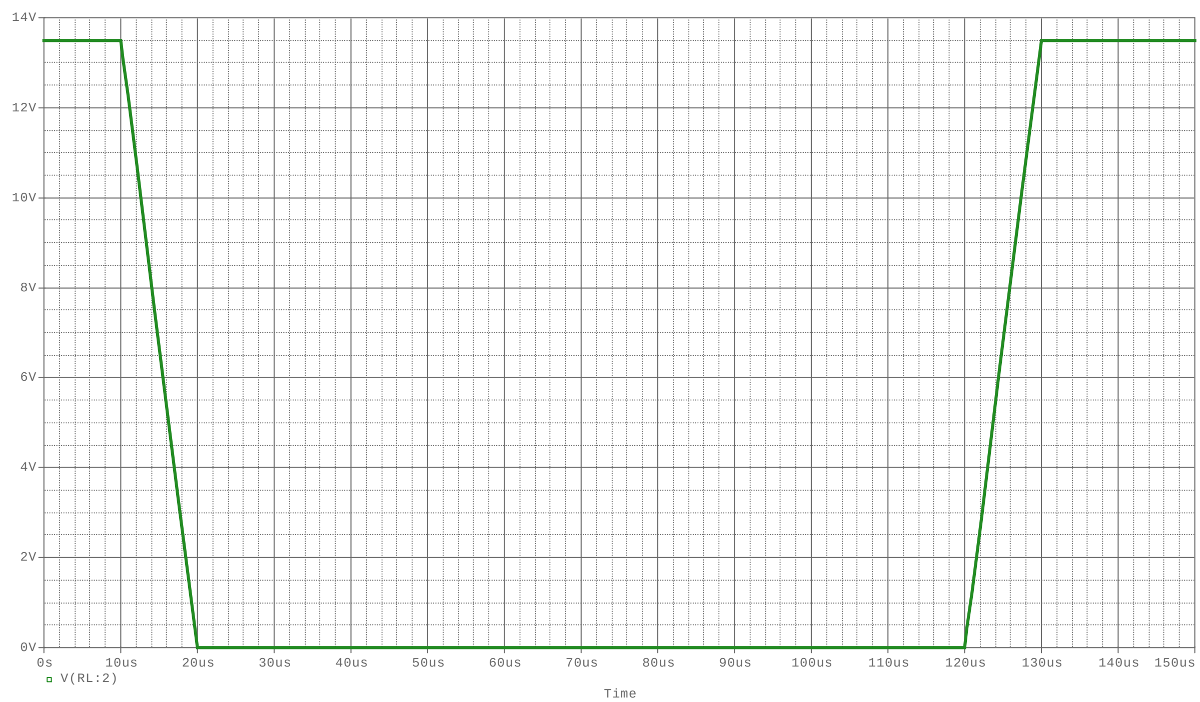


Figure: PSPICE simulation result of the generated CI 260 waveform C transient for T = 100us

T = 300 us

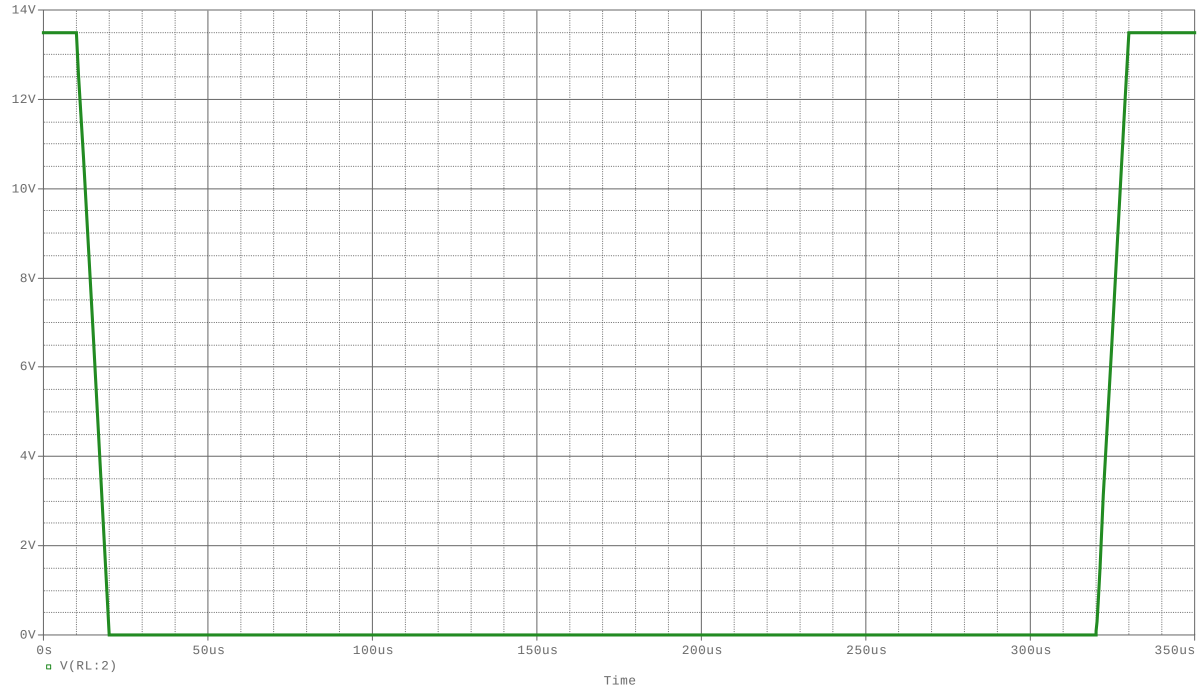


Figure: PSPICE simulation result of the generated CI 260 waveform C transient for T = 300us

T = 500 us

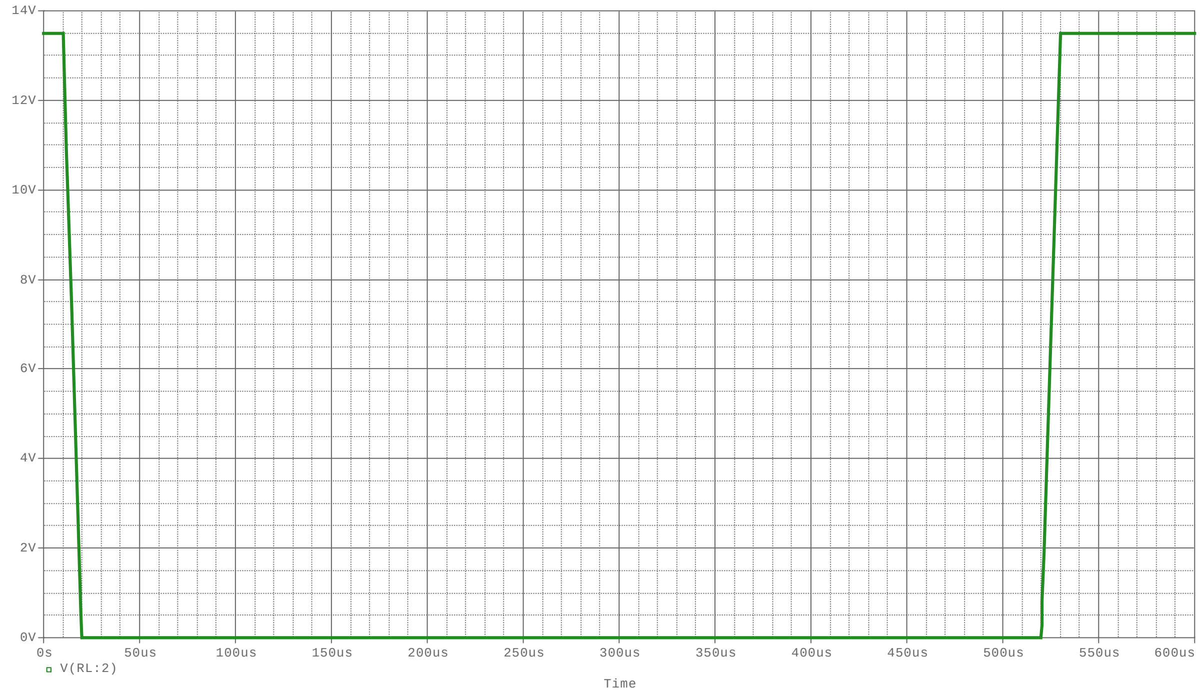
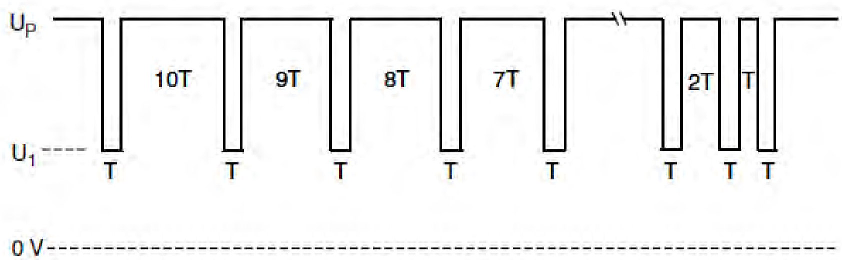


Figure: PSPICE simulation result of the generated CI 260 waveform C transient for T = 500us

CI 260 Waveform D

Figure 23-4: CI 260 Waveform D (Voltage Dip)



Key:

	Power from Vehicle Battery				Regulated Power from another Module			
U_P	13.5V, 27V [2]				Nominal Supply Voltage (e.g. 5 Vdc, 3 Vdc)			
U_1	5 V				80% of Nominal Supply Voltage			
T [1]	100 us	300 us	500 us	2 ms	100 us	300 us	500 us	2 ms
	5 ms	10 ms	30 ms	50 ms	5 ms	10 ms	30 ms	50 ms

(1) Waveform transition times are approximately 10 us

(2) Voltage selected dependent on use of 12 or 24 VDC systems

T = 100 us

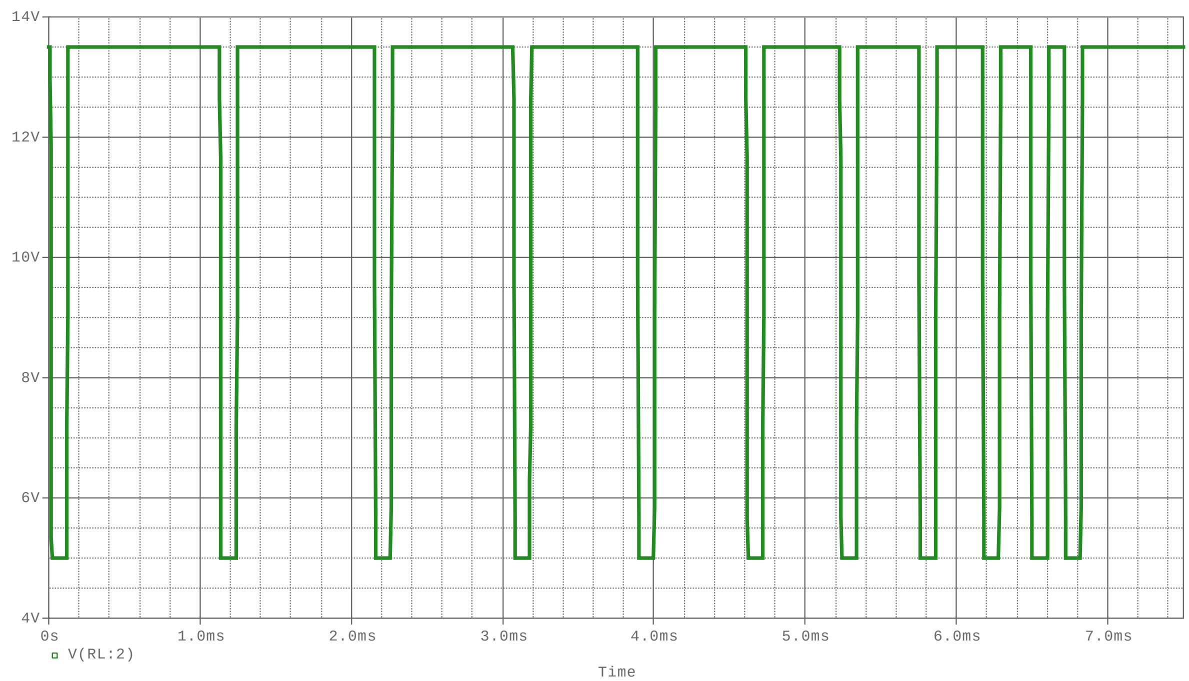


Figure: PSPICE simulation result of the generated CI 260 waveform D transient for T = 100us

T = 300 us

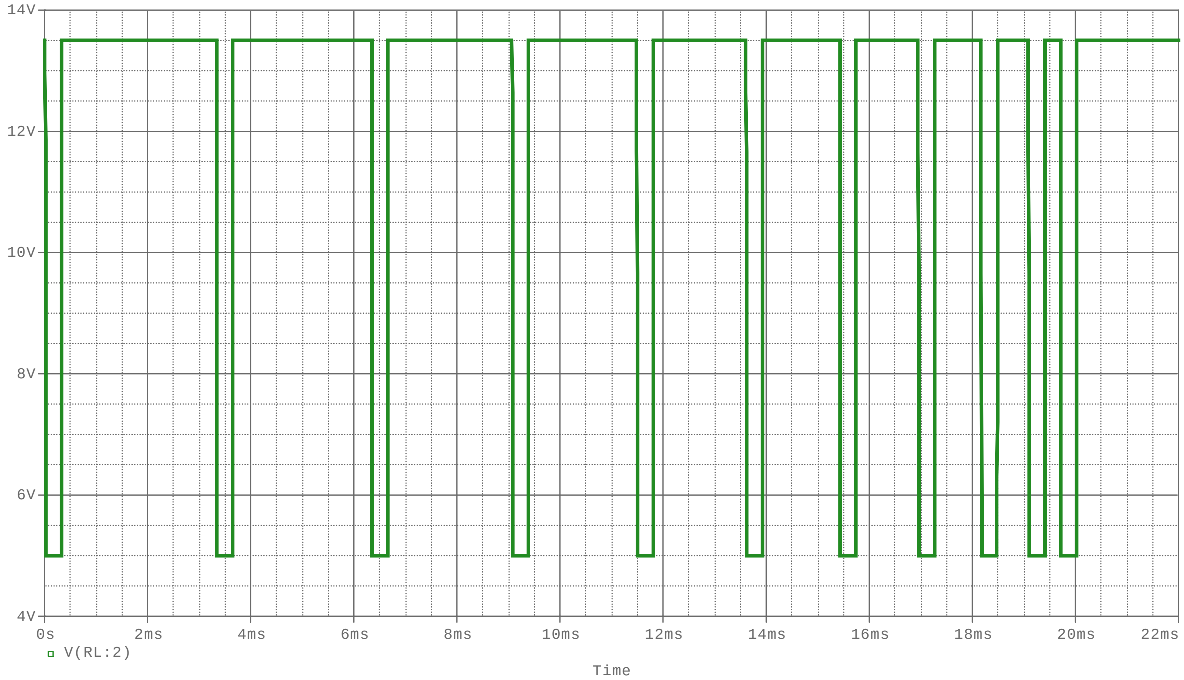


Figure: PSPICE simulation result of the generated CI 260 waveform D transient for T = 300us

T = 500 us

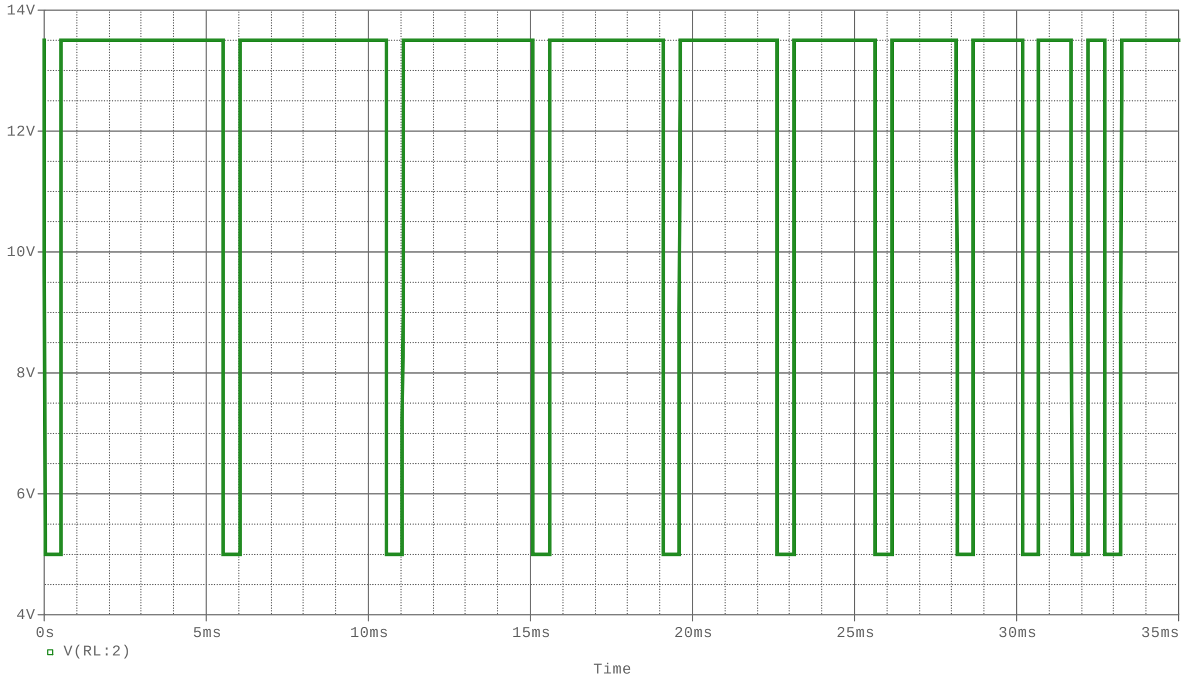


Figure: PSPICE simulation result of the generated CI 260 waveform D transient for T = 500us

T = 2 ms

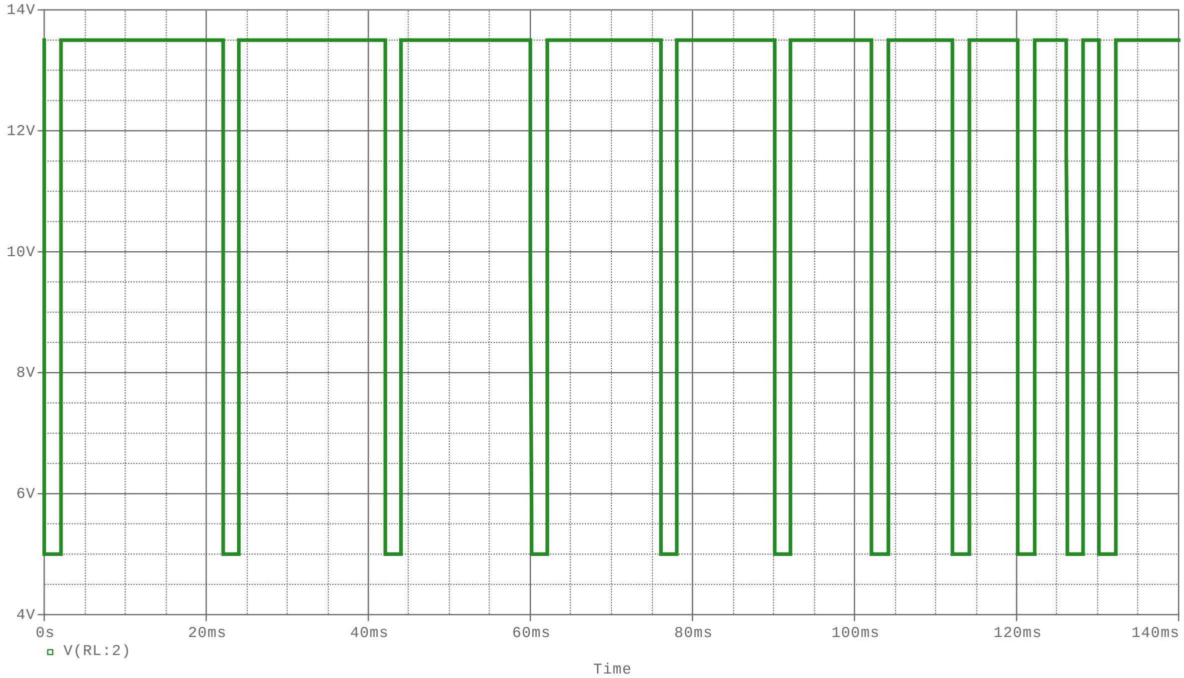


Figure: PSPICE simulation result of the generated CI 260 waveform D transient for T = 2ms

T = 5 ms

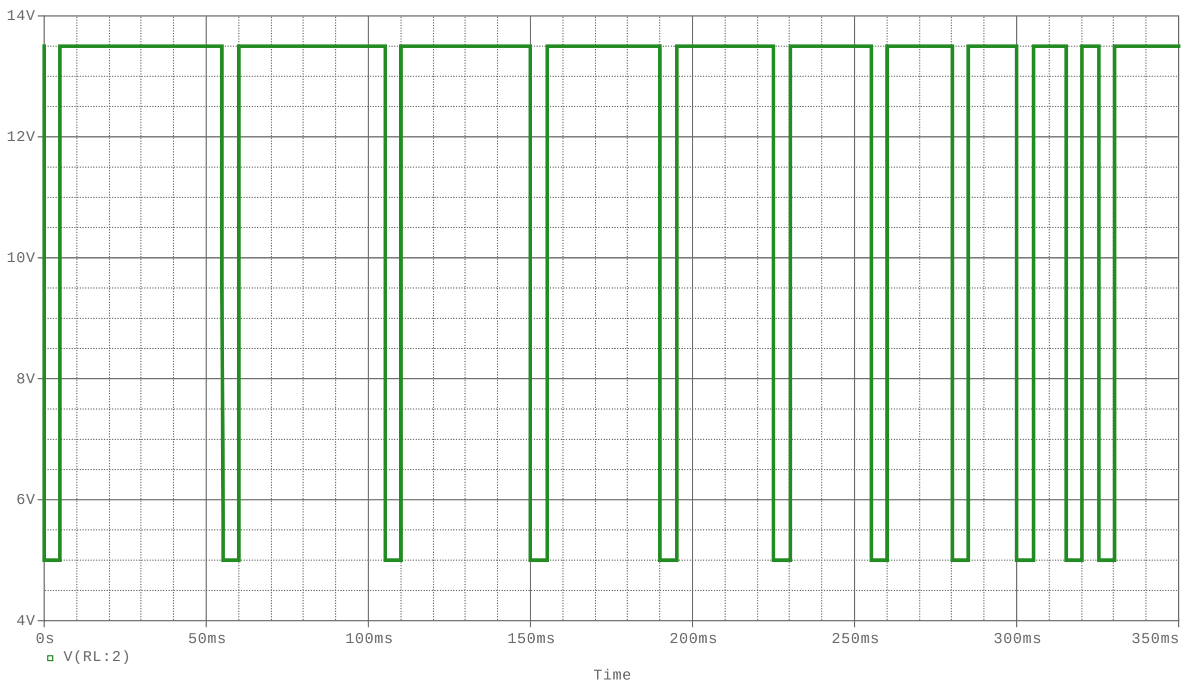


Figure: PSPICE simulation result of the generated CI 260 waveform D transient for T = 5ms

T = 10 ms

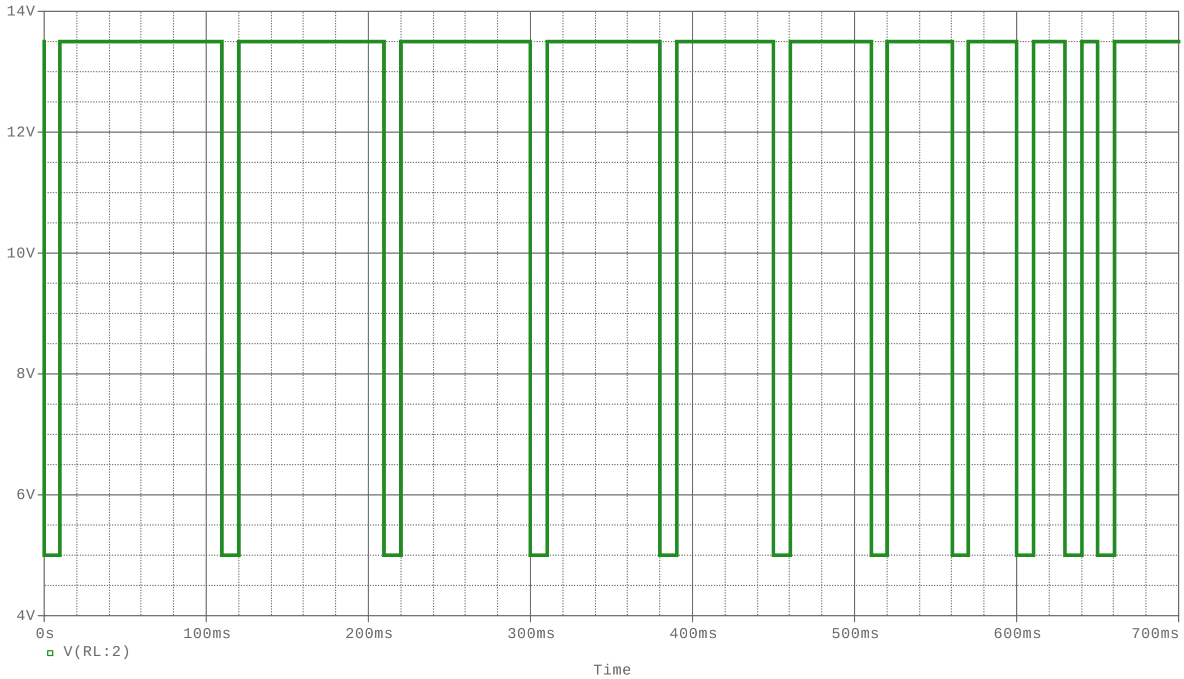


Figure: PSPICE simulation result of the generated CI 260 waveform D transient for T = 10ms

T = 30 ms

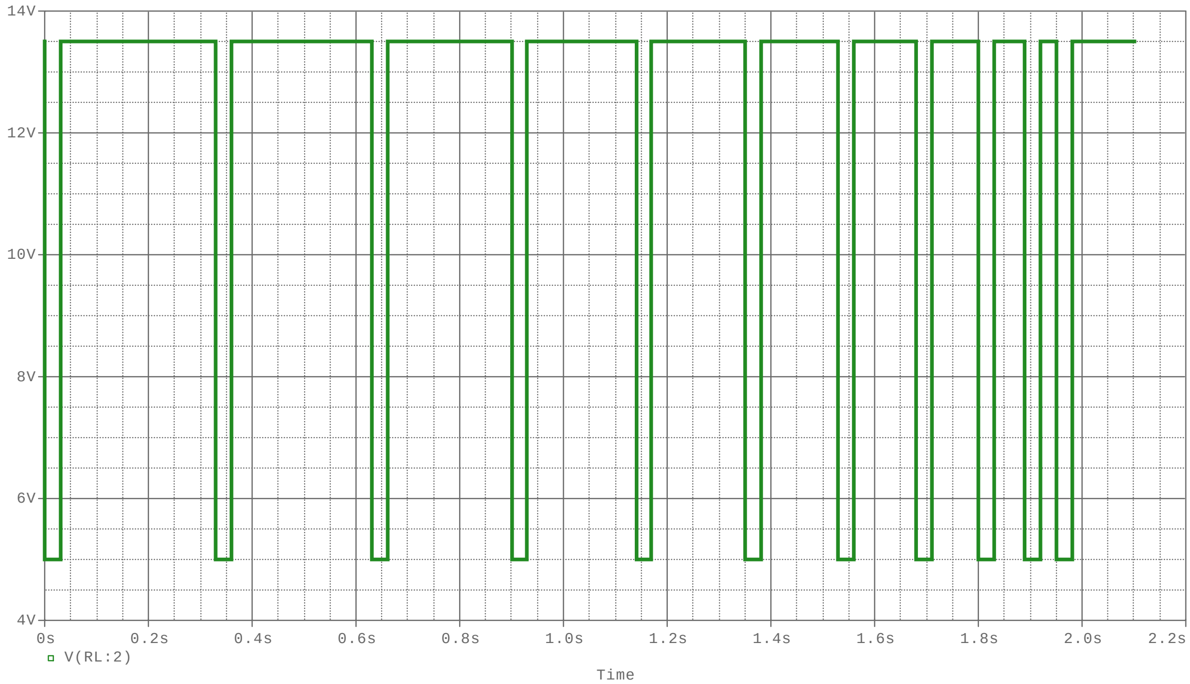


Figure: PSPICE simulation result of the generated CI 260 waveform D transient for T = 30ms

T = 50 ms

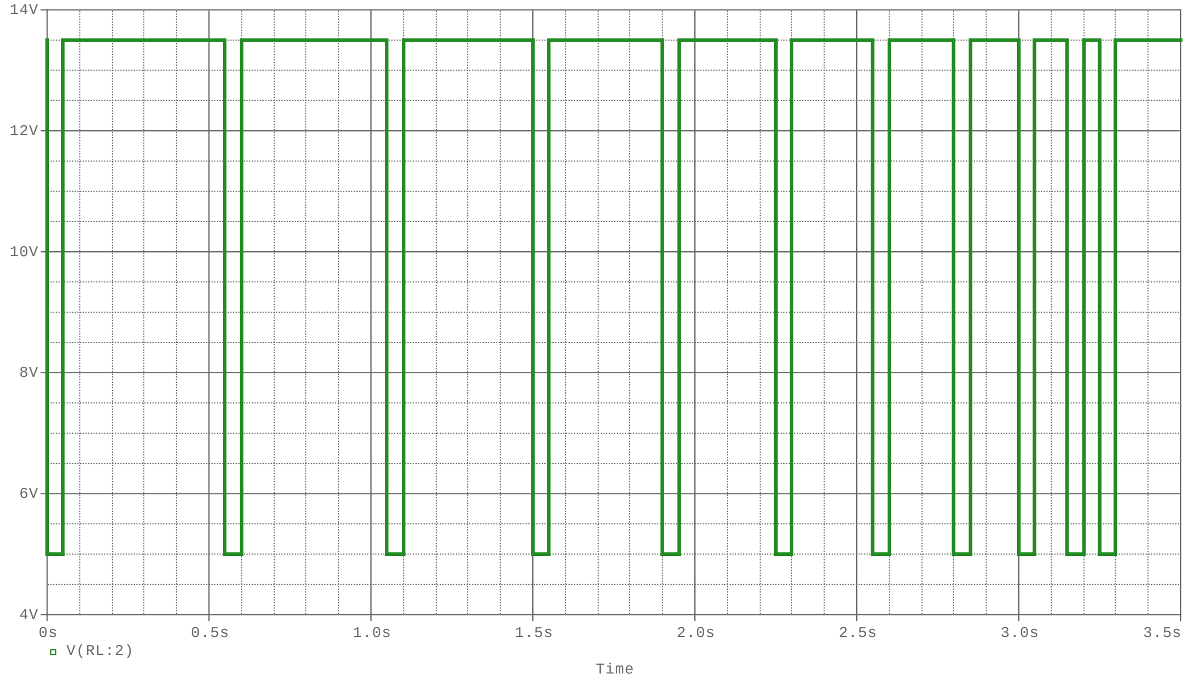


Figure: PSPICE simulation result of the generated CI 260 waveform D transient for T = 50ms

CI 280 requirement: Electrostatic Discharge

DUT should be immune from Electrostatic Discharge (ESD) over stress.

Table 25-1: CI 280 ESD Requirements: Handling (unpowered)

Discharge Sequence	Type of Discharge	Test Voltage Level	Minimum Number of Discharges at each polarity	Functional Performance Status		
				Class A	Class B	Class C
1	Contact discharge C = 150 pF, R = 2kΩ	± 4 kV	3	IV		
2 [1]	Contact discharge C = 150 pF, R = 2kΩ	± 6 kV	3			
3 [1]	Air discharge C = 150 pF, R = 2kΩ	± 8 kV	3			

1. This sequence is not applicable to connector pins

Table 25-2: CI 280 ESD Requirements: Powered (all component surfaces)

Discharge Sequence	Type of Discharge	Test Voltage Level	Minimum Number of Discharges at each polarity	Functional Performance Status		
				Class A	Class B	Class C
1	Air discharge C = 330 pF, R = 2kΩ	± 4 kV	3	I		
2	Contact discharge C = 330 pF, R = 2kΩ	± 4 kV	3			
3	Air discharge C = 330 pF, R = 2kΩ	± 6 kV	3			
4	Contact discharge C = 330 pF, R = 2kΩ	± 6 kV	3	II		
5	Air discharge C = 330 pF, R = 2kΩ	± 8 kV	3			
6	Contact discharge C = 330 pF, R = 2kΩ	± 8 kV	3			
7	Air discharge C = 330 pF, R = 2kΩ	± 15 kV	3			
8 [1]	Air discharge C = 150 pF, R = 2kΩ	± 25 kV	3			

1. This sequence is applicable only to device surfaces that are directly accessible from outside the vehicle (e.g. keyless entry) or interior surfaces without touching any portion of the vehicle. (e.g. door lock switches, head lamp switch, cluster).

Unpowered

Covers the ESD events that can occur during handling and assembly.

Discharge Sequence 1: Test Voltage Level = ± 4 kV

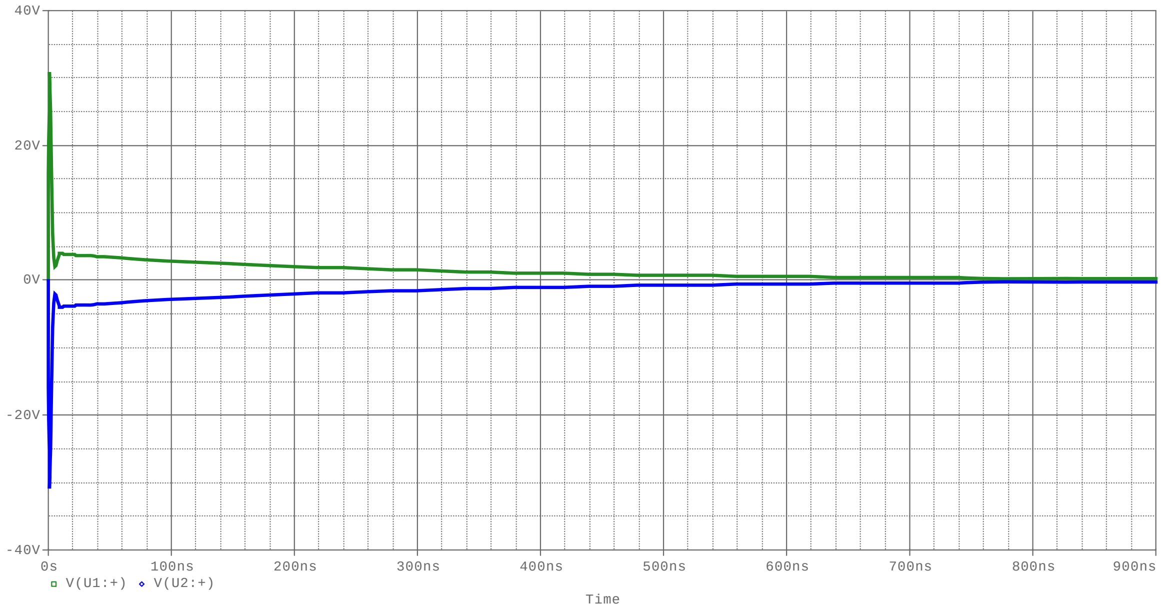


Figure: PSPICE simulation result of the generated CI 280 ESD unpowered sequence 1 transient for Test Voltage of ± 4 kV

Discharge Sequence 2: Test Voltage Level ± 6 kV

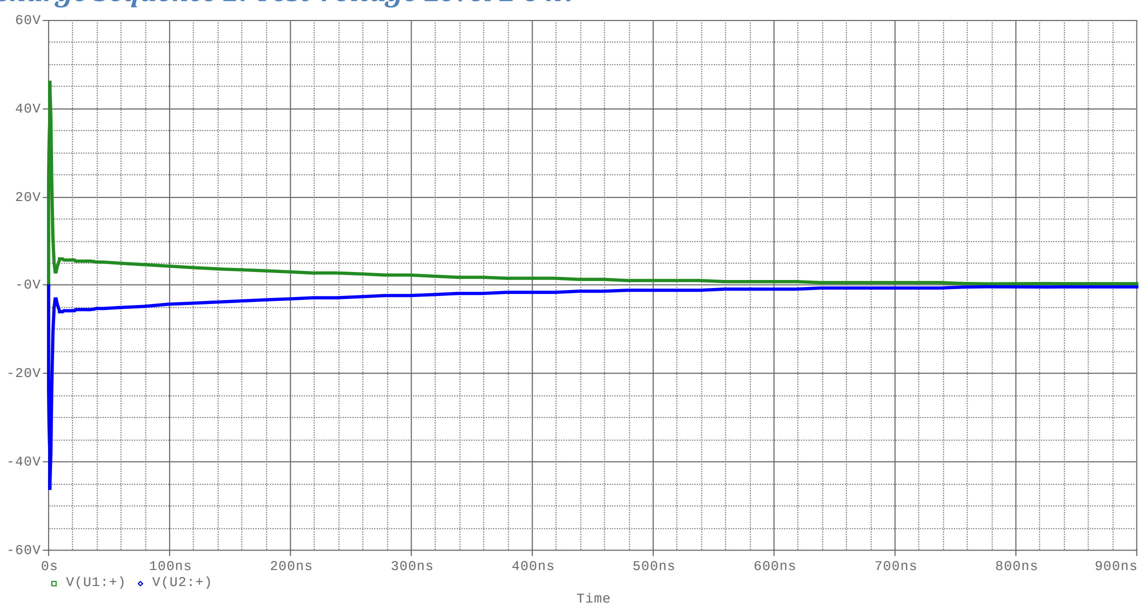


Figure: PSPICE simulation result of the generated CI 280 ESD unpowered sequence 2 transient for Test Voltage of ± 6 kV

Discharge Sequence 3: Test Voltage Level ± 8 kV

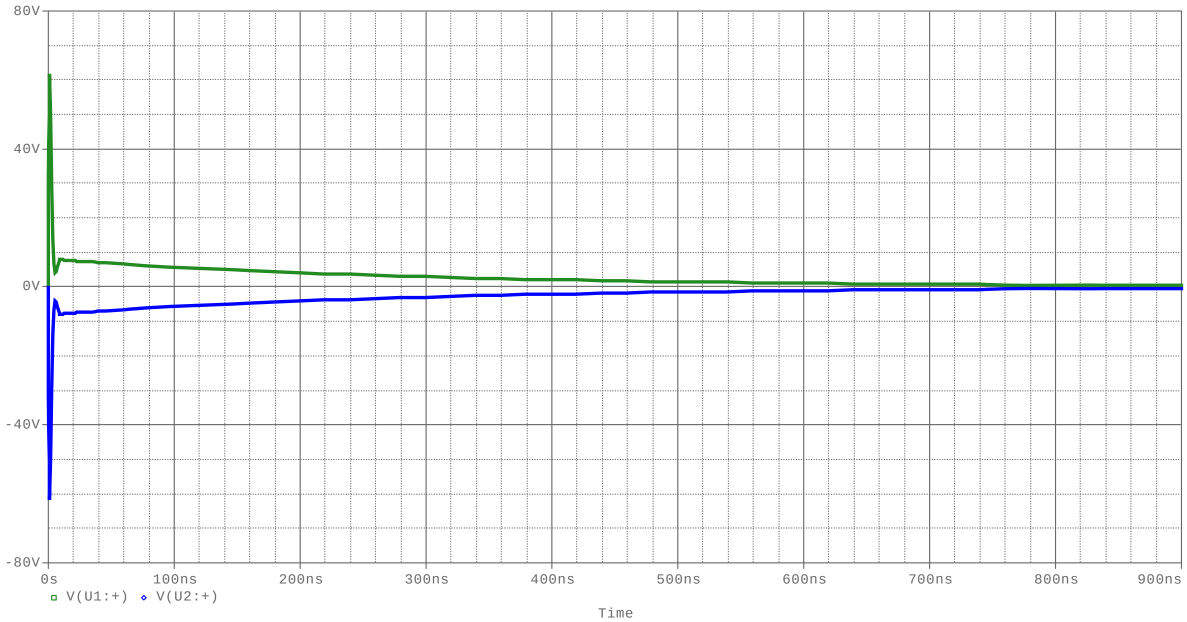


Figure: PSPICE simulation result of the generated CI 280 ESD unpowered sequence 3 transient for Test Voltage of ± 8 kV

Powered

Covers immunity to ESD events that occur during normal operation. The ESD generator model for the contact discharge is assumed to be applicable to the air discharge.

Discharge Sequence 1/2: Test Voltage Level = ± 4 kV

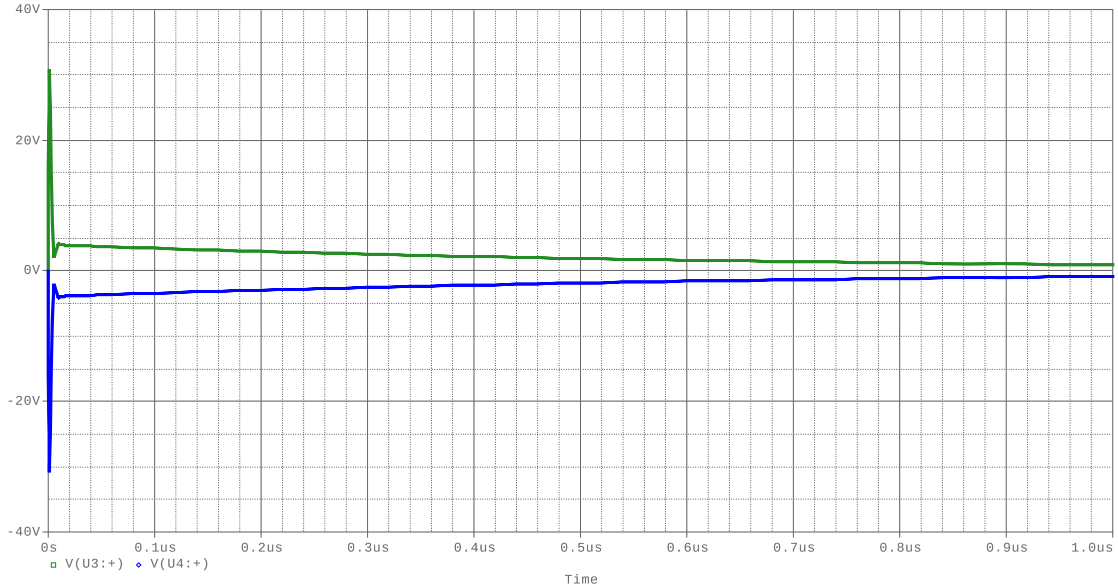


Figure: PSPICE simulation result of the generated CI 280 ESD powered sequence 1/2 transients for Test Voltage of ± 4 kV

Discharge Sequence 3/4: Test Voltage Level = ± 6 kV

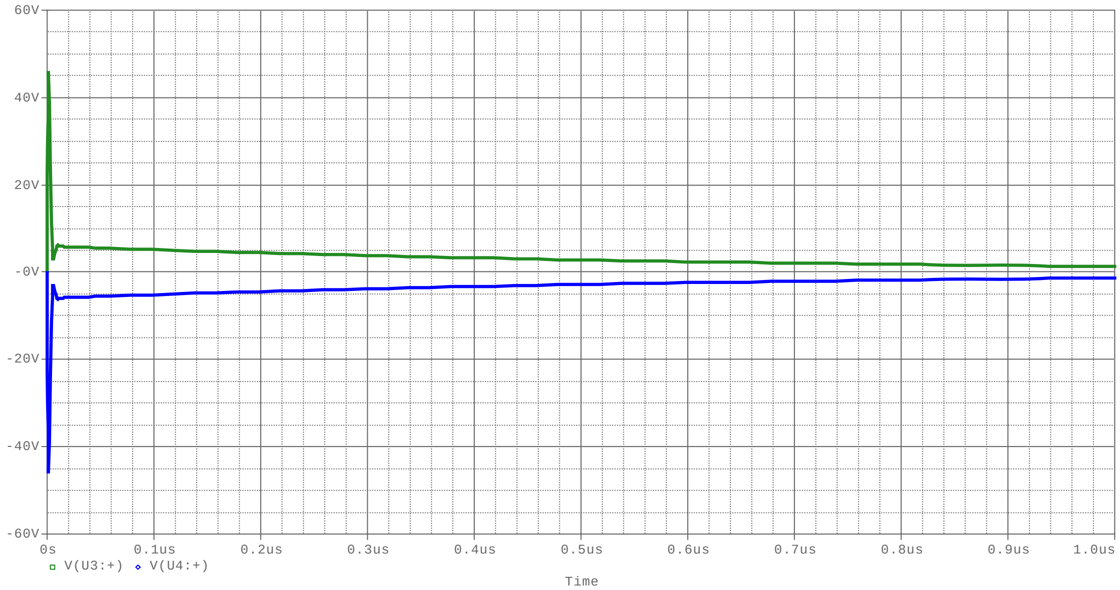


Figure: PSPICE simulation result of the generated CI 280 ESD powered sequence 3/4 transients for Test Voltage of ± 6 kV

Discharge Sequence 5/6: Test Voltage Level = ± 8 kV

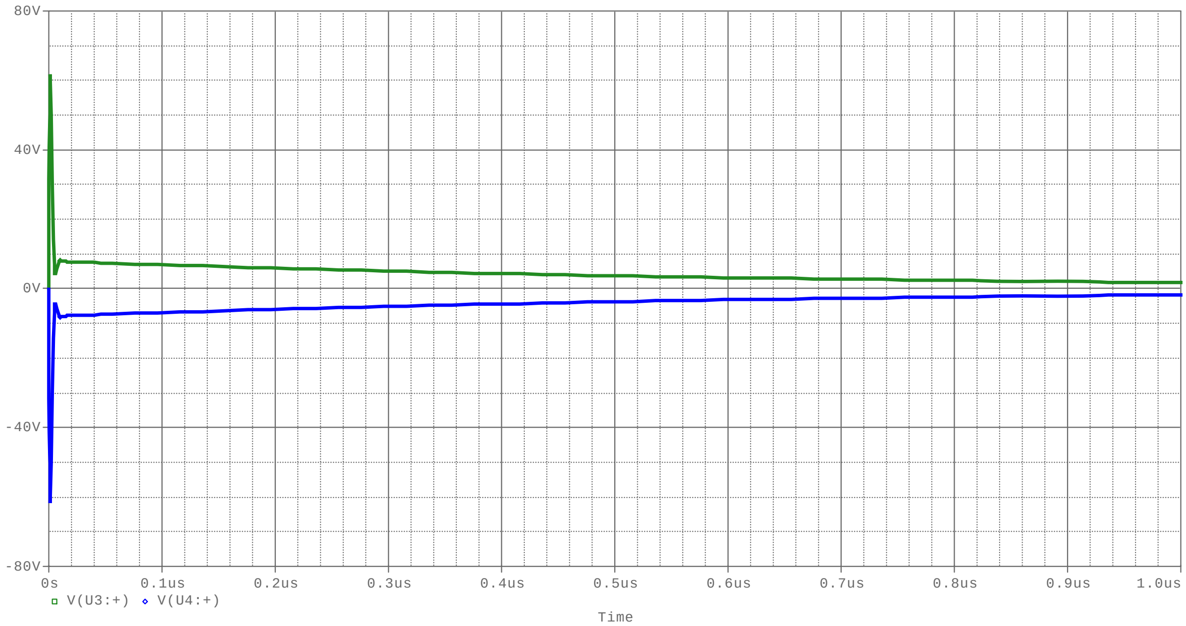


Figure: PSPICE simulation result of the generated CI 280 ESD powered sequence 5/6 transients for Test Voltage of ± 8 kV

Discharge Sequence 7: Test Voltage Level = ± 15 kV

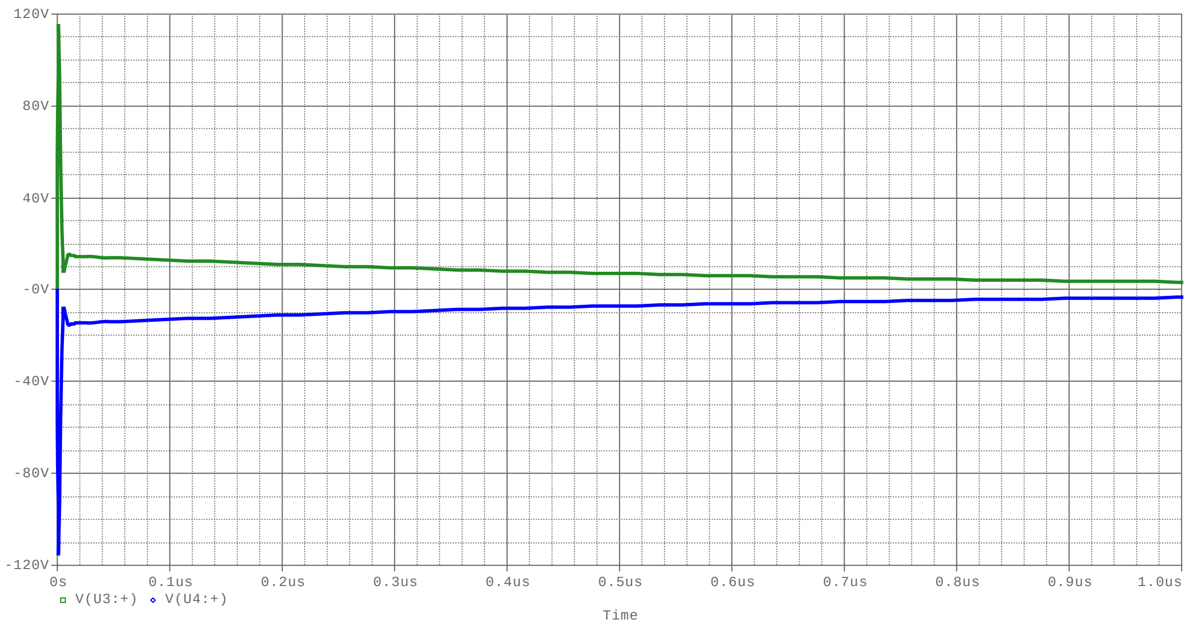


Figure: PSPICE simulation result of the generated CI 280 ESD powered sequence 7 transients for Test Voltage of ± 15 kV

Discharge Sequence 8: Test Voltage Level = ± 25 kV

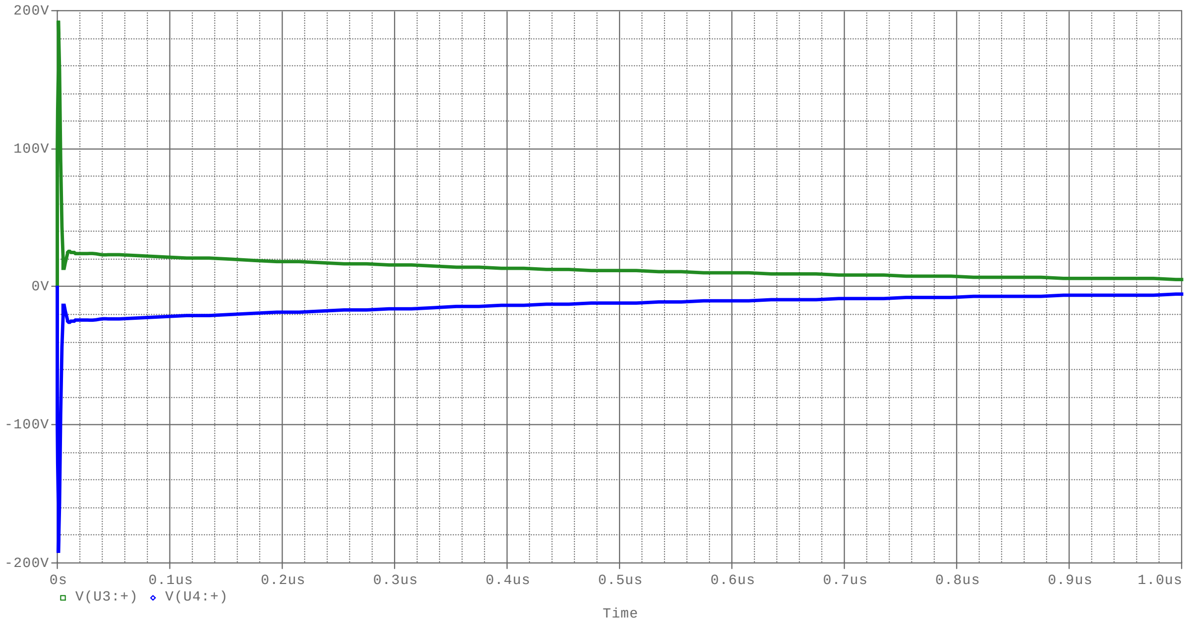


Figure: PSPICE simulation result of the generated CI 280 ESD powered sequence 8 transients for Test Voltage of ± 25 kV

References

1) Electromagnetic Compatibility Specification For Electrical/Electronic Components and Subsystems, General Specification FMX12-7-2016

2) ISO 7637-2:2004, Road vehicles — Electrical disturbances from conduction and coupling —Part 2: Electrical transient conduction along supply lines only, 6-15-2004

3) ISO 16750-2, Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 2: Electrical loads, 11-1-2012

4) Comparison of ISO 7637 Transient Waveforms to Real World Automotive Transient Phenomena, R. Keith. Frazier and Sheran Alles, 2005 International Symposium on EMC, 8-12 Aug. 2005