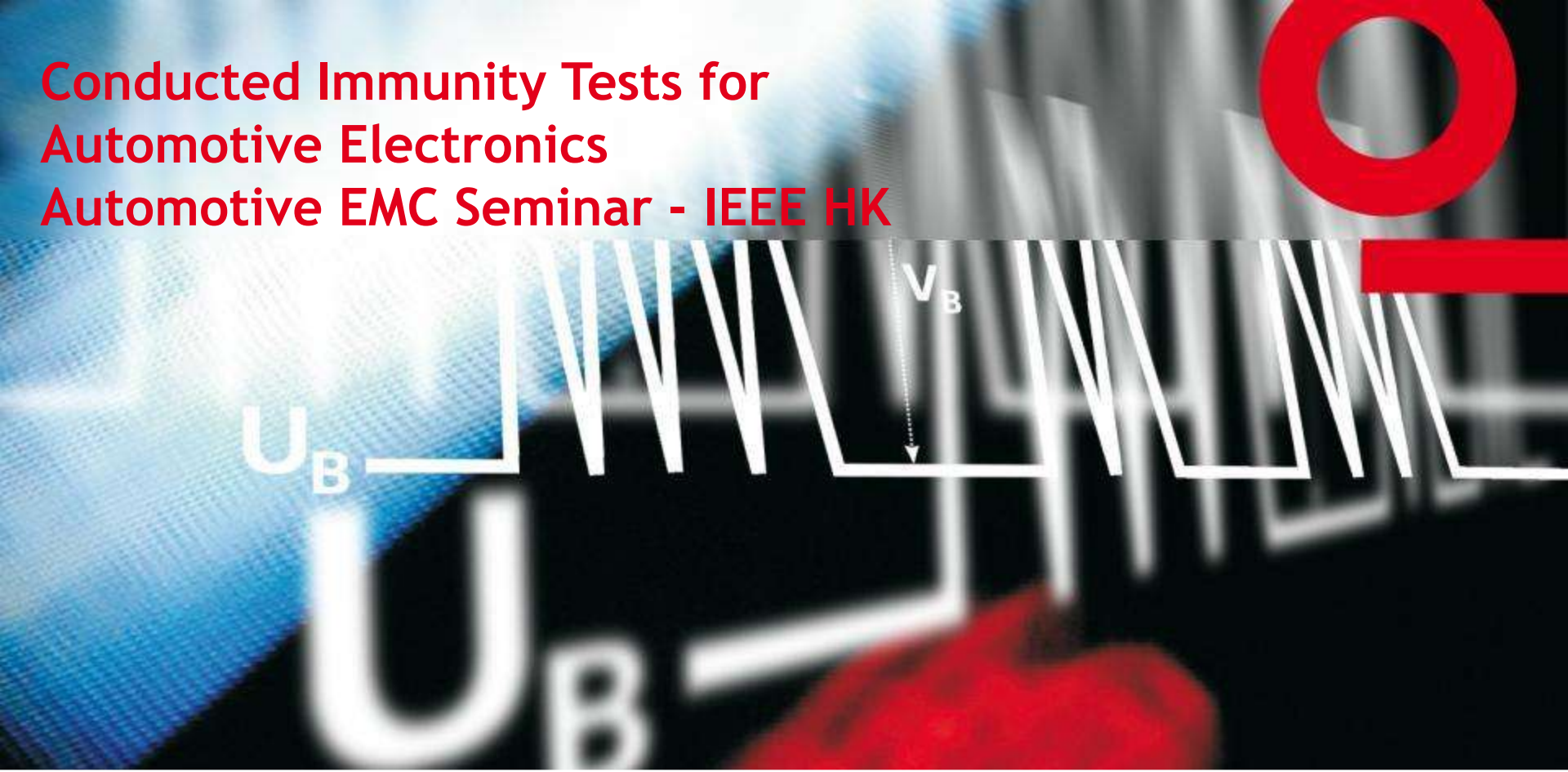
Conducted Immunity Tests for Automotive Electronics
Automotive EMC Seminar - IEEE HK



Jeffrey Tsang
Jeffrey.tsang@teseq.com

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SCHAFFNER
safety for electronic systems

27th November 2006

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Luterbach, Switzerland

- Our competence center for conducted equipment:
  - ESD
  - Burst
  - Surge
  - Power Quality
  - Automotive
- SCS Accredited Calibration Centre
- Headquarters

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Berlin, Germany

- Our competence center for
  - RF Equipment
  - GTEM Cell, Reverberation Chamber
  - EMC System
  - DKD accredited Calibration Centre

Wokingham, UK

- Our competence center for
  - Compliance 3 Software
  - EMC System Project
  - Power Amplifier
  - UKAS accredited Calibration Centre

UKAS CALIBRATION

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Turnkey Projects

- 3m Anechoic Chamber
- Radiated Emission System
- Radiated Immunity System
- ESD
- Conducted Emission
- Conducted Immunity

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Turnkey Projects

- CISPR25 Emission System x2
- 600V/m Radiated Immunity System
- ESD
- BCI System
- Transient Immunity System
- Magnetic Field Immunity
- Stripline, TEM Cell
- Optical EUT Monitoring

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Turnkey Projects

Alpine China

- 200V/m Radiated Immunity System
- Automatic EUT monitoring System

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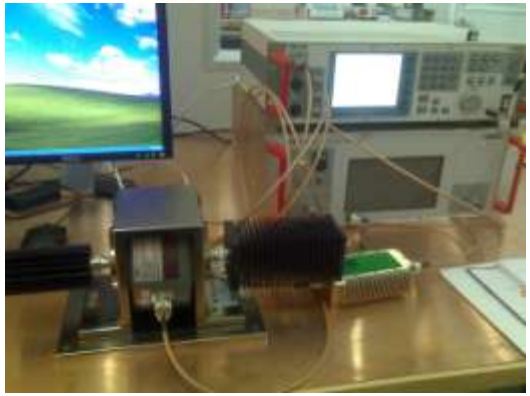
Turnkey Projects



- ESD
- BCI System up 400mA
- Transient Immunity
- Magnetic Immunity
- 1kW Power Amplifier – 200V/m Radiated Immunity System

中国电器科学研究院

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Conducted Immunity Testing on Automotive Electronics:

From ISO 7637 to Introduction of Manufacturer standards

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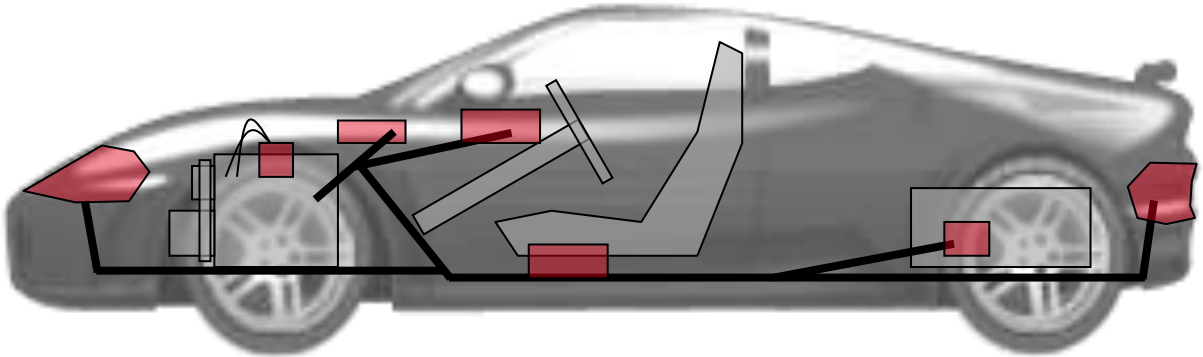
What is EMC?
Special Considerations for Motor Vehicles

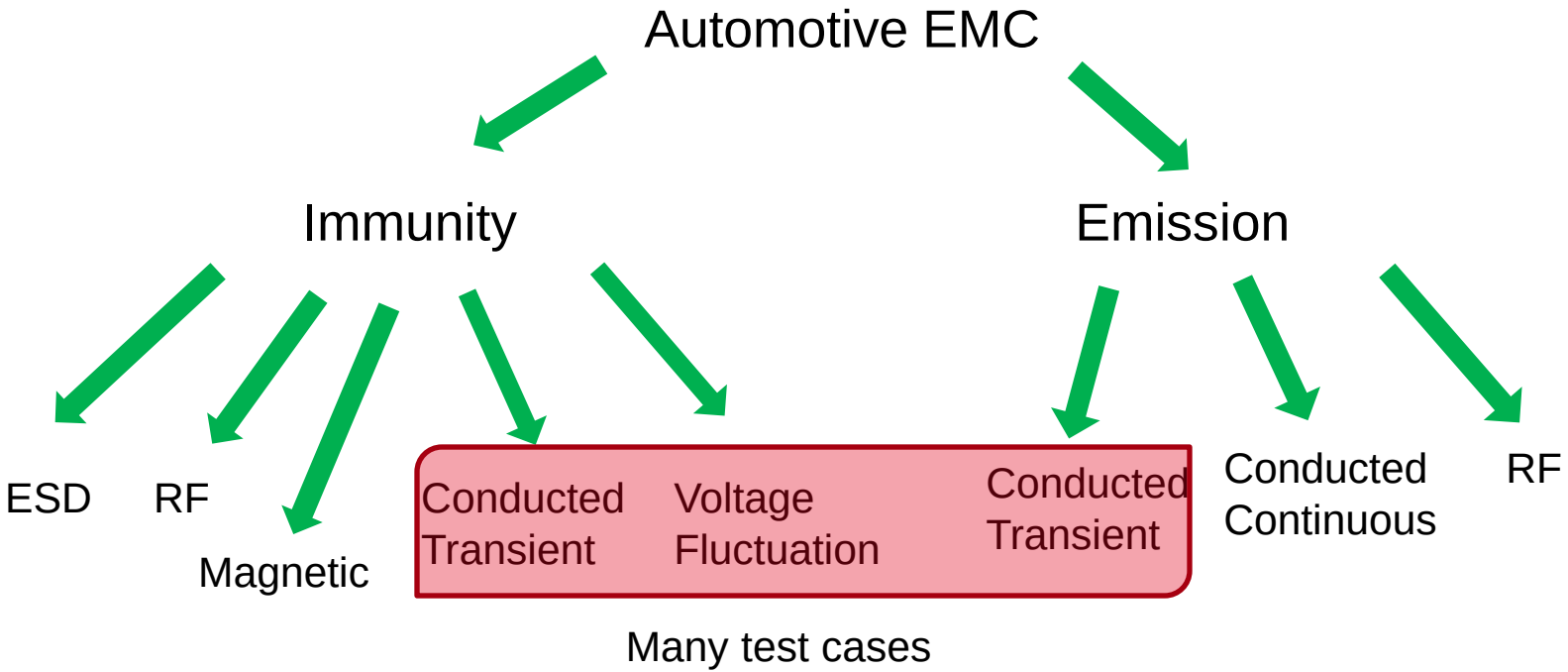
- In ISO 7637 and variants, we are considering transients and voltage drops that are coupled over battery lines and signal lines
- Immunity Testing simulates ‘Conducted EMC’ that occurs during normal or error conditions in a motor vehicle.
- Emissions testing ensures that the noise created by a device is less than specified levels.
- Evaluates the performance of components during simulated real-world EMC events
- These failure conditions are documented and tests defined by International organizations (ISO, SAE) and manufacturers (Ford, VW)

Why EMC is important?

- Causes:
  - Alternators, Converters, Switching Processes
  - Electric Motors, Fuel Pump, Fan Motors
  - Lights, Radio
  - Every kind of electronic device
  - Coupled on Power Lines and Wiring Harnesses
  - Engine Start

- When devices shall be tested:
  - Before production and sampling during production
  - During redesigns or modifications
  - **During initial design phases**



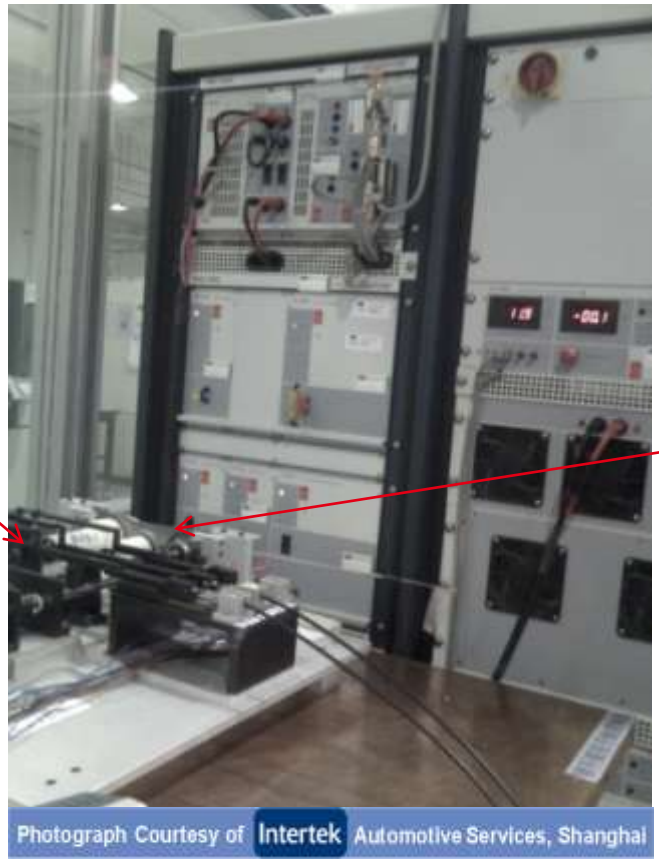


Distinct Characteristics in Automotive Conducted EMC

- DC 12V, 24V, 42V
- Lots of different Transients
  - Positive and Negative Transients
  - Emission and Immunity Tests
- Lots of Voltage Fluctuation
- Extremely detailed in test setup:
  - Harness height and length
  - Separation
- Test Fixture
- Load Simulator
- Very long test time

Automotive Conducted EMC Setup

- EUT is set to be in operation mode(s)
- Test Fixture
- Load simulator



EUT example:
Climate Control
Console

EMC Standards in Automotive Industry

International Bodies

ISO
IEC / CISPR

No so difficult

Regional Requirement

2004/104/EC (e-mark)
SAE (SAE J1113-11, SAE J1113-12)
JASO
GB/T

Much more complicated

Manufacturers (OEM)

BMW
Daimler Chrysler
Fiat
Ford
General Motors
Honda
Hyundai
Mazda
Peugeot
Nissan
Renault
Toyota
Volkswagen
...More!

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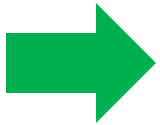
ISO Standards on Automotive Electronics

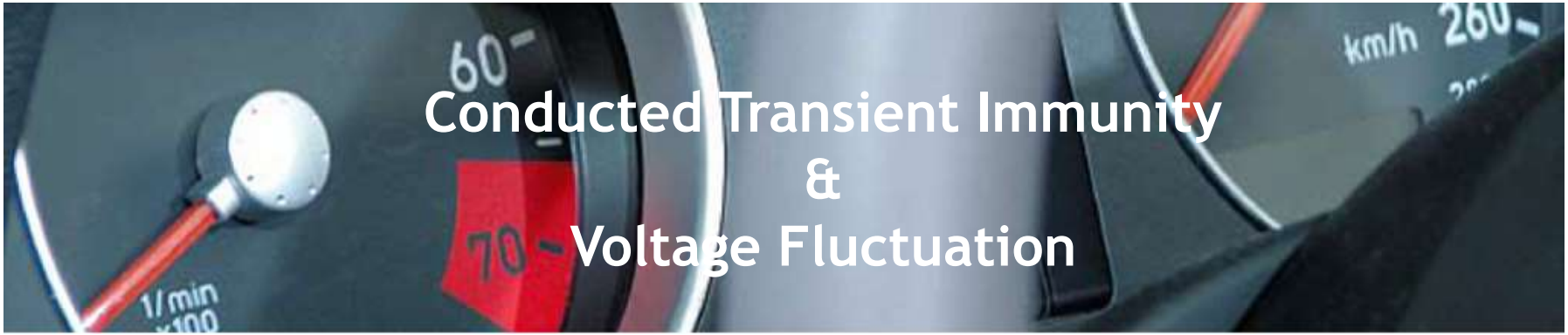
- ISO 7637-2: Conducted Transient on power line
  - 7 tests
- ISO 7637-3: Conducted Transient no non power line
  - 4 tests
- ISO 16750-2: Environmental conditions and testing for electrical and electronic
  - 6 out 10 tests are voltage fluctuation
- ISO 10605: ESD



Lots of the test cases are introduced and modified in OEM Standards

Usually in a more harsh way

All these tests simulate typical electrical environment in a full vehicle



Conducted Transient Immunity
&
Voltage Fluctuation

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OEM standards refer to ISO but different

Different automotive standards require different transient pulses. The requirements are different in:

- Amplitude
- Impulse
- Frequency
- Pulse energy
- Test method, test setup

What are the causes of differences?

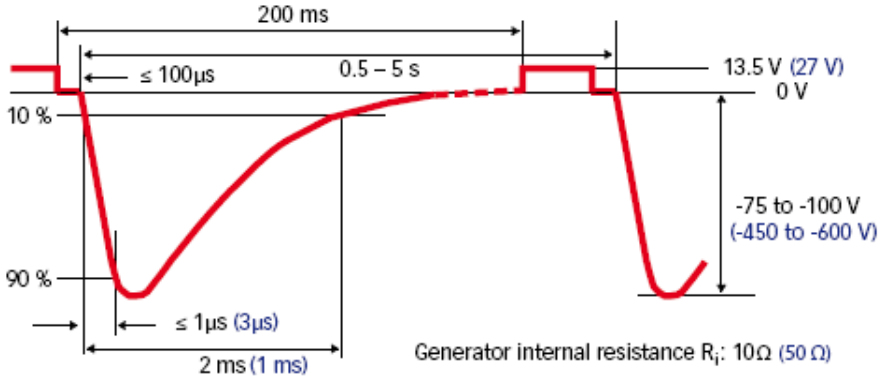
- Wiring harness
- Components
- Generators
- etc.

Conducted Immunity Tests Summary

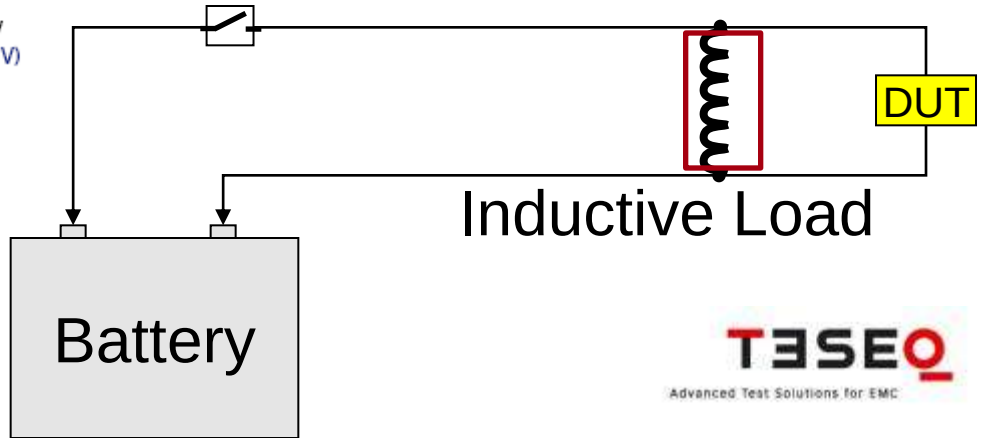
ISO7637-2	Ford ES-XW7T-1A278-AC	Nissan 28401NDS02	Volkswagen TL 82066
Pulse 1	CI 210	EQ/TE 01	Pulse 1
Pulse 2a	CI 220	EQ/TE 02	Pulse 2
Pulse 3a	Pulse A1	EQ/TE 03	Pulse 3
Pulse 3b	Pulse A2	EQ/TE 04	Pulse 4
Pulse 4	Pulse B1	EQ/TE 05	Pulse 4b
Pulse 5a	Pulse B2	EQ/IC 01	Pulse 5b
Pulse 5b	Pulse C	pulse 1	Pulse 6
	Pulse D	pulse 2	
	Pulse E	EQ/IC 02	
	Pulse F	pulse 3a	
	Pulse G	pulse 3b	
	CI 230	EQ/IC 03	
	CI 250	EQ/IC 04	
	CI 260	EQ/IC 05	
	Waveform A	EQ/IC 06	
	Waveform B		
	Waveform C		
	Waveform D		
	Waveform E		
	CI 270		

Test Purpose of ISO 7637-2
Test Pulse 1

This test is a simulation of transients due to supply disconnection from inductive loads; it applies to a DUT if as used in the vehicle, it remains connected directly in parallel with an inductive load.(1)

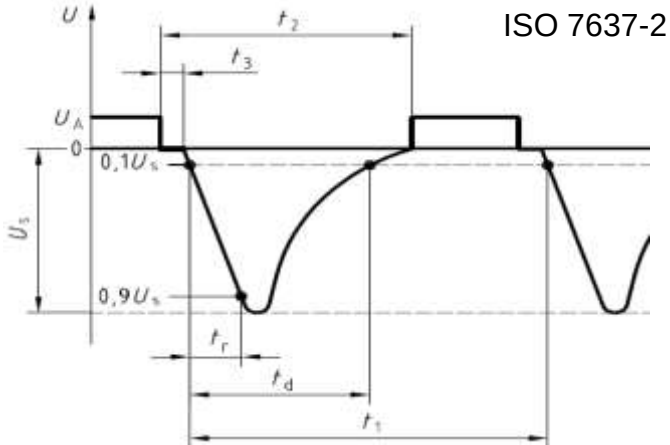


Parameter	12 V system	24 V system
U_s	–75 V to – 100 V	– 450 V to – 600 V
R_i	10 Ω	50 Ω



Test Purpose of ISO 7637-2
Test Pulse 1 Variant

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	$1^{\ 0}_{-05}$ µs	$3^{\ 0}_{-1,5}$ µs
t_1 [a]	0,5 s to 5 s	
t_2	200 ms	
t_3 [b]	< 100 µs	



ISO 7637-2

Ford
ES-XW7T-1A278-AC
CI220 pulse E (12V only)

Nissan
28401NDS02
EQ/IC 01 Pulse1 (12V only)

Volkswagen
TL 82066

Pulse	Number	U_s (V)	t_d (µs)	t_r (µs)	Generator R_i (Ω)	
					12 V	42 V
Pulse 1	5,000 pulses	-100	2,000	1	4	10
					24V	
Pulse 1	5,000 pulses	-150	2,000	1	10	

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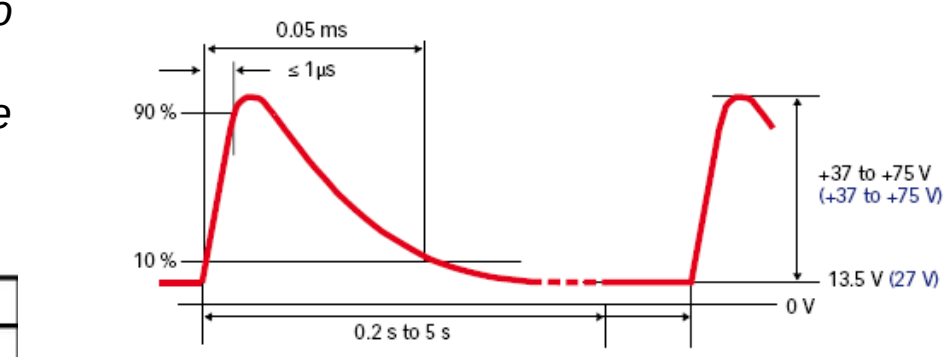
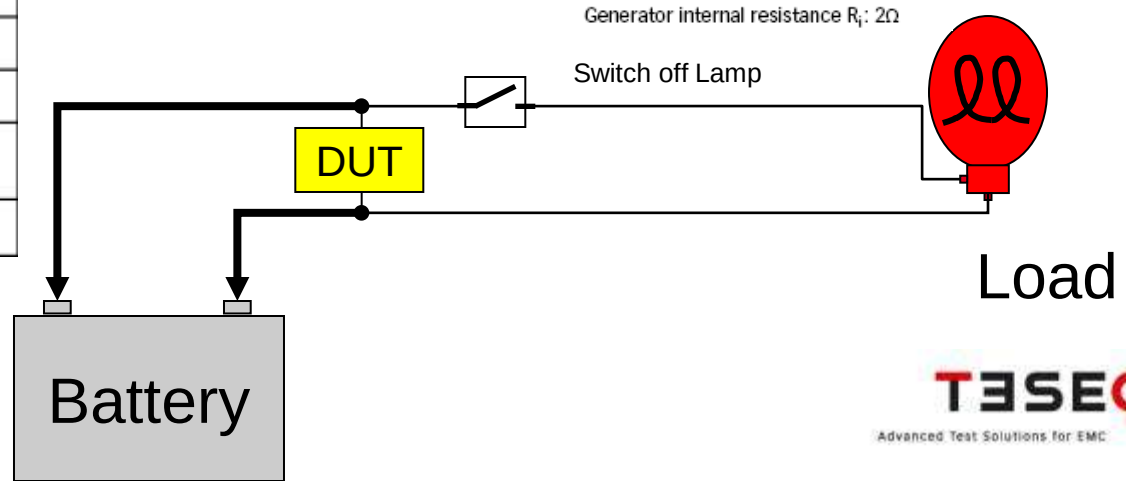
Test Purpose of ISO 7637-2
Test Pulse 2a

Pulse 2a simulates transients due to sudden interruption of currents in a device connected in parallel with the DUT due to the inductances of the wiring harness.

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	$\left(1\ ^{0}_{-0,5}\right)$ µs	
t_1 [a]	0,2 s to 5 s	

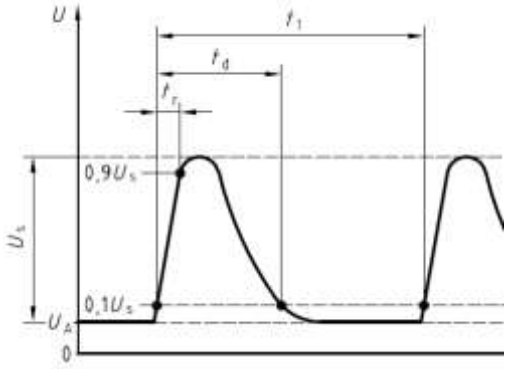




Test Purpose of ISO 7637-2
Test Pulse 2a Variant

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	$\left(1\ {}^{0}_{-0,5}\right)$ µs	
t_1 [a]	0,2 s to 5 s	

ISO 7637-2



Ford
ES-XW7T-1A278-AC
CI220 pulse F (12V only)

Nissan
28401NDS02
EQ/IC 01 Pulse 2a (12V only)

Volkswagen
TL 82066

Pulse	Number	U_s (V)	t_d (µs)	t_r (µs)	Generator R_i (Ω)	
					12 V	42 V
Pulse 2	5,000 pulses	+50	50	1	4	10
						24V
Pulse 2	5,000 pulses	+75	200	1		10

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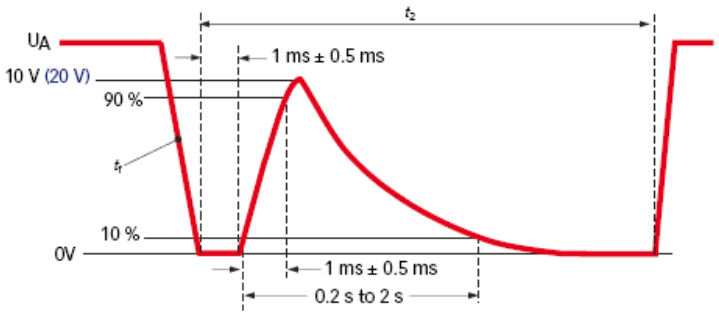
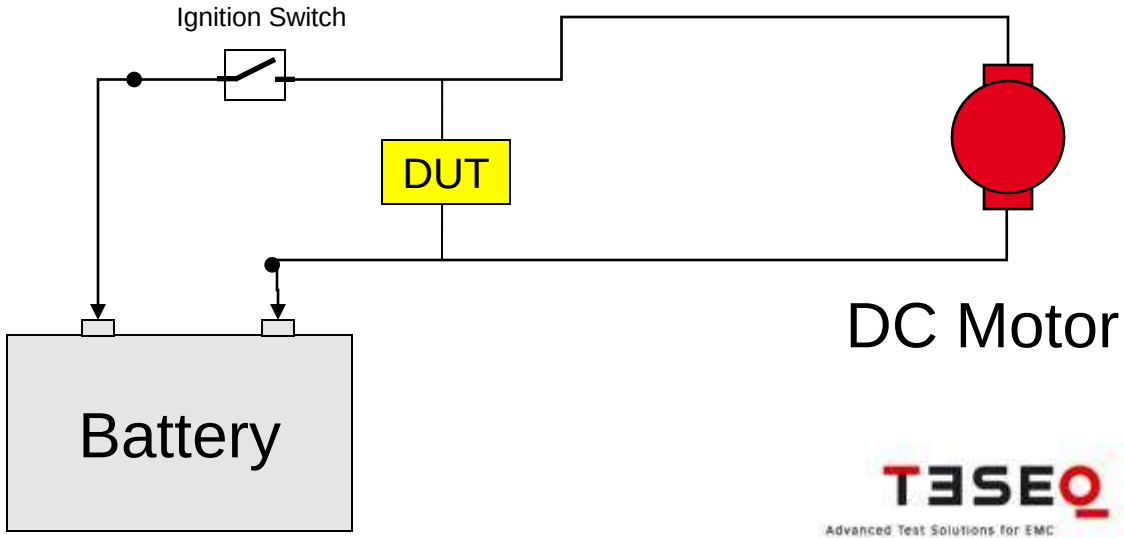
Test Purpose of ISO 7637-2
Test Pulse 2b

Pulse 2b simulates transients from dc motors acting as generators after the ignition is switched off

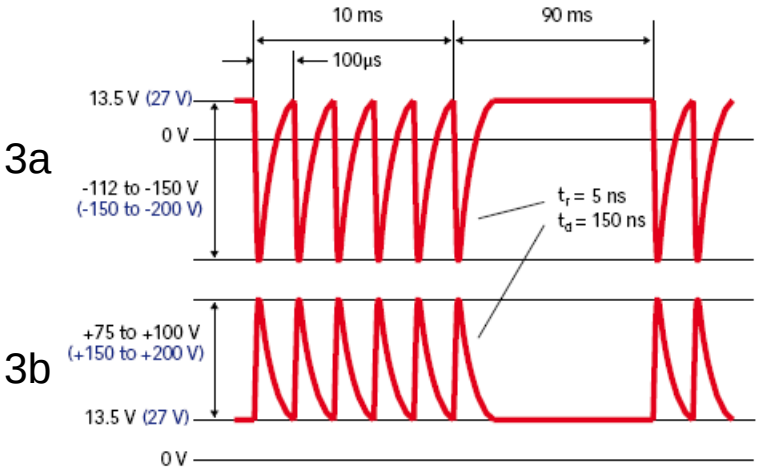
It is more like a voltage fluctuation test. Most car manufacturers had withdrawn this because it is covered by other voltage fluctuation tests





Test Purpose of ISO 7637-2
Test Pulse 3a/3b

Pulse 3 occurs as the result of switching processes. The characteristics of this pulse are influenced by distributed capacitance and inductance of the wiring harness.

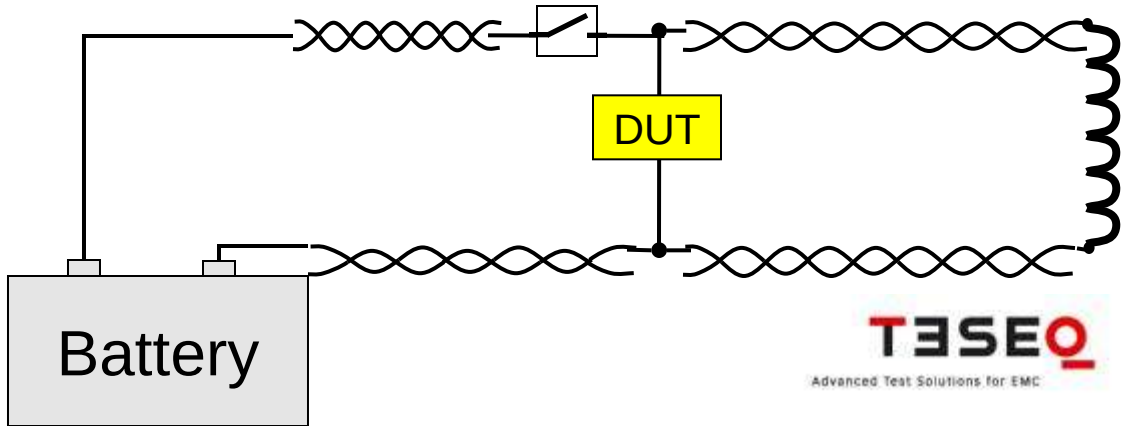


Parameters for test pulse 3a

Parameter	12 V system	24 V system
U_s	– 112 V to – 150 V	– 150 V to – 200 V

Parameters for test pulse 3b

Parameter	12 V system	24 V system
U_s	+ 75 V to + 100 V	+ 150 V to + 200 V



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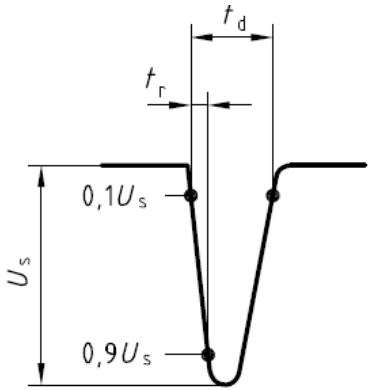
Test Purpose of ISO 7637-2
Test Pulse 3a/3b Variant

Most manufacturers bring these tests into their own EMC standards except Ford

Test pulse 3a	U_s	t_r	t_d
No load	− 200 V ± 20 V	5 ns ± 1,5 ns	150 ns ± 45 ns
Test pulse 3b	U_s	t_r	t_d
No load	+ 200 V ± 20 V	5 ns ± 1,5 ns	150 ns ± 45 ns



General Motor
GMW3097

Nissan
28401NDS02
EQ/IC 02 Pulse 3a/3b

Volkswagen
TL 82066 Pulse 3a/3b

Pulse width
t_d = 100ns

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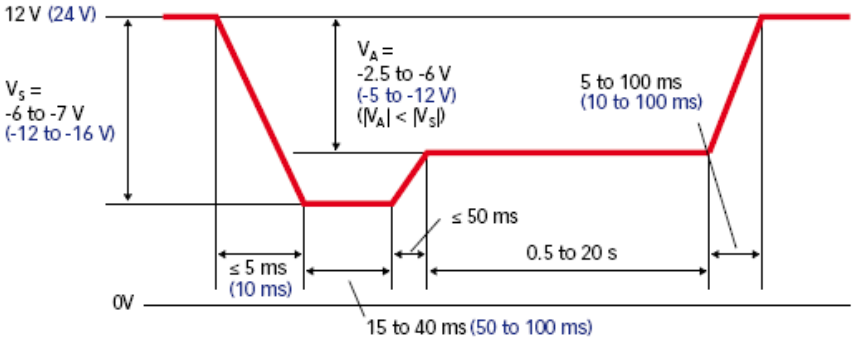
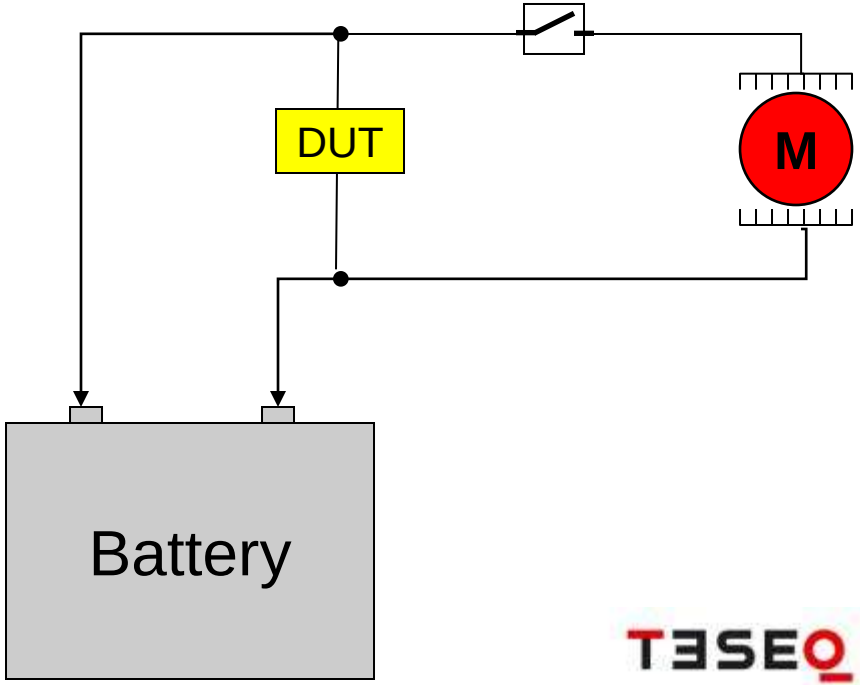
Test Purpose of ISO 7637-2
Test Pulse 4

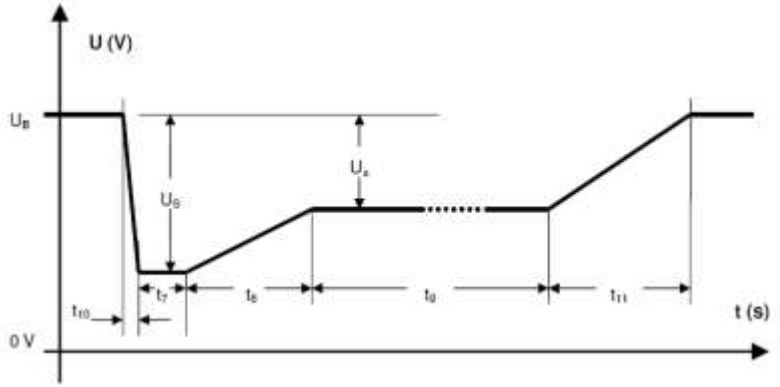
Pulse 4 is the voltage reduction caused by energizing the starter motor circuits of the internal combustion engines





Test Purpose of ISO 7637-2
Test Pulse 4

- All manufacturers requires Starting Profile test but in more complicated way

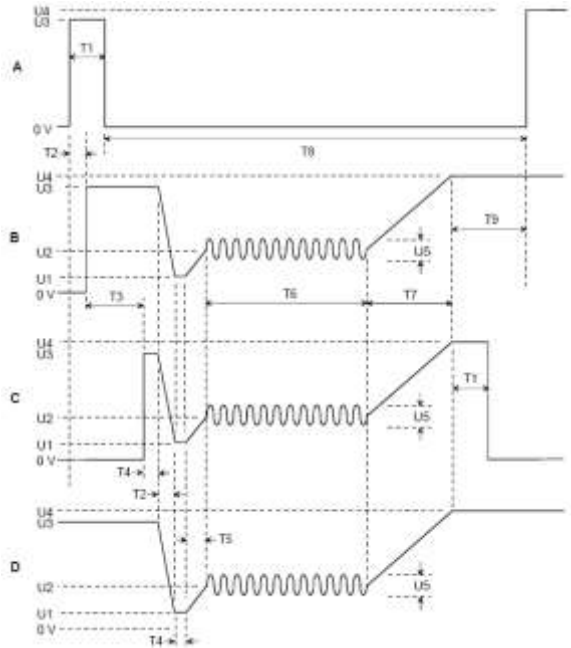


Pulse		Number	U_B (V)	U_S (V)	U_A (V)	t_{10} (ms)	t_9 (ms)
4	12 V	10	12	7	5,5	≤ 5	2,000
4b	12 V	10	12	9	7	≤ 5	1,000
4	24 V	10	24	18	12	≤ 10	3,000
4	42 V	10	36	18	15	≤ 10	2,000
The following applies to the pulses: t_7 = 15 ms, t_8 = 50 ms, t_{11} = 100 ms, Ri = 0 to 0.02 Ω							

Volkswagen
TL 82066 Pulse 4/4b

Test Purpose of ISO 7637-2
Test Pulse 4 Variant

- Very Complicated Starting Profile tests



This test is to be done at -40ºC or below

Ford
ES-XW7T-1A278-AC CI230
Power Cycling

drop resistant

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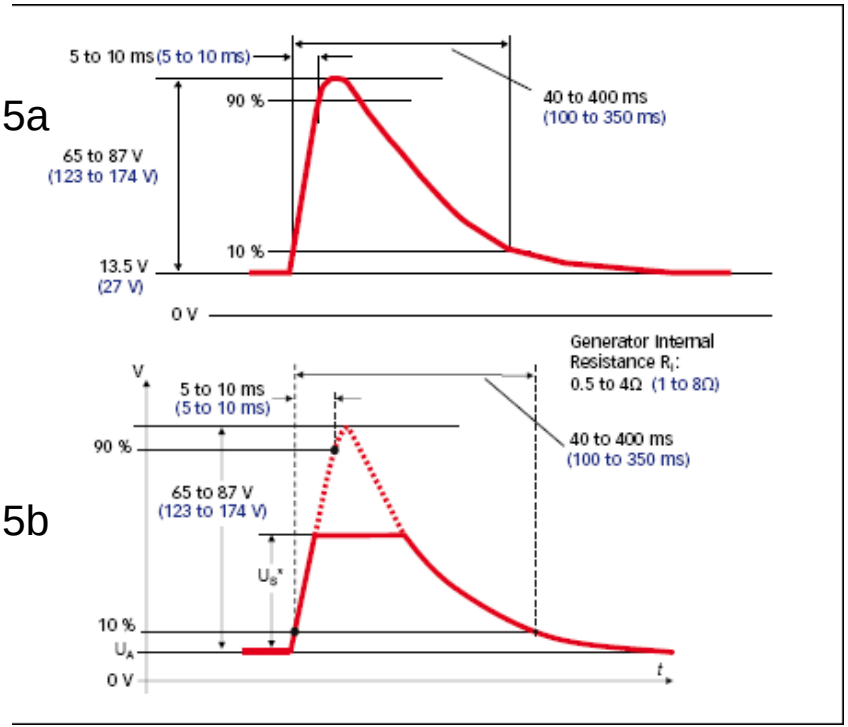
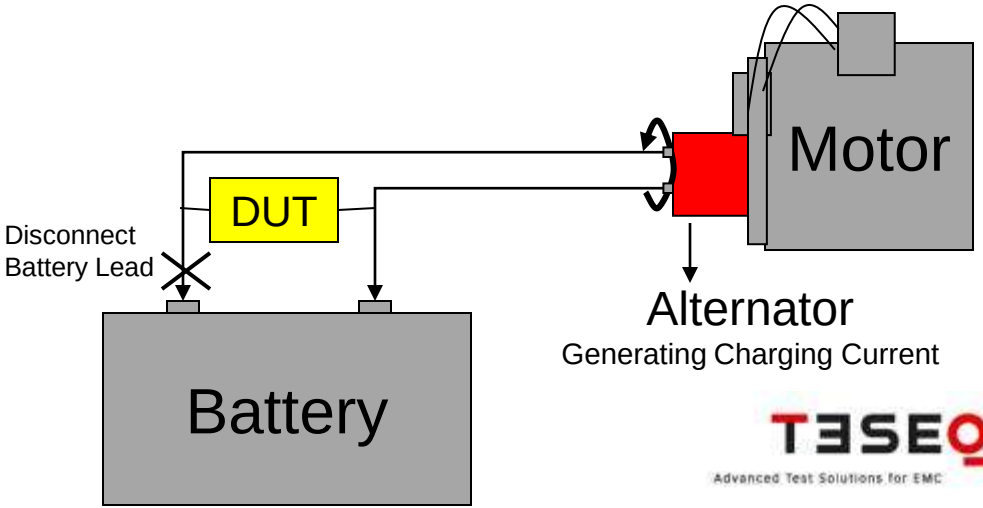
Test Purpose of ISO 7637-2
Test Pulse 5a/5b

5a

5b



Pulse 5 is a simulation of a load dump transient occurring in the event of a discharged battery being disconnected while the alternator is generating charging current with other loads remaining on the alternator circuit at this moment



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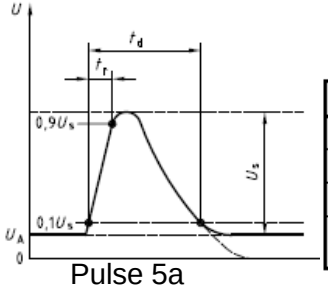
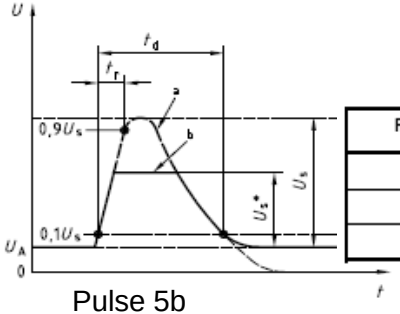
Test Purpose of ISO 7637-2
Test Pulse 5a/5b variant

- All manufacturers requires Load Dump test but almost all of them are specified in different ways
- This pulse generate high energy and often destructive



Pulse 5a

Parameter	12 V system	24 V system
U_s	65 V to 87 V	123 V to 174 V
R_i	0,5 Ω to 4 Ω	1 Ω to 8 Ω
t_d	40 ms to 400 ms	100 ms to 350 ms
t_r	$\left(10\ ^{0}_{-5}\right)$ ms	



Pulse 5b

Parameter	12 V system	24 V system
U_s	65 V to 87 V	123 V to 174 V
U_s'	As specified by customer	
t_d	Same as unsuppressed value	

Ford
ES-XW7T-1A278-AC
CI220 pulse G

Test pulse G - Parameters

Open Circuit Conditions	
U_P	13.5 V
U_S	73.5 V
t_r	1 – 10 ms
t_d	300 ms +/- 20%
t_1	30 s
R_i	0.5

Nissan
28401NDS02
EQ/IC 03 Pulse 5a/5b

Volkswagen
TL 82066 Pulse 5b
Only applicable to 42V system
Ri = 3Ω

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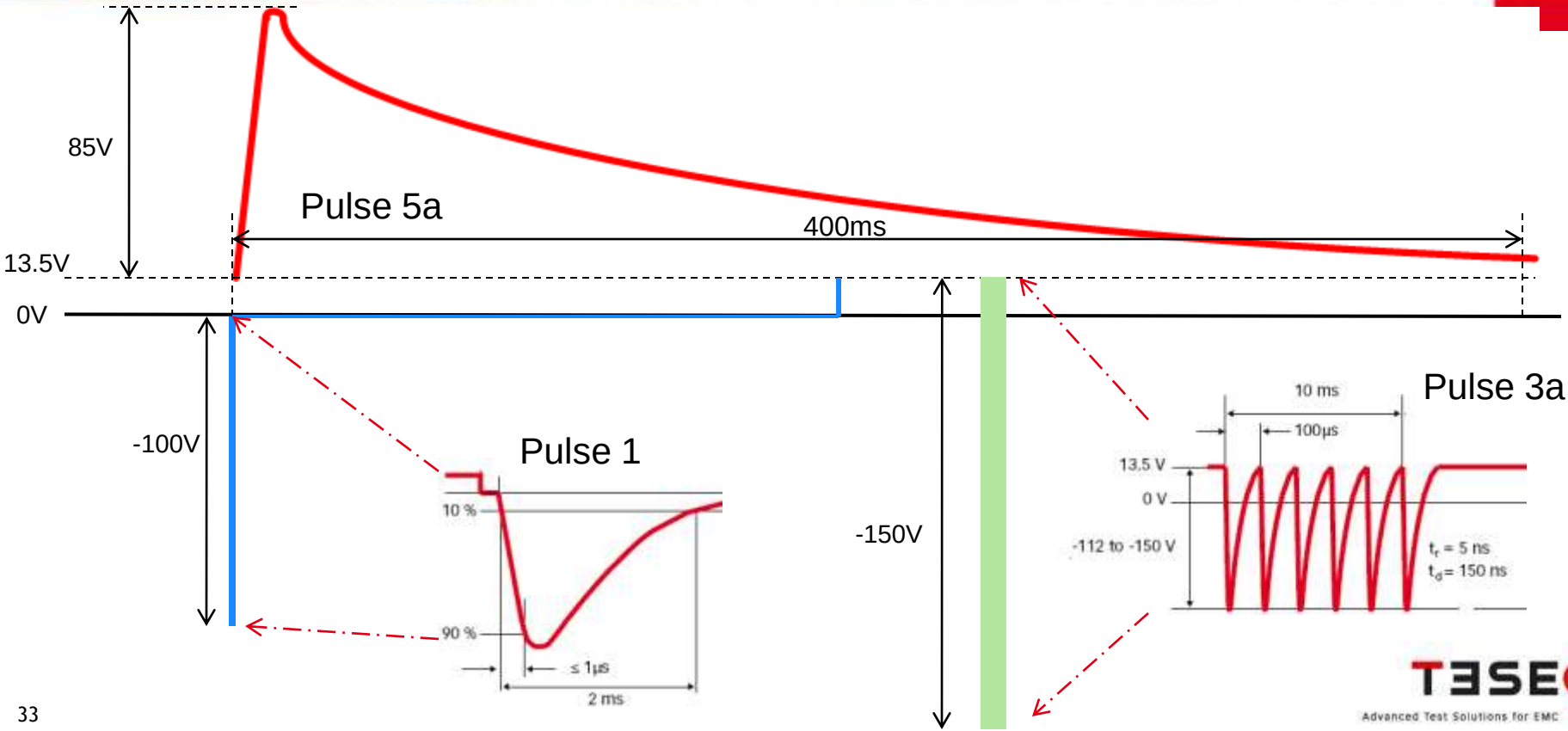
Test Purpose of ISO 7637-2
Test Pulse 5a/5b



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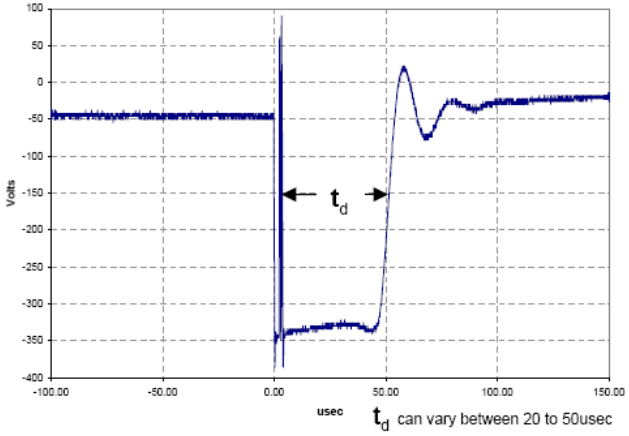
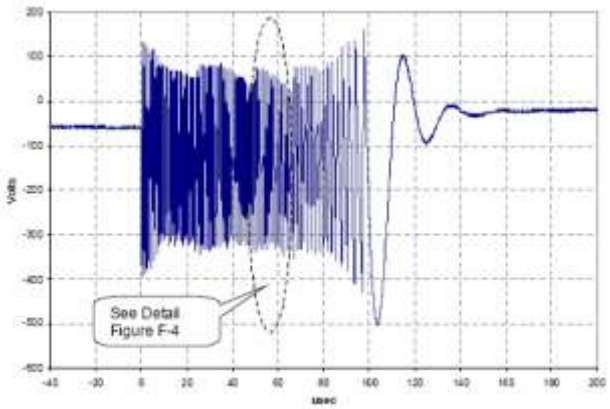
Manufacturer EMC Standards Tests

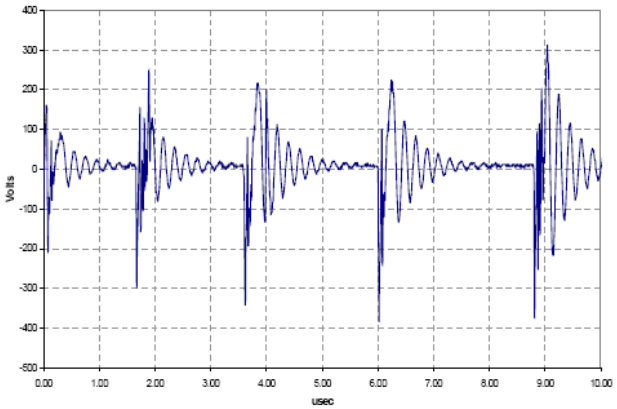
Ford ES-XW7T-1A278-AC CI220



Pulse A1



Pulse A2



Pulse C

These pulses are caused by actual mechanical relay with defined circuitry

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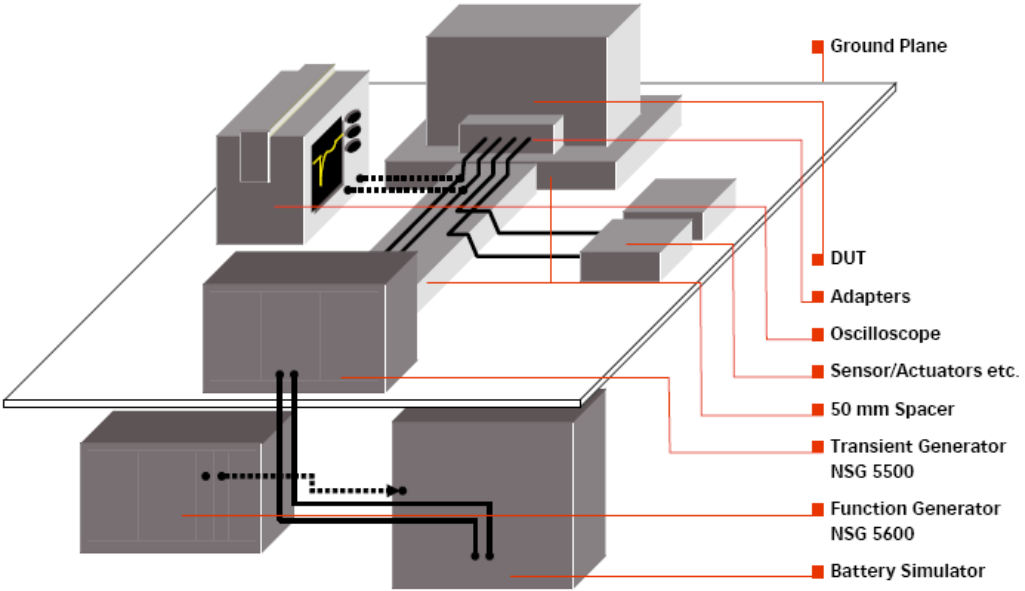
Nissan
28401NDS02
EQ/IC 04 : Resistance to power supply micro-interruptions

Siemens VDO
Fuel Pump Transient test for IPC

Pulse Generation System
Typical Setup



Photograph Courtesy of CVC

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Teseq Pulse Generation System

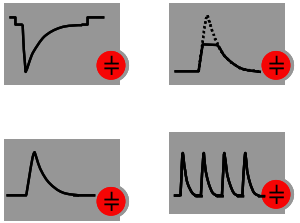
Teseq Conducted Immunity System
Automotive Electronics

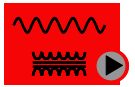
NSG5500

NSG5600

PA 5840

Transients





Voltage
Fluctuation

ISO
SAE
JASO
BMW
Daimler Chrysler
Fiat
Ford
General Motors
Honda
Hyundai
Mazda
Peugeot
Nissan
Renault
Toyota
Volkswagen
Etc..

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Conducted Transient Emissions

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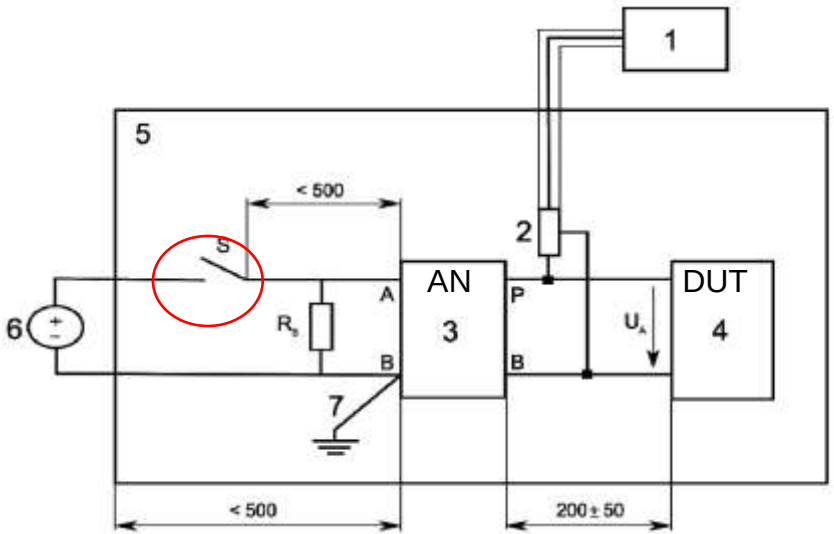
ISO 7637-2 Emission

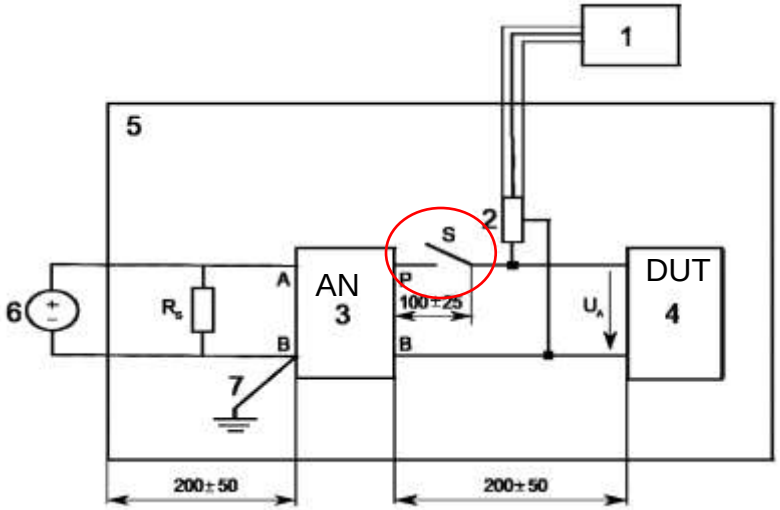
- Automotive EMI
  - CISPR12, 25 -> Continuous Interference
  - ISO 7637-2 -> Transient due to switching process

- ISO 7637-2
  - Must do test
  - Test procedure is straight forward
  - Lots of details in test setup
  - Lots of mal-practice in the market

ISO7637-2 Emissions Test Layout



“Slow Pulse” Setup



“Fast Pulse” Setup

Cable lengths, 50 -0/+10 mm above GND plane, disturbance voltage shall be measured as close to the DUT terminals as possible

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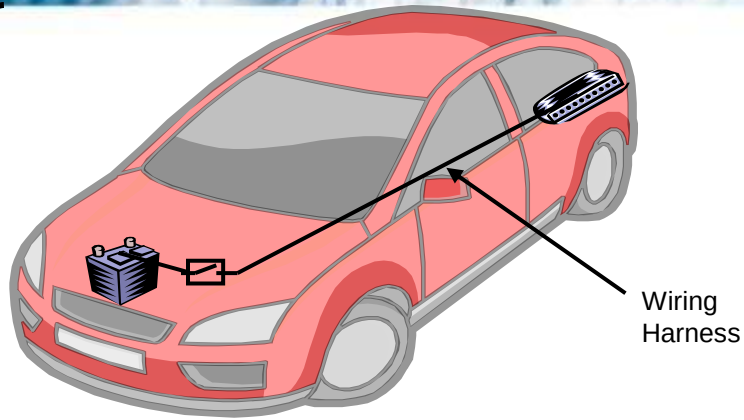
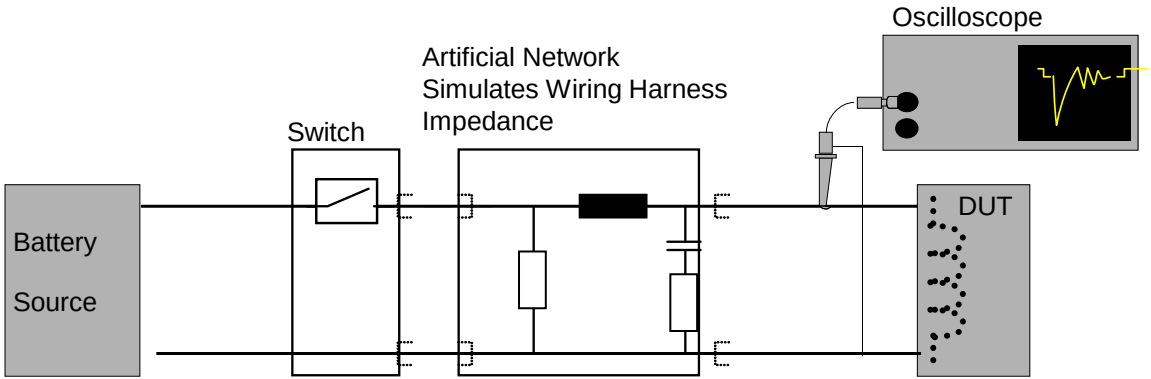
ISO 7637-2 Emissions Test Layout

Application



For applications where the DUT is far from the switch, the setup should have the AN between the switch (simulating the wiring harness) and the DUT.
"Slow Pulse Setup"
Millisecond range or slower

Test Setup



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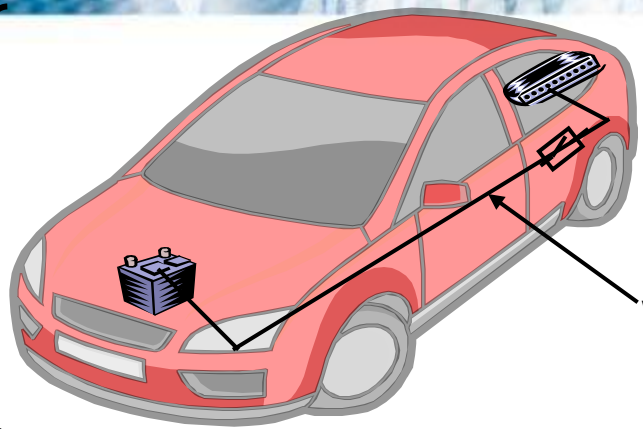
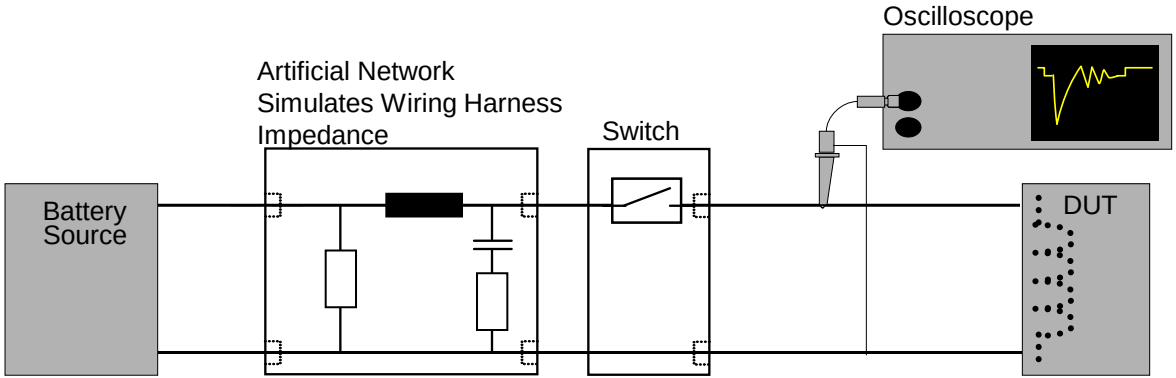
ISO 7637-2 Emissions Test Layout

Application



For applications where the DUT is near the switch, the setup should have the AN before the switch
"Fast Pulse Setup"
nanosecond-to-microsecond range

Test Setup



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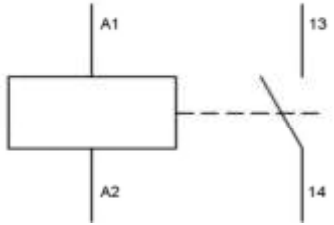
Emissions Relay or Electronic Switch?

When to use a relay and when the electronic switch:

Relay

- Voltages over 400V
- Usually must be approved by OEM
- Poor Repeatability, Slow/Chattering
- Must be replaced
- Should be production relay from the vehicle containing the DUT

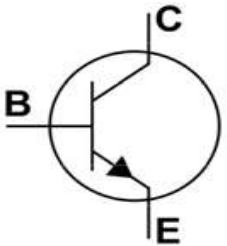


Potter & Brumfield

Bosch

Electronic Switch

- Less than 400V
- Fast and Repeatable
- Voltage Drop Must be Accounted For $\Delta U \leq 1V$ at 25 A



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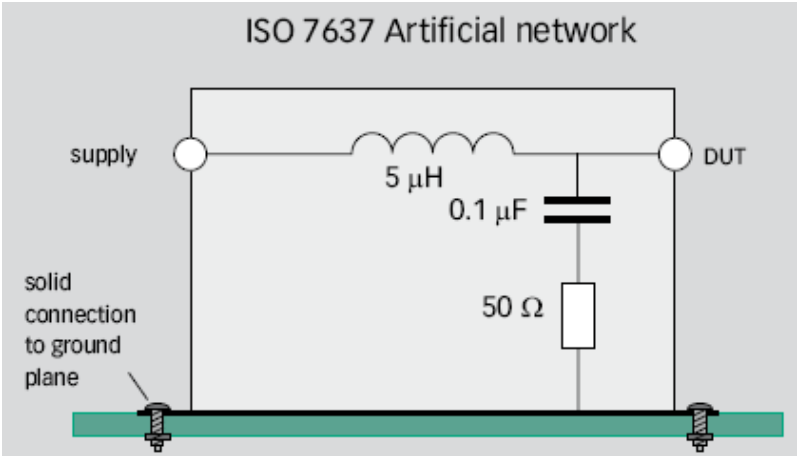
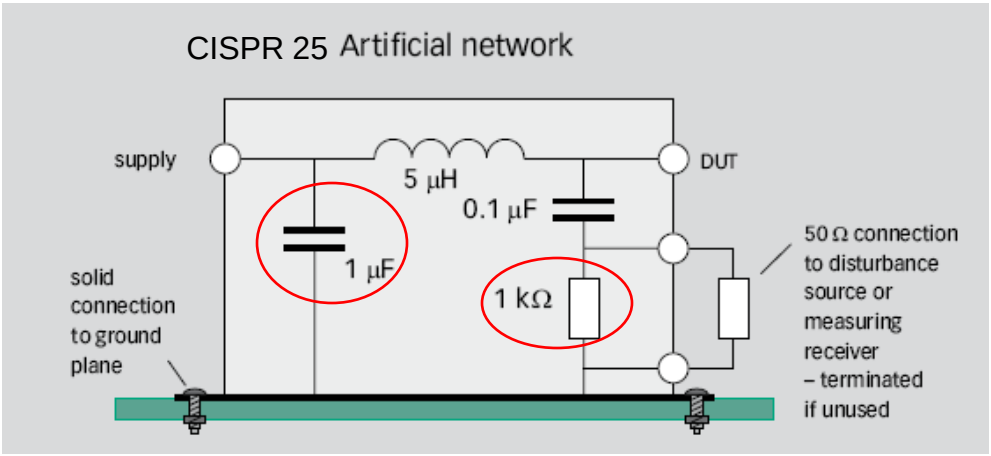
Differences: AN(LISN) defined in ISO7637-2 & CISPR25

ISO 7637 and CISPR 25 Artificial Network are **NOT** the same





Differences Between ISO 7637 and CISPR25 Artificial Networks

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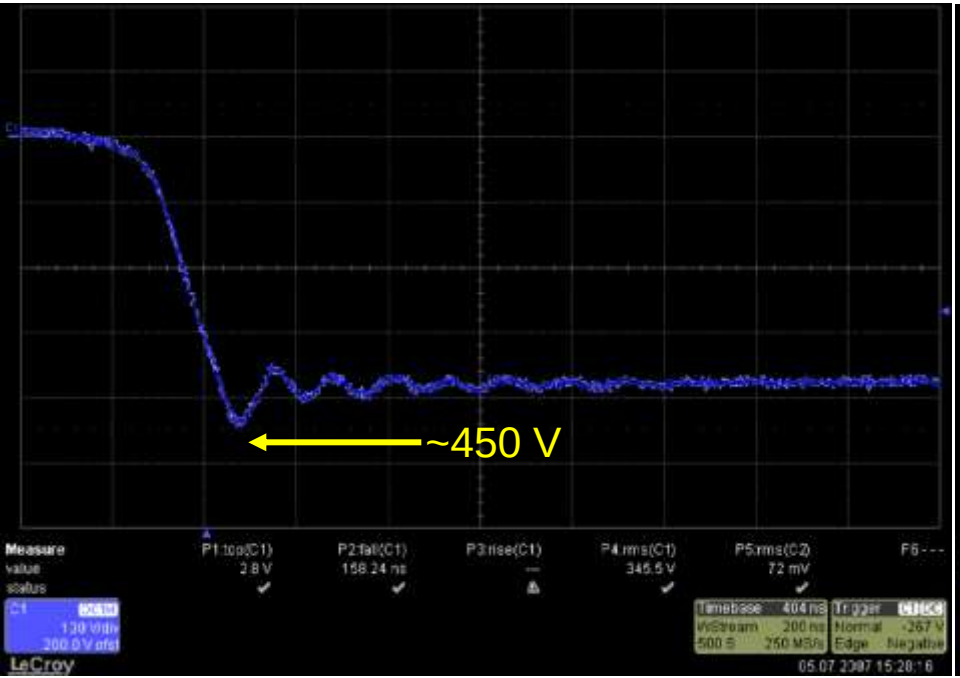
How to measure?

- Test procedure is quiet straight forward but has to be done manually

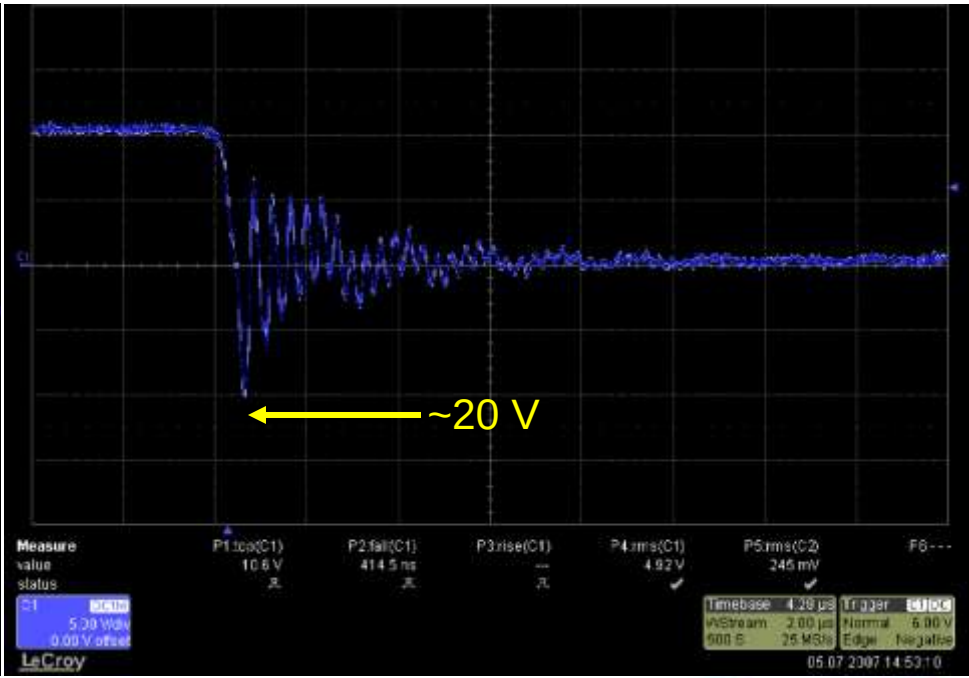
- Search for the worst cases (highest amplitude) by:
  - Changing the switch on/off time
  - Changing the switching repetition

Typical Measurement Result

Very Heavily Inductive



Mixed R/L Load



Much more severe pulses from DUTs with high inductance

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ISO7637-2 Emissions Limits

Table C.2 — Suggested limits for the classification of 12 V equipment

Pulse amplitude (U_S)	Suggested limit for U_S for severity level				
	V[a]	IV	III	II	I
Positive	—	+ 100 V	+ 75 V	+ 50 V	+ 25 V
Negative	—	− 150 V	− 100 V	− 50 V	− 25 V
[a] Values to be determined by vehicle manufacturer and equipment supplier.					

Table C.3 — Suggested limits for the classification of 24 V equipment

Pulse amplitude (U_S)	Suggested limit for U_S for severity level				
	V[a]	IV	III	II	I
Positive	—	+ 200 V	+ 150 V	+ 100 V	+ 50 V
Negative	—	− 600 V	− 450 V	− 300 V	− 150 V
[a] Values to be determined by vehicle manufacturer and equipment supplier.					

Ford
ES-XW7T-1A278-AC
CE410 Limits <+100V, >-150V
Only use Fast Pulse setup

Volkswagen TL 82066
Maximum permissible transient emission

Only use Fast Pulse setup

Table 7 – Maximum permissible transient emission for 12-V and 42-V interference sources

Pulse	U_s (V)	t_d (µs)	t_r (µs)
Pulse 1	≥ -100	≤ 2,000	≥ 1
Pulse 2	≤ +50	≤ 50	≥ 1
Pulse 3a	≥ -150	≤ 0.1	≥ 0.005
Pulse 3b	≤ +100	≤ 0.1	≥ 0.005
Pulse 4	not applicable		
Pulse 5b (only 42 V)	≤ 16	≤ 300,000	10,000

Table 8 – Maximum permissible transient emission for 24-V interference sources

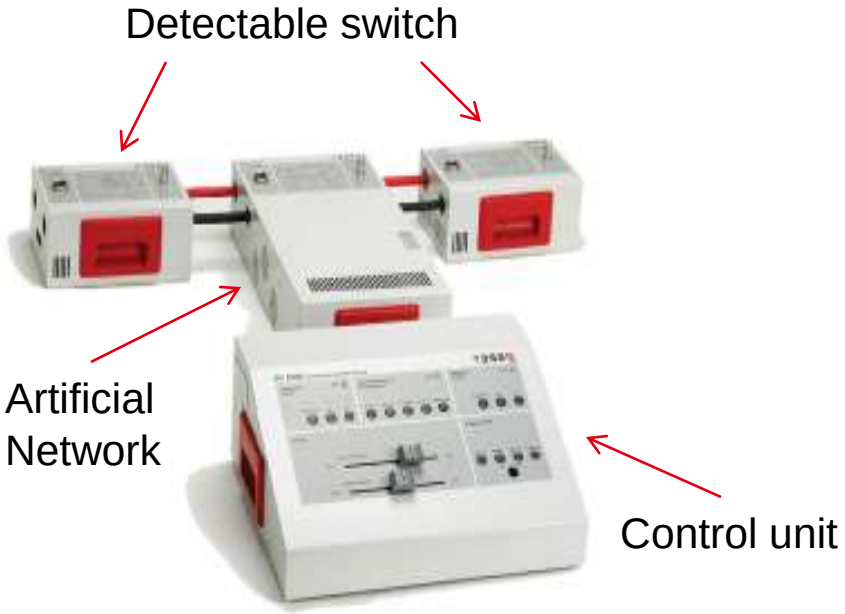
Pulse	U_s (V)	t_d (µs)	t_r (µs)
Pulse 1	≥ -150	≤ 2,000	≥ 1
Pulse 2	≤ +75	≤ 200	≥ 1
Pulse 3a	≥ -150	≤ 0.1	≥ 0.005
Pulse 3b	≤ +100	≤ 0.1	≥ 0.005
Pulse 4	not applicable		
Pulse 5	not applicable		

Nissan 28401NDS02 EQ/MC 01
Measurement of conducted transient emission

Nissan 28401NDS02 EQ/MC 01
Measurement of conducted transient emission

- Complicated Measurement Setup

Teseq Transient Emission System



AES 5500

Photograph Courtesy of HKPC

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Thank you!

Jeffrey Tsang
Jeffrey.tsang@teseq.com

Your Teseq partner:
Hong Kong Denetron International Limited
☎+852 2 707 9132
dhk@denetron.com.hk