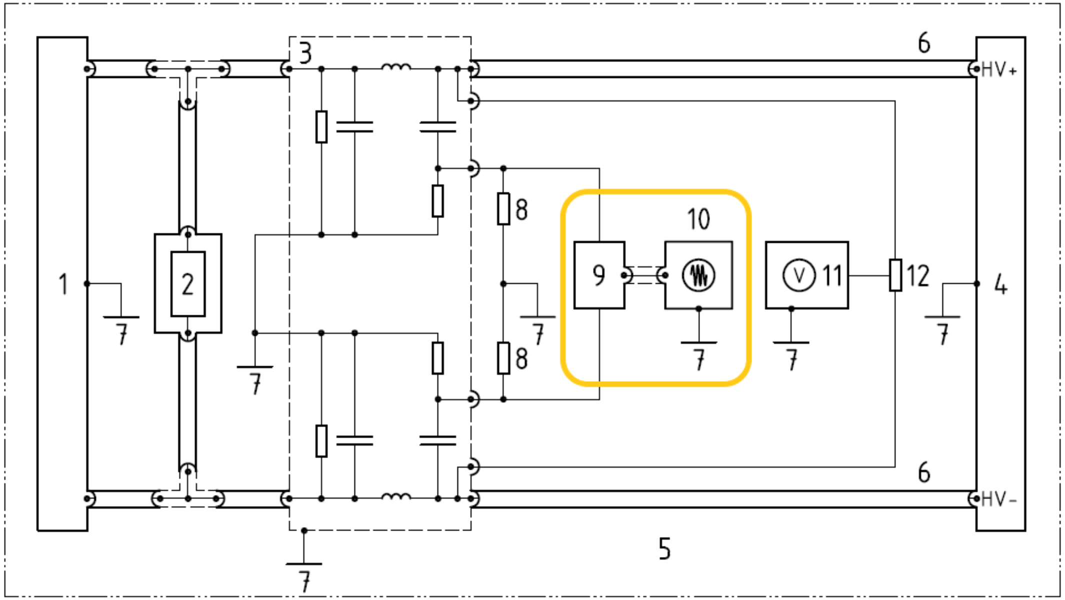
ISO 7637-4

- Electrical transient conduction along shielded high supply lines only
- 4.5 Voltage transient emission test
  - not a topic of this presentation, because no measurement equipment from A-EMC
- 4.6.2 Immunity test for pulsed sinusoidal disturbances (Pulse A)
  - Switching noises of MOSFETs and IGBTs in high voltage switching/commutating systems
- 4.6.3 Immunity test for low frequency sinusoidal disturbances (Pulse B)
  - Sinusoidal waves generated by harmonics from the grid and revolutions from, for example, electric propulsion motors

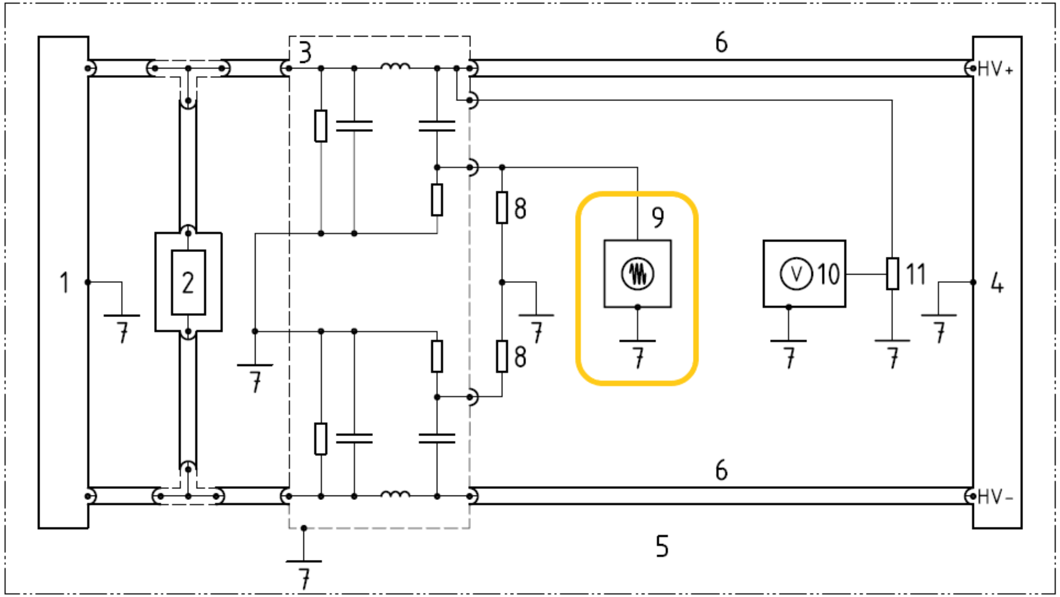
Pulse A: Line to line test



1 high voltage power supply
2 load for high voltage battery
3 shielded high voltage artificial network
4 DUT
5 ground plane
6 high voltage supply line
7 ground connection
8 50 Ω termination
9 balun transformer
10 sine wave generator
11 oscilloscope or waveform acquisition equipment
12 high voltage differential probe

Figure 2 — Transient immunity test set-up for pulsed sinusoidal disturbances pulse A (e.g. “line-to-line”)

Pulse A: Line to ground test



1 high voltage power supply
2 load for high voltage battery
3 shielded high voltage artificial network
4 DUT
5 ground plane
6 high voltage supply line
7 ground connection
8 50 Ω termination
9 sine wave generator
10 oscilloscope or waveform acquisition equipment
11 high voltage differential probe

Figure 3 — Transient immunity test set-up for pulsed sinusoidal disturbances pulse A (e.g. "HV+ line-to-ground")

Pulse A: Signal form and level

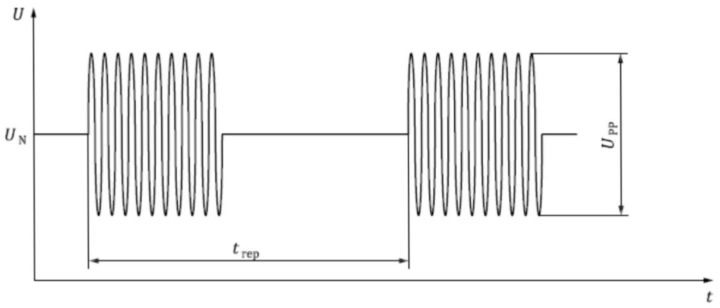


Figure B.1 — Test pulse A, sine wave pulses, e.g. on HV+

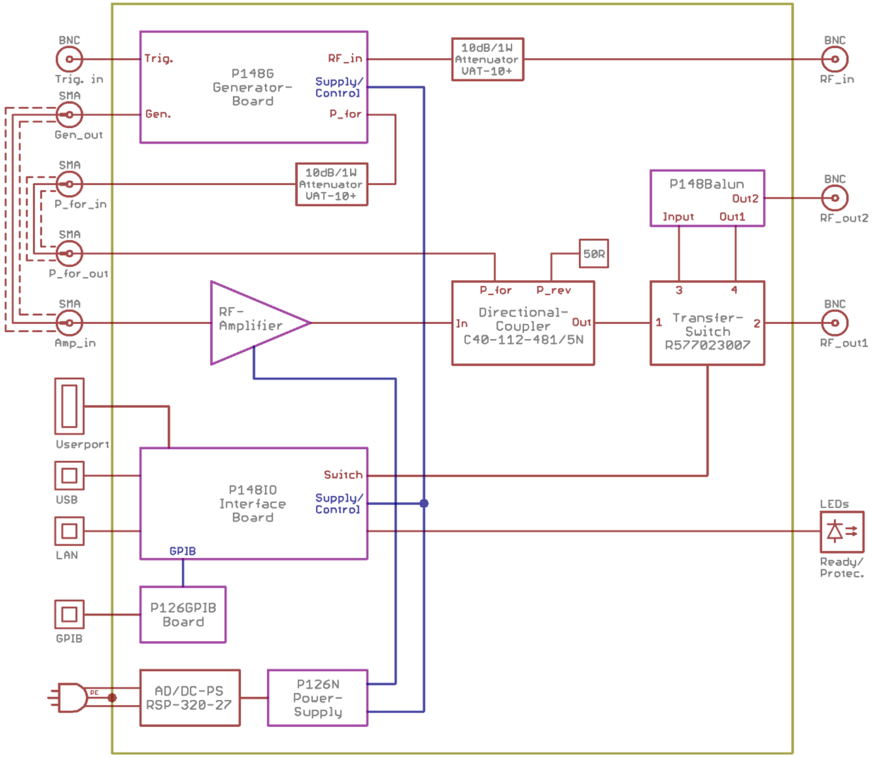
- Sinus Burst (10 Cycles)
- Burst Time 1, 2, 5, 10 µs
- Test Voltage defined in V_{PP} (unusual for RF)
- 20 V_{PP} = 7.07 V_{RMS} → 1 W @ 50 Ω = 30 dBm

Table A.1 — Parameters for test pulse A, pulsed sinusoidal disturbances

Pulse frequency (MHz)	Test voltage U_{pp} (V) [a] severity level				Oscillations per pulse packet	Repetition time (µs)	Test duration (minutes)	Test coupling
	I	II	III	IV				
1	20	50	100	[b]	10	200 / 100 / 50	5 / 5 / 5	HV+ to HV- HV+ to ground HV- to ground
2								
5								
10								

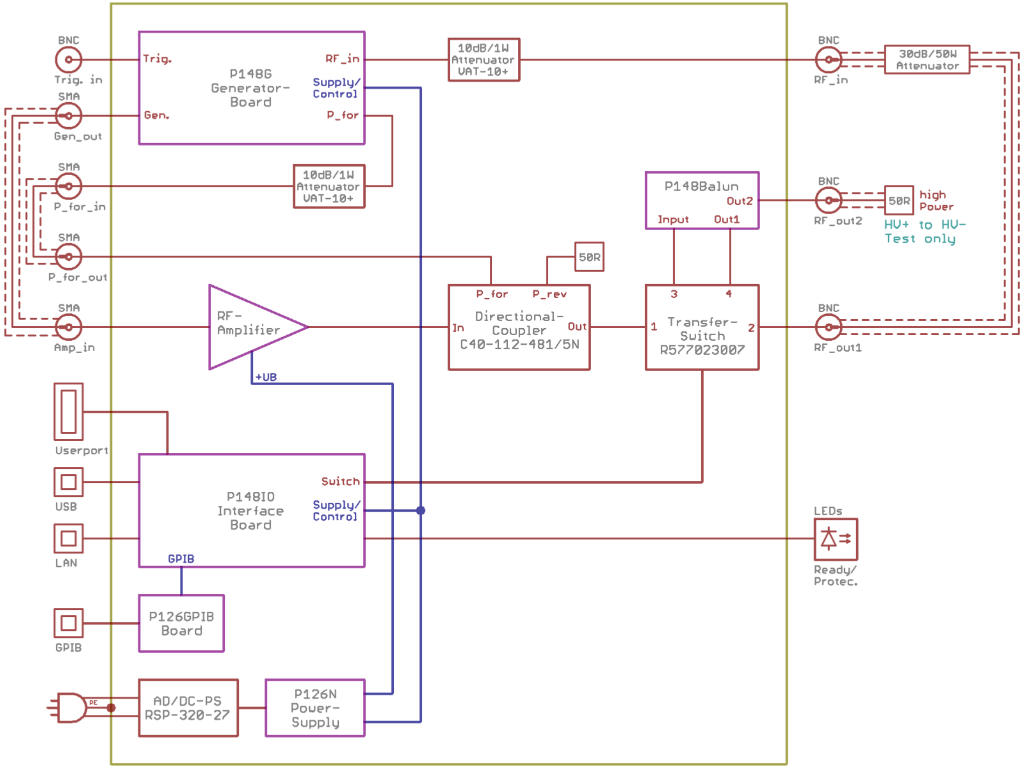
[a] Test voltage shall be set at 50 Ω load. Details shall be defined in the test plan.
Severity level is related to the HV nominal voltage (e.g. 5 % to 10 %).
[b] Severity level class for special applications: Details shall be defined in the test plan.

BLS 300-7637-4-A: Complete solution



- Burst Generator 100 kHz…10 MHz
- RF-Amplifier 100 kHz…400 MHz, 75 W
- Direction Coupler 100 kHz…400 MHz, 40 dB
- Power Meter 100 kHz…10 MHz
  Internal $P_{forward}$ (connect to DC)
  External RF_{in} (N connector front panel)
- Balun 100 kHz…10 MHz
- Transfer Switch unbalance ↔ balanced

BLS 300-7637-4-A: Level setting



- Unbalanced
  Connect RF_out1 with RF_in via attenuator (min. 30 dB/50 W)

- Balanced
  Connect RF_out1 with RF_in via attenuator (min. 30 dB/50 W)

  and connect a sufficent 50 Ω load to RF_out2

- Increase generator level until you measure the desired voltage/power. Measure RF-amplifier forward power, use this forward power during the test.

ISO 7637-4 Pulse A inaccuracies

- Level in Voltage Peak-Peak → in RF-world power @ 50 Ω
- Calculation is only accurate for small signals
- RF-amplifiers slowly go into saturation → Higher power means higher distortion!
- A large power reserve is required to fulfill the condition of a clean sine wave!
- Both connections on the balanced side of recommended balun are terminated with 50 ohms → Load on amplifier side is 25 Ω!
- You need more power for balun losses and unmatching load!
- 25 W not enough for all standard levels → 75 W offer a lot of margin

BLS 300-7637-4-A for more than this standard

- RF-Generator for CW and burst-signals: 100 kHz…10 MHz, -60…0 dBm
  Free defined burst parameter: 1…1000 cycles, 1…255 packets, period time 1 µs…3.64 ms Start and stop of the burst signal at exactly 0 degrees
  Internal and external trigger for burst control

- Powermeter 100 kHz…10 MHz with peak detector
  Internally connected via directional coupler: -20…60 dBm
  External: -60…+20 dBm

- Broadband amplifier from 10 kHz up to 400 MHz with different output power

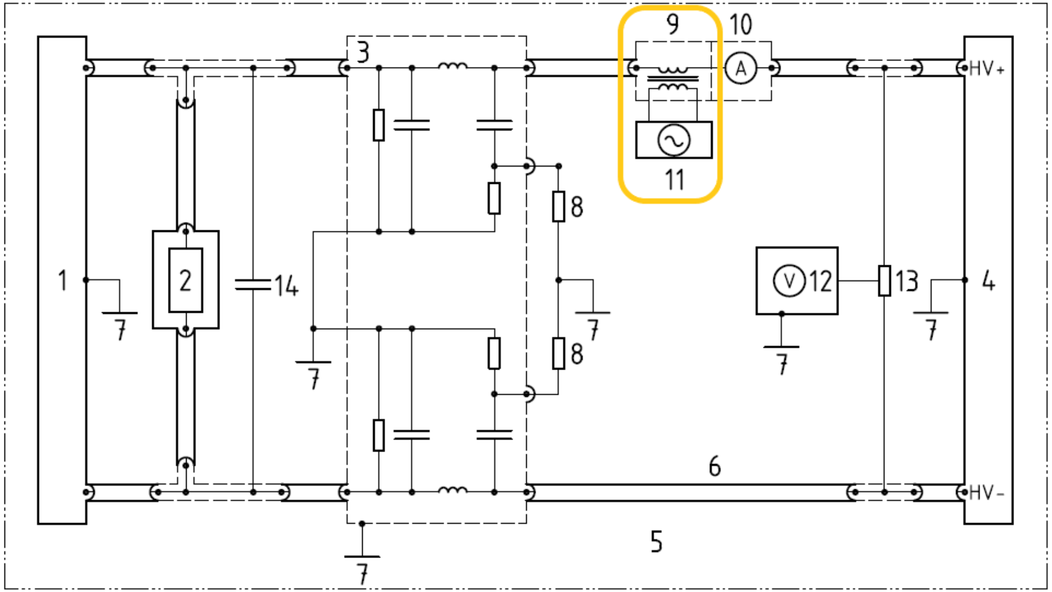
- Userport with galvanical isolated four digital inputs and outputs
  Analog (0…10 V) and digital (state or edge control) EUT monitor, Interlock function
  Temperature measurement with PT1000

BLS 300-7637-4-A control and programming

- Interface USB and LAN is standard, GPIB optional

- SCPI programming language:
  OUTP{?} OFF | 0 | ON | 1 → Set generator output signal
  OUTP:TYPE{?} UNB| BAL → Set transfer switch (Balun)
  FREQ{?} < NR2 / 0.1...10 > → Set generator frequency in Hz
  POW{?} < NR2 / -60.0...0.0 > → Set generator level in dBm
  BURS:COUN{?} < NR1 / 1...255 > | INF → Set number of burst packets
  BURS:NCYC{?} < NR1 / 1...1000 > → Set number of cycles in one burst packet
  BURS:PER{?} < NR1 / 1...3640 > → Set period time
  TRIG:SOUR{?} IMM | EXT → Define burst trigger signal
  MEAS[1][2]? → Measuring power of RF_{in} [1] or $P_{forward}$ [2] and reset peak detector
  CAL:ATT{?} < NR2 / 0.0...60 > → This value of the attenuator is added to the RF_{in} power
  CAL:DC:STAT{?} OFF | 0 | ON | 1 → Defines whether coupler values are added to $P_{forward}$ power

Pulse B: In-line HV+ test



1 high voltage power supply
2 load for high voltage battery
3 shielded high voltage artificial network (HV-AN)
4 DUT
5 ground plane
6 high voltage supply line
7 ground connection
8 50 Ω termination
9 coupling transformer
10 current monitoring (optional)
11 low frequency generator
12 oscilloscope or waveform acquisition
13 high voltage differential probe
14 capacitor ≥100 µF if using high voltage power supply instead of a battery

Figure 6 — Transient immunity test set-up for low frequency sinusoidal disturbances pulse B (e.g. “in-line HV+”)

Puls B: Line to ground test

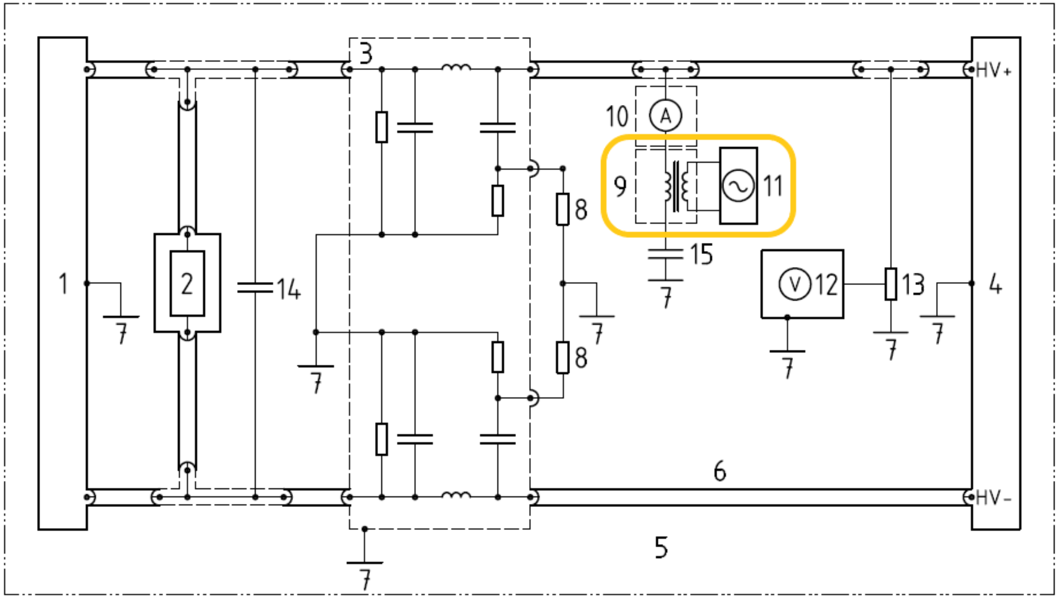


Figure 7 — Transient immunity test set-up for low frequency sinusoidal disturbances pulse B (e.g. "HV+ line-to-ground")

1 high voltage power supply
2 load for high voltage battery
3 shielded high voltage artificial network (HV-AN)
4 DUT
5 ground plane
6 high voltage supply line
7 ground connection
8 50 Ω termination
9 coupling transformer
10 current monitoring (optional)
11 low frequency generator
12 oscilloscope or waveform acquisition
13 high voltage differential probe
14 capacitor ≥100 µF if using high voltage power supply instead of a battery
15 capacitor, e.g. 100 nF (value is adjusted for the frequency at which it is used)

Pulse B: Signal form and level

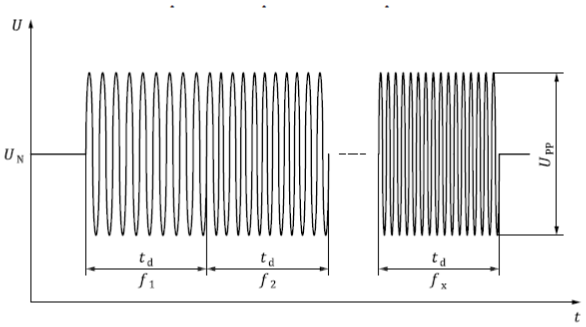


Figure B.2 — Test pulse B, low frequency sinusoidal disturbances

- No pulse → continuous sine wave
- Test level setting with open load (without DUT)
- During test voltage could be much lower dependence of DUT impedance!
- Test time each frequency step is 2 s

Table A.2 — Parameters for test pulse B, low frequency sinusoidal disturbances

Test frequency f_{PWM}	Frequency step	Test voltage U_{pp} (V) [c] severity level				Dwell time per step (s)	Test coupling
		I	II	III	IV		
Optional: <3 kHz [a]	[a]	[a]	[a]	[a]	[b]	2	HV+ to HV- HV+ to ground HV- to ground
3 kHz - 30 kHz	e.g. 1 kHz	5	15	25	[b]		
30 kHz - 300 kHz	e.g. 10 kHz	0,5	1,5	2,5	[b]		

[a] Optional test frequencies and severity levels for applications with relevant harmonics <3 kHz: Details shall be defined in the test plan.

Severity level is related to the HV nominal voltage (e.g. 5 % to 10 %).

[b] Severity level class for special applications: Details shall be defined in the test plan.

[c] The test voltage is set under open load condition.

Pulse B: Amplifier

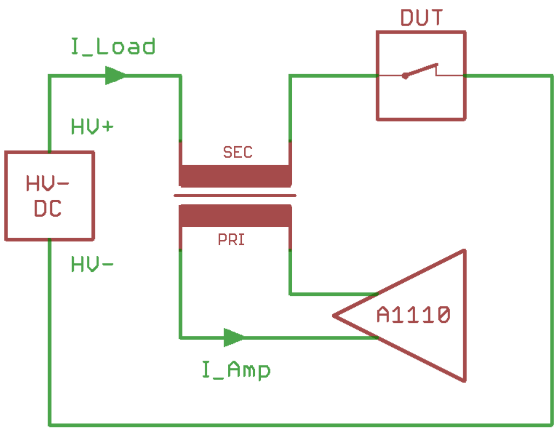
- Amplifier:
  - Frequency range: 3…300 kHz
  - Output voltage: 30 V_{RMS} (3…250 kHz) / 25 V_{RMS} (250…300 kHz)
  - Output current: 16 A_{RMS}
- No special requirements
- Could be easy fulfill with standard BOLAB amplifier

Pulse B: Transformer

- Couple disturbances into the DUT
- Isolate amplifier from high voltage circuit
- No requirements about main inductivity
- No requirements about output impedance

- Iron core for high saturation and soft saturation behavior
- Main inductivity so high as necessary and low as possible → choice 100 uH
- Can be used from 1 kHz with BOLAB amplifier

ISO 7637-4 Pulse B possible problems



Transformer isolate HV+ and load current from amplifier
Beware of transient events:

- when the high voltage supply rise up or fall down
- when current change its value rapidly, e.g. due to switch off of the DUT

Transformer also couples AC load currents to primary side:

- Amplifier supplies a counter current to maintain its voltage
- If this current is too high, amplifier switches off
- High voltage on amplifier output can destroy it!

In case of doubt, overvoltage protection should always be provided at the amplifier output!