Electromagnetic Compatibility (*EMC*)

Introduction about Impulse

Immunity Testing (IEC example)

Agenda

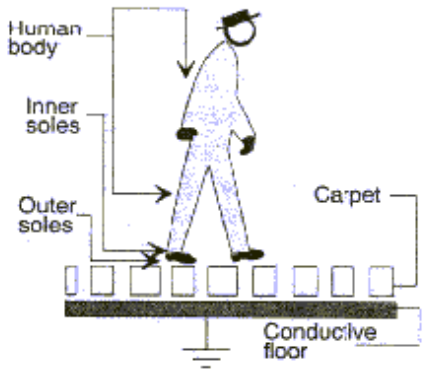
- Electrostatic Discharge (ESD)
  - IEC 1000-4-2
- Radiated, radio-frequency electromagnetic field immunity (Susceptibility / immunity to Radiated Emission)
  - IEC 1000-4-3
- Electrical Fast Transient (EFT) / Burst Immunity
  - IEC 1000-4-4
- Lightning / Surge Immunity
  - IEC 1000-4-5
- Immunity to Conducted Disturbances included by radio-frequency fields above 9KHz
  - IEC 1000-4-6

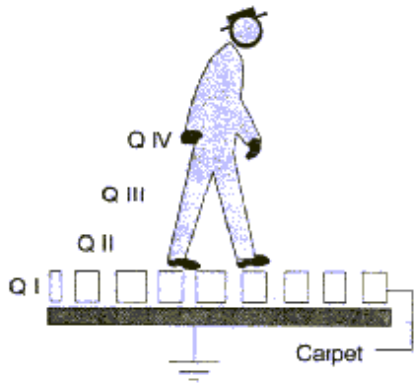
Pulsed Interference Immunity

System Immunity Test

Pulsed Interference Immunity -- ESD

- Buildup of voltage resulting from ESD





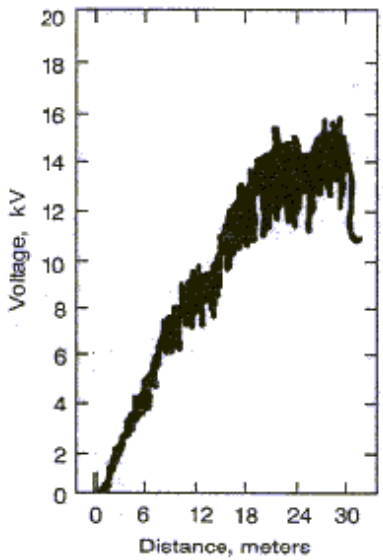


Table 2-2 Materials that exhibit electrostatic discharge

+Ve charge ↑

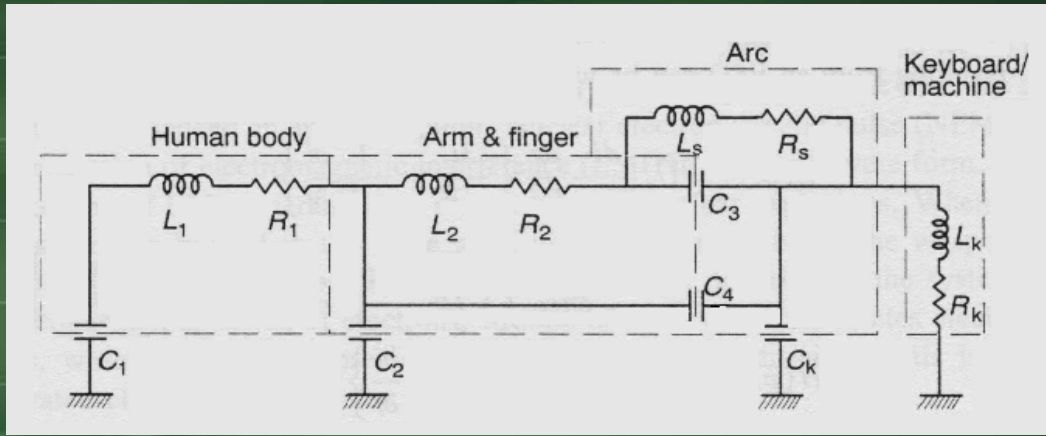
Asbestos
Acetate
Glass
Human Hair
Nylon
Wool
Fur
Lead
Silk
Aluminum
Paper
Polyurethane
Cotton
Wood
Steel
Sealing Wax
Hard Rubber
Mylar
Epoxy Glass
Nickel, Copper, Silver
Brass, Stainless Steel
Synthetic Rubber
Acrylic
Polystyrene Foam
Polyurethane Foam
Polyester
Saran
Polyethylene
Polypropylene
PVC (Vinyl)
Teflon
Silicon Rubber

-Ve charge ↓

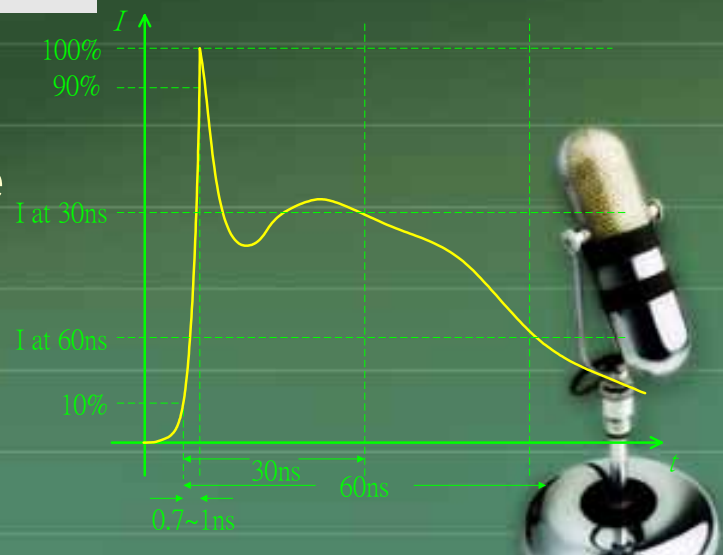
System Immunity Test

Pulsed Interference Immunity -- ESD

- Equivalent circuit model for human body ESD



- ESD waveform
  - First term：finger / forearm discharge
  - Second term：body discharge



System Immunity Test

Pulsed Interference Immunity -- ESD

- E/H fields produced by ESD

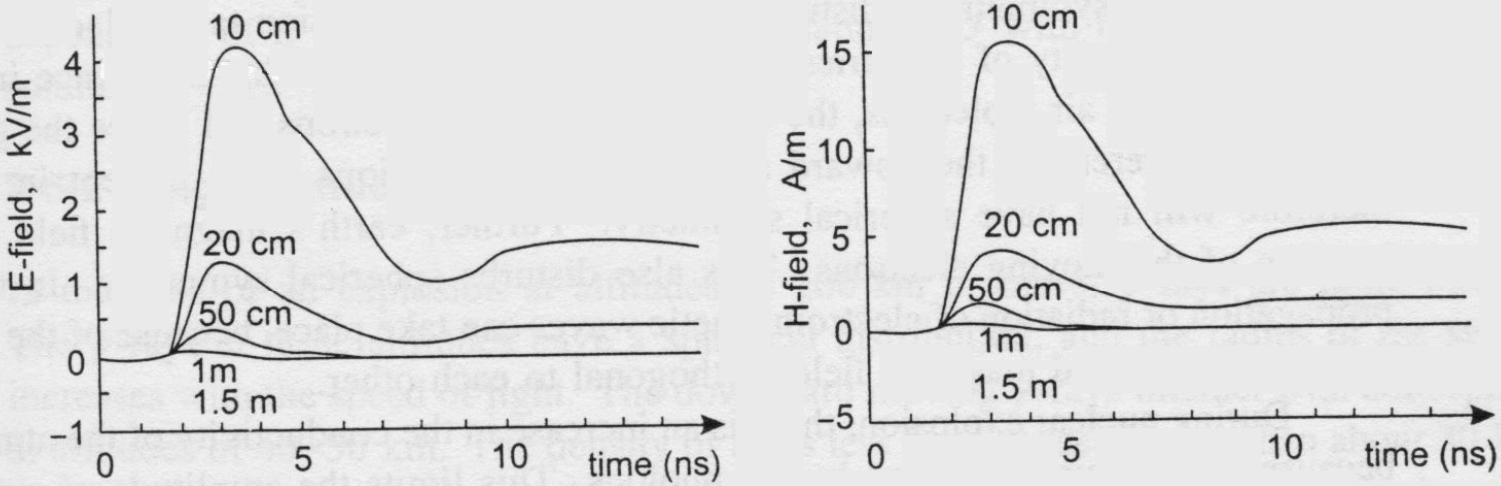


Figure 2-7 *E* and *H* fields produced by a 4 kV electrostatic discharge at various distances from the ESD [*Source: Reference 6*]

IEC 1000-4-2

Electrostatic Discharge immunity test

Electrostatic Discharge

- Test level
- ESD generator
- ESD generator model
- Test set-up
- Test procedure
- Test result

Electrostatic Discharge

Test level

Contact discharge		Air discharge	
Level	Test Voltage kV	Level	Test Voltage kV
1	2	1	2
2	4	2	4
3	6	3	8
4	8	4	15
X	Special	X	Special

- “x” is an open level
- Contact discharge is the preferred test method
- People can’t feel ESD levels below 3kv, but 2kV certainly damages many items

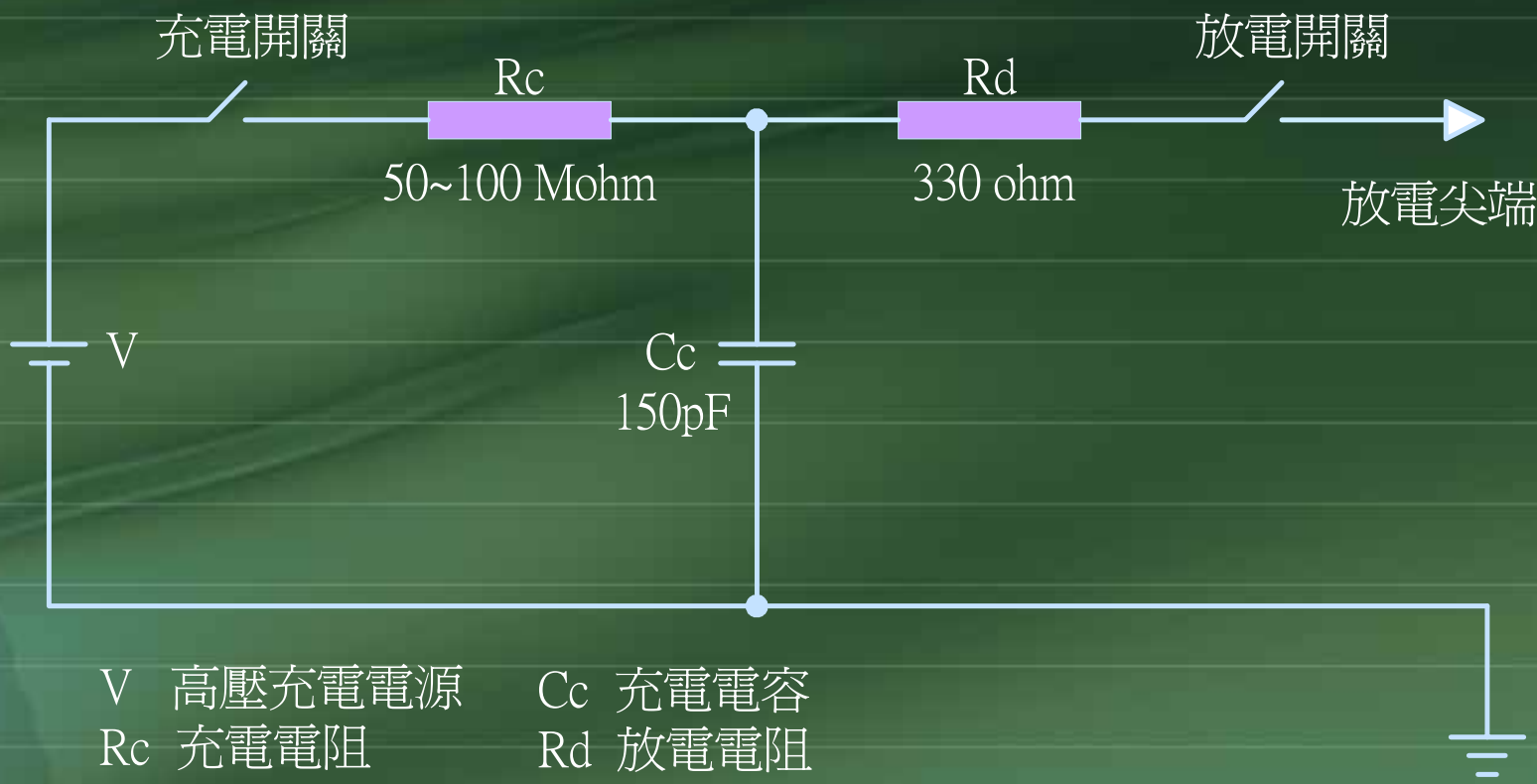
Electrostatic Discharge

ESD generator

- Output voltage
  - Up to 8kv for contact discharge
  - Up to 15kv for air discharge
- Polarity of the output voltage
  - Positive
  - Negative
- Discharge mode of operation
  - Single discharge
  - Time between successive discharge at least 1s

Electrostatic Discharge

ESD generator model

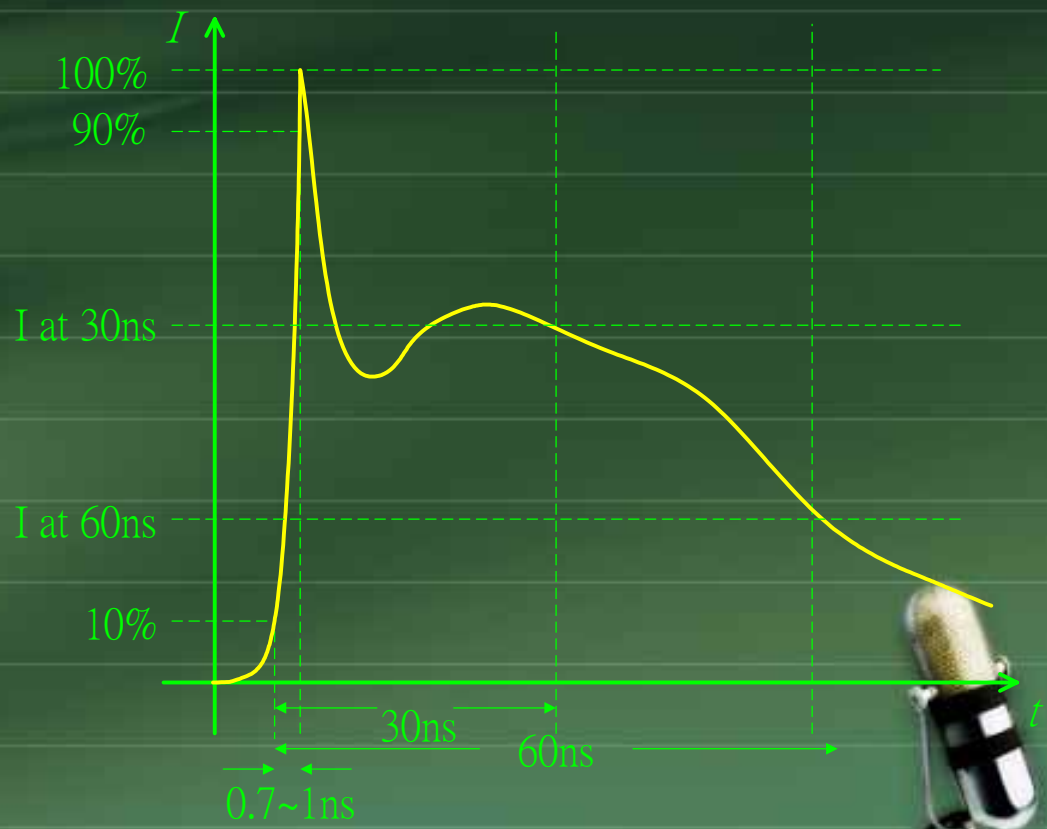


V 高壓充電電源　　Cc 充電電容
Rc 充電電阻　　Rd 放電電阻

Electrostatic Discharge

Typical test waveform of output current

Level	Voltage (kV)	First peak current of discharge (A)	Rise time (ns)	Current at 30ns (A)	Current at 60ns (A)
1	2	7.5	0.7~1	4	2
2	4	15	0.7~1	8	4
3	6	22.5	0.7~1	12	6
4	8	30	0.7~1	16	8



Electrostatic Discharge

Test set-up

- Direct application
  - Contact discharge to the conductive surfaces and to coupling planes
  - Air discharge at insulating surfaces
- Indirect application
  - 水平耦合(HCP)
  - 垂直耦合(VCP)

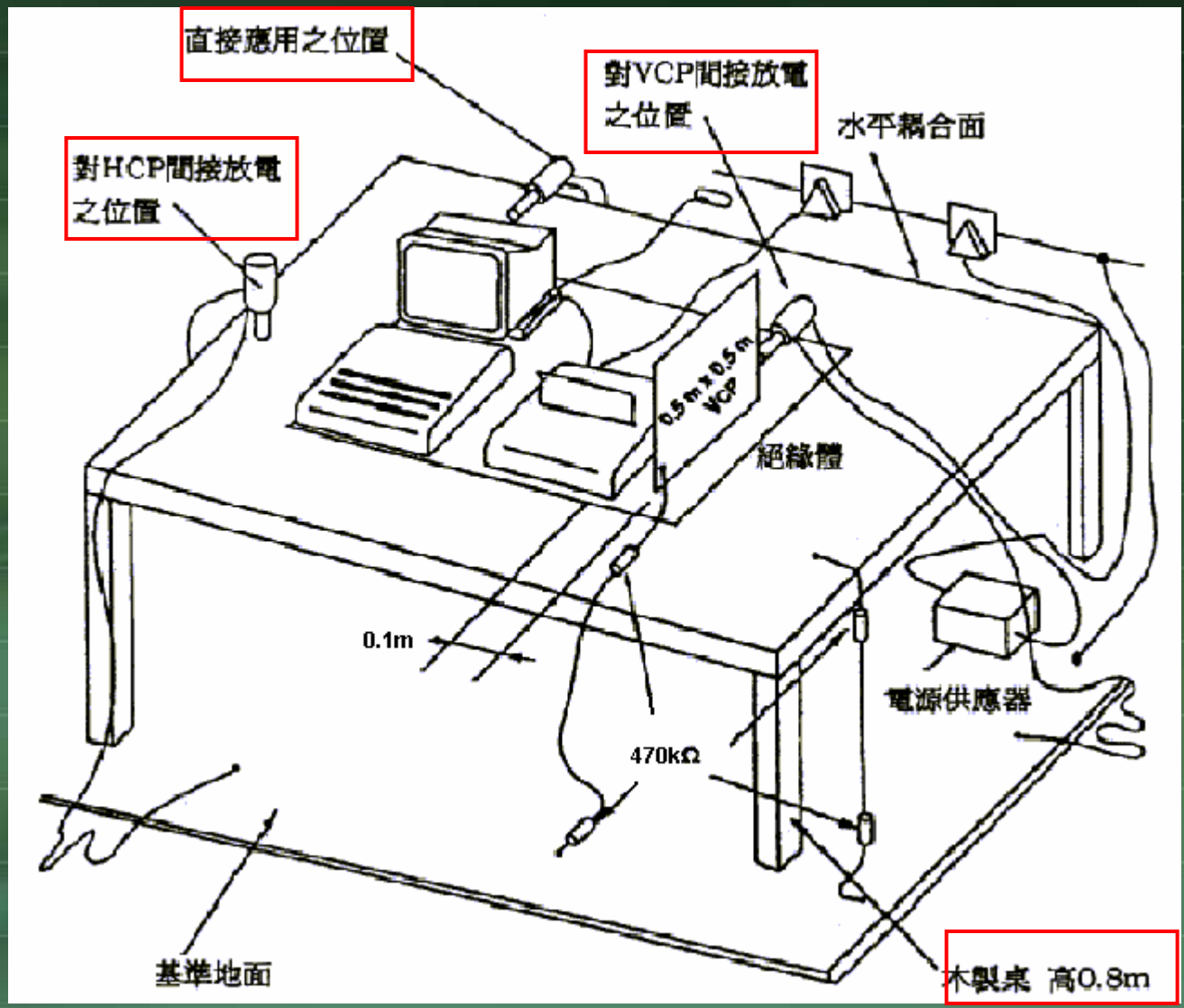
Electrostatic Discharge

Test set-up

- Two type of test
  - Type test performed in laboratories
    - The preferred test method
  - Post-installation test performed on equipment in its final installed conditions
    - Optional, not mandatory

Electrostatic Discharge

Test set-up -- in a laboratory



Electrostatic Discharge

Test procedure

- Verify the laboratory reference conditions
- The correct operation of the equipment
- The execution of the test
- The evaluation of the test result

Electrostatic Discharge

Direct application of discharges

- Applied only to such points and surfaces accessible to personnel during normal usage
- Single discharges
- At least ten single discharges shall be applied in the most sensitive polarity
- ESD generator shall be held perpendicular to the discharge surface

Electrostatic Discharge

Direct application of discharges

- Discharges to objects near the equipment can be simulated by applying the discharge to a coupling plane
  - Horizontal coupling plane under the equipment
    - Discharge point vertically at 0.1m from the equipment
    - At least ten single discharges
  - Vertical coupling plane
    - Discharge point at 0.1m from the equipment
    - At least ten single discharges

Electrostatic Discharge

Test result and test report

- Normal performance within the specification limits
- Temporary degradation or less of performance which is self-recoverable
- Degradation or less of performance which requires operator intervention or system reset to recover
- Degradation or less of function which is not recoverable

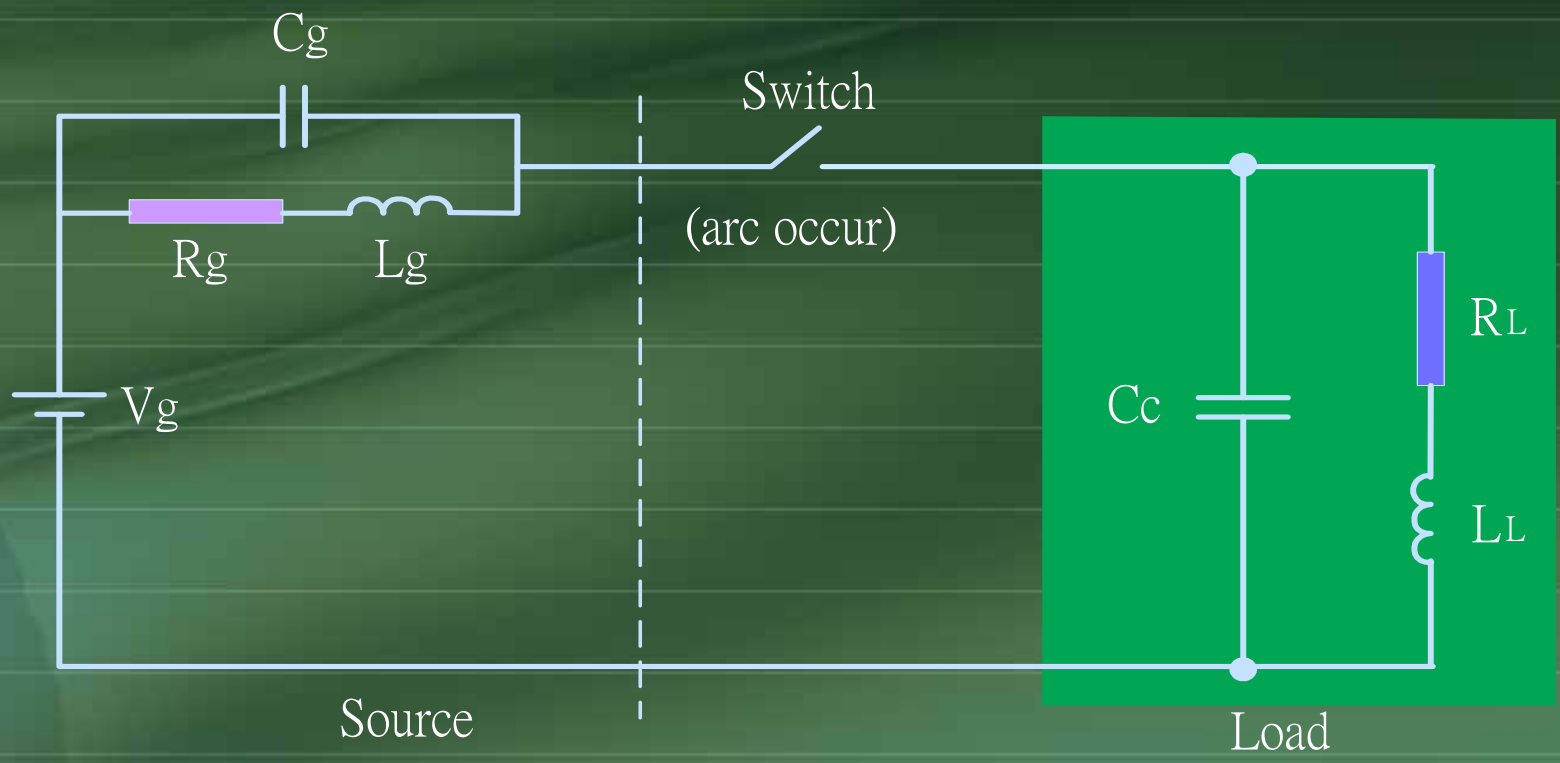
Agenda

- Electrostatic Discharge (ESD)
  - IEC 1000-4-2
- Radiated, radio-frequency electromagnetic field immunity (Susceptibility / immunity to Radiated Emission)
  - IEC 1000-4-3
- Electrical Fast Transient (EFT) / Burst Immunity
  - IEC 1000-4-4
- Lightning / Surge Immunity
  - IEC 1000-4-5
- Immunity to Conducted Disturbances included by radio-frequency fields above 9KHz
  - IEC 1000-4-6

System Immunity Test

Pulsed Interference Immunity -- EFT

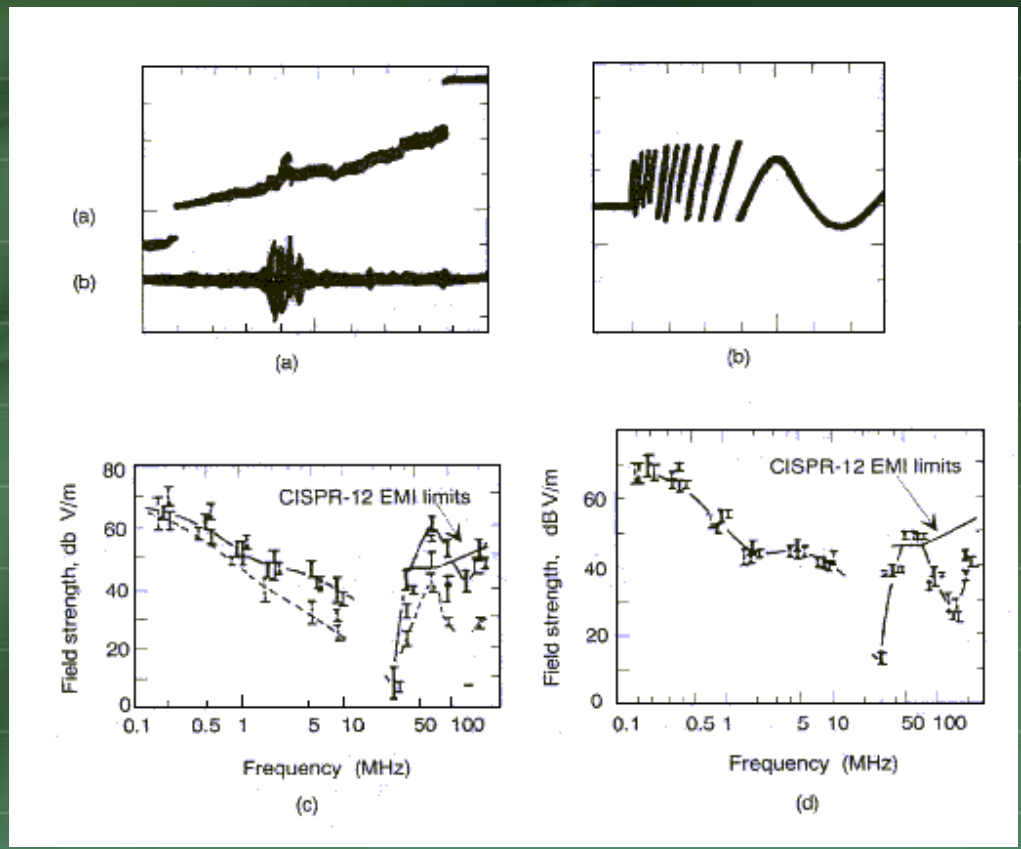
- Equivalent circuit of a relay/switch circuit



System Immunity Test

Pulsed Interference Immunity -- EFT

- Electromagnetic noise from make or break contact of a telephone relay switch



IEC 1000-4-4

Electrical Fast Transient / burst immunity test

Electrical fast transient

- Test level
- EFT generator
- EFT generator model
- Test set-up
- Test procedure
- Test result

Electrical Fast Transient

Test level

Level	On power supply port, PE		On I/O signal, data and control ports	
	Voltage peak kV	Repetition rate kHz	Voltage peak kV	Repetition rate kHz
1	0.5	5	0.25	5
2	1	5	0.5	5
3	2	5	1	5
4	4	2.5	2	5
x	Special	Special	Special	Special

- “X” is an open level
- The test level should be selected for the most realistic installation conditions
- The I/O,data and control signal ports use half the test voltage values applied on power supply ports

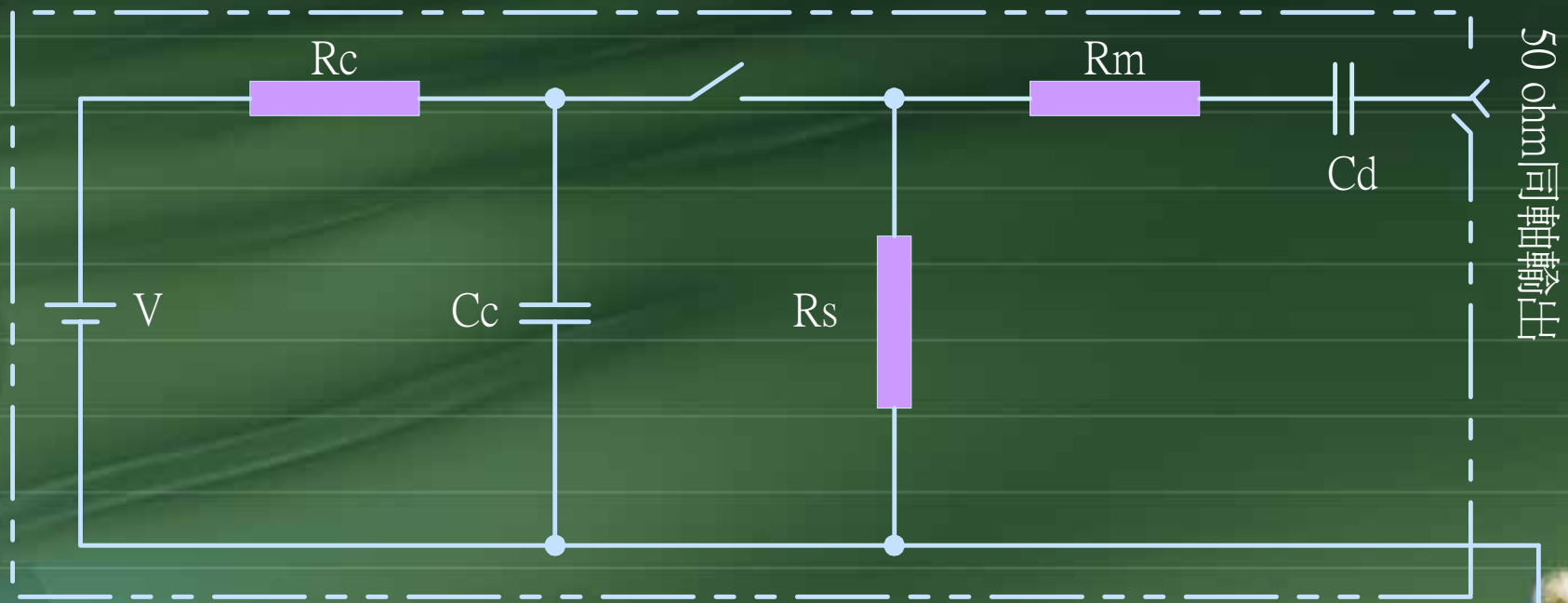
Electrical Fast Transient

EFT generator

- Characteristics for operation into 50Ω load conditions
  - Repetition rate：5 KHz
  - Rise time of one pulse ： 5ns ± 30%
  - Impulse duration (50%) ： 50ns ± 30%
  - Burst duration ： 15ms ± 20%
  - Burst period ： 300ms ± 20%
- Test method
  - Polarity of the output voltage
    - Positive / Negative test
  - Different phases to couple (0^o / 90^o / 180^o)
  - Different lines to couple (Phase / Neutral / Ground)

Electrical Fast Transient

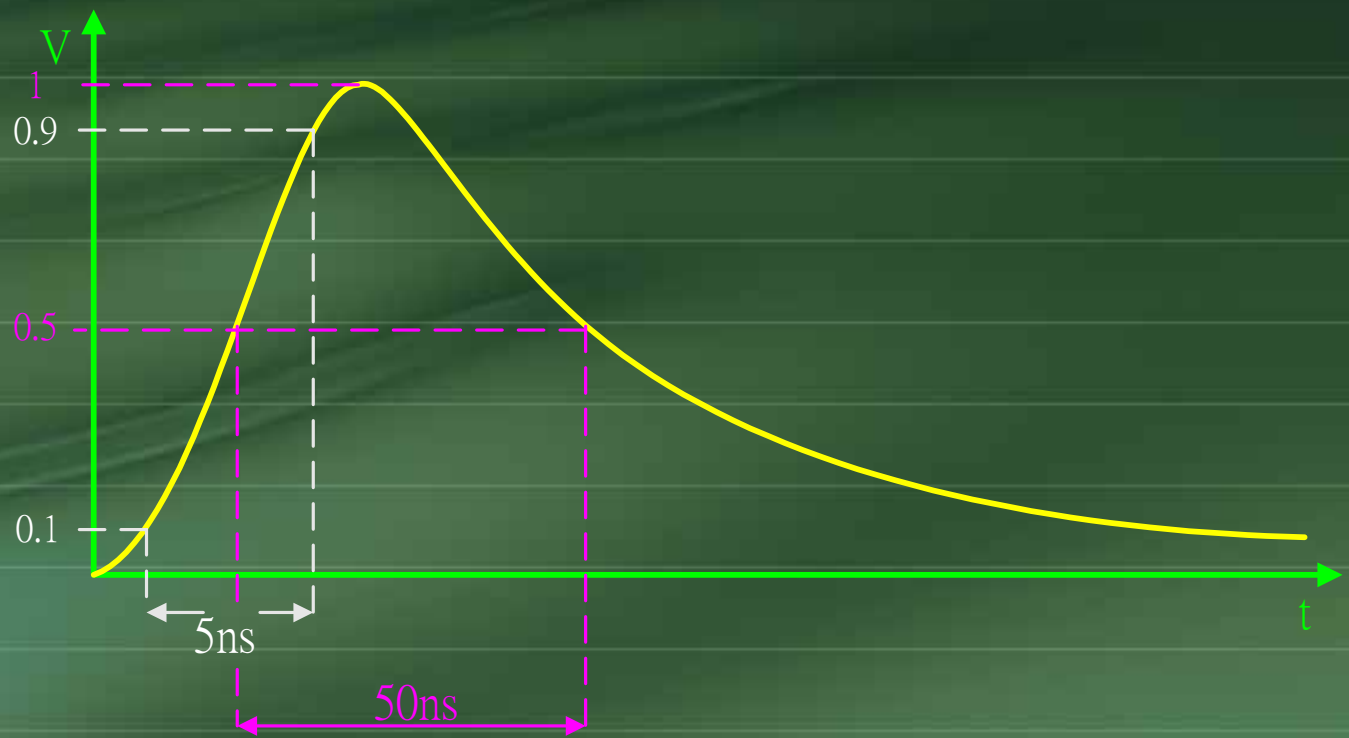
EFT generator model



V	高壓電源	Rs	脈波保持時間整型電阻
Rc	充電電阻	Rm	阻抗匹配電阻
Cc	儲能電容	Cd	直流阻隔電容

Electrical Fast Transient

Single pulse into a 50Ω load



Electrical Fast Transient

General graph of a fast transient/bust

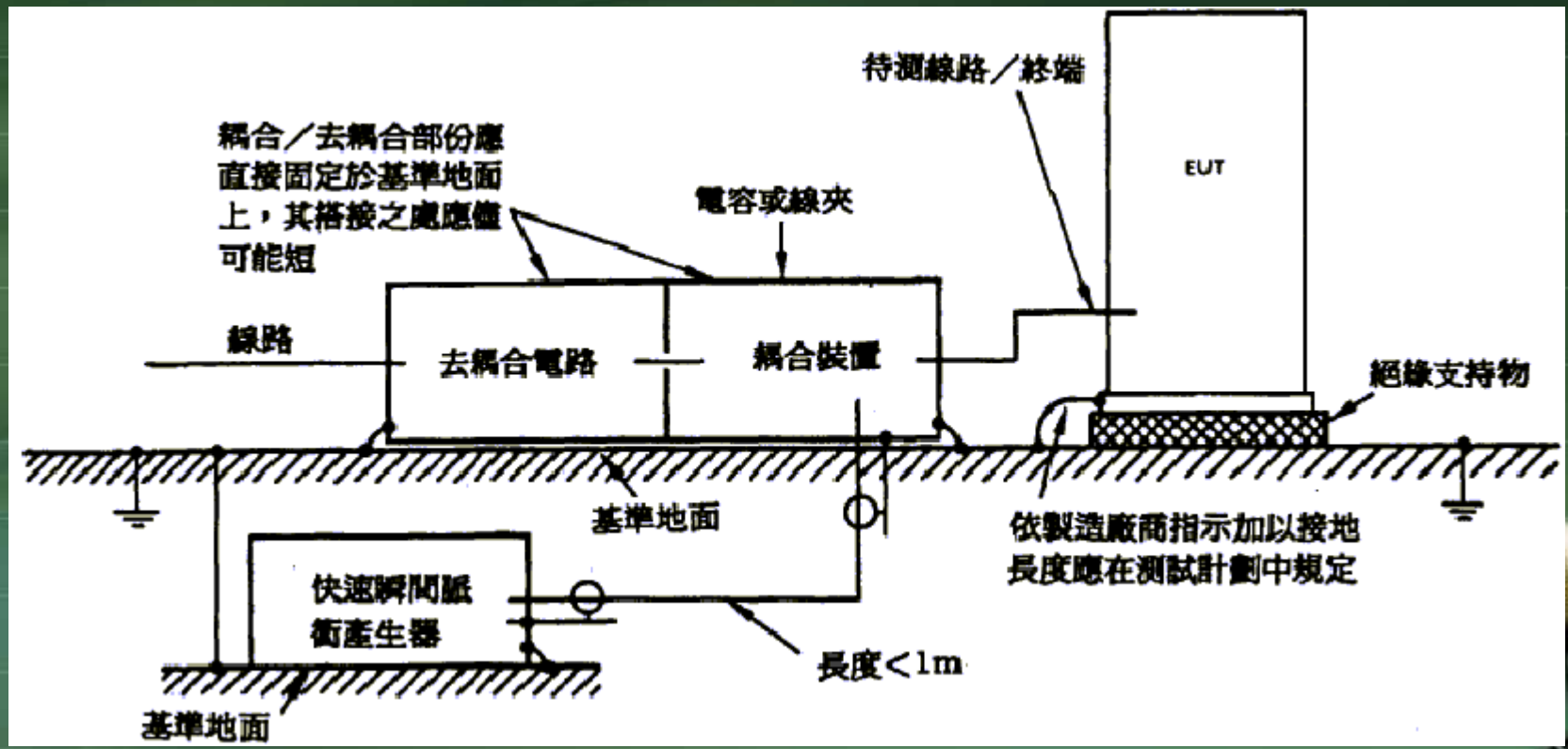
Electrical Fast Transient

Test set-up

- Type test
  - Performed in laboratories
  - The preferred test method
- Post-installation test
  - Performed on equipment in its final installed conditions
  - Optional, not mandatory
  - Without coupling / decoupling networks
    - To simulate the actual electromagnetic environment as closely as possible

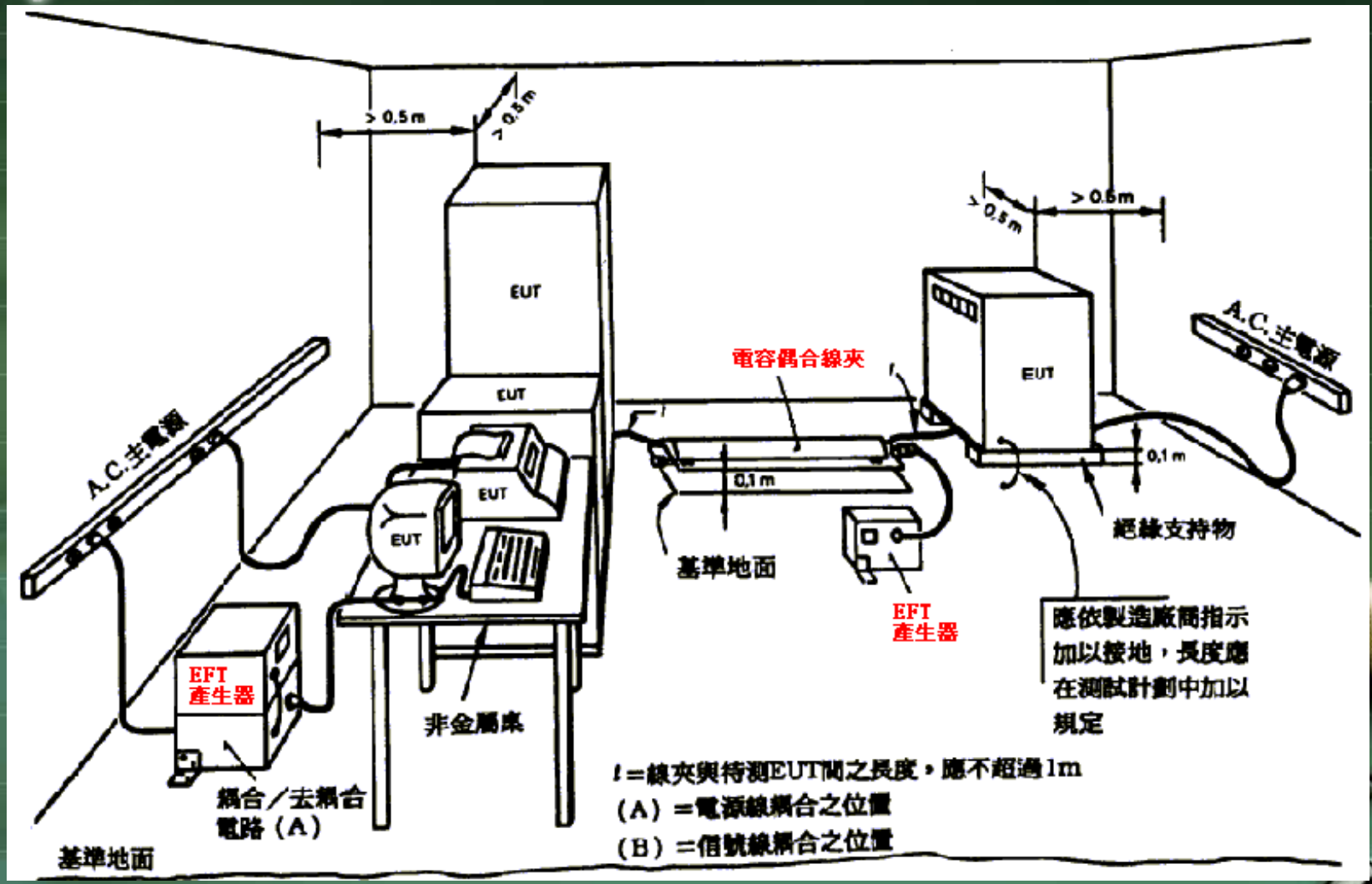
Electrical Fast Transient

Test set-up



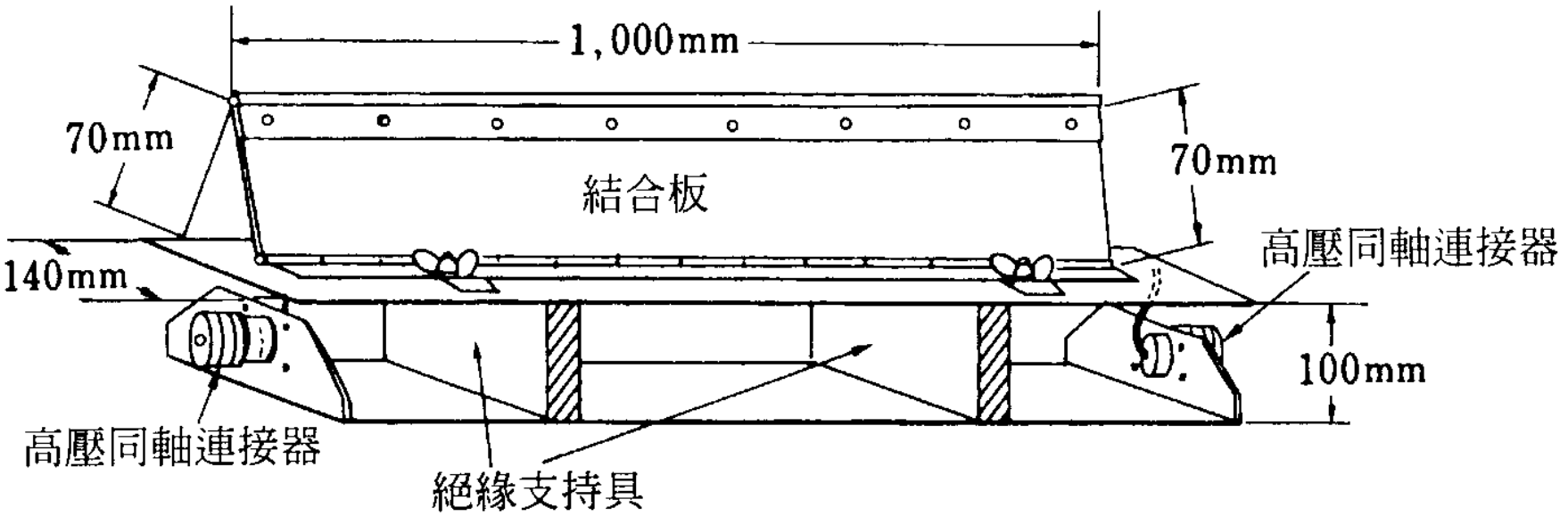
Electrical Fast Transient

Test set-up



Electrical Fast Transient

Test set-up



註) 結合部與所有其他導電構造物的距離除試驗電纜與接地板必須爲 0.5m 以上

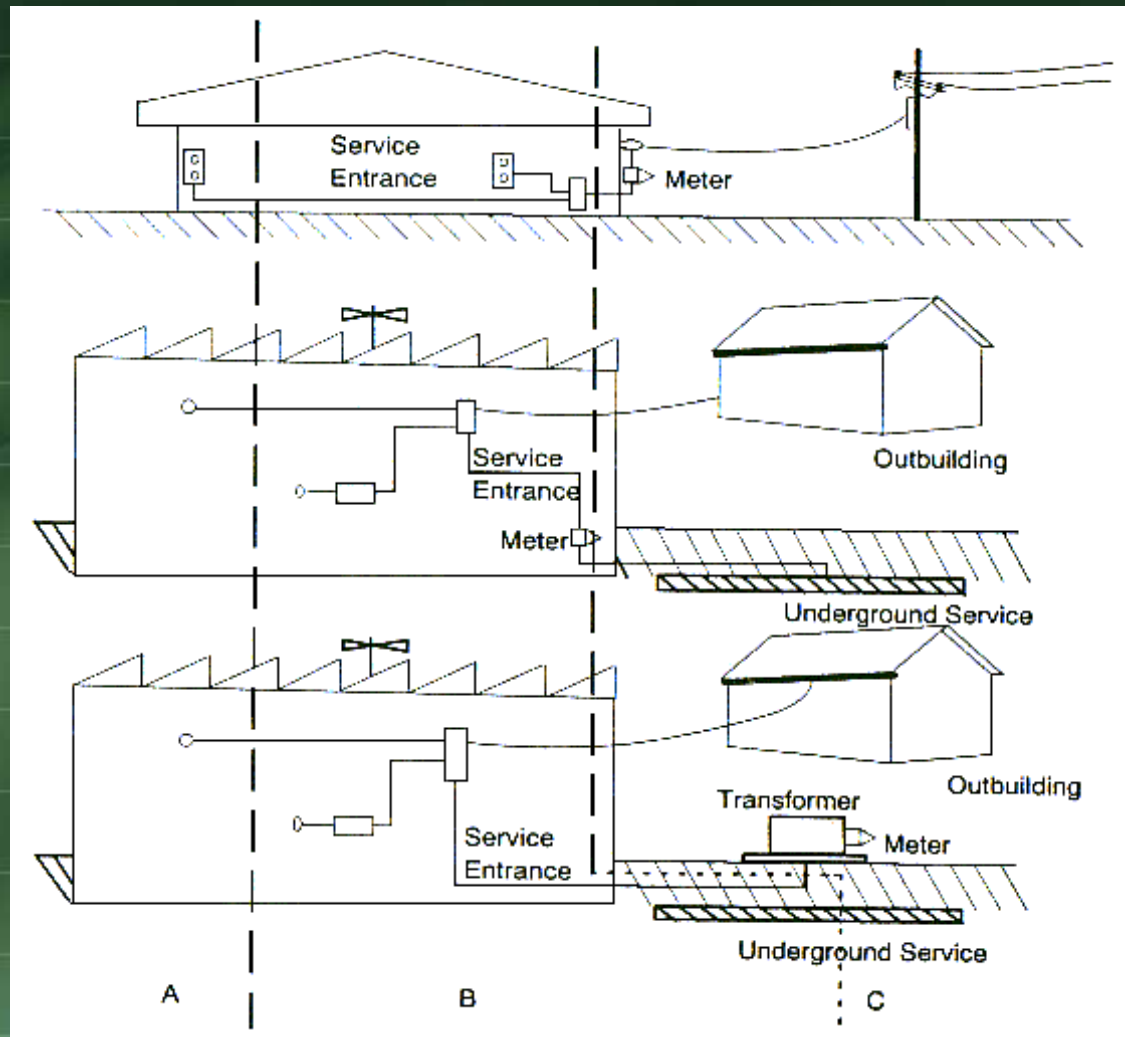
Agenda

- Electrostatic Discharge (ESD)
  - IEC 1000-4-2
- Radiated, radio-frequency electromagnetic field immunity (Susceptibility / immunity to Radiated Emission)
  - IEC 1000-4-3
- Electrical Fast Transient (EFT) / Burst Immunity
  - IEC 1000-4-4
- Lightning / Surge Immunity
  - IEC 1000-4-5
- Immunity to Conducted Disturbances included by radio-frequency fields above 9KHz
  - IEC 1000-4-6

System Immunity Test

Pulsed Interference Immunity -- Surge

- A. Outlet and long branch circuit
- B. Feeders and short branch circuit
- C. Outside and service entrance



System Immunity Test

Pulsed Interference Immunity -- Surge

- In general as surges travel, they become attenuated with distance of travel.
  - Surge travels as a voltage transient between the line and neutral or ground, and it can result in an arc-over whenever the line wire is close enough to a grounded conductor or equipment.
  - It may also travel along well-protected power supply lines to reach the receptor equipment. In this case, the input stages of the receptor may get damaged.
  - It may also result in arc-over within the receptor equipment

System Immunity Test

Pulsed Interference Immunity -- Surge

- There is no universal model that is representative of all surges
  - Voltage, frequency spectrum are vastly different
- What is practical interesting depend on the matter in which a surge is presented to the receptor equipment.

IEC 1000-4-5

Surge

Surge

- Test level
- Surge generator
- Surge test principles
- Surge generator model
- Test set-up

Surge

Test level

3. 嚴酷度位準之選擇：嚴酷度位準依安裝狀態及下表及圖 22至24而加以選擇。對加強耐受性額外之測量，必須模擬實際安裝下主要之保護。

表4　試驗嚴酷度位準之選擇（依安裝狀態而定）

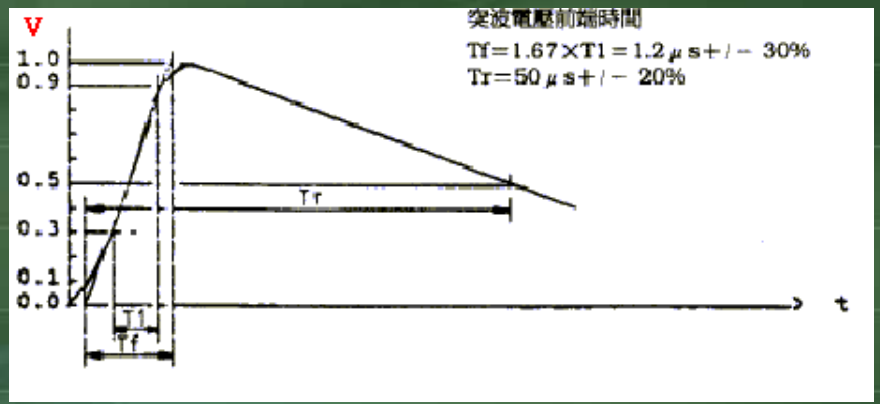
位準等級	試驗嚴酷度位準							
	電源耦合模式		I/O,LDB耦合模式		平衡電路耦合模式		SDB,DB耦合模式	
	線對線	線對地	線對線	線對地	線對線	線對地	線對線	線對地
0	—	—	—	—	—	—	—	—
1	—	0.5kV	—	0.5kV		0.5kV		
2	0.5kV	1.0kV	0.5kV	1.0kV		1.0kV		0.5kV
3	1.0kV	2.0kV	1.0kV	2.0kV		2.0kV		
4	2.0kV	4.0kV	2.0kV	4.0kV		—		
5	—	—	2.0kV	4.0kV		4.0kV		
X								

Surge

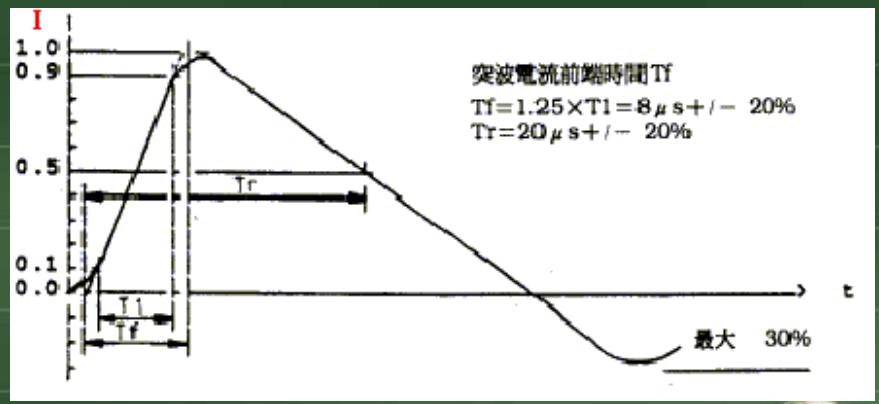
Surge generator

- Combination wave representing high-energy surges for the test of short branch devices
  - The device is closed to the noise source

0.5K~4kV以上



0.25kA~2.0kA以上

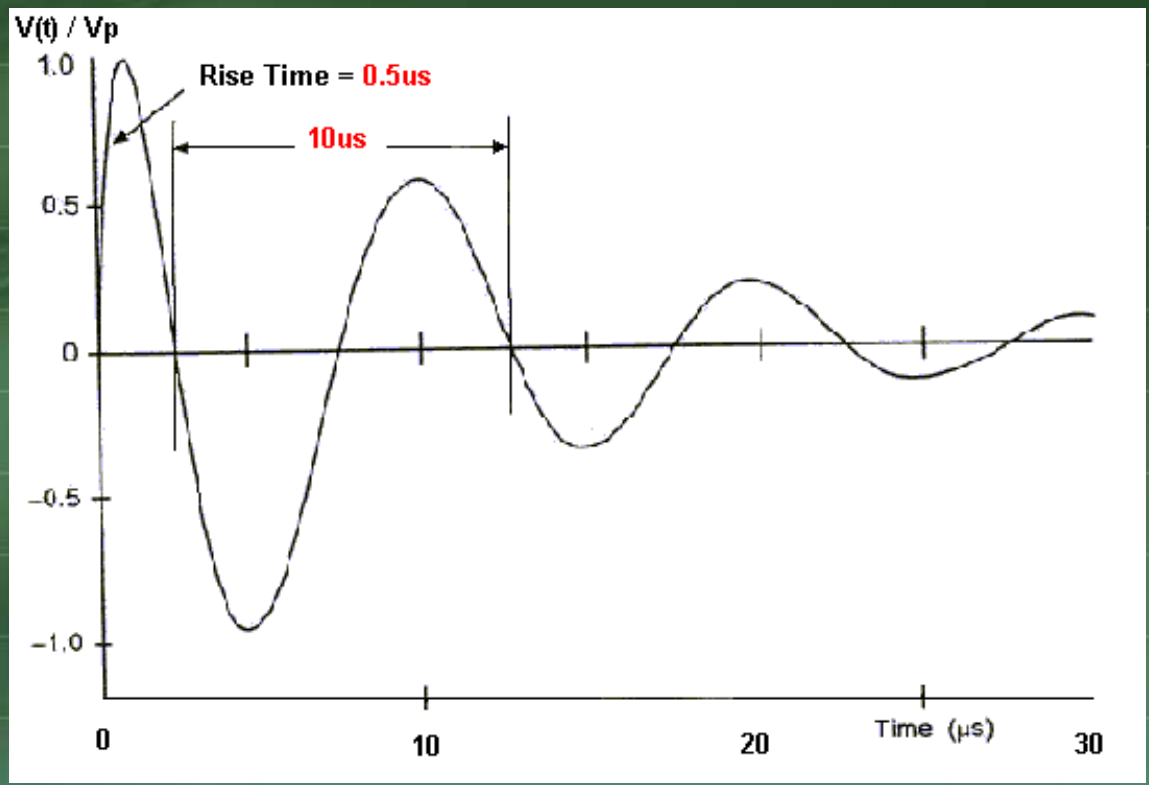


	上升時間	持續時間	上升時間 10%~90%	持續時間 50%~50%
開路電壓	1.2 us	50 us	1 us	50 us
短路電流	8 us	20 us	6.4 us	16 us

Surge

Surge generator

- Ring wave representing oscillatory surges for the test of long branch devices
  - Due to resonance, surge on power line usually exhibits damped oscillatory waveform 100k~1MHz



Surge

Surge test principles

- Surge test on low-voltage power supply lines
  - Power lines carry voltage up to 1KV
- Surge duration
  - Less than 1ms or less than one half-cycle of the power frequency
- Surge test once per minute
- Safety of the personnel and equipment in surge test is very important.
  - Receptor under test is located inside a special enclosure

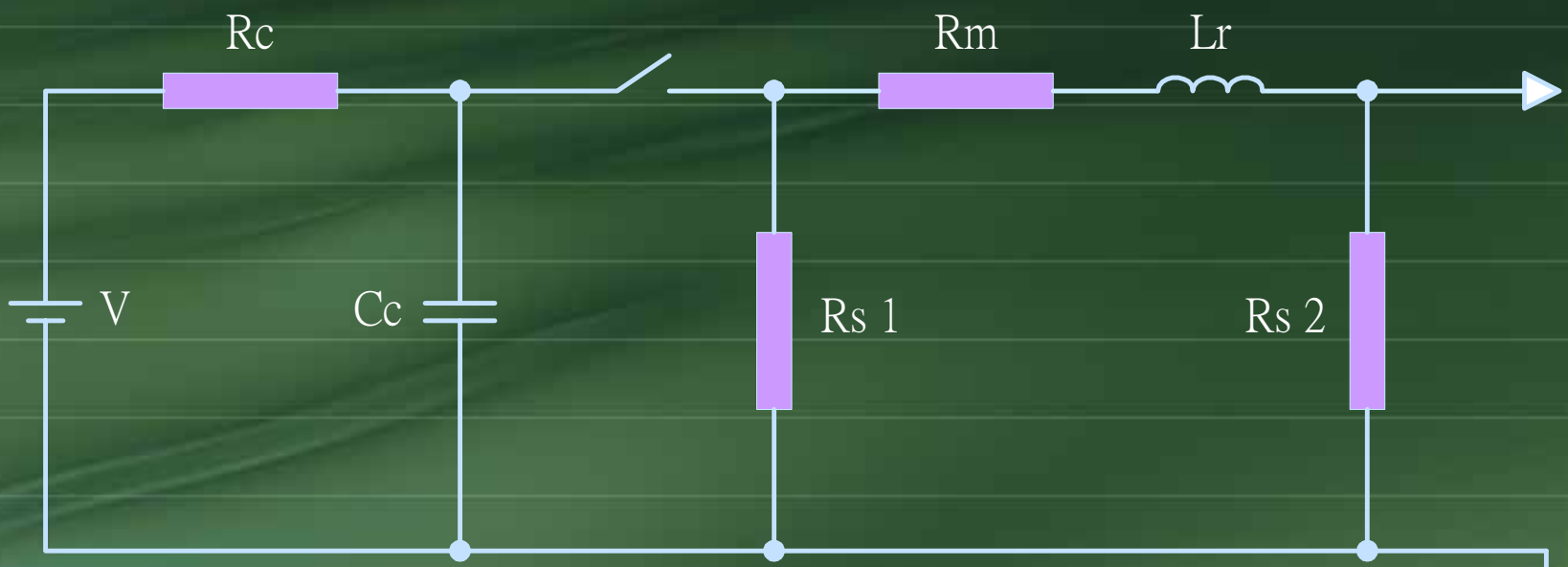
Surge

Surge test principles

- Receptor equipment under test may be tested with normal power supply, and/or not.
  - The unpowered testing is usually done first.
    - Easy to analyze the effect of surge and evaluate the surge protection devices
  - The powered testing is a must.
    - To evaluate the functional performance of equipment during a surge

Surge

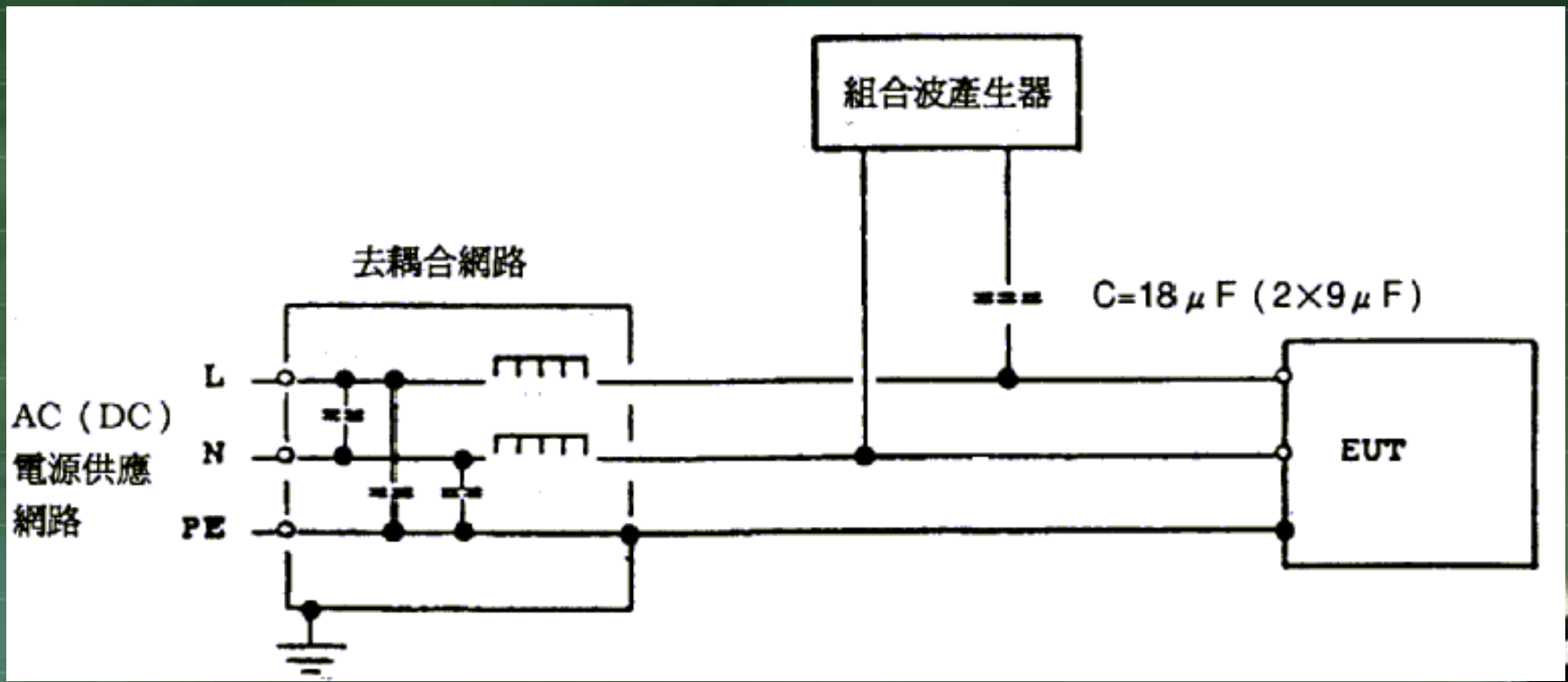
Surge generator model



V 高壓電源
Rc 充電電阻
Cc 儲能電容
Rs 脈波保持時間整型電阻
Rm 阻抗匹配電阻
Lr 上升時間整型電感

Surge

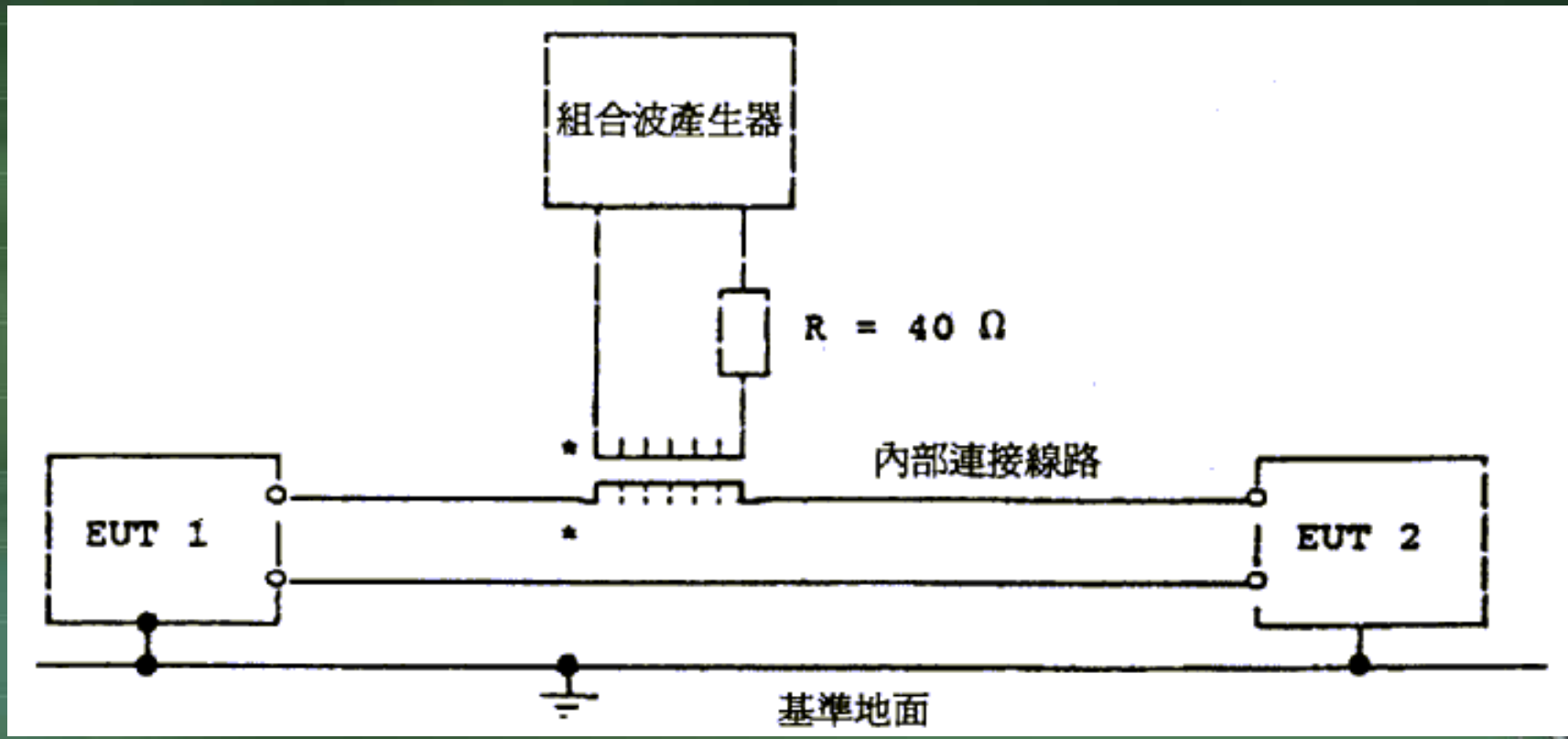
Test set-up



電容耦合

Surge

Test set-up



電感耦合