Chroma Turnkey Test & Automation Solution Provider

APPLICATION NOTE

Chroma 19501 Partial Discharge Test Guide – Photocoupler

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Chroma ATE Inc.

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1. Objective

The photocoupler uses light as a medium to provide signal transmission and isolation. With characteristics feature in well electrical isolation between the input and output terminals, it is often used to bridge the high-voltage circuit and the low-voltage signal circuit. It is a safety-regulated component that must get the safety standard certification of the sales area before it can be sold.

The regulation requires the photocouplers are 100% withstand voltage tested and partial discharge inspected during fabrication to ensure no partial discharge occurs under the maximum working voltage of which may cause material variation due to long-hour work and endanger the safety of personnel. This test guide explains the content of safety regulations and the matters needing attention in production inspection.

2. Regulatory requirements

Regulations and requirements related to high voltage safety of photocouplers:

(1) IEC 60747-5-5 is the global safety standard for photocouplers.
(2) UL 1577 is the American UL safety standard for photocouplers.
(3) VDE 0884-5 is the safety standard of the German Institute of Electrical Engineers for photocouplers (equal to the European standard EN).
(4) The requirements for high-voltage testing items in the regulations are collated in Table (1).

Table (1) Photocoupler Regulatory Test Requirements

Regulations and Scope	IEC 60747-5-5 VDE 0884-5	UL 1577
Isolation test (Withstand voltage test)	Yes	Yes
Partial discharge test	Yes	No

1 Regulation – IEC 60747-5-5 (VDE 0884-5)

1.1 Name: Semiconductor devices – Discrete devices – Part 5-5 : Optoelectronic devices – Photocouplers

1.2 High voltage test requirements

1.2.1 Clause 8.3 Isolation resistance between input and output R_{IO}

1.2.1.1 Test method – Use DC voltage to measure the insulation resistance between input and output terminals

1.2.1.2 Test voltage (V_{IO}) – 500Vdc

1.2.1.3 Test time – 60 sec.

1.2.1.4 Judgment condition – different specifications for different test phases, minimum insulation resistance requirement is $R_{IO} \geq 10^{12}\,\Omega$.

1.2.1.5 Execution phase – Sample test

1.2.2 Clause 8.4 Isolation test

1.2.2.1 Test method – Use AC voltage or DC voltage to test the insulation withstand voltage between the input and the output terminals.

1.2.2.2 Test voltage – Test with the isolation voltage specified by the component specification.

1.2.2.3 Test time

- Sample test: 60 sec.
- Routine test: Increase the test voltage to 120%, 1 or 2 seconds

1.2.2.4 Judgment condition

- Flashover cannot occur inside or outside the component during the test
- No insulation breakdown during the test

1.2.2.5 Execution phase – Sample test and routine test

1.2.3 Clause 8.5 Partial discharges of photocouplers

1.2.3.1 Test method – Use AC voltage to perform partial discharge test between input and output terminals.

1.2.3.2 Test voltage definition

- $V_{pd} = F \times V_{IOWM}$ if $V_{IOWM} \geq V_{IORM}$
- Remark

(1) F: Multiplying factor

Test Phase	F
Routine test	1.875
Sample test and After life test	1.6
After endurance tests	1.2

(2) V_{IOWM}: Maximum working isolation voltage

(3) V_{IORM}: Maximum repetitive peak isolation voltage

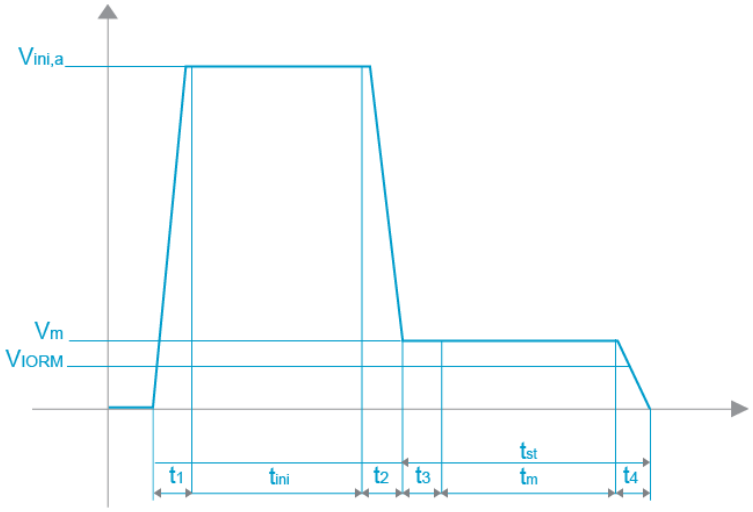
1.2.3.3 Test time

- Refer to the test condition in Table (2) for test method (a) and (b).

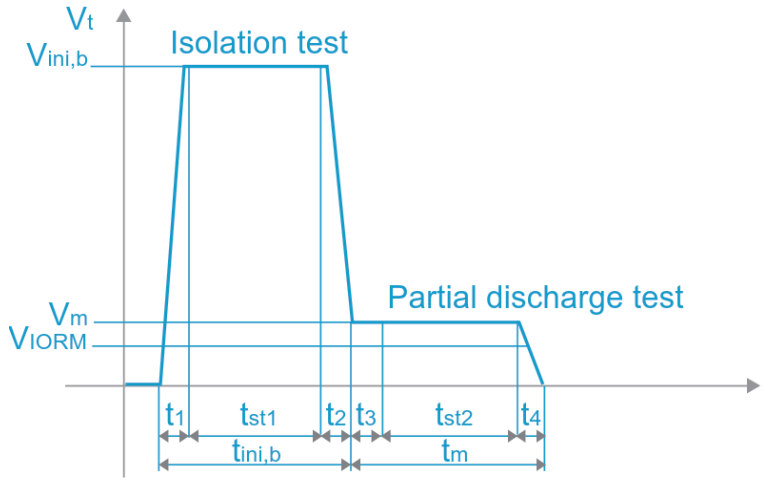
Table (2) Test Condition

Condition	Method (a)	Method (b)
t_{ini}	60sec	1sec
t_{st} typ.	12sec	1.2sec
t_m	10sec	1sec
t_{st2} typ.	--	1.2sec
t_1 , t_2	100V/sec or 1000V/sec	--
t_3 , t_4	1sec	--
Vpd	F x V_{IOWM} or V_{IORM}	1.875 x V_{IOWM} or V_{IORM}

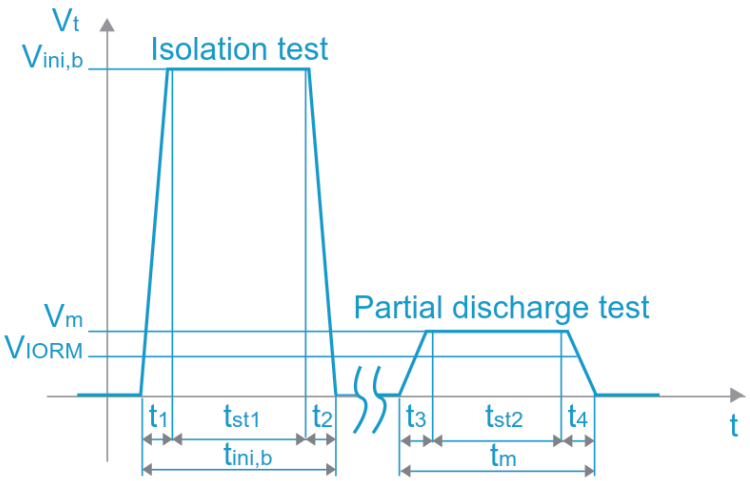
- Test Method (a)



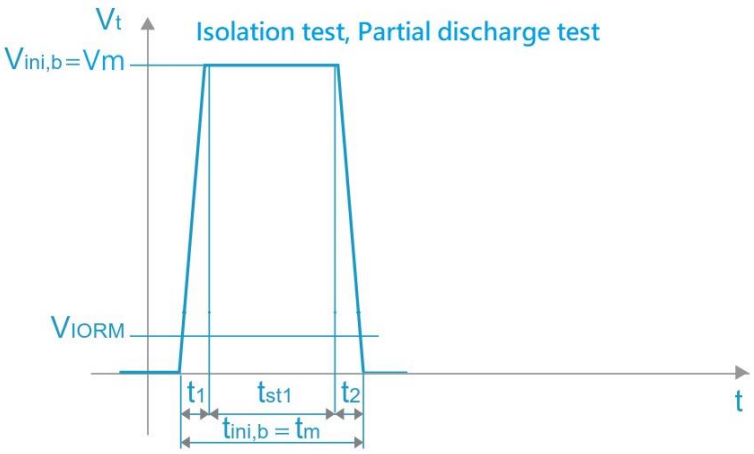
- Test Method (b)



Method b1



Method b2



Method b3

- Remark
  - (1) Select one of the following for test method (b)
    - i. B1: Continuous test for insulation withstand voltage and partial discharge
    - ii. B2: Phase test for insulation withstand voltage and partial discharge
    - iii. B3: Simultaneous test for insulation withstand voltage and partial discharge

1.2.3.4 Judgment condition – ≤ 5pC

1.2.3.5 Execution phase – Sample test and Routine test

1.3 Test equipment requirements (PD)

1.3.1 Output voltage – requirement < 5% error

1.3.2 Filter center frequency (f_0) range – 150 kHz ~ 2 MHz

1.3.3 Filter bandwidth (Δf) – requirement <15KHz

1.3.4 Coupling capacitor – ≥ 1 nF

1.3.5 Calibrator requirements

1.3.5.1 Execution time – Daily execution and interval for changing DUT (Device Under Test)

1.3.5.2 Minimum resolution – 1pC

1.3.5.3 Calibrator output – 5pC

1.3.5.4 Rise time – < 50nS

1.3.5.5 Delay time – 100uS ~ 1000uS

2 Regulation – UL 1577

2.1 Name : Electrically Isolated Semiconductor Devices

2.2 High voltage test requirements

2.2.1 Provision – 14 Dielectric Voltage-Withstand Test

2.2.2 Test method – Use AC voltage to perform insulation withstand voltage test between input and output terminals

2.2.3 Test voltage – Test with the isolation voltage specified by the component specification.

2.2.4 Test time – 60 seconds or increase the test voltage to 120%, the test time can down to 1 second.

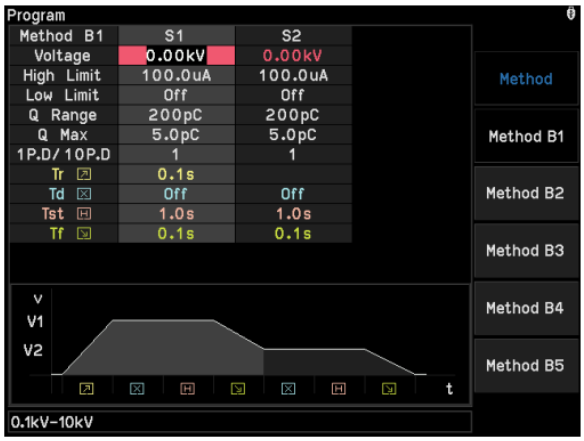
2.2.5 Test requirement – No insulation breakdown occurs during the test.

2.2.6 Execution phase – Sample test and Routine test

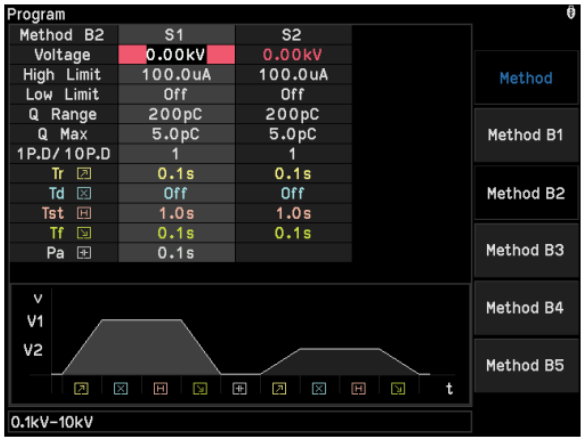
3. Equipment operation

1 Select the test mode based on the desired execution mode or factory production configuration.

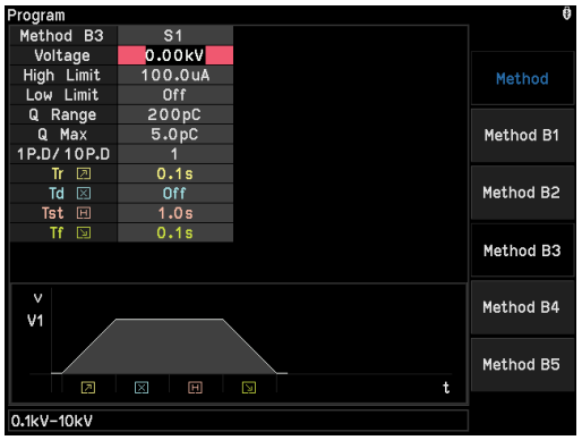
1.1 b1: Continuous test for insulation withstand voltage and partial discharge



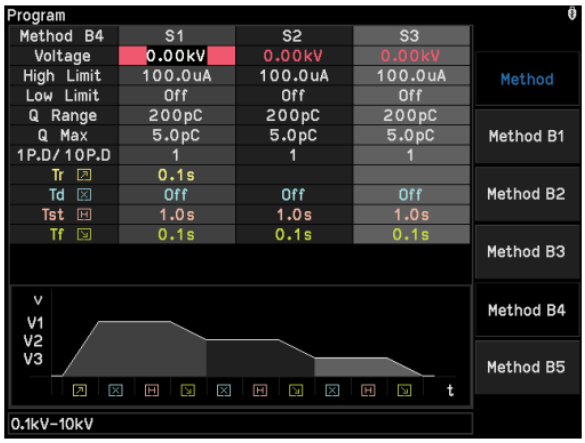
1.2 b2: Phase test for insulation withstand voltage and partial discharge



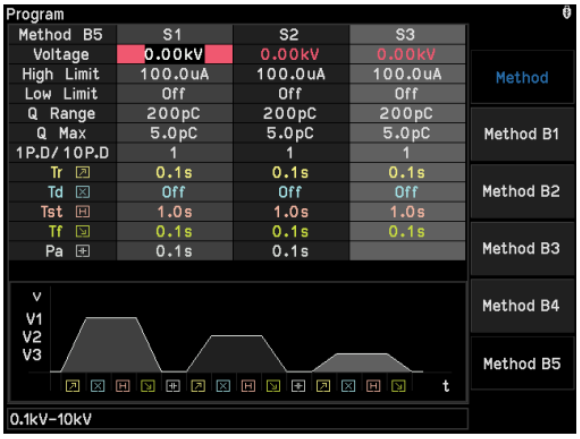
1.3 b3: Simultaneous test for insulation withstand voltage and partial discharge



1.4 b4: Add quality inspection of the 3rd phase besides the regulation requirements for insulation withstand voltage and partial discharge using continuous tests as the output method.

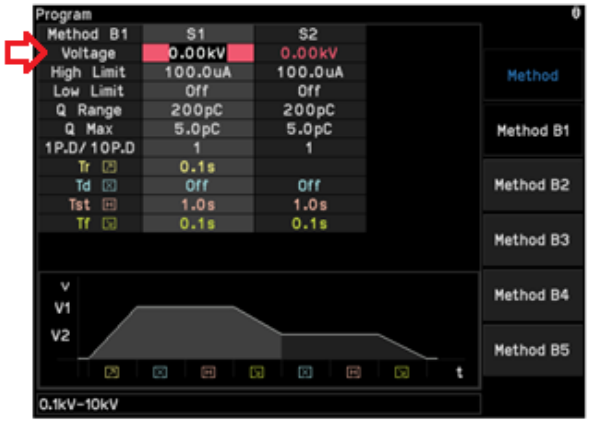


1.5 b5 Add quality inspection of the 3rd phase besides the regulation requirements for insulation withstand voltage and partial discharge using phase test as the output method.



2 Description of each parameter setting

2.1 Set voltage: The DUT (Device Under Test) sets the test voltage according to the regulation requirement. Take the b1 test method as an example:



2.1.1 S1: Set insulation withstand voltage for testing

For example, in the material specification table shown in Figure (1), the Viso test voltage is 5000 Vrms or it can be increased to 6000 Vrms shortening the test time to 1sec. Choose of the conditions as the production test specifications.

Parameter	Symbol	Min.	Typ.	Max.	Units	Test Conditions	Figures	Notes
Input-Output Momentary Withstand Voltage*	V_{ISO}	5000			V_{RMS}	RH ≤ 50%, t = 1 minute, T_A = 25 °C		1, 2

* The Input-Output Momentary Withstand Voltage is a dielectric voltage rating that should not be interpreted as an input-output continuous voltage rating.

Notes:
1. Device considered a two-terminal device: pins 1, 2, 3 and 4 shorted together, and pins 5, 6, 7 and 8 shorted together.
2. In accordance with UL 1577, each optocoupler is proof-tested by applying an insulation test voltage > 6000 V_{RMS} for 1 second.

Figure (1)

2.1.2 S2: Set partial discharge voltage for testing

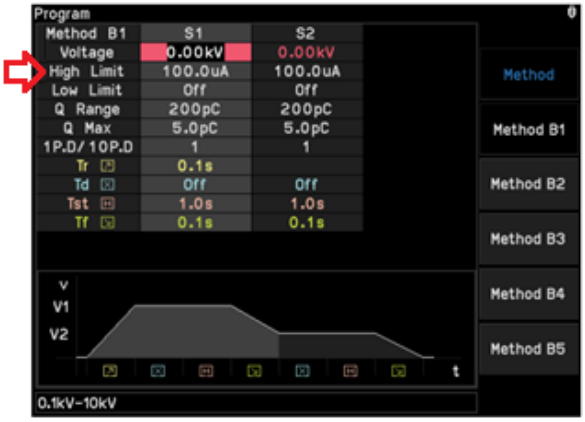
Take the sample specification table in Figure (2) as an example, the Vpd test voltage uses 2137 Vpeak (1512 Vrms) as the production test specification.

IEC/EN/DIN EN 60747-5-5 Insulation Related Characteristic (Option 060 and 560 only)

Description	Symbol	Option 060 and 560	Units
Pollution Degree (DIN VDE 0110/1.89)		2	
Maximum Working Insulation Voltage	V_{IORM}	1140	V_{PEAK}
Input to Output Test Voltage, Method b $V_{IORM} \times 1.875 = V_{PR}$, 100% Production Test with $t_m = 1$ sec Partial Discharge < 5 pC	V_{PR}	2137	V_{PEAK}
Input to Output Test Voltage, Method a $V_{IORM} \times 1.6 = V_{PR}$, Type and sample test, $t_m = 10$ sec, Partial Discharge < 5 pC	V_{PR}	1824	V_{PEAK}
Highest Allowable Overvoltage (Transient Overvoltage, $t_{ini} = 60$ sec)	V_{IOTM}	8000	V_{PEAK}
Insulation Resistance at T_S, $V_{IO} = 500$ V	R_S	$>10^9$	Ω

Figure (2) Sample Specification Table

2.2 Set leakage current high limit: According to the amount of DUT's stray capacitance, a continuous current will flow through these stray capacitance. It is recommended to set the high limit of leakage current to 3~5 times of the normal product current.



Example: The stray capacitance of a photocoupler is about 1pF; capacitive reactance calculation Xc = 1/2πfc (f=50Hz)

Under the condition of 6000Vrms voltage, its leakage current (I) is approximately equal to 2uA;

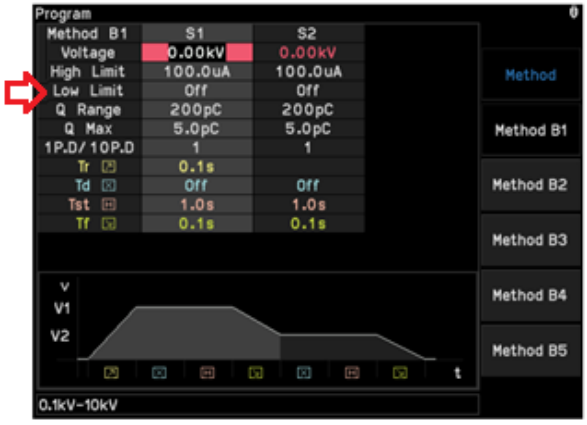
Thus, the high limit of leakage current can be set to 10uA max.

- Remark: The recommended leakage current high limit is 10uA.

  (It does not include the additional leakage current value generated by the test circuit through automated wiring and test fixtures.)

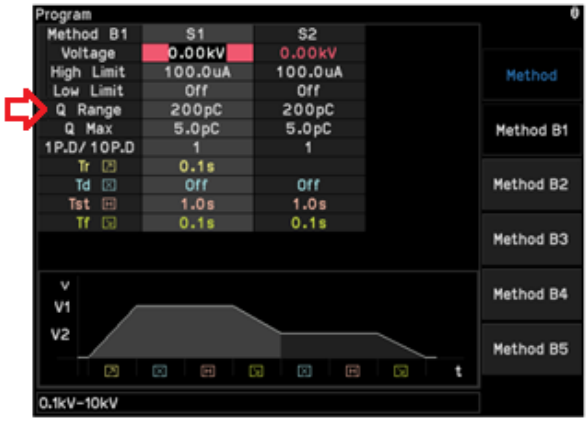
2.3 Set leakage current low limit

2.3.1 The low limit of leakage current is commonly used to judge if there is good contact between the DUT and the test instrument. Same as the example in item 2.2, the leakage current of the photocoupler is about 2uA under the condition of 6000Vrms, so it can set the low limit of leakage current to 1uA to check if the test wiring connection is normal. However, since the stray capacitance is very small, it is sometimes affected by the test wire or test fixture, causing the low limit of leakage current unable to judge if the cable connection is normal or not.

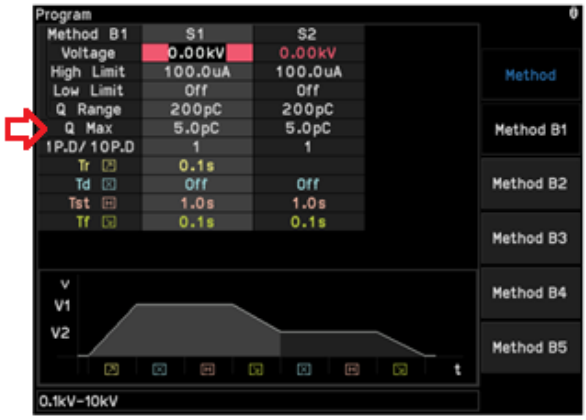


2.3.2 The 19501-K partial discharge tester is equipped with HVCC (High voltage contact check) function that can be enabled directly to check the connection of test cable.

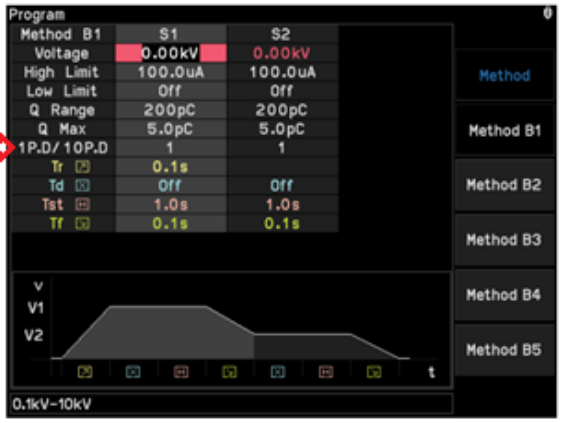
2.4 Set Q Range: It sets the PD measurement range. Set the Q Range to 200pC. (The measurement range is 1.0pC~200.pC).



2.5 Set max. discharge (Q max.): It sets the maximum discharge capacity allowed for partial discharge (pC). Refer to IEC 60747-5-5 regulation to set Q max. to 5pC.



2.6 Set partial discharge times (1P.D/10P.D): It sets the occurrence number of partial discharge that is over the Qmax. It is usually recommended to be set to 1P.D.



2.6.1 Setting to 1P.D means that when the PD is detected over the 5pC high limit, the test equipment will stop output.

2.6.2 Setting to 5P.D means that at least once in 4 consecutive half-wave voltage cycles is over 5pC. The device will stop output only when it is over 5 times consecutively as shown in Figure (3) below.

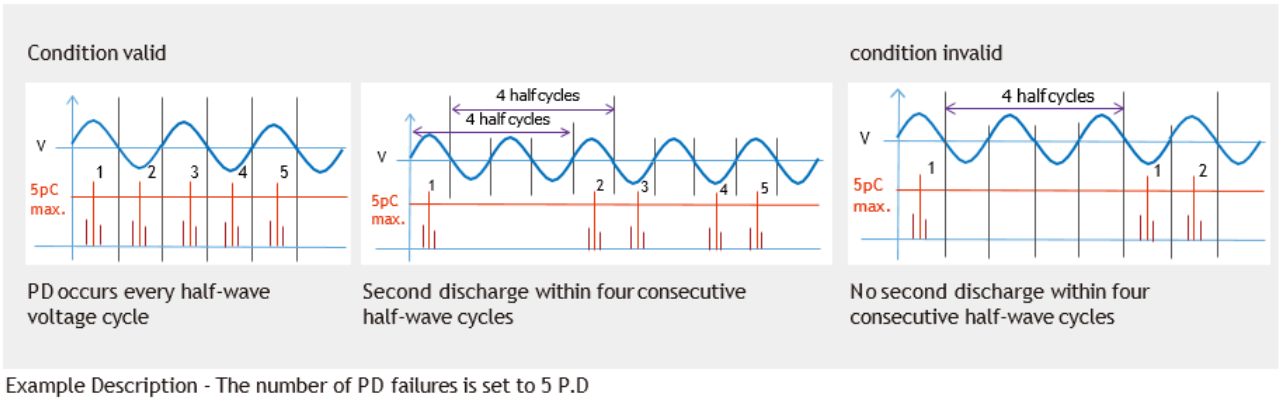


Figure (3) Discharge Count

2.7 Set rising time (Tr):

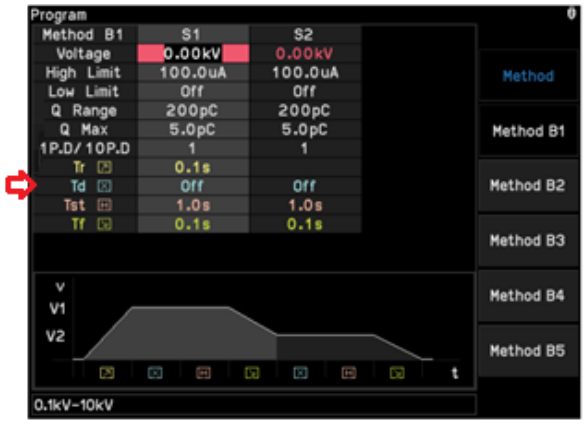
2.7.1 As the AC voltage output test usually does not require a long rising time, setting the device to the default 0.1sec for testing or adding the rising time can reduce the damage caused by instantaneous poor insulation of the photocoupler.

2.7.2 If the test method (a) in the IEC 60747-5-5 regulation is applied, the voltage rising rate must meet the requirements of 100V/sec or 1000V/sec for setting the rising time.

2.8 Set delay time (Td):

2.8.1 In order to enable PD detection to perform judgments when the voltage is stable, it can add delay time as desired, so that the PD judgment will start after the delay time when the set voltage is met. In general, it is recommended to set it to 0.3sec.

2.8.2 If the test method (a) in the IEC 60747-5-5 regulation is applied, the delay time (td) must be set to 1sec.



2.9 Set test time (Tst): It sets test time according to the requirement of IEC 60747-5-5 regulation, and the test time for test method (a) and method (b) is different. See the test time in Table (3) below.

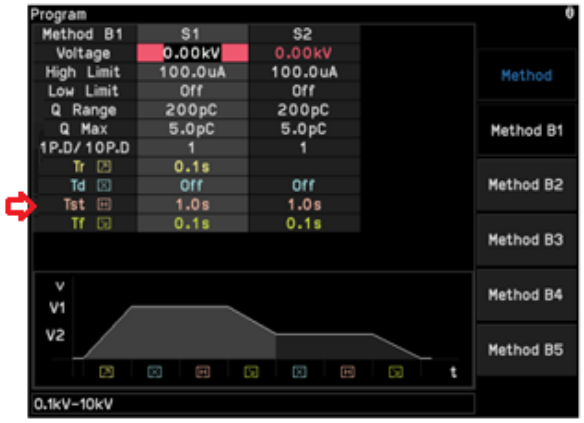


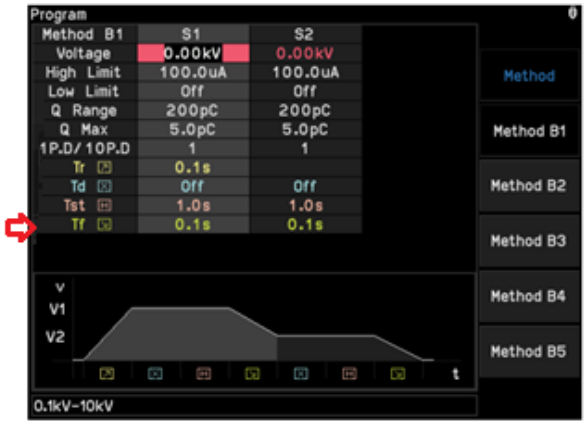
Table (3) Test Time

Condition	Method (a)	Method (b)
S1 Tst	60sec	1sec
S2 Tst	10sec	1sec

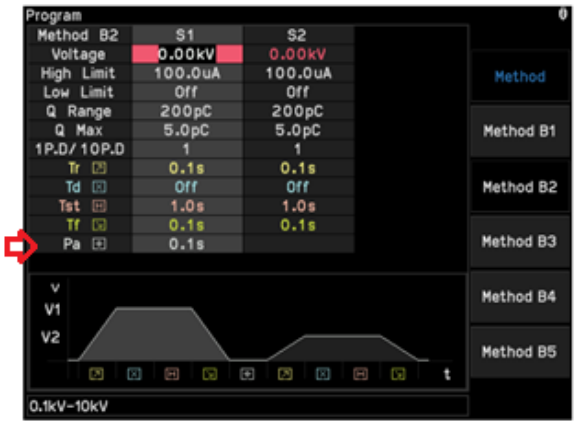
2.10 Set falling time (Tf)

2.10.1 As the AC voltage output test usually does not require a long falling time, it can be done by setting the device to the default 0.1sec for testing.

2.10.2 If the test method (a) in the IEC 60747-5-5 regulation is applied, the voltage falling rate must meet the requirements of 100V/sec or 1000V/sec for setting the falling time.



2.11 Set pause time (Pa): This item is only valid in test method b2 and b5 mode. The pause time is the time for voltage transition from S1 to S2 phase. During this time, there will be no voltage output from the test equipment, allowing users to switch the external test fixture for use



4. Test method

1 Test wire connection

1.1 Short-circuit and connect the Input and Output pins of the photocoupler to the high voltage end (HV) and low voltage end (LOW) of the test equipment respectively. The test wire connection method is shown in Figure (4).

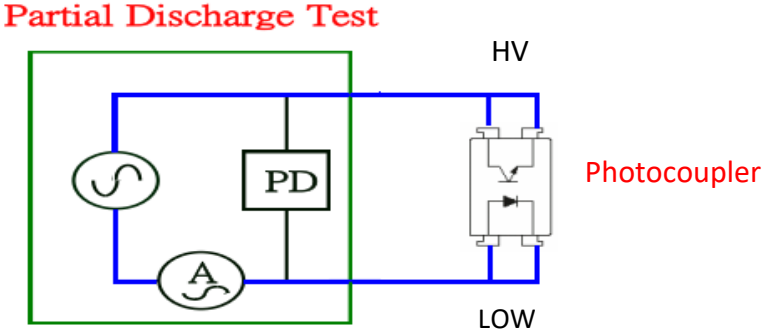


Figure (4) Test Wire Connection Diagram

2 Kelvin measurement HVCC connection

2.1 If the high voltage contact check (HVCC) is function turned on, the connection will be changed from 2-terminal to Kelvin measurement, and an external short-circuit fixture must be used to achieve the contact check function. The test wire connection is shown in Figure (5).

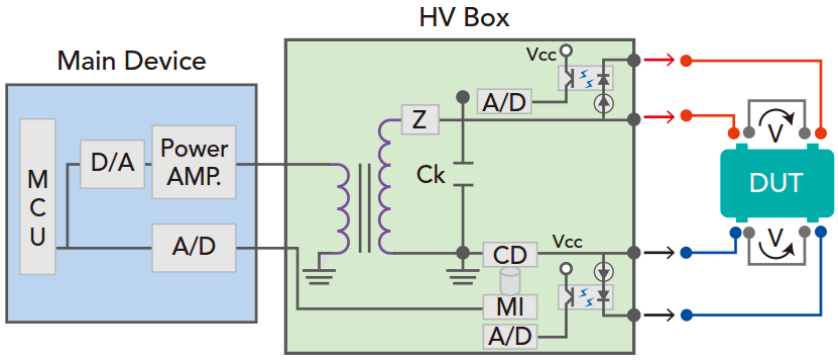


Figure (5) Kelvin measurement HVCC Connection Diagram

2.2 For users who enable the HVCC function, the Finger design of the external test fixture Kelvin measurement connection is suggested as Figure (6) shown below.

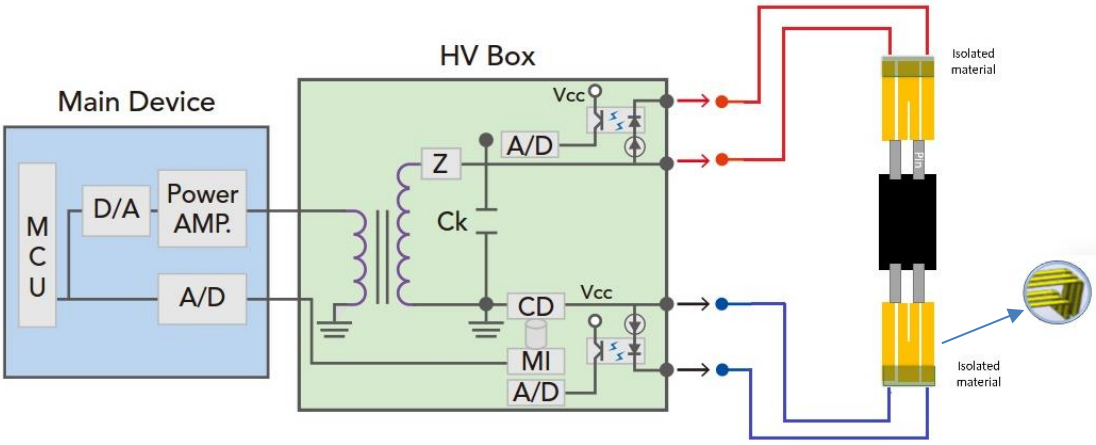


Figure (6) Finger Design for Kelvin measurement Connect Check

3 Other testing suggestions

3.1 The amount for a single test is preferably 1pcs. The more PIN numbers of the photocoupler or the increased amount of a single test, the larger the exposed area of the relative metal (PIN leg). It will increase the impact of environmental interference on PD testing.

3.2 Connect with the test socket of automated equipment

3.2.1 It is better to directly contact the HV BOX probe with the test socket of the automated device.

3.2.2 If it is necessary to use external test leads, the shorter the wire, the better (<50cm).

3.3 Reduce the test environment interference

3.3.1 Install a metal isolation cover to the LOW terminal and ground it

3.3.2 The smaller the exposed metal area of the LOW terminal on the test fixture, the better.

3.4 Use high-strength insulating materials to avoid PD discharge from the fixture when selecting the fixture materials.

3.5 Automated mechanism and fixture design personnel

3.5.1 The designer must have relevant knowledge of high-voltage test applications, and take the insulation distance requirement into consideration at the beginning of the design.

3.5.2 The test fixture should clearly identify the applicable DUT size and pin pitch. It is helpful to evaluate the DUT's applicability when changed.

3.5.3 Any design change needs to take the insulation withstand voltage requirements of the fixture into consideration.

3.5.4 Reduce the use of conductive metal materials as much as possible for the parts related to the test socket to avoid increasing environmental noise interference.

5. Reference documents

[1] IEC 60747-5-5: 2013

[2] UL1577:2009

[3] IEC 60270:2000

[4] Chroma 19501-K Partial Discharge Tester User's Manual