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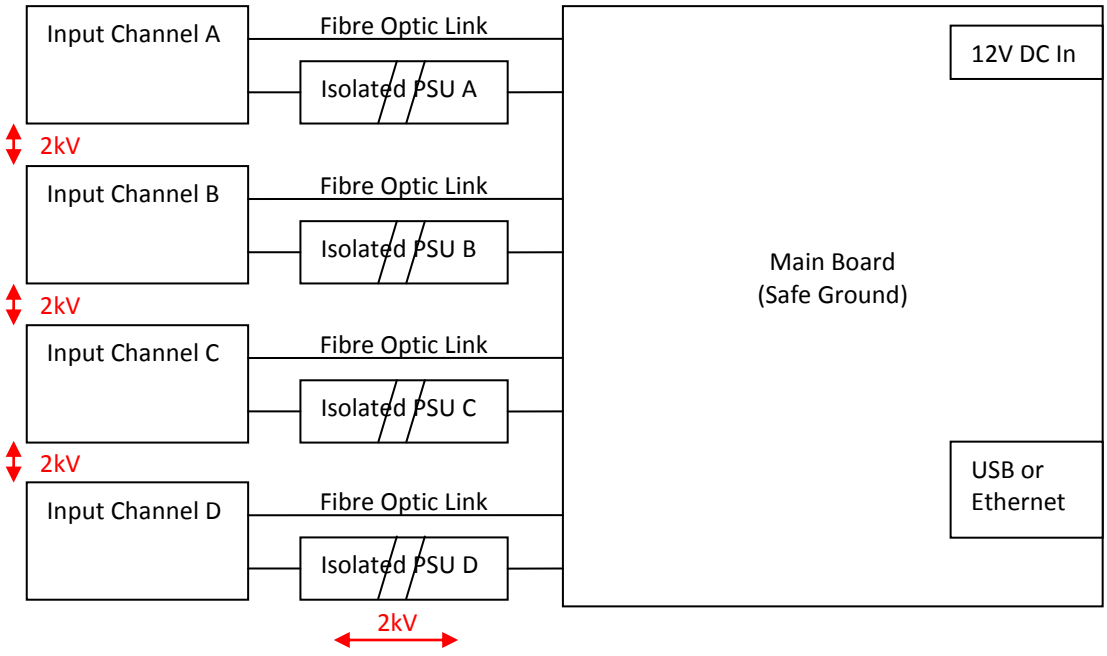
CS448 Insulation Voltage Rating

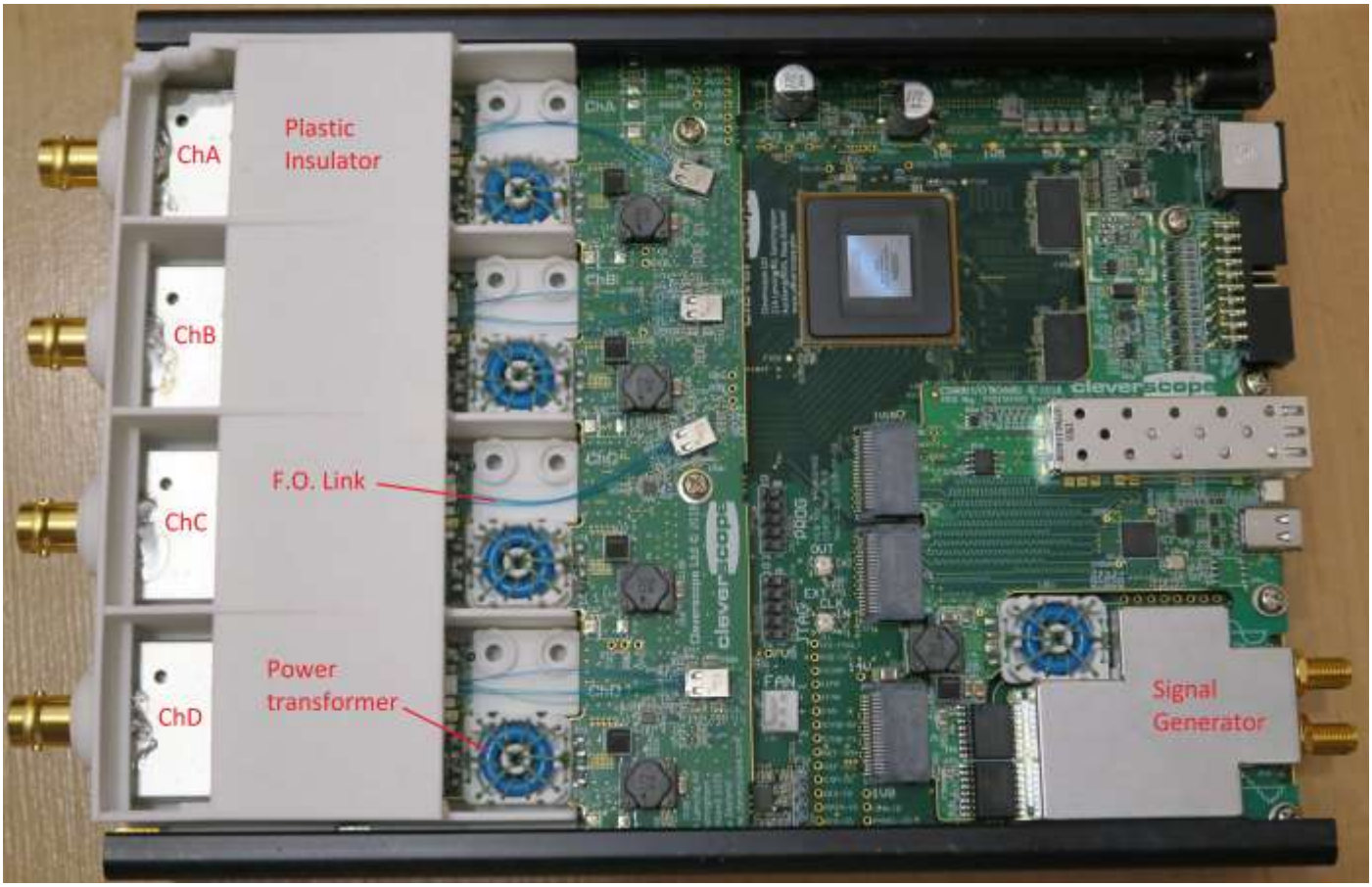
Overview

The CS448 Isolated Oscilloscope has insulation between input channels and to ground so that the input channels can be individually referenced to different voltages up to $1kV_{AC}$ Cat III (mains circuits) or $2kV_{AC\ RMS\ or\ DC}$ (other types of circuits). Typical application would be for measurements on power electronic equipment such as motor controllers and power converters. This document explains the insulation and derives the voltage rating.

The following diagram shows the input channels which connect to the main board via fibre optic links and isolated power supplies. The main board is referenced to “safe” ground and connects to a computer via USB or Ethernet.



This internal photo shows the plastic insulator between the channels, the fibre optic links (thin blue/green wires) and the isolated power supply transformers (blue toroids):



Safety Standard

As the CS448 is test equipment for laboratory use, the standard applied is:

IEC 61010: Safety requirements for electrical equipment for measurement, control, and laboratory use
Part 1: General requirements.
Part 2-030: Particular requirements for equipment having testing or measuring circuits.

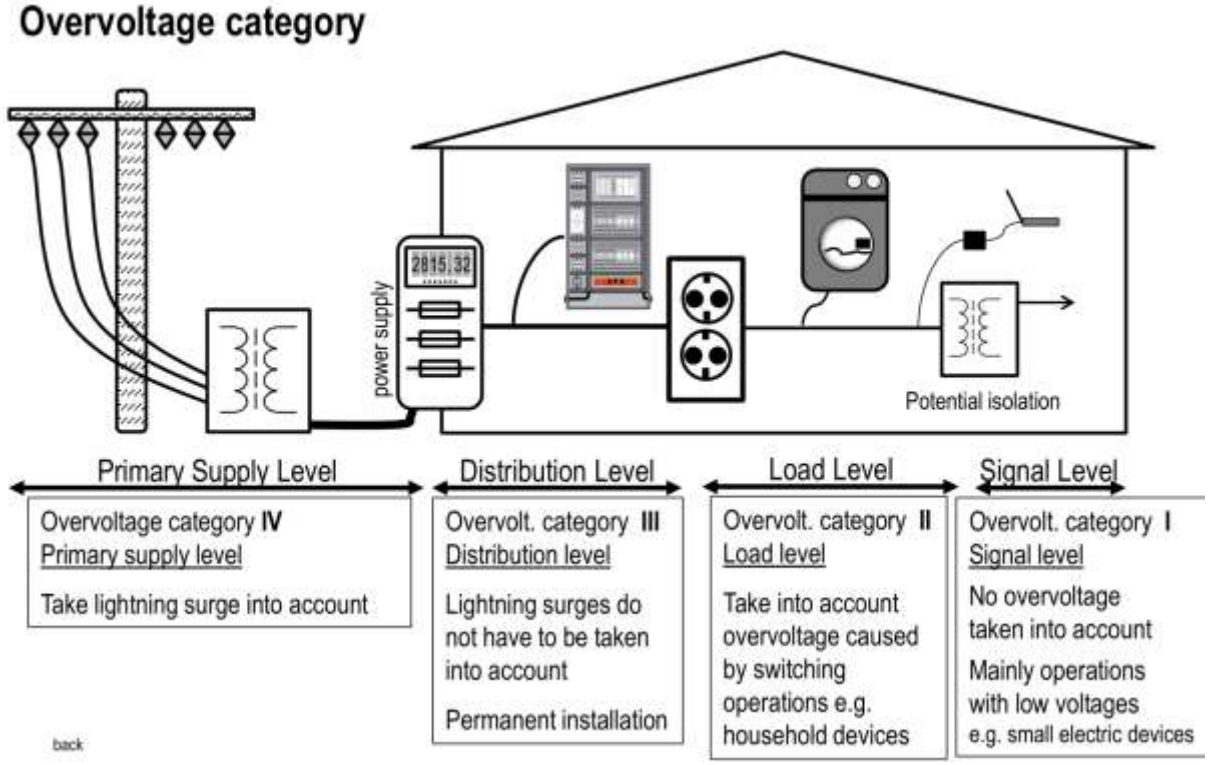
Conditions for use are altitude <2000m and pollution degree 2, typical of an office or laboratory environment.

Analysis

The plastic insulators in the CS448 have a minimum clearance of 16.4mm and minimum creepage path of 20mm, and are constructed from a material with a Comparative Tracking Index of 600V (material group I). The voltage rating of the insulator depends on the type of circuit that will be measured. This is because of the possible transient voltage conditions that may occur in the circuit being measured.

Mains Circuits

For example, say we want to measure the voltage on a resistor current shunt in one of the phases on a mains network. The reference on the channel input would change voltage with the mains voltage and the insulation inside the CS448 would see the full mains voltage. In this case the voltage rating of the insulation will depend on the Overvoltage Category for the location where the measurement is being made. The Overvoltage Category determines the amount of expected transient overvoltage at this location:



Typically the measurements made with the CS448 would be at the distribution level, i.e. within the building after the main circuit breaker. So this is Category III.

The CS448 has 16.4mm clearance.

From IEC 61010-2-030 Table K.101, 14.3mm is the minimum clearance for ≤1000$V_{AC\ RMS\ or\ DC}$ reinforced insulation.

Table K.101 – CLEARANCES for measuring circuits of MEASUREMENT CATEGORIES II, III and IV

Nominal a.c. r.m.s. line-to-neutral or d.c. voltage of MAINS being measured V	CLEARANCE mm					
	BASIC INSULATION and SUPPLEMENTARY INSULATION			REINFORCED INSULATION		
	MEASUREMENT CATEGORY II	MEASUREMENT CATEGORY III	MEASUREMENT CATEGORY IV	MEASUREMENT CATEGORY II	MEASUREMENT CATEGORY III	MEASUREMENT CATEGORY IV
≤ 50	0,04	0,1	0,5	0,1	0,3	1,5
> 50 ≤ 100	0,1	0,5	1,5	0,3	1,5	3,0
> 100 ≤ 150	0,5	1,5	3,0	1,5	3,0	6,0
> 150 ≤ 300	1,5	3,0	5,5	3,0	5,9	10,5
> 300 ≤ 600	3,0	5,5	8	5,9	10,5	14,3
> 600 ≤ 1 000	5,5	8	14	10,5	14,3	24,3
> 1 000 ≤ 1 500[a]	8	11	18	14,3	19,4	31,4

[a] Only for d.c. voltage.

Also the CS448 has 20mm creepage.

From IEC 61010-02-030 K.101.3 Table K.13, 20mm is the minimum creepage for ≤2000$V_{AC\ RMS\ or\ DC}$ reinforced insulation (reinforced is twice the distance shown in the table).

Table K.13 – CREEPAGE DISTANCES for secondary circuits

Secondary WORKING VOLTAGE a.c. r.m.s. or d.c.	Printed wiring board material		Other insulating material						
	POLLUTION DEGREE 1	POLLUTION DEGREE 2	POLLUTION DEGREE 1	POLLUTION DEGREE 2			POLLUTION DEGREE 3		
	All material groups	Material group I, II or IIIa	All material groups	Material group I	Material group II	Material group III	Material group I	Material group II	Material group III [b]
V	mm	mm	mm	mm	mm	mm	mm	mm	mm
10	0,025	0,04	0,08	0,40	0,40	0,40	1,00	1,00	1,00
12,5	0,025	0,04	0,09	0,42	0,42	0,42	1,05	1,05	1,05
16	0,025	0,04	0,10	0,45	0,45	0,45	1,10	1,10	1,10
20	0,025	0,04	0,11	0,48	0,48	0,48	1,20	1,20	1,20
25	0,025	0,04	0,125	0,50	0,50	0,50	1,25	1,25	1,25
32	0,025	0,04	0,14	0,53	0,53	0,53	1,3	1,3	1,3
40	0,025	0,04	0,16	0,56	0,80	1,10	1,4	1,6	1,8
50	0,025	0,04	0,18	0,60	0,85	1,20	1,5	1,7	1,9
63	0,040	0,063	0,20	0,63	0,90	1,25	1,6	1,8	2,0
80	0,063	0,10	0,22	0,67	0,95	1,3	1,7	1,9	2,1
100	0,10	0,16	0,25	0,71	1,00	1,4	1,8	2,0	2,2
125	0,16	0,25	0,28	0,75	1,05	1,5	1,9	2,1	2,4
160	0,25	0,40	0,32	0,80	1,1	1,6	2,0	2,2	2,5
200	0,40	0,63	0,42	1,00	1,4	2,0	2,5	2,8	3,2
250	0,56	1,0	0,56	1,25	1,8	2,5	3,2	3,6	4,0
320	0,75	1,6	0,75	1,60	2,2	3,2	4,0	4,5	5,0
400	1,0	2,0	1,0	2,0	2,8	4,0	5,0	5,6	6,3
500	1,3	2,5	1,3	2,5	3,6	5,0	6,3	7,1	8,0
630	1,8	3,2	1,8	3,2	4,5	6,3	8,0	9,0	10,0
800	2,4	4,0	2,4	4,0	5,6	8,0	10,0	11	12,5
1 000	3,2 [a]	5,0 [a]	3,2	5,0	7,1	10,0	12,5	14	16
1 250			4,2	6,3	9,0	12,5	16	18	20
1 600			5,6	8,0	11	16	20	22	25
2 000			7,5	10,0	14	20	25	28	32

So the limiting distance in the case of **Mains Circuits** is clearance giving **≤1000$V_{AC\ RMS\ or\ DC}$**. Hence the CS448 shows **1kV Cat III** on the front label.

Note that for Category IV measurements the rating would be 600V.

Other Types of Circuits

A more typical use of the CS448 would be to measure the signals in power electronics equipment such as a transistor bridge circuit. For example a variable speed motor controller or a photovoltaic power inverter. Here the voltages seen by the insulation can be complex waveforms such as high frequency square waves with transient overshoot.

In this case IEC 61010-1 refers to K3.3 Table K.17 which shows 16mm clearance is enough reinforced insulation for ≤5000V_{PEAK} (reinforced is twice the distance shown in the table on the next page).

Table K.17 – CLEARANCES for BASIC INSULATION in circuits having recurring peak voltages or WORKING VOLTAGES with frequencies above 30 kHz

Voltage peak value	CLEARANCES	
	Frequencies up to 30 kHz	Frequencies above 30 kHz
V	mm	mm
0 to 330	0,01	0,02
400	0,02	0,04
500	0,04	0,07
600	0,06	0,11
800	0,13	0,26
1 000	0,26	0,48
1 200	0,42	0,76
1 500	0,76	1,1
2 000	1,27	1,8
2 500	1,8	2,6
3 000	2,4	3,5
4 000	3,8	5,7
5 000	5,7	8

Also for these types of circuits IEC 61010-1 refers to K.3.4 Table K.13 (shown on previous page) for creepage. 20mm is the minimum creepage for ≤2000$V_{AC\ RMS\ or\ DC}$ reinforced insulation (reinforced is twice the distance shown in the table).

So the limiting distance in the case of these **Other Types of Circuits** is creepage giving **≤2000$V_{AC\ RMS\ or\ DC}$**. Hence the CS448 can be used for DC bus voltages up to 2000V_{DC}, allowing the use with common transistor voltages of 650V, 1200V and 1700V.

Note that in this case it is the creepage distance that is the limiting factor. Creepage is a long term effect where the surface on the insulation can break down due the continual stress from a voltage across the insulation, and so it is determined by RMS or average DC value of the stress and not the transients. This is seen in table K.13 where the voltage spec is RMS or DC, not peak.

Clearance on the other hand is determined by the short term voltage because a transient peak can cause ionisation and break down across a gap. So clearance ratings include the transient voltages, and hence the use of Overvoltage Category for Mains Circuits. In this case the transistor bridge circuit is normally separated from the mains by an input rectifier and DC bus capacitance, which will limit the transient overvoltage seen on the mains to a much reduced value. We see from table K.17 that the 16.4mm clearance in the CS448 is sufficient for up to 5000V_{PEAK} and so is enough for any transients or overshoot that may be seen in a power electronic transistor bridge circuit.

Signal Generator

The Signal Generator (shown on the right in the photo on page 2) is also insulated from the main board ground. The clearance is 3.7mm and creepage is 8mm. The digital isolator used to control the Signal Generator is an ISO7840DW which has a rated working voltage of 600VRMS. So the Signal Generator insulation voltage rating is:

For Mains Circuits:	300V Cat II	(limited by clearance)
For Other Types of Circuits:	600$V_{AC\ RMS}$	(limited by ISO7840DW)