APPLICATION NOTE

TRANSIL
CLAMPING PROTECTION MODE

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INTRODUCTION

The Transil is an avalanche diode specially designed to clamp overvoltages and dissipate high transient power. A Transil has to be selected in two steps :

A) Check that the circuit operating conditions do not exceed the specified limit of the component.
. For non-repetitive ”shock” operation,
. For repetitive load operation,
. For continuous operation.

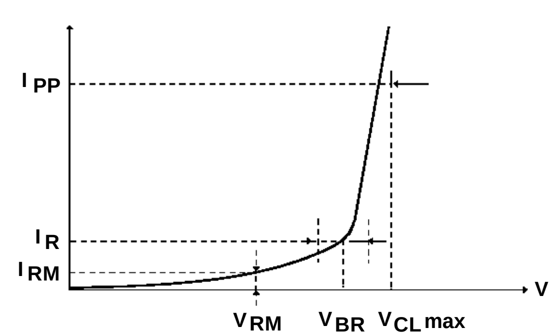
B) Check that the maximum value of the clamped voltage under the most adverse conditions corresponds to the specification of the circuit, i.e. there is no danger for the protected circuits.

REVIEW OF TRANSIL CHARACTERISTICS

1. THE PEAK REVERSE VOLTAGE V_{RM} is the voltage which the Transil can withstand in continuous operation.

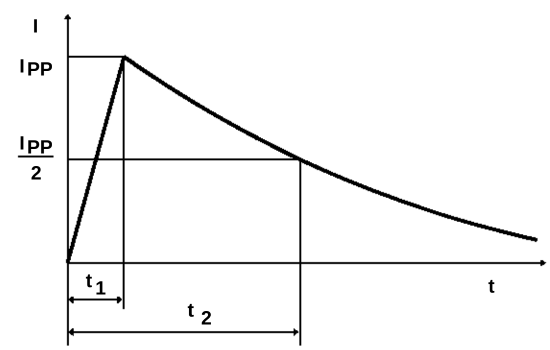
2. THE BREAKDOWN VOLTAGE OR KNEE VOLTAGE V_{BR} is the voltage value above which the current in the Transil increases very fast for a slight increase in voltage. The breakdown voltage V_{BR} is specified at 25°C and its temperature coefficent is positive. The V_{BR} tolerance is normally ± 5% or - 5% + 10%, however it is important to note that Transil technology results in much lower tolerance in mass production than other technologies.

Figure 1 : Main Characteristics of a Transil.



3. THE CLAMPING VOLTAGE V_{CL} as specified in the data-sheets is the maximum value for a ”standard” current pulse with a peak value of I_{PP}, specified for any type of Transil (fig.2). If the Transil is subjected to a different pulse, the value of V_{CL} can be calculated using the application note ”CALCULATION OF TRANSIL APPARENT DYNAMIC RESISTANCE”. The clamping factor is represented by V_{CL}/V_{BR}. This ratio between the maximum value of overvoltage for a given current and the maximum voltage which the diode can withstand in continuous operation characterizes the degree of protection.

Figure 2 : Standard Exponential Pulse. This type of pulse corresponds to most of the standards used for the protection device.



	t1 µs	t2 µs
WAVE ”8/20µs”	8	20
WAVE ”10/1000µs”	10	1000

4. TRANSIL PEAK POWER DISSIPATION

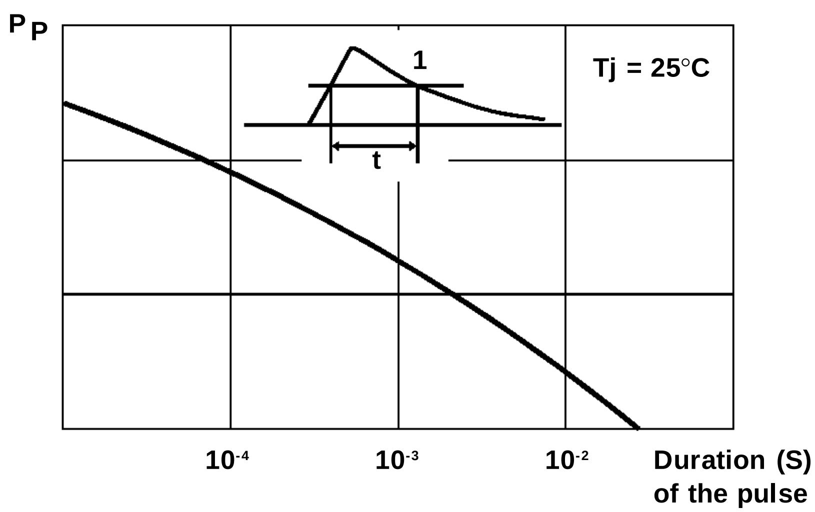
The first protection devices, designed to meet electrotechnical standards, were mostly used for overvoltages of short duration (1/50 µs waves of the type shown in fig.2) encountered on high voltage lines.

Research carried out by CNET (French Telecommunications Agency), confirmed by other organisations, tends to show that low-power electronic equipment is subjected to over voltages of a much longer duration, better represented by a 10/1000 µs exponential wave.

Transils are meant to protect electronic equipment and hence have been designed to perform well for over voltages which last several tens of milliseconds.

The performance of Transils has thus been determined with reference to the standard exponential wave 10/1000 µs.

Figure 3 : Maximum Power for an Exponential Pulse of Duration t.



The peak power dissipated in the Transil is given by :

$$P_P = V_{CL} \times I_{PP}$$

This maximum corresponds to non-repetitive operation. If the pulse has a different duration, a curve similar to that in fig.3, provided in the datasheets, enables the specifications of the Transil to be determined.

If the initial temperature exceeds 25°C, the power (Pp) should be reduced in accordance with the curve of fig.4 which is the same for all Transils.

If the current surge through the Transil is not exponential, the diagrams of fig.5 should enable the equivalent exponential pulse to be calculated.

Figure 4 : Varation of Peak Power as a Function of the Initial Temperature.

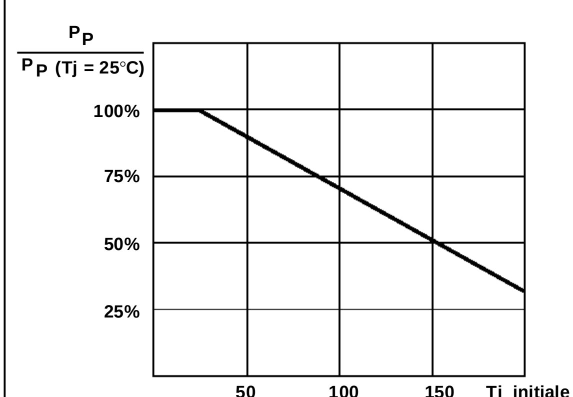
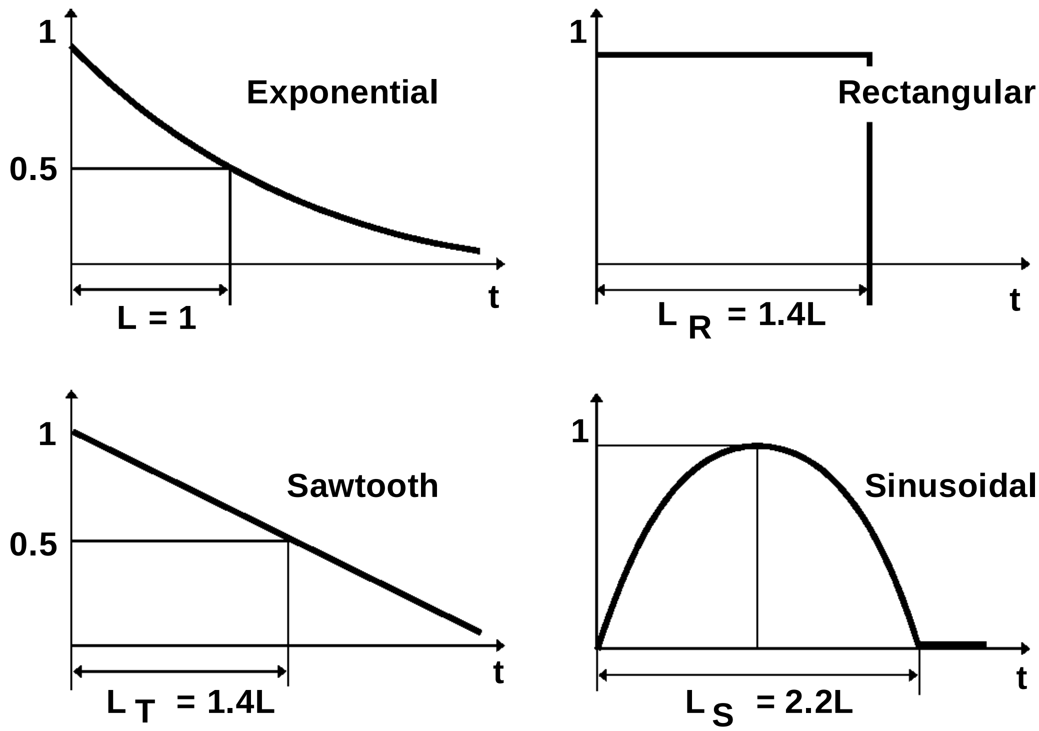


Figure 5 : The four pulses shown below, each of the same peak value, result in identical power being dissipated in a Transil. For example, the rectangular pulse which gives the same dissipation as the exponential pulse of the same peak value is 1.4 times longer in duration.



5. TRANSIL MEAN POWER DISSIPATION

In repetitive operation, the specification to be considered is mean power P_{AV}.

$$P_{AV} = f \times W$$

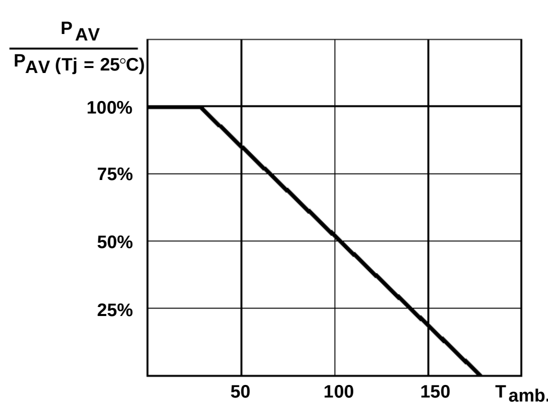
(f : frequency, W : energy dissipated at each pulse)

The junction temperature calculated from this power should never exceed the specified maximum junction temperature.

This temperature is calculated from the thermal resistance, exactly like for a diode.

$$T_j = Tamb + R_{th} \times P_{AV}$$
$$R_{th} = R_{th(j-a)} \text{ for } axial\ lead\ Transil$$

Figure 6 : Maximum Average Power as a Function of Ambient Temperature.



6. SPEED

The primary purpose of a Transil is to clamp overvoltages produced by current surges.

A conventional lightning arrester system only responds with a certain delay which can reach 2 µs. A metal oxide varistor does not respond immediately either (delay of about 25 ns).

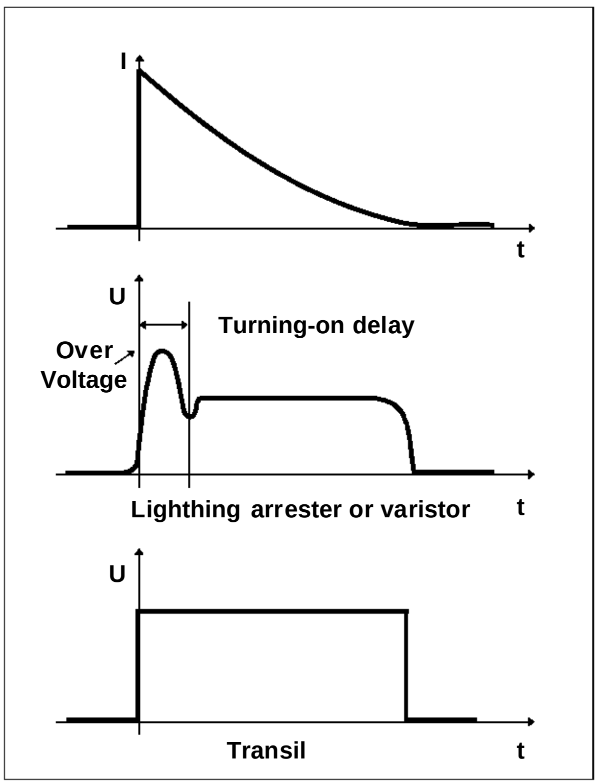
If a current with a very low rise time flows through these components, an overvoltage could appear before the device reacts.

In the case of a Transil, the avalanche phenomenon of a silicon diode is extremely fast (theoretical value about one picosecond).

Laboratory tests have never succeeded in producing overvoltages across Transils, even by using special devices producing very steep current gradients (dischargers, mercury relays).

In conclusion it can be said that Transils respond instantaneously in clamping, on condition that di/dt overvoltages are not introduced by connection inductances.

Figure 7 : Voltage Response of a Classical Component used for Protection and a Transil.



The low capacitance Transil and the bidirectional models have clamping times of about 5 ns. These times remain negligible for practically all applications.

7. SPEED IN "DIODE" OPERATION.

A Transil operating as a rectifier is not a fast recovery diode (it has a high stored charge). As a result, Transils cannot be used for the rectifier function instead of fast recovery diodes.

On the other hand, a Transil operating as a diode has very low forward recovery time (and a very low forward peak voltage VFP). This property can be used for particular applications since no other existing diode has a lower turn-on time for a given VBR (or VRM) voltage.

8. CALCULATION EXAMPLE

Figure 8 : Behaviour of a Transil Operating as a Diode at Turn-off.

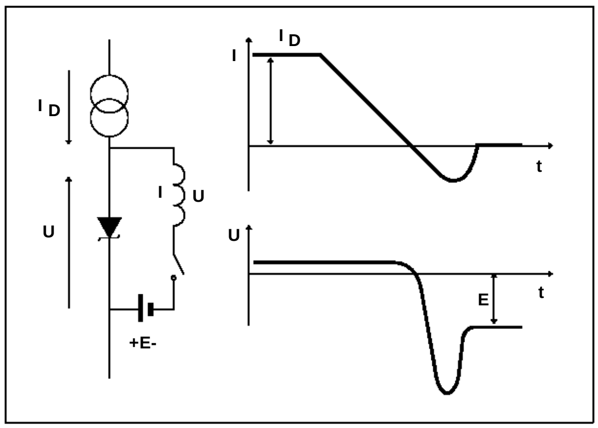
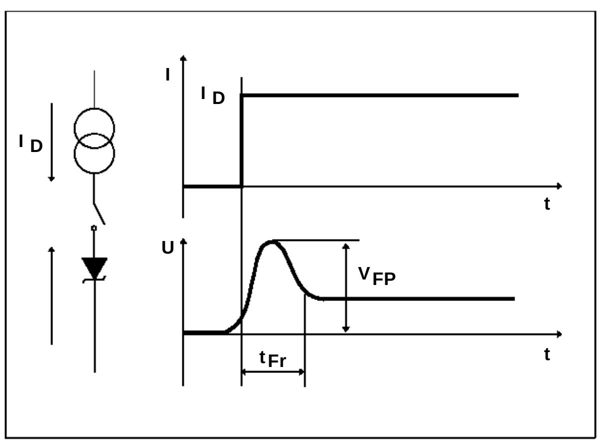


Figure 9 : Behaviour of a Transil Operating as a Diode at Turn-on.

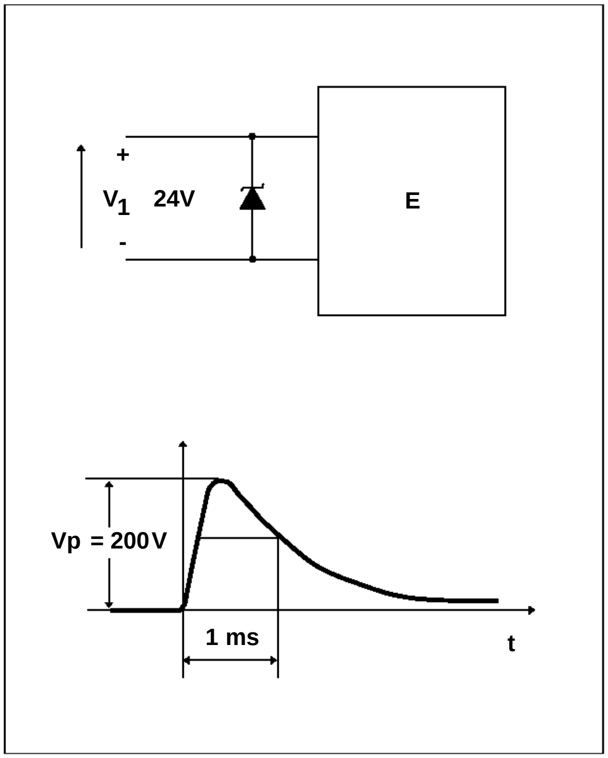


8.1. NON-REPETITIVE SURGES.

A source (V_1) with a rated voltage of 24 V supplies equipment E which is to be protected against overvoltages. This source is subjected to random non repetitive exponential overvoltages with amplitudes of 200 V and a duration of 1 ms at 50% (standard wave) (see fig.10). The equivalent internal impedance Φ of the source with respect to 1 ms exponential waves is 13 Ω.

The maximum ambient temperature is 80°C. In no circumstances should equipment E be subjected to a voltage higher than 50 V.

Figure 10 : Protected Equipement And Surge



8.1.1. Selection of the protection voltage

In the absence of specific information, we assume that voltage V1 varies by ±20%, ie between 20 V and 29 V.

The protection voltage V_{RM} of the Transil should then be greater than or equal to 29 V.

8.1.2. Predetermination of the peak power Pp

The equipment E cannot withstand a voltage above 50 V → $V_{CL} \leq$ 50 V.

Assuming that there is a Transil which meets this criterion, an initial calculation of the Transil power can be made.

$$P_P = V_{CL} \times I_P \text{ where } I_P = \frac{V_P - V_{CL}}{\Phi}$$

$$I_P = \frac{+200 - 50}{13} = 11.5A$$

$$P_P = 50 \times 11.5 = 575W$$

This power corresponds to an operating temperature of 80°C. The data sheets indicate power at 25°C so we have to correct the power according to the curves of admissible power versus initial temperature.

So we obtain :

$$P_P\,(25°C) = \frac{P_P\,(80°C)}{0.8}$$

$$P_P\,(25°C) = \frac{575}{0.8} = 719W$$

8.1.3. Selection of the Transil.

We can now establish an initial specification of the Transil to use.

$$V_{RM} \geq 29V$$

$$V_{CL} \leq 50V \text{ for } I_P = 11.5V$$

$$P_P\,(25°C) = 719W/1ms$$

The type corresponding to these characteristics is the 1.5 KE 36 P.

$$V_{RM} = 30.8\ V$$

$$V_{BR}\ nom = 36\ V\ ;\ min\ 34.2\ V\ ;\ max\ 39.6\ V$$

$$V_{CL}\ max = 49.9\ V\quad I_{PP} = 30\ A$$

$$P_P = 1500W/1ms$$

$$\alpha_T = 9.9 \times 10^{-3}$$

8.1.4. Determination of the clamping voltage V_{CL}.

To determine the voltage V_{CL} at 11.5 A, we can use the I_{PP}/V_{CL} parameters included in the 1.5 KE data sheets.

$$V_{CL} \text{ at } I_P \approx V_{BR} \max + R_D \times I_P$$

$$R_D \leq \frac{V_{CL} - V_{BR}}{I_{PP}}$$

$$V_{CL} \ at \ 11.5A \approx 39.6 + \frac{49.9 - 36}{30} \times 11.5 = 44.9V$$

8.1.5. Temperature correction

The voltage at 80°C is :

$$V_{CL}(80°C) = V_{CL}(25°C)\,[1 + \alpha_T(T_j - 25°)]$$
$$V_{CL}(80°C) = 44.9\,[1 + 9.9\,10^{-4}\,(80 - 25)]$$
$$V_{CL}(80°C) \approx 47.3V$$

This value is below the 50 V limit. The Transil ensures the protection.

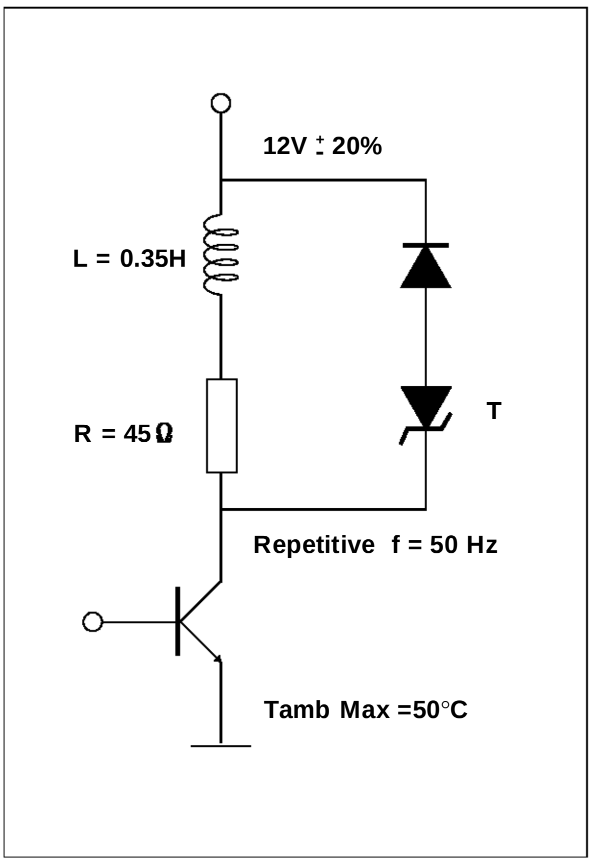
8.2. REPETITIVE SURGE.

We have to protect the transistor shown in fig.11 with a Transil whose clamping voltage, Vcl, does not exceed 85 V.

Calculation method

To avoid a long calculation, we assume :

Figure 11 : Transistor Protection



$V_{CL} \approx V_{BR}$ only true in the case of repetitive surges.

Experience shows this hypothesis is confirmed in most cases with a Transil, therefore a Transil ought to be selected initially according to its thermal characteristics.

8.2.1. P_{AV}

An approximate value can be obtained by supposing that all the energy contained in the inductance is absorbed by the Transil. This hypothesis is close to reality when the ratio

$$\frac{V_{BR}}{V} \ is \ significant.$$

$$P_{AV} = \frac{1}{2} \times LI^2 f = \frac{1}{2} \times 0.35 \left[\frac{12 + 2.4}{45}\right]^2 \times 50$$
$$= 0.9\ W$$

8.2.2. First choice

We choose the type BZW O4P64

$$V_{BR} \max = 82.5\,V$$
$$Rth = 100°C/W$$

8.2.3. Tj calculation

$$T_j = T_{amb} + P_{AV} \times R_{th} = 50 + 90 = 140°C$$

This value is compatible with the Transil characteristics.

8.2.4. Determination of V_{CL}

We see on the data sheets that for such a low current level $V_{CL} \approx V_{BR}$ max

8.2.5. Temperature correction

$$V_{CL}(140°C) = V_{CL}(25°C)\,[1 + \alpha_T(140–25)]$$
$$V_{CL}(140°C) = 92.5\ V$$

This value is too high.

8.2.6. Second choice

BZW04P58 V_{BR} max = 74.8 V
V_{CL}(140C) = 83.5 V

The Transil BZW04P58 is suitable for this application.

N.B: This example shows that due to the component dispersion, we have to add the variation due to the temperature.