CHOICE OF PROTECTION IN AUTOMOTIVE APPLICATIONS(CLASSICAL TOPOLOGY)

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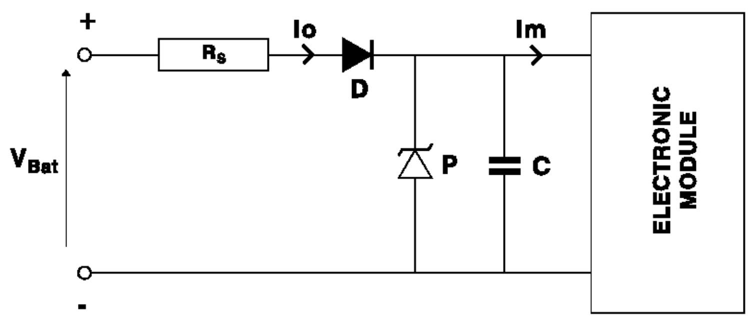
1. INTRODUCTION

This paper describes a protection schematic based on discrete components, together with a general method of choosing the components to suppress the surge effects on automotive modules.

Figure 1 : General Protection Topology



2. GENERAL PROTECTION SCHEMATIC :

2.a Positive impulsive overvoltages :

This type of overvoltage is clamped by the protection component P at maximum voltage V_{CL}. Resistance R_S limits the dissipated energy in the protection component without compromising the clamping function.

2.b Negative impulsive overvoltages :

There are two ways to limit these :

- Without diode D : the protection component operates as a rectifier diode and clamps the voltage at the unit terminals to approximately 1 V.

- With diode D : the diode is reverse-biased and therefore protects the unit.

One important thing to take into account is the peak reverse voltage limit of D. V_{RRM} = 400V seems a good compromise (see curve N° 6 of the ISO/TC22 standard).

2.c Positive continuous overvoltages :

During this phase, the protection component must be in the stand- by phase (very low current passing through the component).

2.d Negative continuous overvoltages :

This protection is achieved by diode D which is reverse -biased.

2.e Impulsive voltage drop :

During this phase, the unit is fed by capacitor C while diode D prevents C from discharging into the battery circuit.

3. THE CHOICE OF COMPONENTS :

3.a Diode (D)

The following parameters will constitute the selection criteria :

- The average current used by the electronic module.

- The maximum repetitive peak reverse voltage V_{RRM}

- The maximum ambient temperature T_{amb}.

The following inequality must apply in all cases :

$$T_{amb} + R_{th} P < T_j \max$$

where

$$P = V_{TO} I_F (AV) + rd\, I^2_F(R_{MS})$$

R_{th} = thermal resistance (Junction - ambient) for the device and mounting in use.

3.b Resistance (R_S)

Its presence allows a "size" (and thus cost) reduction of the protection component.

Its value is a function of the following elements :

V_{bat} min : lowest battery voltage which is specified in the technical note issued by the manufacturer.

V_{CC} min : minimum voltage needed for the electronic unit in operation.

I_{CC} max : maximum supply current of the electronic module.

The maximum value of Rs will be :

$$R_S \max = (V_{bat} \min - V_{CC} \min)/I_{CC} \max$$

3.c Capacitor (C)

Its role is to make sure that the voltage at the terminals of the electronic unit is greater than or equal to Vcc min while the starter circuit is active.

Its value depends on :

V_{bat} : voltage across the battery before the disturbance

V_{CC} min : see par. 5.b

T : length of the disturbance (130 ms: see application note 4.1, paragraph III.4)

The minimum value of C will be :

$$C\min = (130 * 10^{-3}/R_{eq})/\ln (V_{CC} \min/V_{bat})$$

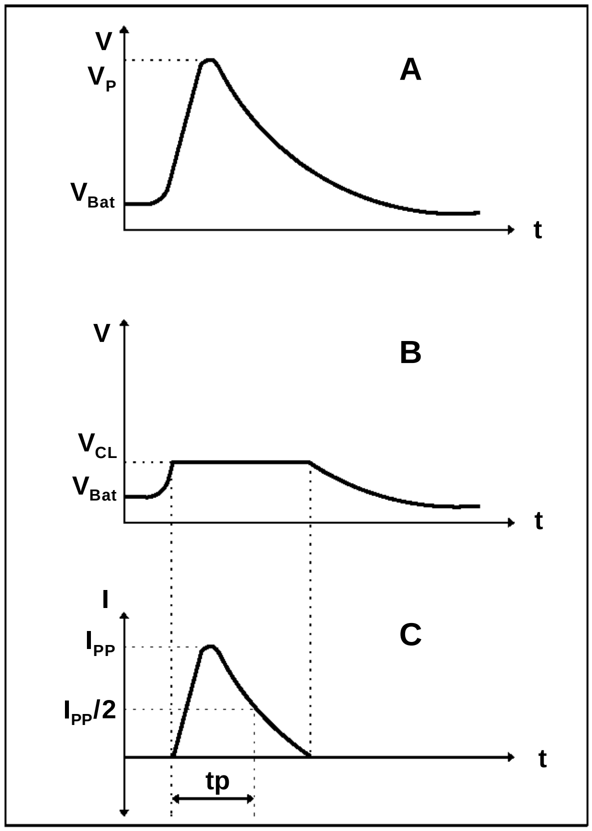
with R_{eq} = equivalent resistance of the electronic unit

$$R_{eq} = V_{CC} \min/I_{CC} \max$$

3.d Protection component (P)

- How it works :

Figure 2 : Transil Behaviour



A : Disturbance

B : Voltage across the protection device

C : Current through the protection device

The role of the protection device is to suppress the destructive effects of the surge (Fig.2a), the most agressive being the load dump impulse.

To achieve this, the TRANSIL clamps the spike at a maximum value V_{CL} (Fig.2b). A surge current flows through the suppressor during this phase (Fig.2c).

4. THE CHOICE OF THE PROTECTION DEVICE

4.a Parameters to take into account

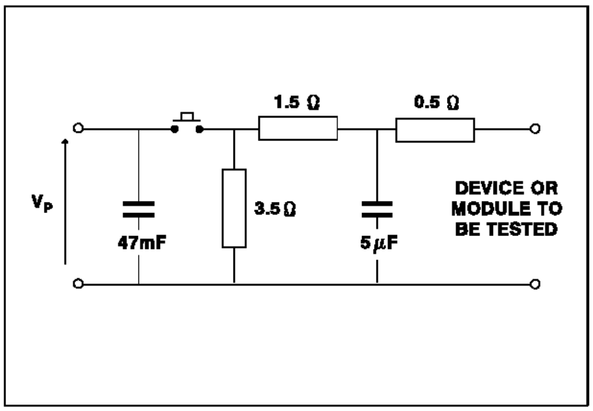
To choose the TRANSIL we have to know the surge parameters and the application requirements.

- Surge parameters

The surge is defined by the peak value Ip and the duration tp of the current wave flowing through the protection device during the clamping.

As shown in the ISO/TC22 standard the most energetic impulsive disturbance is the load dump surge. Most car manufacturers recommend the SCHAFFNER NSG 506 generator to synthesise this wave. See fig.3.

Figure 3 : Equivalent circuit of Schaffner generator



This circuit allows us to determine the parameters of the current wave seen by the TRANSIL.

The peak current I_P is equal to :

$$I_P = (V_P - V_{CL}) / (R_G + R_S)$$

Where

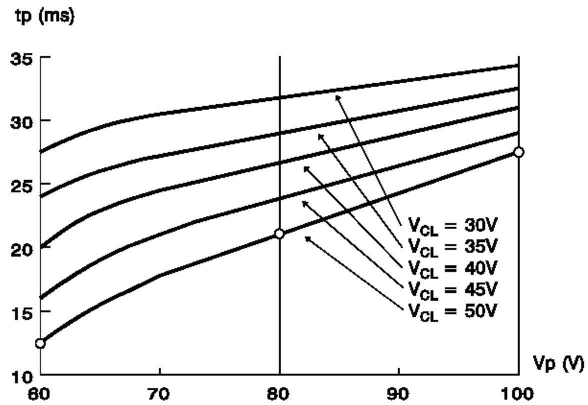
V_P = Peak voltage of the surge (+ 80V)
V_{CL} = Clamping voltage of the transil

R_G = Series resistance of the generator (2 Ohms)

R_S = Series resistance of the module to be protected (see chapter 3.b)

For example with V_P = 80V, V_{CL} = 40 V and R_S = 0 Ohm, we have I_P = 20A

Figure 4 : Current pulse duration versus VP and VCL



The curves of figure 4 give the duration tp of the current wave in the TRANSIL during clamping. This parameter depends on the peak voltage V_P of the surge and on the clamping voltage V_{CL} of the protection device. For example with V_P = 80V and V_{CL} = 40V, tp = 27.5 ms.

- Application requirements

Three values are necessary :

- The maximum operating voltage, which is the greatest battery potential. Often the car's electrical equipment has to withstand two battery voltages (due to starting aids: see ISO/TC22 standard). These parameters define the minimum stand off voltage V_{RM} of the TRANSIL.

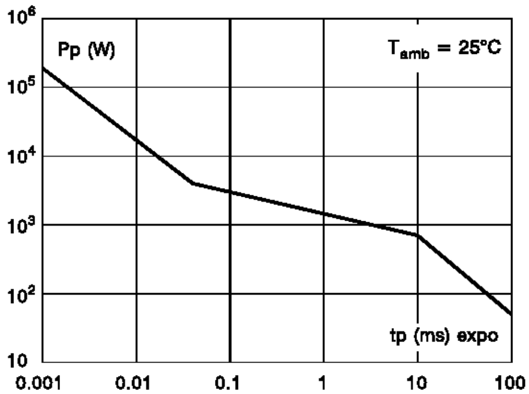
- The minimum destructive voltage, which is the voltage value over which the device will be destroyed. This limit determines the maximum clamping voltage V_{CL} of the protection device.

- The maximum ambient temperature T_{amb} that would decrease the power dissipation capability of the TRANSIL.

4.b Choice of the protection device

The choice of component is made with the help of the parameters t_P, P_P in the curve $P_P = f(t_P)$ from the "PROTECTION DEVICES" data book.

Figure 5 : Peak pulse power versus exponential pulse duration (1.5KE, 10V < VBR < 250 V)

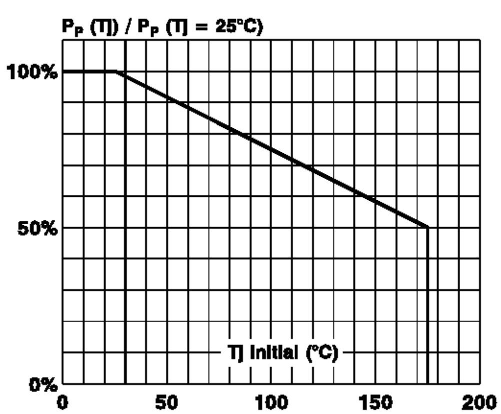


If the operating point defined by t_P and $P_P = V_{CL} * I_P$ is on or below the curve, the TRANSIL can operate in the application at 25°C of ambient temperature.

4.c The ambient temperature effect :

Component characteristics are given at an ambient temperature of 25°C (die temperature before clamping action). The following chart shows the effect of junction temperature on the power suppression capability.

Figure 6 : Allowable power dissipation versus junction temperature



This curve gives the derating to be applied to the peak power capability of the protection device according to junction temperature.

The second temperature effect is the shift of V_{BR}.

$$V_{BR} \text{ (at T)} = V_{BR} \text{ (at 25°C)} * (1 + \alpha_T \text{ (T-25)})$$

Where α_T is the temperature coefficient of V_{BR}.

4.d Calculation of clamping voltage V_{CL}

The clamping voltage V_{CL} can be estimated as follows :

$$V_{CL} = V_{BR} \max + (Rd\ IP)$$

Where Rd is the dynamic resistance of the TRANSIL

Table 1 - Typical Rd for wave of t_P = 30 ms at 25°C

	BZW04 P23	P6KE 30P	1.5KE 30P	BZW50 -22	LDP24AS
Rd typ (Ω)	1.2	0.75	0.35	0.15	0.12

5 - EXAMPLE :

A / Disturbances

The load dump is the most agressive

B / Battery voltage

The electronic unit will have to function with a battery voltage of 11 V.

C / Ambient temperature

Tamb = 85°C

D/ Electrical characteristics of the module

Table 2 - Module characteristics

PARAMETERS	V_{CC}	I_{CC}
DESCRIPTION	Supply voltage	Supply current
MIN	8	-
TYP	12	400
MAX	32	600
UNIT	Volts	mA

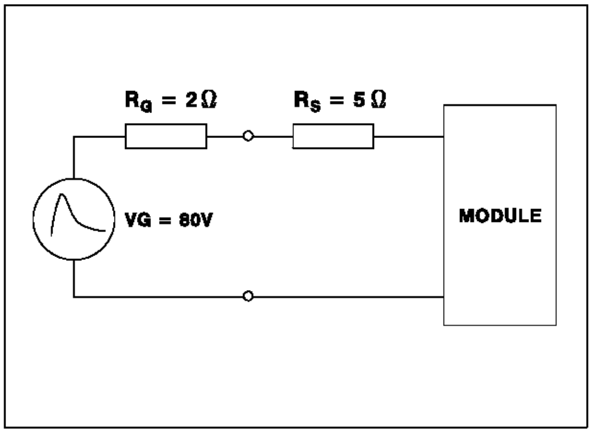
E / Analysis

E/1 Calculation of R_S max

$$R_S \text{ max} = (V_{bat} - V_{CC} \text{ min})/I_{CC} \text{ max}$$
$$R_S \text{ max} = (11-8)/0.6 = 5 \text{ Ohms}$$

E/2 Diagram

Figure 7 : Application Diagram



E/3 Peak current

$$I_{PP} = (V_G\text{-}V_{CL})/(R_G+R_S) = (80\text{-}32)/7=6.9\text{A}$$

E/4 Peak power

$$P_P = V_{CL} * I_{PP} = 32 * 6.9 = 221 \text{ W}$$

E/5 Conduction time

$$t_P = 30 \text{ ms}$$

E/6 Choice of the TRANSIL

Table 3 - Transil characteristics

TYPE	**POWER CAPABILITY** (tp = 30 ms)	
	at 25°C	at 85°C
BZW04	60 W	45 W
P6KE	80 W	64 W
1.5KE	200 W	160 W
BZW50	700 W	525 W
LDP24A	1980 W	1800 W

E/7 Conclusion

Diode BZW50-22 is an efficient protection device within the 85°C temperature range, and the V_{CL} max is given as follows :

$$V_{BR} \text{ (85°C)} = V_{BR} \text{ (25°C)} \times (1 + \alpha_T(85\text{-}25))$$
$$= 29.8 * (1 + 9.6 * 10\text{-}4 * 60)$$
$$= 31.5\text{V}$$
$$V_{CL} \text{ (85 °C)} = V_{BR} \text{ (85 °C)} + \text{Rd } I_P$$
$$= 31.5 + (0.15 * 6.9)$$
$$= 32.5 \text{ V}$$

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