APPLICATION NOTE

SLIC PROTECTION

A. BREMOND

I INTRODUCTION

The goal of the telecommunication network (fig.1) is to permit the data exchange (speech or digital) between two (or more) subscribers.

The network is made up of different parts which are subject to various disturbances.

The most susceptible elements are the lines, due to their lenght and their geographical location.

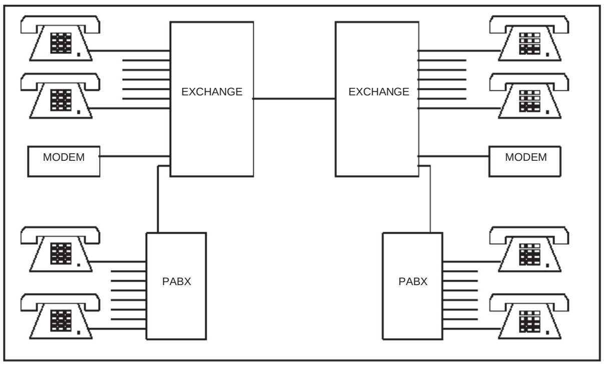
Disturbances strike the lines and are then propagated to the extremities of the lines at which lie telephone set and the subscriber line interface card (SLIC).

So the lines receive two kinds of overvoltages :

Surges of short duration with high peak voltage value (a few hundred micro-seconds for a few thousand volts). These are generated by atmospheric phenomena.

Surges of long duration with medium voltage value (greater than one second for a few hundred volts RMS) which are due to the mains AC power networks.

Fig.1 Classical telecommunication network topology.

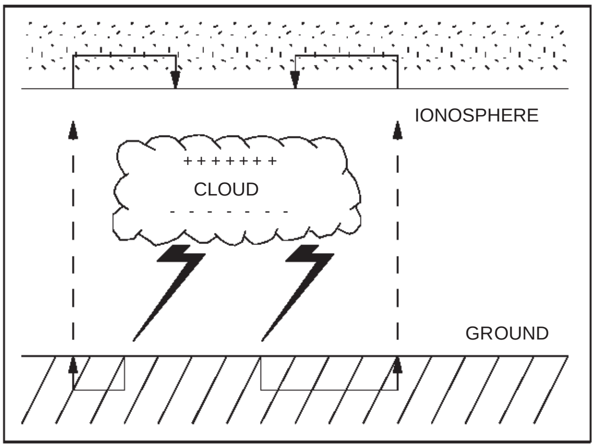


The purpose of this application note is to analyse these 2 kinds of overvoltages and to propose different protection solutions dedicated to the SLIC.

II OVERVOLTAGES ACROSS TELECOMMUNICATION LINES :

II.1 Atmospheric effects :

Fig.2 Lightning phenomenum



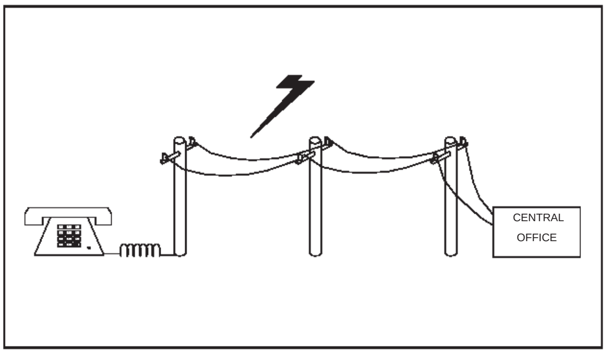
Lightning phenomena are the most common surge causes. They are mainly due to a voltage difference between the ground and the clouds (a few 100 kV). Two kinds of strikes may occur. Negative discharge with a peak current of 50 kA, rise time of 10µs to 15µs and 100µs duration.

Positive discharge with a peak value of 150 kA, rise time between 20µs and 50µs and a duration between 100ms and 200ms.

The lightning effect appears on the lines in two ways.

- Direct shock.
- Induced shock.

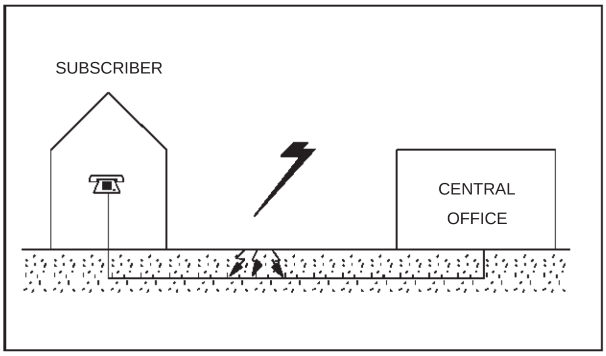
Fig.3 Direct lightning strike.



The Fig.3 shows the first case which is produced mainly on overhead lines.

Induced shock is more frequent than a direct shock. Lightning strike the ground and a current flows in the cable shield. This current produces a voltage gradient which in some places is above the insulation capability of the cable material (Fig.4).

Fig.4 induced strike.



II.2 Proximity and crossing with AC mains lines :

For these kinds of surges two cases may be seen :

The first one is due to the falling of an AC mains cable on a telephone line.

The second case is produced by the proximity of a subcriber line with an AC mains line or equipment (mainly capacitive coupling).

It is interesting to note for these types of disturbances a RMS value of a few Amps for a duration of between 1 s and 15 mn.

III PRIMARY AND SECONDARY PROTECTION :

The figures in chapter II give us an idea of the energy which may appear on the lines. (so in the field these surge values are lower due to the losses of ground resistance, the capacitive coupling and so on, but are signifiant nevertheless).

We have to divide these disturbances into two families :

High peak value and short duration (lightning)

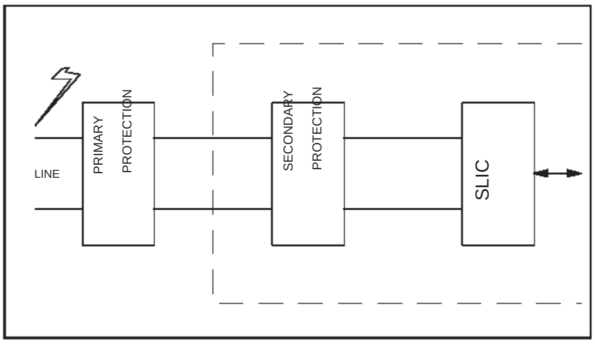
Short peak value and long duration (crossing with AC power).

For both cases the present state of the art of silicon protection devices does not permit the suppression of these levels of energy.

A second parameter to keep in mind is the very low clamping factor (1) needed by the IC's used to realize the line interface. This fact necessitates the designer to use a protection solution with silicon (fast response time/low clamping factor).

High energy values and low clamping factor impose two protection levels.

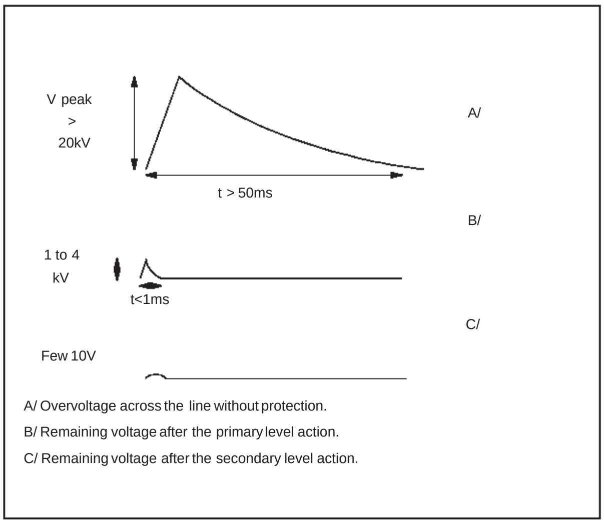
Fig.5 Primary/secondary protection topology.



The first level called primary protection (fig.5) located on the connecting terminal of the exchange, suppresses the major part of the disturbance. The second level called secondary protection reduces the remaining overvoltage.

(1) the clamping factor is the ratio of the normal operating voltage over the maximum clamping voltage.

Fig.6 Primary/secondary protection levels effects



The figure 6 shows the goal of both protection levels.

In this example the surge across the line without protection will be a few 10 kV peak value for a few 10 ms length (Fig.6A)

After the primary protection the major part of the energy is cancelled (Fig.6.B). The remaining overvoltage may be a few kV (depend on the dv/dt of the surge and the surge arrestor technology used).

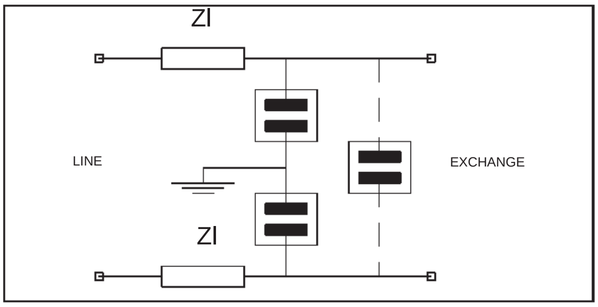
Across the second level protection the voltage does not exceed a few 10 Volts.

III.1 Primary protection :

Actually two kinds of primary protection are used :
- carbon gaps.
- gas tubes.

III.1.A Carbon gaps :

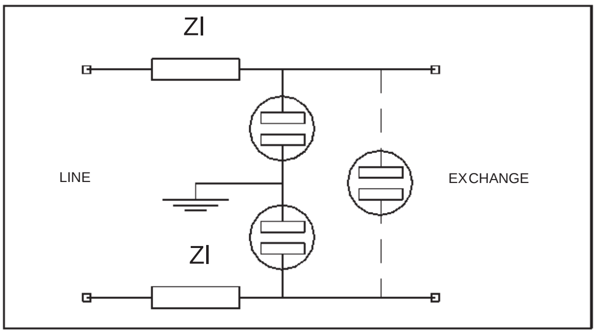
Fig.7 Carbon gap based primary protection.



These components are made by two carbon electrodes. In fact the carbon gap is the low cost primary protection but it has two major disadvantages :
- its short life duration
- its variable spark threshold.

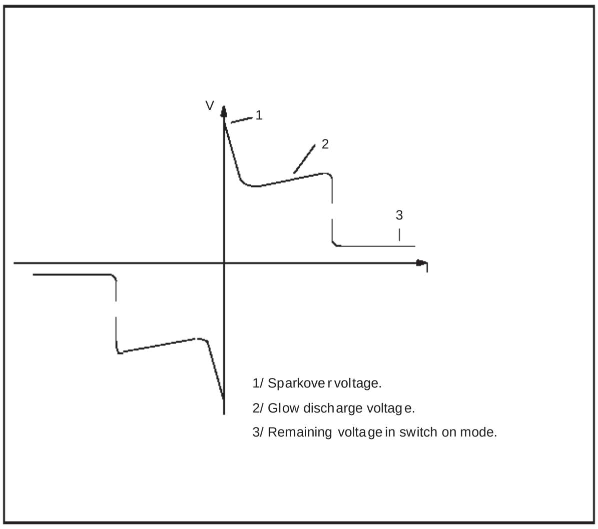
III.1.B Gas tubes :

Fig.8 Gas tube based primary protection.



These components are made by two metallic electrodes in a sealed case. Generaly the sealed tub contains a low pressure gas.

Fig.9 Gas tube characteristics.

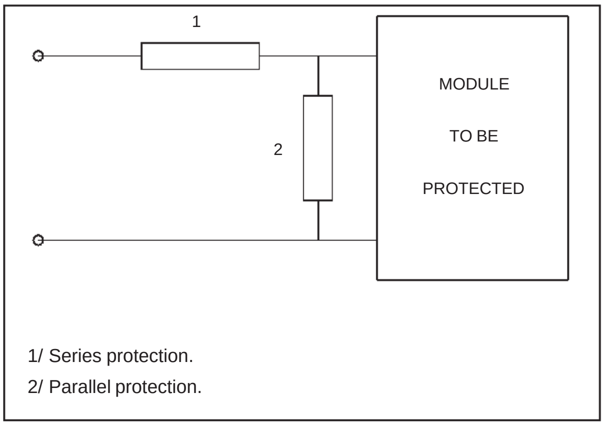


The major disadvantage of this kind of device is its response time, in fact the maximum voltage across the gas tube depends on the dv/dt of the surge.

III.2 Secondary protection :

III.2.A Series and parallel protection :

Fig.10 Series and parallel protection.



The secondary protection level is generaly achieved with two types of devices :

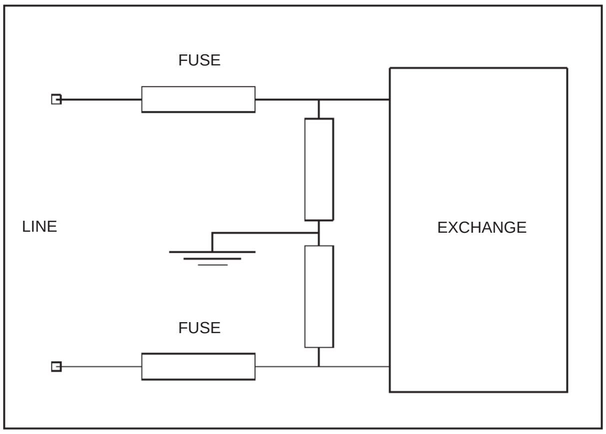
The series protection ensures the protection against the proximity or the crossing with AC power lines.

The parallel protection operates to suppress the overvoltages due to the lightning effects.

* Series devices :

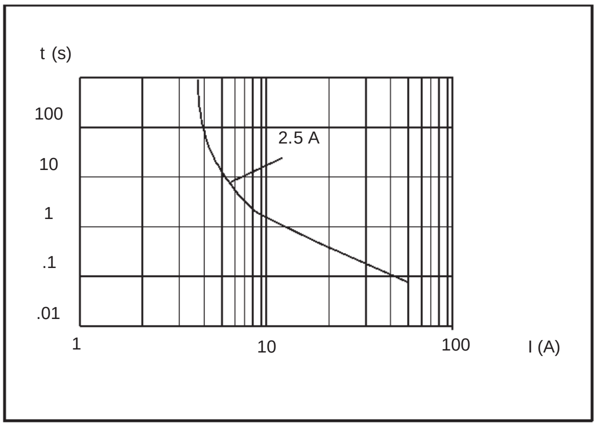
Series devices operate by opening of the circuit or by an increment of the resistance.

Fig.11 Fuse protection.



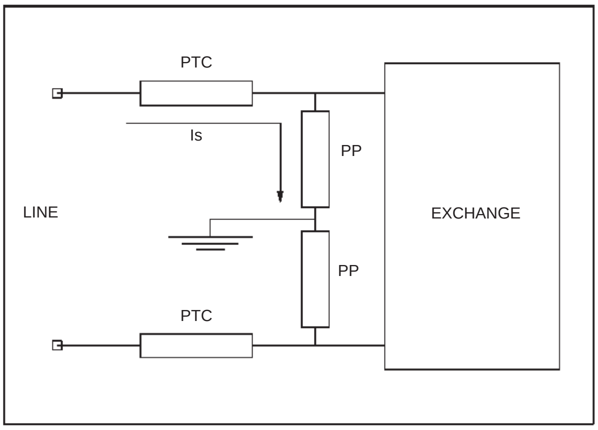
The fuse is classical case of protection by opening of the circuit. Figure 11 shows an exchange protected by fuses and figure 12 represents an example of the limit curve of the fusing action.

Fig.12 Fuse fusion function.



These components provide an absolute security after action, but their major disadvantage is the need for maintenance.

Fig.13 PTC based protection.

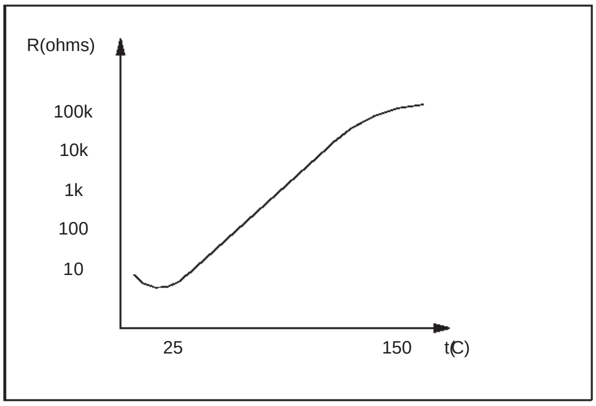


The PTC thermistor is a device which operates by very rapid resistance increase as a function of the temperature.

When the surge occurs across the line, the parallel protection PP is activated.

The surge current Is, generated by PP action, flows through the PTC and increases its internal temperature. As shown on the figure 14 the resistance value of the PTC rises quikly with the temperature.

Fig.14 Resistance versus temperature.



The major disadvantage of the fuse does not exist with the PTC. Unfortunatly this kind of component presents a big tolerance, a long time to return to its stand off point and a drift of its value.

An other series device is the resistance which permits to limit the current through the parallel protector.

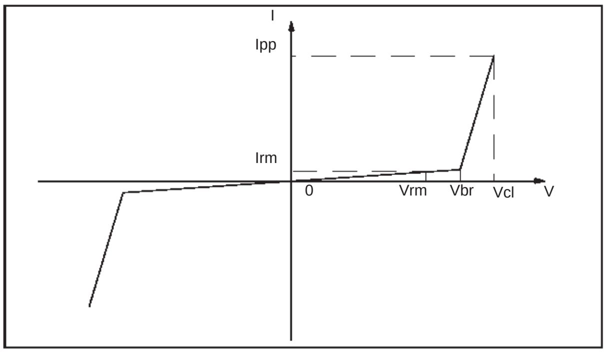
* Parallel devices :

The parallel protection function may be assumed by different devices based on different technologies.

In fact it is clear that the future in term of SLIC topology is based on the use of IC.So the consequent requirement for good response times and high clamping factor necessitates the use of silicon protection.

Parallel silicon protection functions in two different modes.

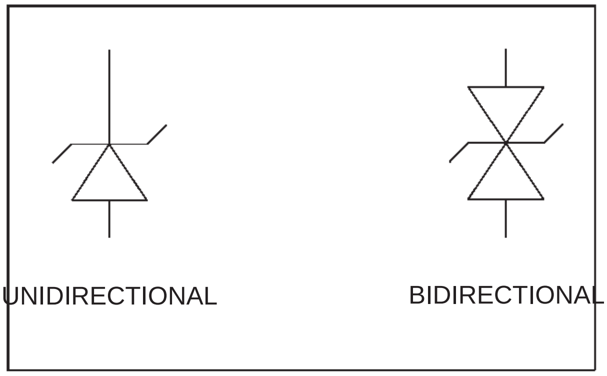
Fig.15 Clamping characteristics.



* Clamping mode :

This device named TRANSIL is based on the breakdown effect. During the stand off time the working point is located between 0 and V_{RM} (see curve of fig.15) and the device draws a very low leakage current (< 5 µA at 25°C). When a surge occurs across the line the working point is located between V_{BR} and V_{CL} the increase of the voltage is low (good clamping factor) and the current drawn very high.

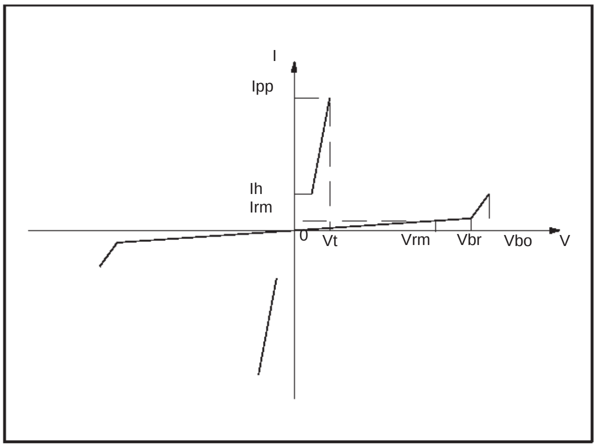
Fig.16 TRANSIL symbols.



The TRANSIL may be uni or bidirectional.

During the clamping action the major part of the energy is dissipated in the TRANSIL.

Fig.17 CROWBAR characteristics.



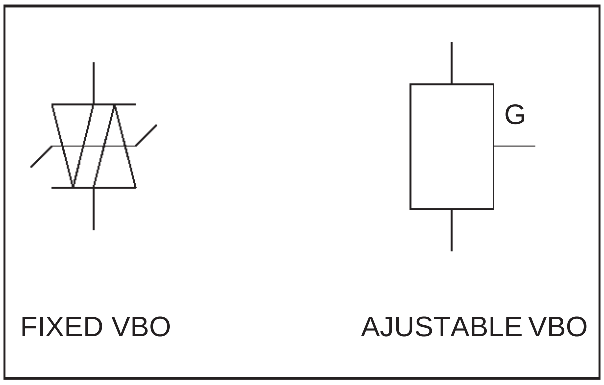
* Crowbar mode :

The CROWBAR device named TRISIL is based on the breakover effect. In fact in normal operating the device operates in the area between 0 and V_{RM} (see curve fig.17) and the bias current through the protection is very low (< a few µA at 25°C).

When the surge occurs the TRISIL begins to work in the clamping mode between V_{BR} and V_{BO}. After that the device fires and operates like a short circuit.

After the surge, the current decreases and falls below the holding current IH. This condition causes the TRISIL to switch off and the return to the stand off area.

Fig.18 TRISIL symbols.



There are two kinds of TRISIL, the fixed breakover voltage type and the device with adjustable breakover voltage.

During the surge suppression action of the TRISIL the major part of the energy is dissipated in the series elements of the line.

This last fact makes the TRISIL better adapted to protect againt the high energy of the lightning overvoltages.

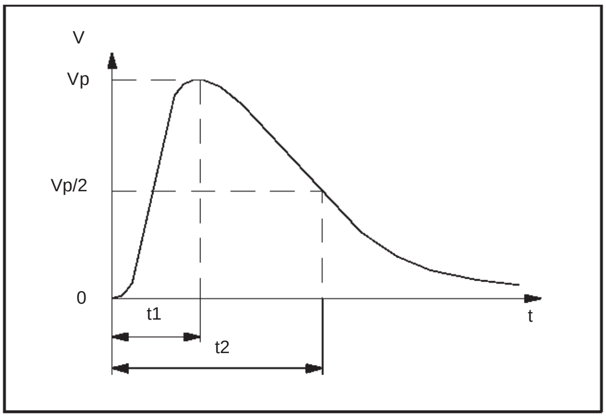
IV STANDARDS :

These standards define the two kinds of overvoltage (lightning and crossing).

IV.1 Lightning simulation :

The lightning overvoltage is simulated by a bi-exponentional wave, which are defined by the rise time t1 and the duration t2 between the start and the passage of the deacrising edge at half peak value (fig.19).

Fig. 19 Standard wave.



Each country published its standard, which can be summarized by the times t1 and t2, the peak voltage of the wave and the surge generator diagram.

The table here after gives a unexhaustive list of the standard :

COUNTRY	AUTORITY	WAVEFORM (µs)
ENGLAND	BRITISH TELECOM	10/700
FRANCE	PTT	0.5/700
GERMANY	BUNDESPOST	10/700
ITALY	SIP	0.5/700 1/100
SPAIN	COMPANY TELEPHONICA DE ESPANA	1/1000
SWEDEN	TELEVERKET	10/700
SWITZERLAND	PTT - BETRIEBE	10/700 1.2/50
USA	BELL	10/1000 10/360 2/10
	FCC	10/560 10/160 2/10

The following figures give us the diagram of the surge generators mainly used :

Fig. 20 10/700µs wave generator.

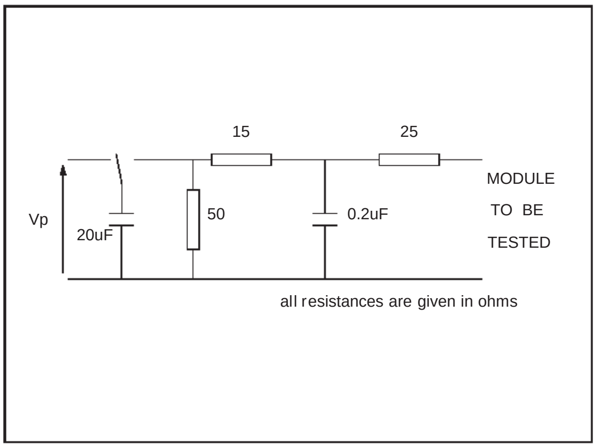


Fig. 23 1.2/50µs wave generator.

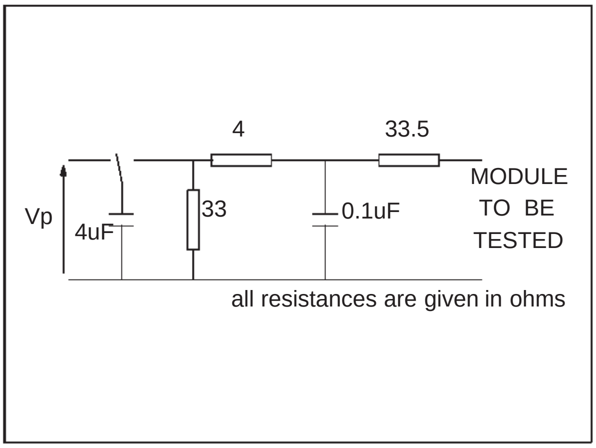


Fig. 21 0.5/700µs wave generator.

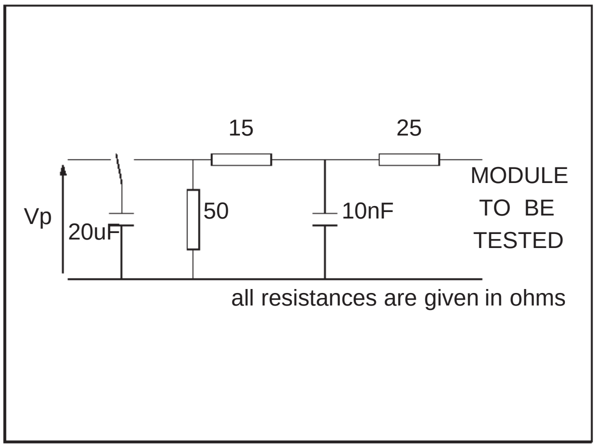


Fig. 24 10/560µs wave generator.

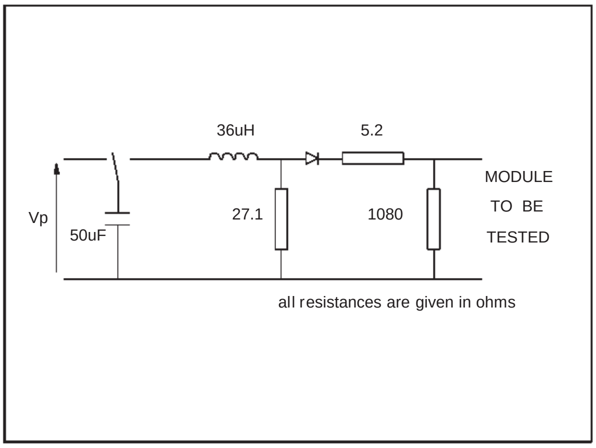


Fig. 22 1/1000µs wave generator.

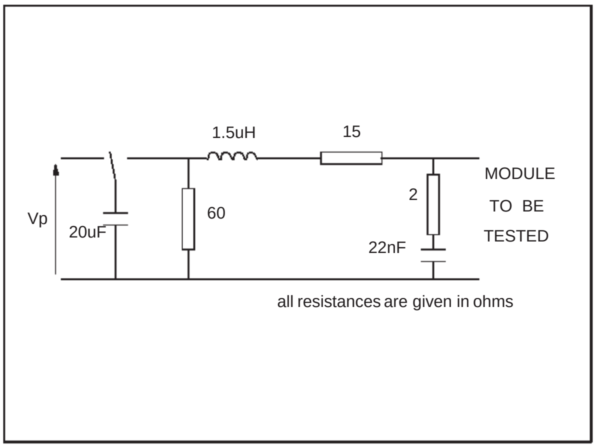


Fig. 25 10/160µs wave generator.

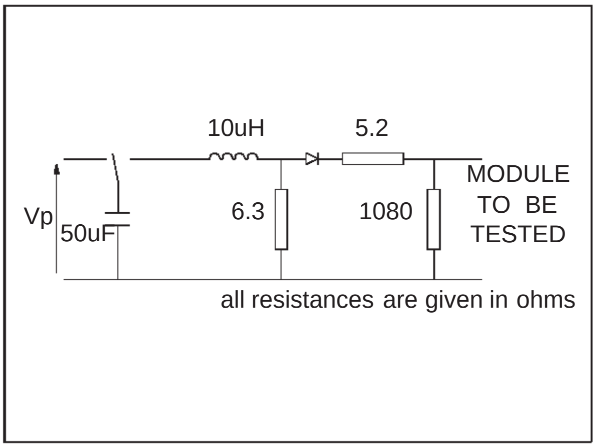
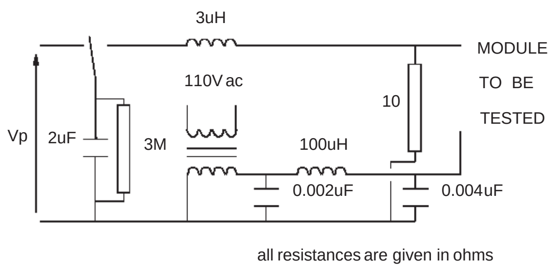


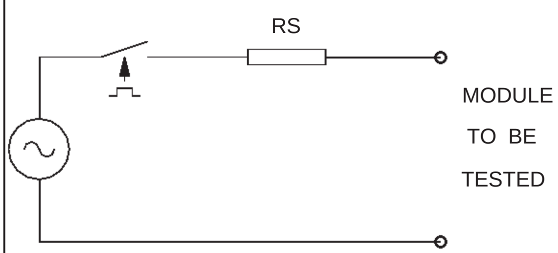
Fig. 26 2/10µs wave generator.



IV.2 Crossing or proximity with main ac lines :

Crossing or proximity are simulated by a sinus generator (50 or 60 Hz) which injects through a series resistor during a defined time (fig.27).

Fig. 27 Crossing simulation generator.



Here after are given some examples of crossing simulation

COUNTRY	VOLTAGE Volts RMS	SERIES RESISTOR (Ohms)	DURATION
ENGLAND	0 TO 250 0 TO 650 0 TO 430 (50 Hz)	40 TO 400 150 150	15 mn 1 s 2 s
FRANCE	O TO 1000 > 1000 (50 Hz)	20 3000	trains of 1 s ”ON” 2 s ”OFF” 10 times with 3 mn between each trains
GERMANY	300 (50 Hz or 16.6 Hz)	600	200 ms
ITALY	300 650 220	600 200 10 or 600	500 ms 500 ms 15 mn
USA	0 - 50 50 - 100 100 - 600	150 600 600	15 mn 15 mn 60 x 1 s application

.V SLIC FUNCTION :

V.1 SLIC generalities :

The SLIC function is defined by the nemotechnic word BORCHT :

- Battery feeding
- Overvoltage protection
- Ringing
- Signalling
- Cofidec
- Hybrid
- Test

The important parameters to define the OVERVOLTAGE PROTECTION are the battery feeding and the ringing signal.

V.1.A Battery feeding :

This sub-function of the SLIC is characterized by :

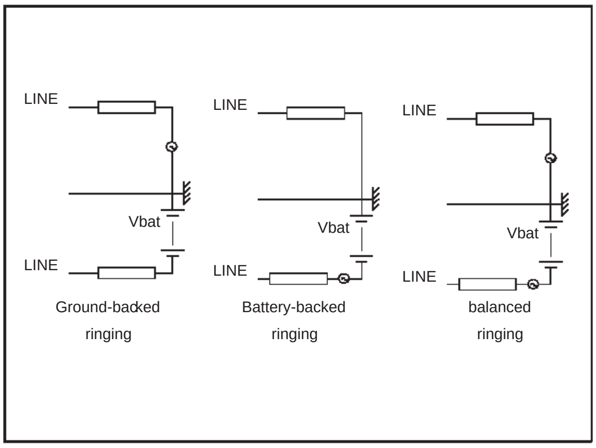
- the battery voltage typical value (generaly between 45 and 65 V)
- the tolerance of the voltage value
- the possibility to switch from one value to another one (case of line cards designed to operate equally on normal and long lines)

V.1.B Ringing signal :

For the ringing two parameters are to be taken into account :

- the voltage value (generaly between 70 and 100 V RMS)
- the ringing configuration (fig.28)

Fig. 28 Different ringing configurations.

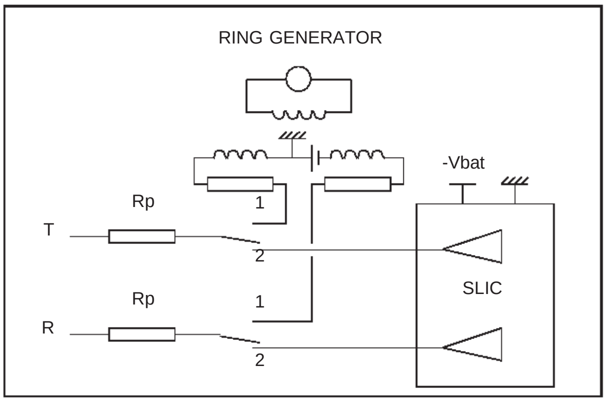


V.2 Different kinds of SLIC :

There are two SLIC families :

- the SLIC without integrated ring generator.
- the SLIC with integrated ring generator.

Fig. 29 SLIC without integrated ring generator.

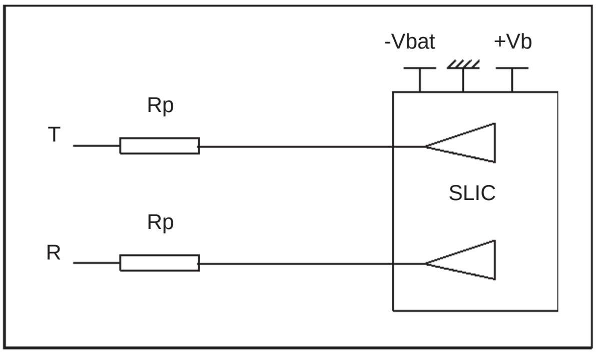


V.2A SLIC without integrated ring generator :

For this case the SLIC IC is supplied between the ground and the battery voltage (- Vbat).

The relay operates the selection of functions, ringing mode in position 1 and the other modes in position 2.

Fig. 30 SLIC with integrated ring generator.



V.2 B SLIC with integrated ring generator :

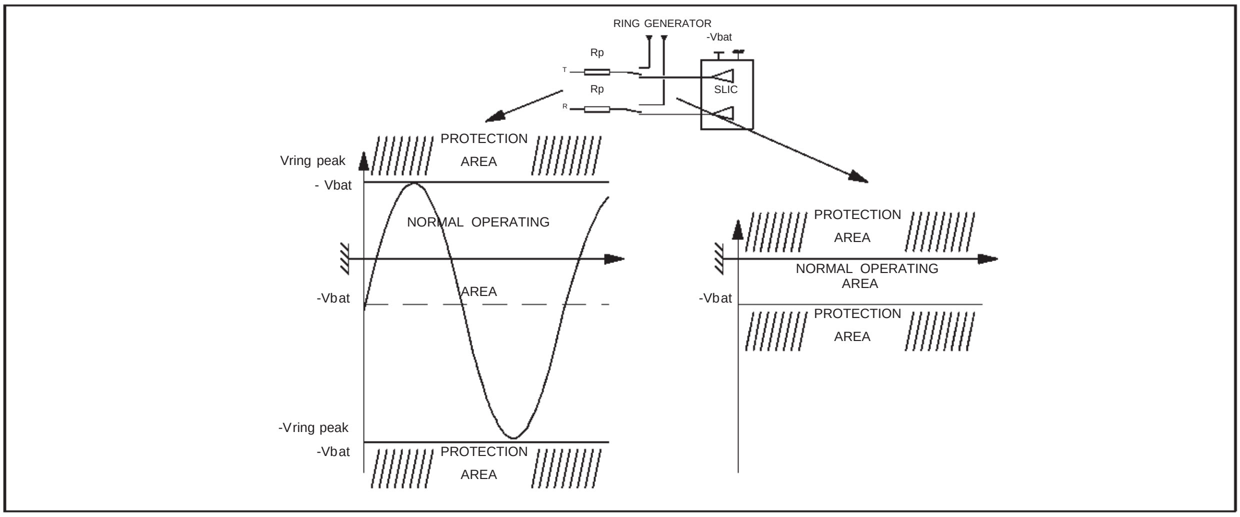
This kind of SLIC, only composed by the L3000 family of SGS THOMSON, is supplied between the ground, the battery (-Vbat) and a positive voltage (+VB) up to +72 V.

V.3 Goal of the SLIC protection :

The purpose of the protection is to suppress all overvoltages out of the normal operating range voltage of the SLIC.

We have to take into account the two kinds of SLIC seen in paragraph V.2.

Fig. 31 Goal of the protection for the SLIC without integrated ring generator.



V.3.A SLIC without integrated ring generator :

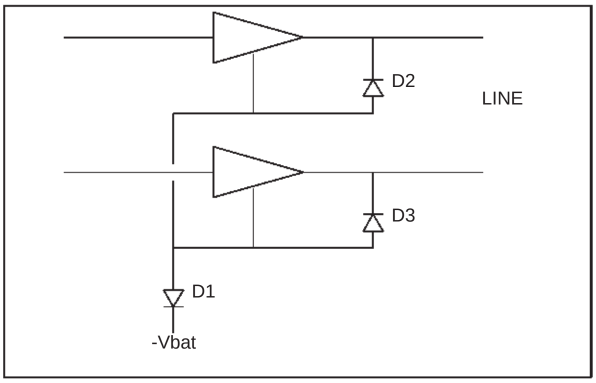
As shown in the Fig.31 the protection areas are located differently before and after the ring relay.

Before the relay the protection must operate over the peak value of the ring signal (generally +90V and -190V). As the relay protection does not require a very precise clamping threshold, we usually use a symetrical overvoltage suppressor (generaly + or - 200V).

After the relay the protection acts to suppress all spikes over the ground and under the battery voltage (-Vbat).

It is important to note that the integrated circuit needs a protection threshold closest than the supply voltage.

Fig. 32 Internal diodes network of the TDB7722.

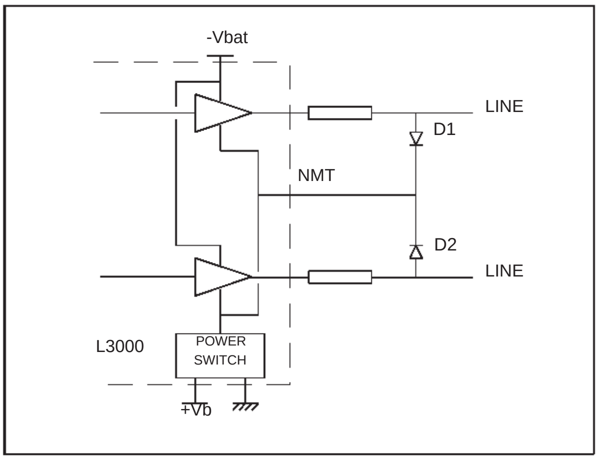


In certain cases (the TDB7711/7722 of SGS THOMSON) an internal network of diodes permits to oversupply the output stages of the SLIC (see Fig.32).

V.3.B SLIC with integrated ring generator :

The integrated circuit L3000 of SGS THOMSON is presently the only SLIC of this kind. It operates between ground and battery voltage for all the modes except for the ringing where the normal area is included between +VB (up to 72V) and battery voltage (-VBat) (see Fig.33). The protection will take into account this fact and operates over +VB and under -VBat.

Fig. 33 External diodes network used with the L3000.

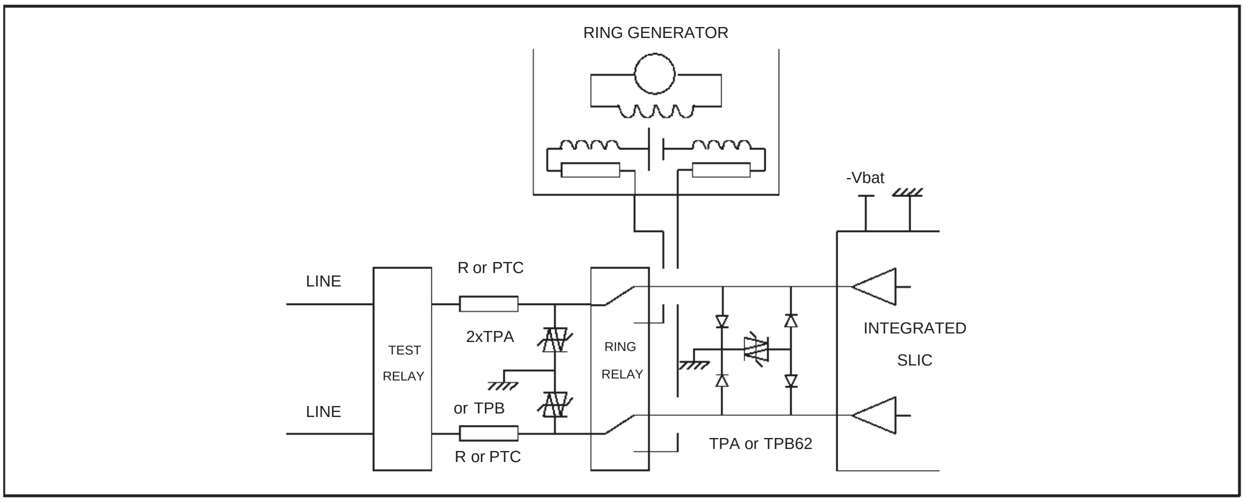


The diodes D1 and D2 (fig 33) act when the L3000 operates out of the ringing mode and when a positive overvoltage is clamped at +VB. The output stages are then temporarily oversupplied at +VB.

VI APPLICATION DIAGRAMS :

VI.1 SLIC without integrated ring generator

Fig. 34 Axial leaded solution

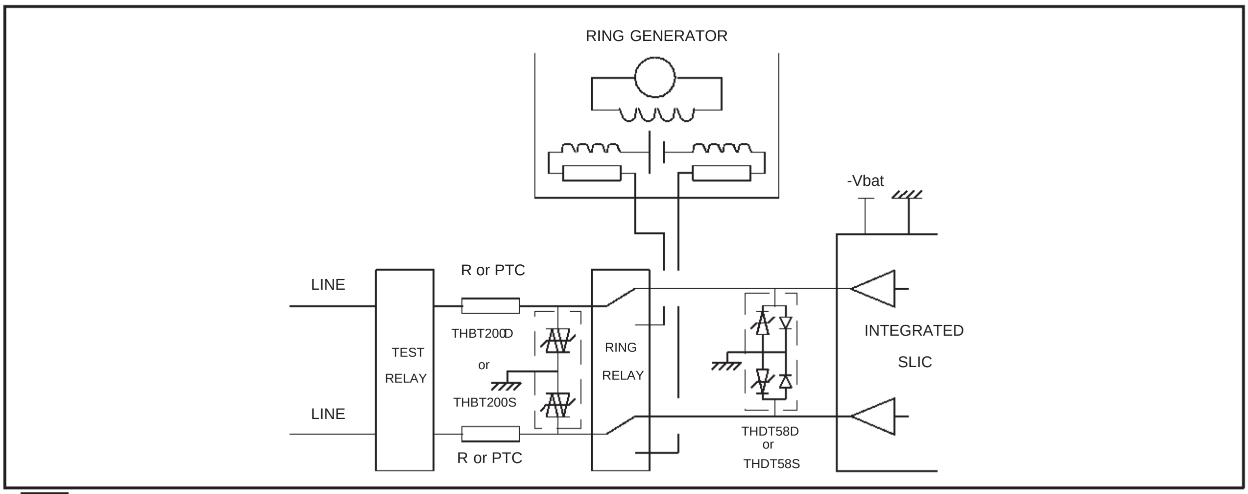


This basic diagram (fig 34) uses TRISIL TPA or TPB solution. Before the ring relay both lines are protected to the ground by 200 V bidirectional devices.

After the relay the positive surges are clamped to the ground by two diodes (one per line). For the negative one two diodes switch the overvoltage to a 62 V TRISIL.

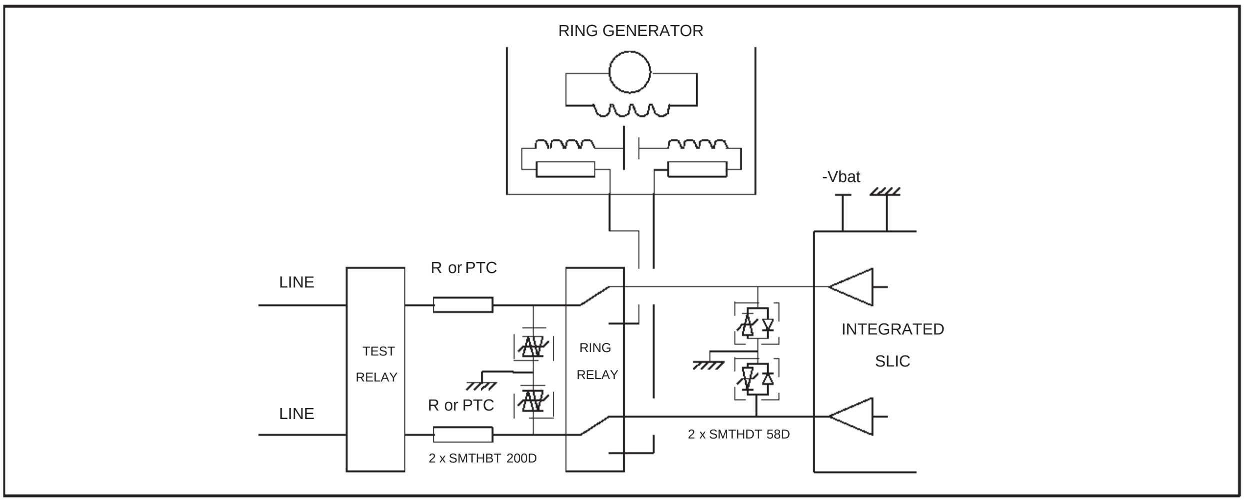
Remark : The diodes choice is very important in order to minimize their peak forward voltage (V_{FP}).

Fig. 35 TO 220 or SIP 3 version



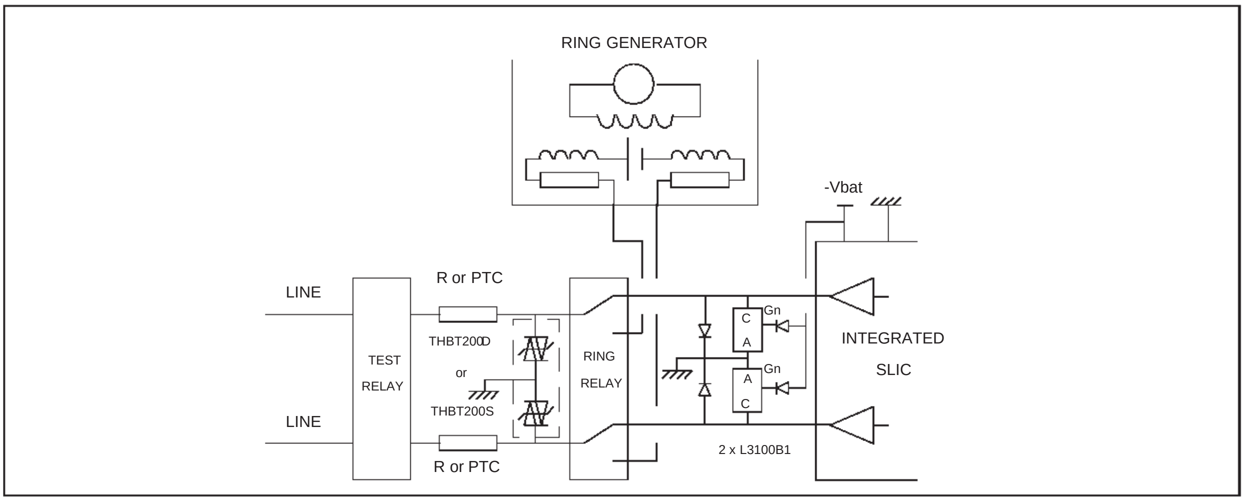
This topology (fig. 35) assumes the same protection function as precedent one with the following advantages :
- Only two packages.
- Reduction of printed board area used by the protection.
- Cost effective solution.

Fig. 36 Surface mount solution



The figure 36 is exactly the same silicon solution with :
- Surface mount packages (SOD 15).
- Better cost solution in SMD version.
- Same cost as the TO 220 version.

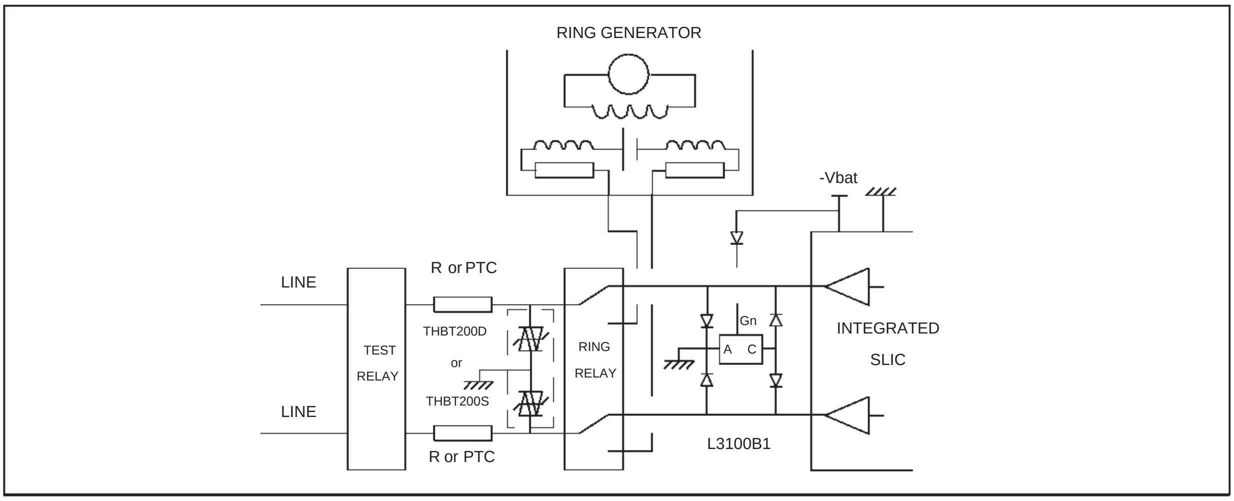
Fig. 37 Programmable breakover voltage solution (2 x L3100B1)



The protection behaviour is improved by a breakover value very close to the battery voltage (fig. 37).

This kind of solution is well adapted to the variable battery voltage application, for example short / long line switching.

Fig. 38 Programmable breakover voltage solution (1 x L3100B1)

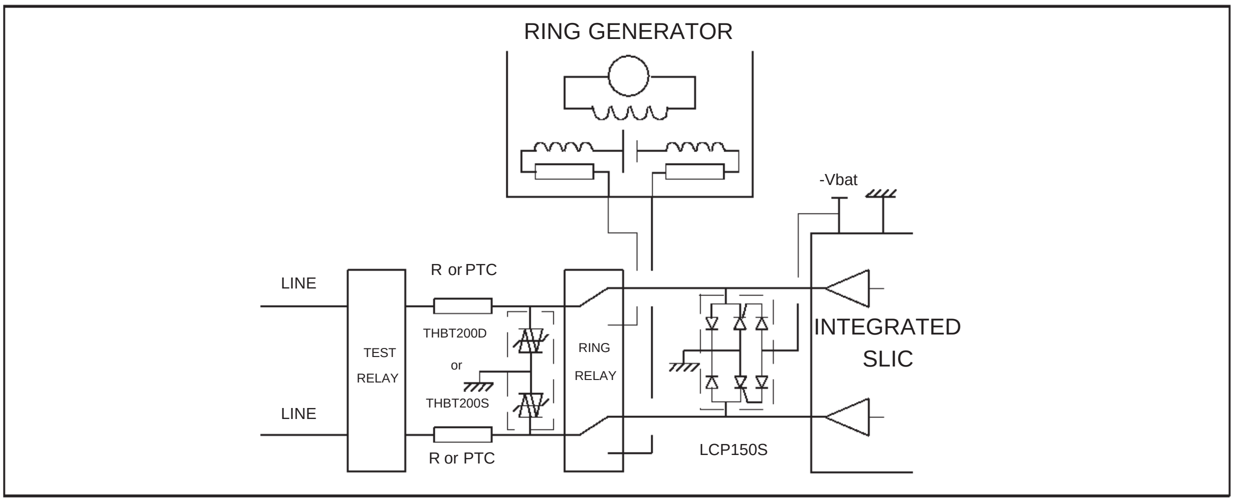


The figure 38 has the same electrical behaviour as the precedent one with.

– Lower cost

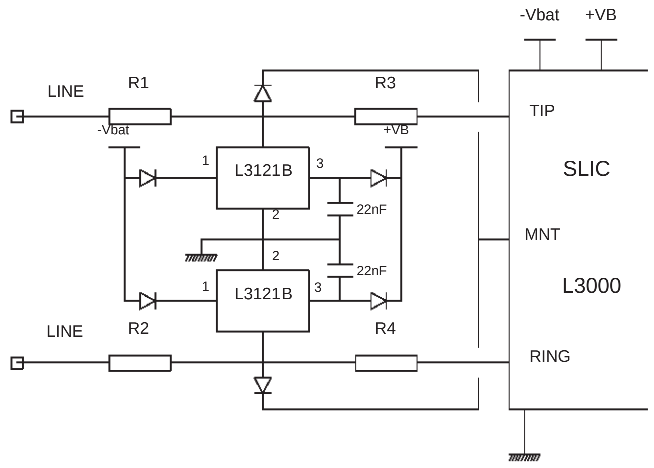
Remark : The maximum voltage across the line during the device firing is increased by the V_{FP} of the diode.

Fig. 39 Monochip programmable breakover voltage solution



This solution (fig. 39) performs the new generation of SLIC protection. It is the full integration of protection devices and peripherical diodes.

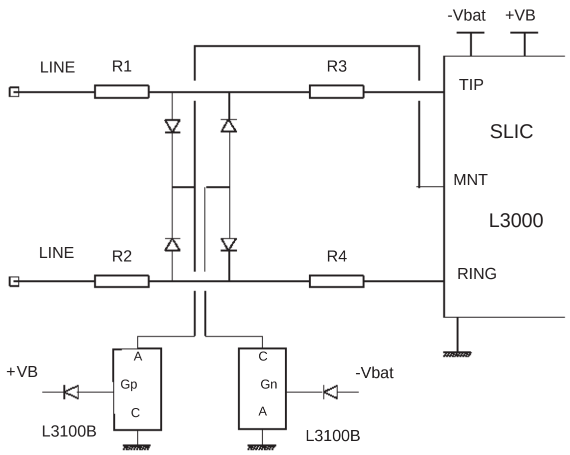
Fig. 40 L3000 protection with 2 L3121B



.VI.2 SLIC with integrated ring generator (L3000).

This topology (fig. 40) is the most efficient one for this kind of SLIC.

Fig. 41 L3000 protection with 2 L3100B



The figure 41 has the same electrical behaviour as previous one but with low cost.

VI.3 Common protections for several SLIC

These types (fig. 42 and 43) of application allow to decrease the cost of the protection per line. The major problems of these solutions are.

- The short circuit of all the lines when the protection fire
- The remaining current through the protection device after the surge is too high to permit the automatic switch off of the protection. In fact only a software action (low power state) permits to assume the switch off.

Fig. 42 Common protection for SLIC without integrated ring generator

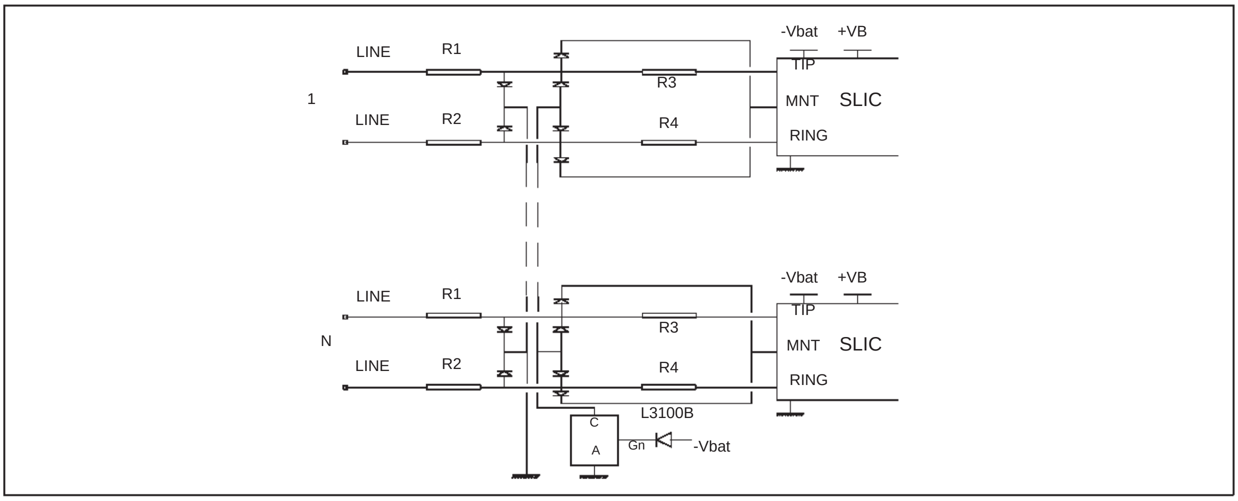
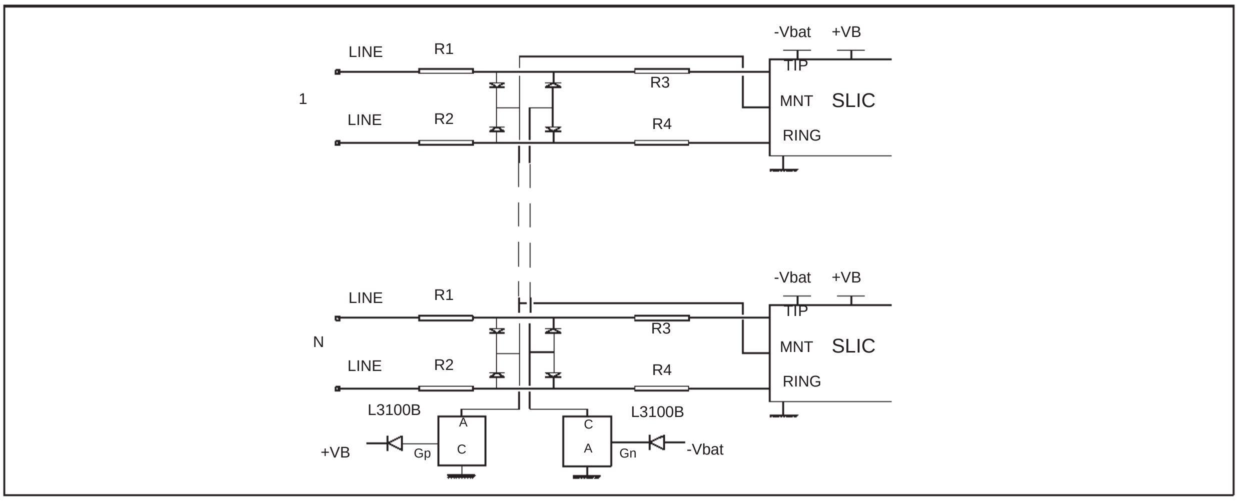


Fig. 43 Common protection for SLIC with integrated ring generator



In conclusion SGS-THOMSON have got a large range of protection solutions in order to optimize your application diagram. These solutions take into account.

The type of SLIC.

The battery voltage.

The pc board surface.

The cost.

And will permit you to solve your SLIC protection problem.

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