

1.0 Introduction

The line interface circuitry of any telecommunications system requires varying degree of high voltage protection circuitry, to meet safety, regulatory and performance related requirements.

Safety and regulatory approvals apply to equipment which will be connected to the PSTN (Public Switched Telephone Network). The line interface circuits are components of such equipment and are, therefore, not approved on their own. They do however, effect the ability of the equipment to comply with the approval criteria of various standards bodies. MITEL's line interface circuits comply with the applicable requirements, when integrated into a properly design system. Protection circuitry requirements also vary depending on the equipment design.

MITEL SLICs (Subscriber Line Interface Circuits) and COICs (Central Office Interface Circuits) are fabricated using Thick-Film Hybrid Technology which achieves high density and excellent high voltage performance, required for a reliable isolation barrier. MITEL hybrids incorporate various technologies, including high voltage bipolar, to achieve optimum circuit design and high reliability. The high voltage capability, reduces the requirements of the protection circuitry, without compromising reliability.

Background

A telecommunication system comprises subscriber stations linked together through cooper loop plant through a central office switching network, with many solid state electronic circuits deployed throughout. The loop plant may be twisted pairs housed in shielded cables, buried in the ground, or suspended across hydro poles. In many rural areas, the loop plant is comprised of large gauge, individual copper wires stretched across telephone or hydro poles.

In most cases the loop plant co-exist with high voltage electrical lines and is subjected to overvoltage conditions, or transients, created by direct conduction or induction from these sources. These overvoltages can enter the subscriber or network equipment through the mains supply

powering the equipment, as well as entering through a Tip and/or Ring pair of the loop plant. Due to the magnitude of the voltages, they are considered hazardous.

The other source of hazardous voltage is caused by lightning. Current created by a direct or indirect lightning stroke may enter the conductive shield of a suspended cable, or it may enter a buried cable by means of ground current. Since the cable shield has finite resistance, potential gradient is created along its length. The current created will travel in both directions, looking for a path to ground. Most importantly this creates surge voltages, on the conductors of the cable, and may appear at both ends of the loop.

Regulatory Bodies

FCC in the U.S., DOC in Canada, Austel in Australia, are examples of regulatory bodies. The bodies are mainly concerned with protection of the Telephone Network and its maintenance personnel, from hazardous voltages which may originate from equipment which is connected to the Network. This document will use the term " Safety of the Network" when discussing regulatory concerns. The main issue of safety of the network is, isolation of the equipment connected to the network, from mains voltages which power the equipment. In N.A., the mains voltage for powering telecom equipment is usually 120Vac rms (60 Hz). In the U.K. this voltage is usually 240Vac rms (50 Hz).

Safety Bodies

These bodies are mainly concerned with protection of the user, of equipment connected to the Telephone Network, from hazardous voltages which may originate from the Network. This document will use the term "Safety of the User" when discussing safety concerns. The main issue of safety of the user is, isolation of user access points of the equipment, from induced AC current/voltages, AC power line crossing and high voltage transients such as lightning which can occur in the Network. Network voltages under normal conditions are usually Vring (A.C. Ringing Voltage) max. 150Vac rms (the total peak voltage 268V) superimposed upon Vbat, Battery Supply Voltage, (max. 56Vdc). Network voltages under fault conditions are usually 1500V

peak dc (lightning strike, carbon block/gas discharge protection) and 600 Vac rms power line crossing.

UL in the U.S., CSA in Canada, Standards Australia, are examples of safety bodies.

Safety and Regulatory Bodies

In the U.K., both safety and regulatory concerns are covered by BABT which bases its HV (High Voltage) requirements on BS6301, BS7002. The European HV requirements are based on the UK and are EN41003, EN60950.

2.0 Protection

As previously mentioned, protection from hazardous voltage is required for safety of the network service personnel and the end user, as well as to protect the solid state, relatively low voltage, circuitry of the subscriber and network equipment.

Electrical protection is implemented in three stages:

- Primary protection,
- Secondary protection,
- Isolation barrier.

Primary and secondary protection circuits are usually add-on circuits, independent of the actual line interface circuitry. The isolation barrier, however, is usually part of the design of the line interface circuit. The barrier can be a transformer which electrically isolates the primary from the secondary windings, or a high impedance path which allows very little current flow. The degree of isolation and leakage current limits are application, as well as regulatory and safety body dependent.

2.1 Primary Protection

Primary protection is used where the loop plant is terminated from the outside environment, usually where it enters the building or area where the switching function is performed. At the central office, which houses the network switching equipment, the loop is commonly terminated by a feeder distribution interface (FDI), which contains the primary protectors. One electrode is connected to a telephone cable conductor and the other to the system ground. The oldest and most commonly used primary protector is the carbon block spark gap. This protector is the least expensive but has a relatively short life and exhibits sparkovers anywhere from 300 to 1000V. Another commonly used suppressor is the

gas tube protector, which is sometimes used in conjunction with heat coils or heat sensitive circuit interrupters, but are more expensive. Metal oxide varistors (MOVs) and other solid state devices have been used in more recent primary protection schemes in CO equipment.

2.2 Secondary Protection

The Solid state circuitry of modern switching equipment is not usually robust enough to handle the voltages of the primary protector clamping voltage. For this reason, and a few others, a secondary level of high voltage protection is required. Like the primary protector, the secondary protector must shunt the current created from the overvoltage condition, to ground. Because of the primary protector, the secondary protector handles a reduced voltage. Because the Tip and Ring pairs are now running inside a building, the possibility of a fire hazard exists, if too much current flows.

Most commonly, the secondary protection resides on the line cards of the central office equipment, PBXs and other subscriber equipment.

2.3 Secondary Protection - Tradeoffs and Considerations

There are tradeoffs and considerations to the various implementation possibilities and the trade offs are ultimately cost related.

To meet safety requirements, it is necessary to provide dependable current limiting. This is usually in the form of a fuse, fusible link, or fusible resistor, which must interrupt the current flow if it exceeds a safe limit. UL 1459 defines the safe current limit as that current flow which will not cause a Bussmann MDQ 1.6A Slo-Blo to open circuit. The MDQ 1.6A is in series with the AC power crossing tester's ground connection.

It is obvious that the smaller the current rating of the fuse, the better for fire hazard safety. However, from a system performance point of view, it is undesirable to have the fuse blow due to intermittent transients which may appear on a routine basis. This is exactly the case in areas which experience frequent electrical storms. Therefore, to avoid nuisance failures, the fuse rating should be as large as possible. Practically, the fuses should not be larger than 1A slo-blows to ensure that they reliably open circuit before the MDQ 1.6A, during the AC power crossing tests.

2.4 Isolation Barrier

Both safety of the network and safety of the user are covered in all specifications by addressing requirements for the "protection barrier".

For safety of the network, the protection barrier isolates the high voltages originating from the power mains of the equipment, from Tip and Ring connections to the Network. In this case, we refer to the equipment being at a HV (High Voltage) potential and the T/R being at a LV (Low Voltage) potential.

For safety of the user, the protection barrier isolates the high voltages originating from the Network, from the low voltage user access points of the equipment. In this case, the Network is considered the HV and the equipment LV.

The protection barrier must provide:

1. Physical Isolation: actual distances between conductors of the low voltage side (LV) and conductors of the high voltage side (HV). Physical distances are covered under creepage and clearance requirements in some specifications. Physical distances vary depending on the voltage potential. In some specifications, conductor coatings or insulation can decrease the physical distance requirements.

2. Electrical Isolation: the electrical integrity of the protection barrier is tested for hazardous voltage and hazardous leakage currents.

a) dielectric strength of the potential barrier is tested. This is performed by applying a high potential and checking for breakdown.

b) leakage current of the protection barrier is tested.

c) leakage voltage of the protection barrier is tested.

3.0 Description of Regulatory and Safety Testing

3.1 FCC Part 68 (U.S.) and DOC C503 (Canada)

Electrical Isolation

1. Test the EUT-to-Network barrier: 1000Vac applied. Less than 10mA leakage current allowed. The EUT can be powered or unpowered. (EUT = Equipment UnderTest.)

Interpretation: applied to a line interface hybrid the Tip and Ring pin connections are tied together, and all other pin connections (ground, analog and digital inputs and outputs, ± 5 and 12Vdc) connections are tied together. 1000Vac is applied between these two groups of pins. Not more than 10mA of current can flow.

2. Test the EUT-to-Powerline barrier: 1500Vac applied. Less than 10mA leakage current allowed. The EUT is not powered.

Interpretation: this test applied to the power supplies isolation from the power mains (120Vac 60Hz) to and the secondary voltages (± 5 , 12Vdc) and all other connections. This test doesn't apply to the line interface directly. But, if the secondary power supplies of a EUT did not meet this isolation requirement, the EUT could still pass isolation to the network, if the line interface provided the additional isolation, i.e., $1000 + 1500 = 2500\text{Vac}$.

Electrical DC Surge

Metallic voltage surge (800V): simulate induced metallic surge voltages resulting from lightning. The primary protectors in the building reduce the voltage appearing at the EUT. The test voltage is 800Vdc $10 \times 560\mu\text{sec}$ applied both polarities to the T/R interface of the EUT in both On and Off Hook states.

Interpretation: secondary protection circuitry (fuses, varistors, resistors, etc.) is in place for this test.

Longitudinal voltage surge (1500V): simulate longitudinal surge voltages which could result due to lightning strikes on the telephone line. The test voltage is 1500Vdc $10 \times 160\mu\text{sec}$ applied both polarities from T and R of the interface of the EUT in both On and Off Hook State.

Interpretation: Secondary protection circuitry (fuses, varistors, resistors, etc.) is in place for this test.

Longitudinal voltage surge (2500V): simulate lightning strikes to the AC power mains. 2500Vdc $2 \times 10\mu\text{sec}$ applied between the phase and neutral terminals of the AC power line.

Interpretation: this test doesn't apply to the line interface directly BUT, if the secondary power supplies of a EUT did not meet this requirement, the EUT could pass, if the line interface met this requirement.

Summary: the EUT should remain unaffected by these voltage surges. In particular, longitudinal balance should not be degraded below the acceptable (pass) limits. Some failure modes are accepted, i.e., if the EUT has an intentional designed failure mode which connects telephone or auxiliary connections with earth ground; and the EUT would become noticeably and substantially unusable by the user. Refer to FCC Part 68.302 (f).

Adequate protection circuitry can be used to avoid failure during these tests.

3.2 UL 1459 (US) and CSA a2.2 (Canada)

Electrical AC Surge

Because most telephone wiring runs alongside the electrical conductors supplying power to buildings, the NEC (National Electric Code) requires that all telecommunication wiring entering a building must pass through a primary protector designed to shunt the circuit should voltages greater than 600V suddenly appear on the telephone lines. This protection allows for voltages of less than 600V to remain on the telephone lines. Depending on the impedance, current may flow continuously through the wiring in the building as well as the telephone circuit within the equipment. This condition may result in ignition of either the wiring, unit, or both, creating a potential fire hazard. UL has assigned a 1.6A slo-blo fuse (Bussmann MDQ 1.6A) as the equivalent to premise's wire flame threshold.

Overvoltage testing, UL1459 Issue 2 sect. 50A: this test consists of applying 60Hz ac voltages both longitudinally (between Tip/Ring leads and ground) and metallically (between Tip and Ring leads)

Test	Test	Vrms	Amps	Series Ω	Time
M1	L1	600	40	15	1.5 sec
M2	L2	600	7	85.7	5 sec
M3A	L3A	600	2.2	273	30 min
M3B	L3B	600	Note 1	Note 1	30 min
M4	L4	Note 2 120	Note 3 25	Note 3 4.8	30 min 30 min

Note 1: Current is just below interrupt value of protection fuse.

Note 2: Voltage is 200Vrms or just protection clamping device voltage.

Note 3: Current is just below the secondary protector trip current.

Pass Conditions:

- 1) The 1.6A slo-blo fuse in the test equipment generating the voltages, must not blow.
- 2) The cheesecloth wrapped around the equipment under test must not be charred or burned.

Interpretation: the possible blowing of the 1.6A tester fuse is dependant on the secondary protection circuit used with the particular interface. The protection circuitry must be designed around the interface's voltages handling capability (i.e., before it goes to a low impedance state). This can be achieved by the use of MOVs, fuses, fusible resistors, etc., in the secondary protection circuit.

Ideally the hybrid interface should not flame during this test. Realistically, it doesn't matter as long as this doesn't cause the equipment to fail the flame test.

Protection Circuits used with Mitel Line Interfaces

The Mitel Loop Start/Ground Trunk interfaces such as the MH88630, MH88631 and MH88632, are transformerless designs using high impedance paths to provide the isolation barrier function. With the protection circuitry illustrated in Figures 1, 2 & 3, these interfaces can meet the applicable requirements of UL1459, CANICSA C22.2 No. 225-M90 Fcc part 68 and DOC CS-03.

The Mitel Off-Premise SLICs, such as the MH88620, MH88625 and MH88628, are also transformerless designs with high voltage withstand capability. Protection circuitry for an OPS/DID PBX application is shown in Figure 3. Figure 4 illustrates protection circuitry used with the OPS SLICs in a modern central office switch.

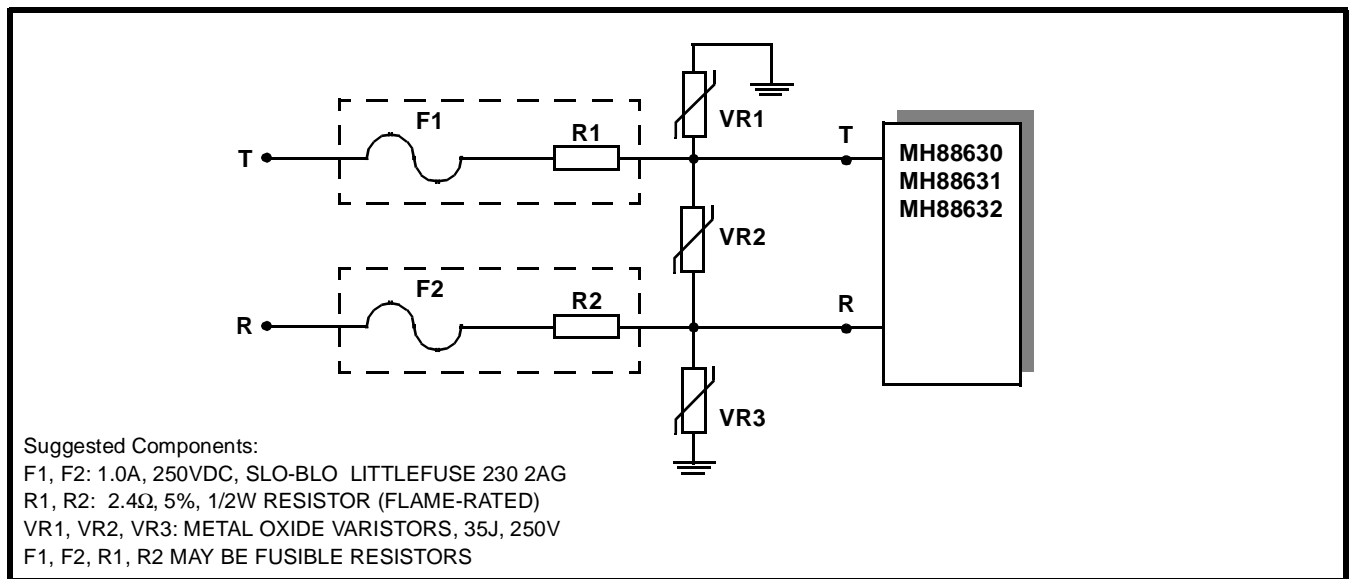


Figure 1 - LS/GS Central Office Interface Circuit (COIC) Application

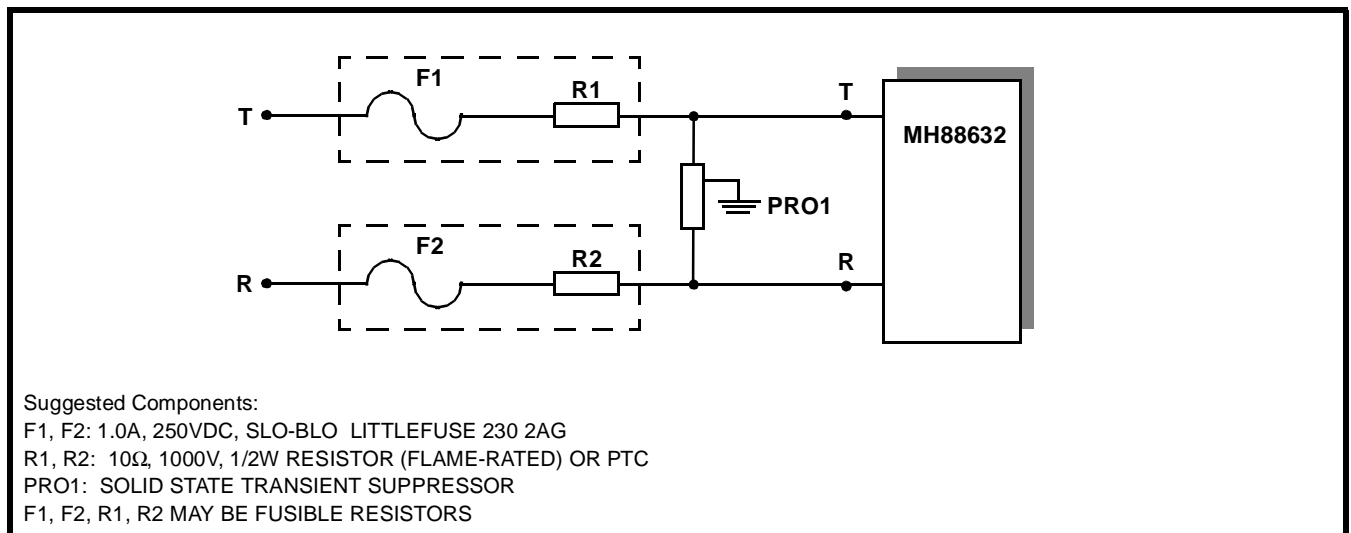


Figure 2 - LS/GS Central Office Interface Circuit (COIC) Application

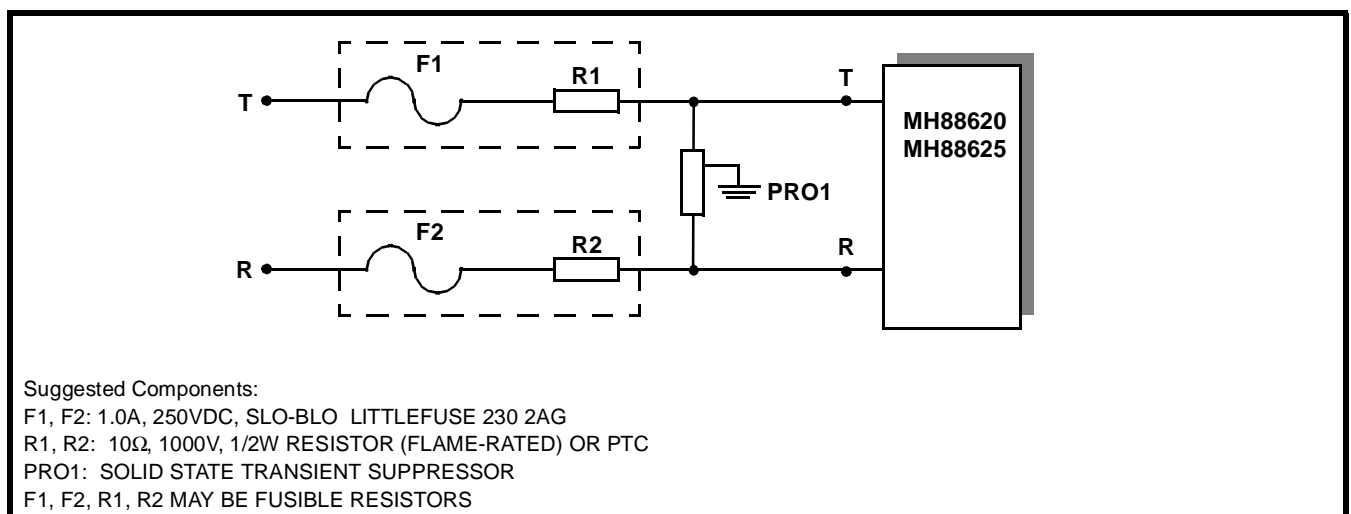
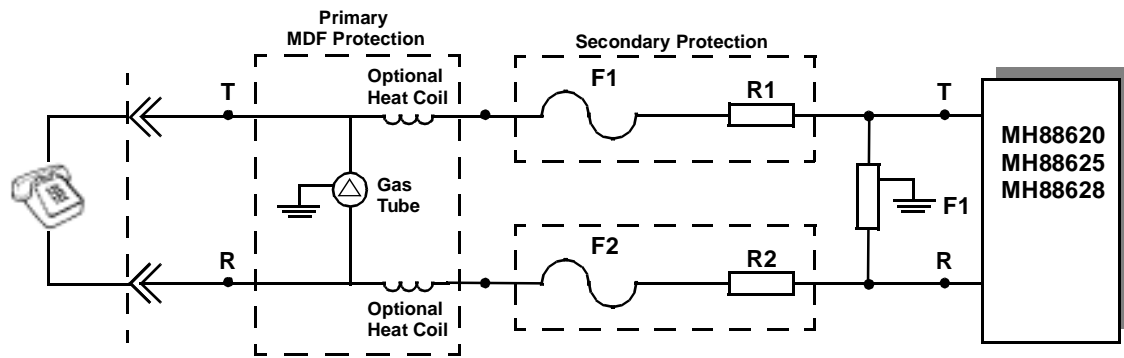


Figure 3 - OPS/DID Subscriber Line Interface Circuit (SLIC) Application



Suggested Components:

F1, F2: 1.0A, 250VDC, SLO-BLO LITTLEFUSE 230 2AG

R1, R2: 10Ω, 1000V, 1/2W RESISTOR (FLAME-RATED) OR PTC

PRO1: SOLID STATE TRANSIENT SUPPRESSOR

F1, F2, R1, R2 MAY BE FUSIBLE RESISTORS

Figure 4 - Protection Circuitry used with OPS SLICS in a Modern Central Office Switch