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Options for Lowering the Capacitance in TSPD Devices

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APPLICATION NOTE

INTRODUCTION

In some of the Telecom applications, the capacitance is a critical factor because it can cause disturbances and bad resolution in the telecom systems. The Gas Discharge Tube (GDT) is one of the most traditional devices used for telecom protection because the typical capacitance values are from 1 to 1.25 pf. However, as known, they are relatively slow, and unfortunately, some gas tubes' electrodes burn out after a few hundred hits making them inefficient and unreliable.

Different from the GDTs, the Thyristor Surge Protective Device (TSPD) offers a very reliable operation and consistency in terms of switching. The TSPD is capable of draining a surge current pulse to ground whenever a transient voltage appears between its two terminals (this occurs when a specific maximum voltage, delimited by the maximum breakover voltage of the device, is reached). Nevertheless, the capacitance of the TSPDs is higher than the capacitance of the GDTs since the TSPDs are semiconductor devices. A certain capacitance value will be

always be present, and it will depend on the structure and die size of each semiconductor device. Therefore, the main purpose of this note is to describe some solutions for lowering the capacitance in the TSPD devices manufactured by ON Semiconductor.

INDUSTRIAL STANDARD

Bellcore GR-1089-CORE and GR-974-CORE

According to the industrial standard, Bellcore GR-1089-CORE, the levels of protection to be covered by the TSPDs are classified in three main categories:

- Primary Protection – (Central Offices, Switchboards)
- Secondary Protection – (Modems, Internet Hardware, COAX, and HFC)
- Station protection – (Modems, Home telephone sets, Voicemail)

This industrial standard also establishes that each of the previous categories have different lightning surge ratings depending on the telephone lines' density and the kind of applications. These surge ratings are described in the following tables:

Table 1. Primary Protection

Standard Number	Peak Surge Voltage (V)	Voltage Waveform (μ s)	Current Waveform (μ s)	Rating IPP (A)
Bellcore GR-1089-CORE First Level	2500	2 x 10	2 x 10	500
	1000	10 x 1000	10 x 1000	100
Bellcore GR-1089-CORE Second Level	5000	2 x 10	2 x 10	500

Table 2. Secondary Protection

Standard Number	Peak Surge Voltage (V)	Voltage Waveform (μ s)	Current Waveform (μ s)	Rating IPP (A)
Bellcore GR-1089-CORE First Level	2500	2 x 10	2 x 10	150
	1000	10 x 1000	10 x 1000	50
Bellcore GR-1089-CORE Second Level	5000	2 x 10	2 x 10	150

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Table 3. Station Protection

Standard Number	Peak Surge Voltage (V)	Voltage Waveform (μs)	Current Waveform (μs)	Rating IPP (A)
Bellcore GR-1089-CORE	1000	10 x 1000	10 x 1000	300
Bellcore GR-1089-CORE	2000	1.2 x 50	8 x 20	1000

Additionally, the industrial standard Bellcore GR-974-CORE establishes that the capacitance of the Telecommunications Line Protector Units (TLPUs) between terminals and for each terminal to ground, shall be a maximum of 200 pf when measured at 1 MHz with a

1 volt test signal voltage and a 0 volt dc bias. The actual TSPDs manufactured by ON Semiconductor (MMT05B230, 260, 310T3, and MMT10B230, 260, and 310T3 series) offer a capacitance value lower than 200 pf, their typical values are shown below:

Table 4. Secondary Protection

Device Number	1 Vrms @ 1 MHz			15 mVrms @ 1 MHz		
	0 V	1.5 V	2 V	0 V	1.5 V	2 V
	(pf)	(pf)	(pf)	(pf)	(pf)	(pf)
MMT05B230T3	41	36	35	51	40	38
MMT05B260T3	39	33	32	48	37	36
MMT05B310T3	36	31	30	45	35	34

Table 5. Primary Protection

Device Number	1 Vrms @ 1 MHz			15 mVrms @ 1 MHz		
	0 V	1.5 V	2 V	0 V	1.5 V	2 V
	(pf)	(pf)	(pf)	(pf)	(pf)	(pf)
MMT10B230T3	149	128	124	185	139	66
MMT10B260T3	141	122	118	168	126	60
MMT10B310T3	130	111	108	159	120	55

However, there are some applications in which the capacitance is required to be much lower than 200 pf. For those applications, it has been validated that the concepts shown in the figures below are good options to follow:

Option 1

This option is only considering one arrangement of two diodes, MUR120, connected in inverse-parallel in series with the TSPD. The total capacitance value of the complete arrangement, including the TSPD, could be theoretically calculated by using the following formulas:

- Capacitance in parallel: $C_T = C_1 + C_2 + \dots + C_n$
- Capacitance in series: $1/C_T = (1/C_1) + (1/C_2) + \dots + (1/C_n)$

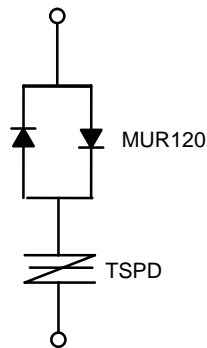
Based on these formulas and knowing that the typical capacitance value of a diode, MUR120, measured at 15m Vrms @ 1 MHz (0 Vdc bias) is 46 pf, the total capacitance for the arrangement could be calculated as:

$$\text{Diodes } \parallel \text{ capacitance} = 46 \text{ pf} + 46 \text{ pf} = 92 \text{ pf}$$

$$\text{MMT10B230T3 (TSPD)} = 185 \text{ pf}$$

$$\text{therefore, the total capacitance} = (1/C_T) = (1/92) + (1/185) = 61.4440 \text{ pf.}$$

Option 1



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In addition to the theoretical calculations, this option can be validated by measuring the arrangement through an LCR METER (HP 4284A), which would measure similar

readings of capacitance (refer to the values in Table 6 and Table 7 below).

Table 6. Secondary Protection

Device Number	1 Vrms @ 1 MHz (Option 1)			15m Vrms @ 1 MHz (Option 1)		
	0 V	1.5 V	2 V	0 V	1.5 V	2 V
	(pf)	(pf)	(pf)	(pf)	(pf)	(pf)
MMT05B230T3	32	28	27	32	28	27
MMT05B260T3	30	26	25	30	26	25
MMT05B310T3	28	24	23	28	24	23

Table 7. Primary Protection

Device Number	1 Vrms @ 1 MHz (Option 1)			15m Vrms @ 1 MHz (Option 1)		
	0 V	1.5 V	2 V	0 V	1.5 V	2 V
	(pf)	(pf)	(pf)	(pf)	(pf)	(pf)
MMT10B230T3	102	85	82	62	60	58
MMT10B260T3	97	81	78	59	57	55
MMT10B310T3	89	74	71	54	52	50

Based on the previous capacitance measurements, it is possible to observe that the theoretical calculations made for MMT10B230T3, connected in series with two diodes, MUR120, replicates with the real capacitance measurements done in the same arrangement through the LCR METER. The theory resulted in a capacitance value of 61.44 pf, while the real measure resulted in 62 pf, which represents almost the same value of capacitance.

Option 2

In the same way than in the option 1, the option 2 shows how it could be possible to reduce even more the capacitance value of a TSPD and it is basically based in the same principal than in the option 1, the only difference is that this option contemplates to connect two arrangements of diodes MUR120 in series with the TSPD thereby the capacitance of the complete arrangement would be significantly reduced.

In a similar way than for the option 1, the capacitance value of the option 2 could be theoretically calculated by using the same formulas previously mentioned:

- Capacitance in parallel: $C_T = C_1 + C_2 + \dots + C_n$
- Capacitance in series: $1/C_T = (1/C_1) + (1/C_2) + \dots + (1/C_n)$

let's take the same example than for the option 1:

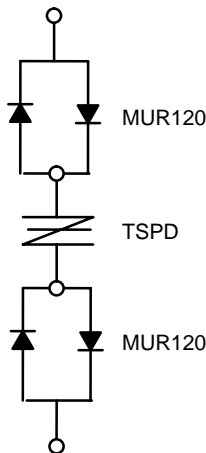
Diodes || capacitance = 46 pf + 46 pf = 92 pf (arrangement 1)

Diodes || capacitance = 46 pf + 46 pf = 92 pf (arrangement 2)

MMT10B230T3 (TSPD) = 185 pf

therefore, the total capacitance = $(1/C_T) = (1/92) + (1/92) + (1/185) = 36.83$ pf.

Option 2



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This option can also be validated by measuring the arrangement through an LCR METER (HP 4284A), which

would measure similar readings of capacitance (refer to the values shown in Table 8 and Table 9 below.

Table 8. Secondary Protection

Device Number	1 Vrms @ 1 MHz (Option 2)			15 mVrms @ 1 MHz (Option 2)		
	0 V	1.5 V	2 V	0 V	1.5 V	2 V
	(pf)	(pf)	(pf)	(pf)	(pf)	(pf)
MMT05B230T3	25	22	21	25	23	22
MMT05B260T3	24	20	19	24	21	20
MMT05B310T3	22	19	18	22	20	19

Table 9. Primary Protection

Device Number	1 Vrms @ 1 MHz (Option 1)			15 mVrms @ 1 MHz (Option 2)		
	0 V	1.5 V	2 V	0 V	1.5 V	2 V
	(pf)	(pf)	(pf)	(pf)	(pf)	(pf)
MMT10B230T3	53	46	45	38	37	36
MMT10B260T3	50	44	43	36	35	34
MMT10B310T3	46	40	39	33	32	31

Based on the previous capacitance measurements, it is possible to observe that the theoretical calculations made for this option (MMT10B230T3 connected in series with two diodes, MUR120) replicate with the real capacitance measurements done in the same arrangement through the LCR METER. The theory resulted in a capacitance value of 36.83 pf, while the real measure resulted in 38 pf, which represents almost the same value of capacitance.

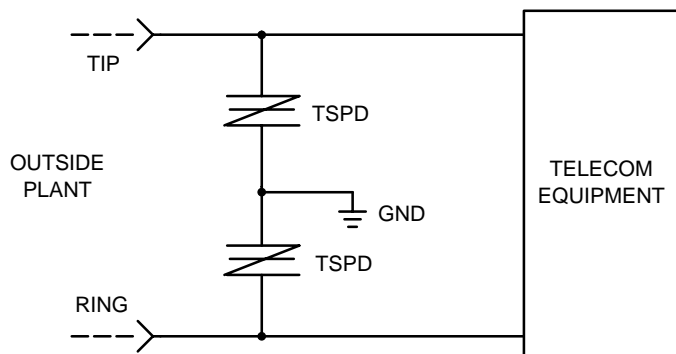
In addition to the previous capacitance measurements, it is also very important to consider and validate the surge capability of the diodes, MUR120, under the 10 x 1000 μsec waveform to establish whether the diodes are able to cover the ratings for secondary and primary protection or not. Based in this, a surge of 10 x 1000 μsec characterization was done in a sample of ten diodes, MUR120, to check their behavior. The surge stand point and the results are shown in the table below:

Table 10. Surge Capability of the Diodes

	Surge Current 10 x 1000 μsec							
	50 A	75 A	100 A	125 A	150 A	175 A	200 A	225 A
Waveform	Fail/Sample	Fail/Sample	Fail/Sample	Fail/Sample	Fail/Sample	Fail/Sample	Fail/Sample	Fail/Sample
10 x 1000 μsec	0/10	0/10	0/10	0/10	0/10	2/10	6/10	9/10

Based on these results, it could be established that the diodes, MUR series, would be able to cover the surge ratings needed for the two series of TSPD devices that ON Semiconductor manufactures (MMT05B230T3 and MMT10B230T3 series).

Therefore, as a reference, the most common TSPD configuration used to protect a telecom system of two wires (TIP and Ring) is shown below:



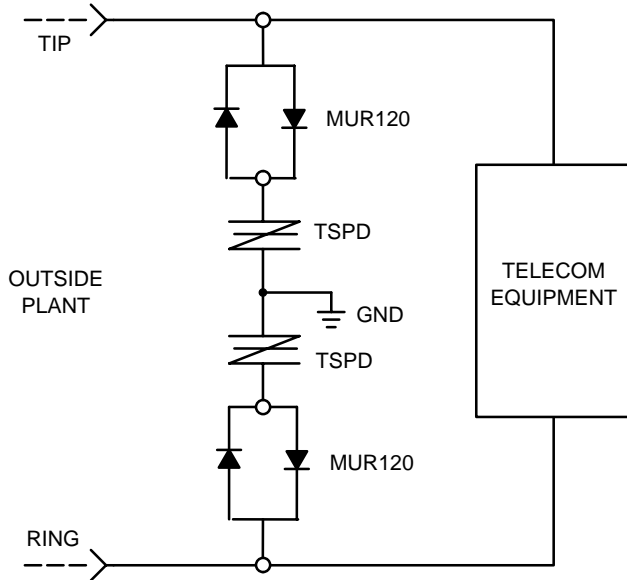
- If it is used, MMT05B230T3 devices, the capacitance between each terminal to ground would be in the order of 42 pf when measured at 1 Vrms @ 1 MHz, 0 Vdc.
- If it is used, MMT10B230T3 devices, the capacitance between each terminal to ground would be in the order of 149 pf when measured at 1 Vrms @ 1 MHz, 0 Vdc.

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For this configuration, the capacitance of the Telecommunications Line Protector Units (TLPUs) for each terminal to ground is lower than 200 pf when measured at 1 MHz with a 1 volt test signal voltage and a

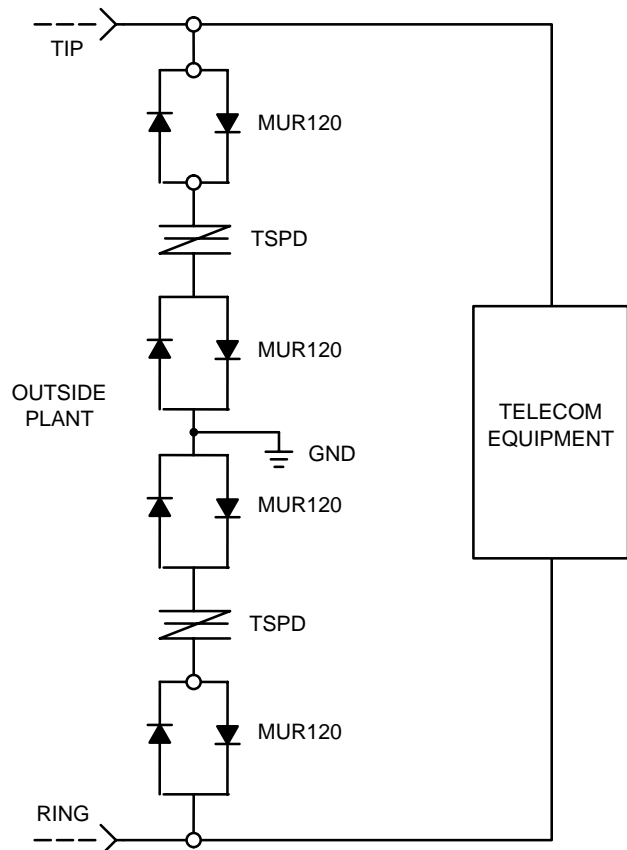
0 volt dc bias (which is within the range established by the industrial standard, Bellcore GR-974-CORE). However, to lower the capacitance value, follow either the Option 1 or Option 2:

Option 1



- If it is used, MMT05B230T3 devices, the capacitance between each terminal to ground would be in the order of 32 pf when measured at 1 Vrms @ 1 MHz, 0 Vdc which represents a lower value than the one from the original configuration.
- If it is used, MMT10B230T3 devices, the capacitance between each terminal to ground would be in the order of 102 pf when measured at 1 Vrms @ 1 MHz, 0 Vdc which also represents a lower value than the one from the original configuration.

Option 2



- If it is used, MMT05B230T3 devices, the capacitance between each terminal to ground would be in the order of 25 pf when measured at 1 Vrms @ 1 MHz, 0 Vdc which represents a lower value than the one from the configuration of Option 1.
- If it is used, MMT10B230T3 devices, the capacitance between each terminal to ground would be in the order of 53 pf when measured at 1 Vrms @ 1 MHz, 0 Vdc which represents a lower value than the one from the configuration of Option 1.

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The two options show how the capacitance value of each TSPD is lowered by connecting diodes in series with them. The functionality of the circuit is similar in both options since the TSPD devices will be acting as open circuits whenever the signal voltage in the Tip and Ring lines are lower than their VBO. Typically, the voltage in the Tip and Ring lines is between 50 V and 140 V, depending on the kind of application. If a transient voltage occurs in any of the two telecom lines (Tip or Ring), the corresponding TSPD device will be triggered draining the surge current to ground and protecting the Telecom equipment. As soon as the surge current drops below the IH value of the TSPD, it will go to the off-state and will then be ready to act again if another transient voltage occurs. It is important to mention

that the diodes would be driving the same surge current as the TSPD devices. The TSPD will be operating anytime the VBO is reached, and will not get damaged if the maximum surge current rating is not exceeded.

In summary, there are two options to lower the capacitance of the TLPU's in applications in which the capacitance value is critical. It is important to mention that designers should take into account that extreme environment temperatures could affect the surge performance of the diodes. It is a fact that they can operate between 15°C to 40°C, so to use any of these concepts out of this temperature range, it would be necessary to do additional surge characterizations.

Notes

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