Comparing Circuit Protection Technologies for 48 V DC in High Surge Environments

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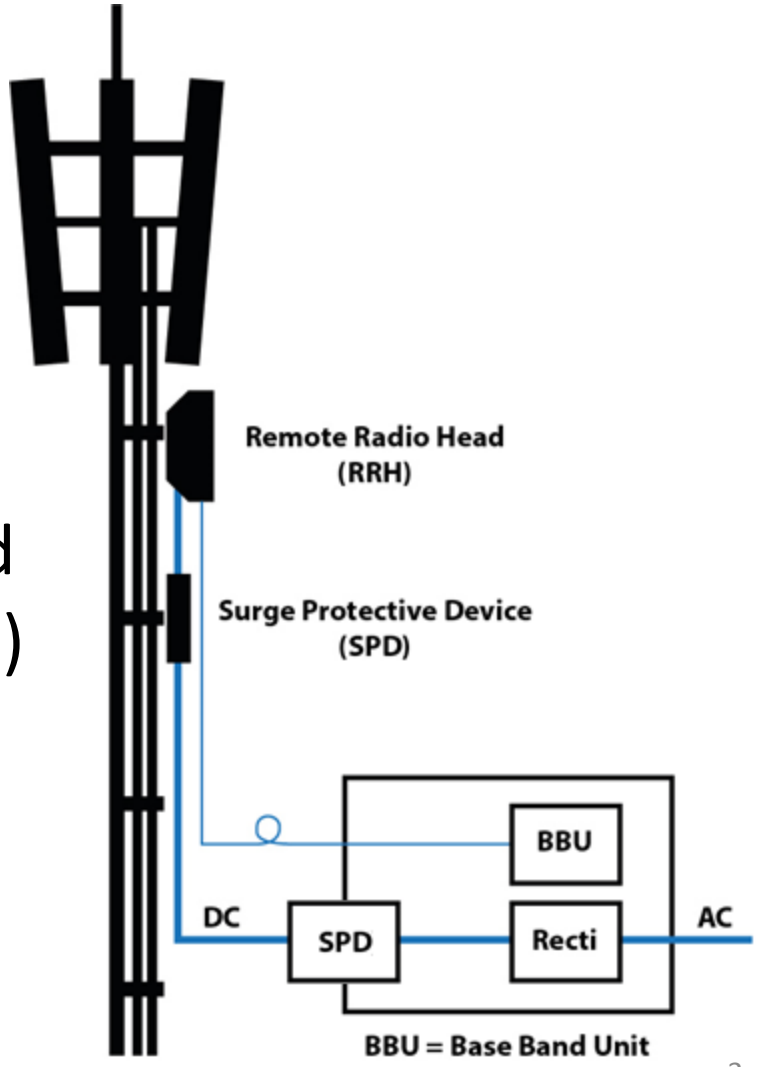
Agenda

- Example Application - Remote Radio Head (RRH)
- Protection of 48 V DC power supply input
  - Components commonly used for over voltage protection (integrated/board level)
  - GDTs in series
    - Overview
    - Bourns test board
    - Performance
- Comparisons and Summary

Fiber To The Antenna (FTTA)

- Remote Radio Head
  - Mounted near antennas
  - Typ. 48 V DC Supply
  - Protected by Tower Mounted Surge Protective Device (SPD)
  - Integrated over-voltage protection to address SPD "let through"



Observations

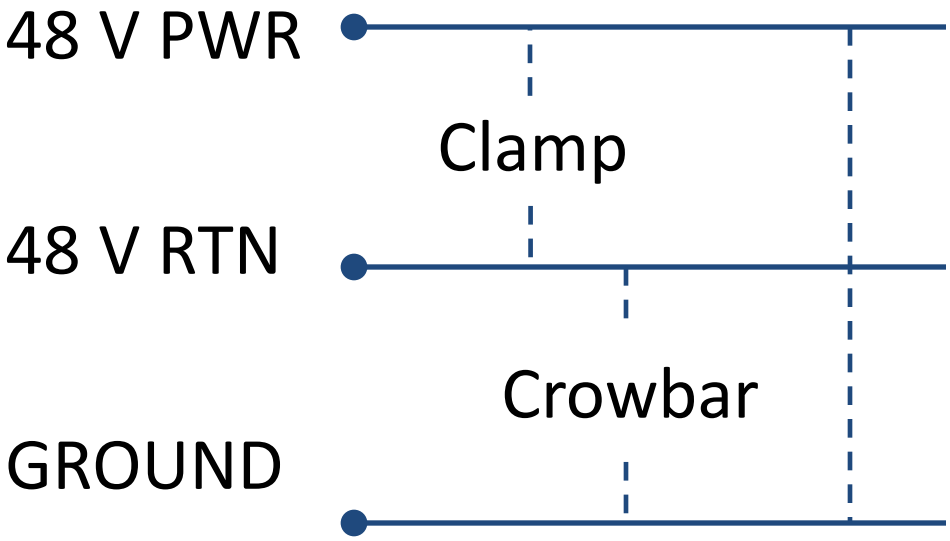
- Rapid adoption of the FTTA architecture
- Radio OEMs still indicate a need to reduce failure rates
  - Some are increasing surge withstand requirements for the RRH
    - Increasing 8/20 peak current rating
    - Adding 10/350 waveform requirement
- There have been incremental improvements to protection components

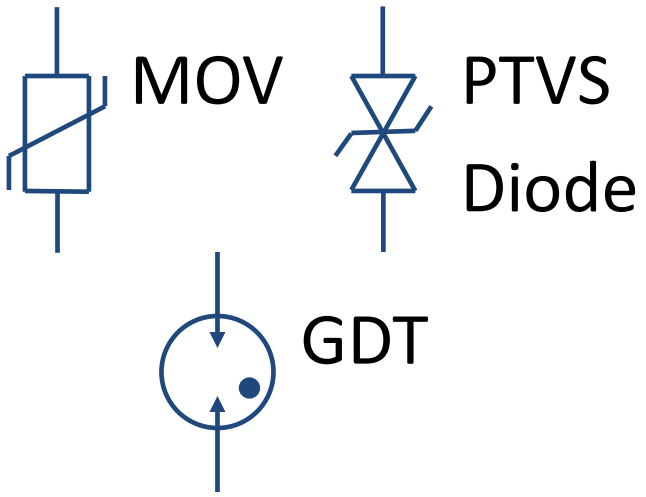
Integrated Over Voltage Protection

- Typ. 2-wire/3-wire 48 V DC power supply
  - e.g. PWR, PWR RTN, GROUND
- Over voltage protection is placed inside the RRH at the power supply input
- Clamping and Crowbar over voltage protection
  - Clamping Devices
    - Metal Oxide Varistor (MOV)
    - Power Transient Voltage Suppressor (PTVS)
  - Crowbar Devices
    - Gas Discharge Tube (GDT)
- Recent interest in GDTs in series

Clamping vs. Crowbar

Typical 3–wire Power Interface



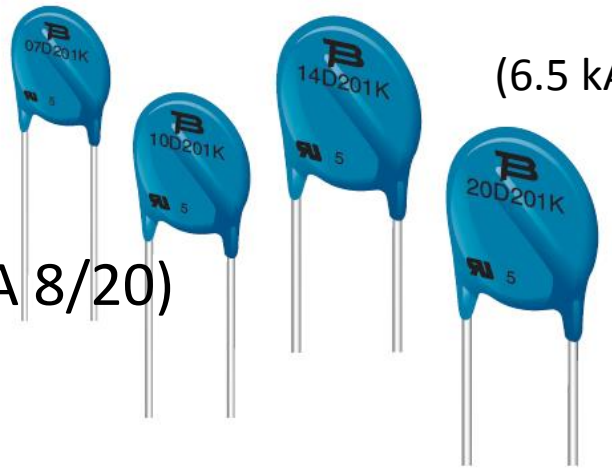


Metal Oxide Varistor (MOV) - for power

- A Metal Oxide Varistor (Variable Resistor) is a voltage dependent resistor – resistance decreases with rising voltage
- Prevents damage from transient events by acting as a voltage "clamp", or limiting voltage to a desired level

Metal Oxide Varistor (MOV) - for power

- Pros
  - Fast response time (10 ns - 25 ns)
  - Good clamping performance
  - Scale to handle large surges (e.g. 10 kA 8/20)
  - Lowest cost (for comparable surges)



(6.5 kA)

- Cons
  - Current ratings may require multiple MOVs in parallel
  - Repeated surges cause wear (leaded disc-type packages) and increase leakage
  - While clamping, voltage rises with surge current (less rigid)

Power TVS

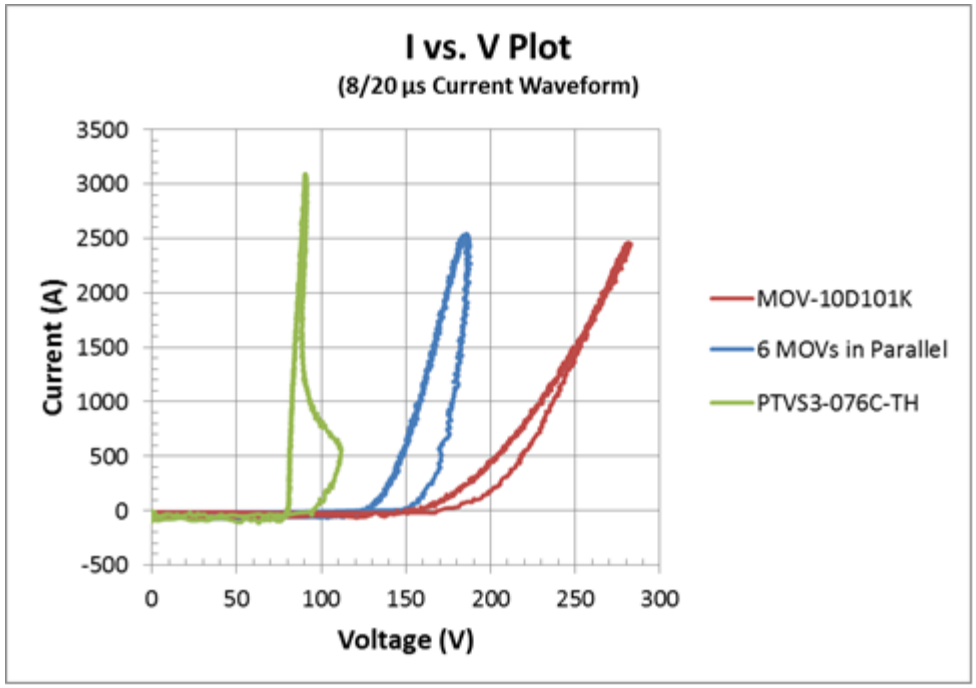
- Power Transient Voltage Suppressor (PTVS) are solid state devices that use diode avalanche breakdown to shunt surge energy
- Used on AC and DC power supplies in harsh environments
- Prevent damage from transient events by acting as a voltage “clamp”

Power TVS

- Pros
  - Excellent clamping performance – which reduces stress on protected components
  - Small solution size, with potential for stand-alone protection
  - Solid state, high reliability (no wear out mechanism for rated surges)
  - Scale to handle large surges: 3 kA – 15 kA 8/20
- Cons
  - Can be damaged if surge rating is exceeded
  - Cost increases with surge level

MOV vs. PTVS Clamping Performance

PTVS3-076C-TH vs. 1 and 6 MOVs Test Plots (8/20 Surge)



PTVS3-076C-TH exhibits a much better clamp performance than six MOV-10D101K components in parallel.

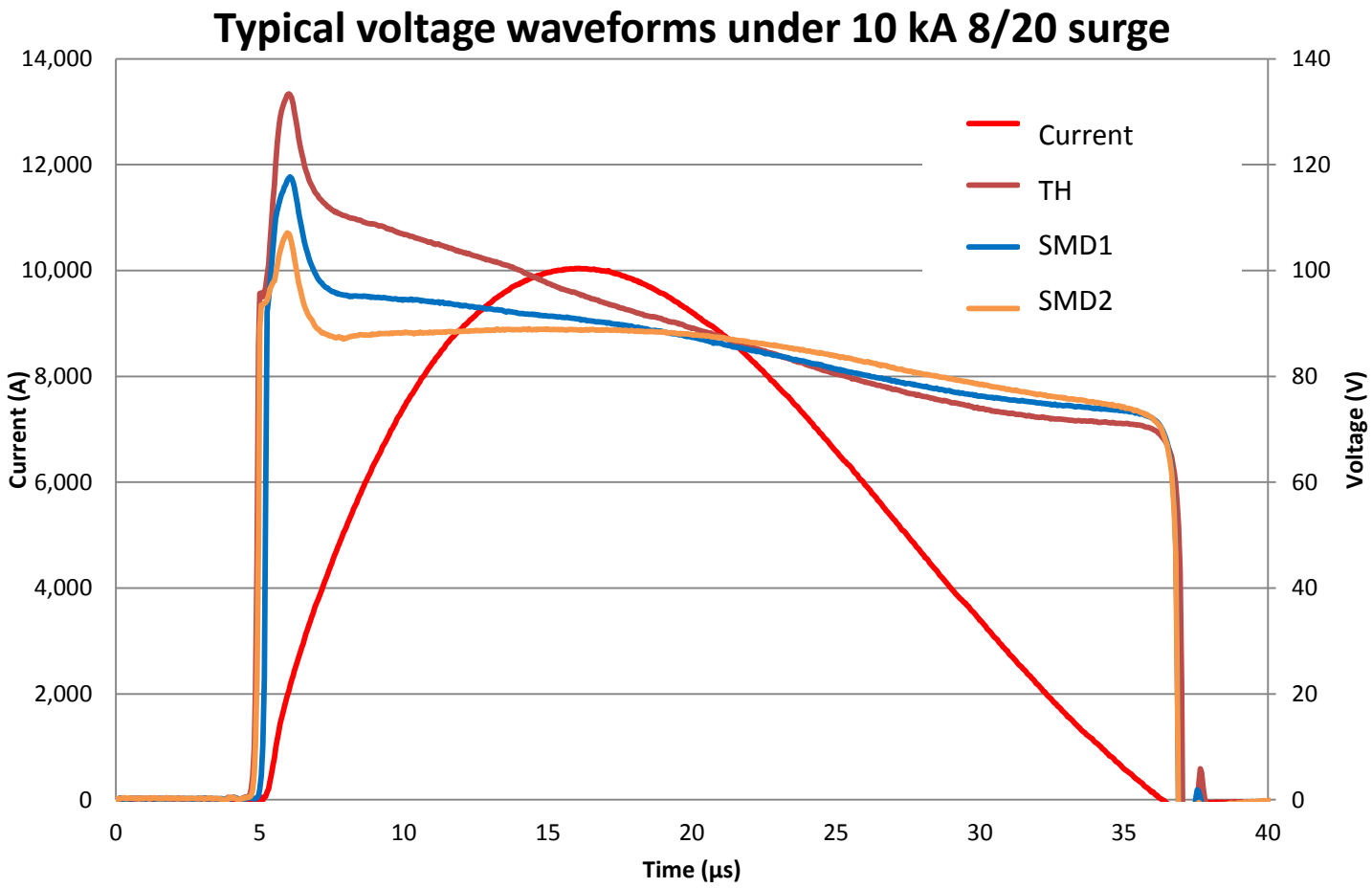
Power TVS Packaging Affects Performance

Through Hole
TH

Surface Mount
SMD1

Surface Mount
SMD2

Power TVS Packaging Affects Performance



Gas Discharge Tubes

GDTs are an arrangement of electrodes within a gas that operate by ionizing the gas when a sufficient voltage is applied

GDTs prevent damage from transient surges by acting as a “crowbar” or by approximating a short circuit to shunt surge energy, typically to ground

Gas Discharge Tubes

- Pros
  - Handle large surges (e.g. up to 60 kA for 8/20 waveform)
  - Well understood operation and well characterized
  - Exhibit low capacitance (e.g. < 2 pf, used on high speed signals)
  - ***Also characterized for long duration surges***
  - New smaller, low profile packages
- Cons
  - Wide tolerance
  - Reaction time is dependent on the rate of rise of the voltage.
  - Relatively high let through voltage - rarely afford stand alone protection
  - On a DC supply, hold over may occur following a surge

GDT Spark Over Specifications

Characteristic	Model No.		
	2029-09-SMLF	2029-15-SMLF	2029-23-SMLF
DC Sparkover ±20 % @ 100 V/s	90 V	150 V	230 V
Impulse Sparkover (1) 100 V/µs (Typical) 100 V/µs (99 %)	 275 V 375 V	 325 V 375 V	 450 V 500 V
Impulse Sparkover (1) 1 kV/µs (Typical) 1 kV/µs (99 %)	 525 V 600 V	 525 V 625 V	 650 V 750 V

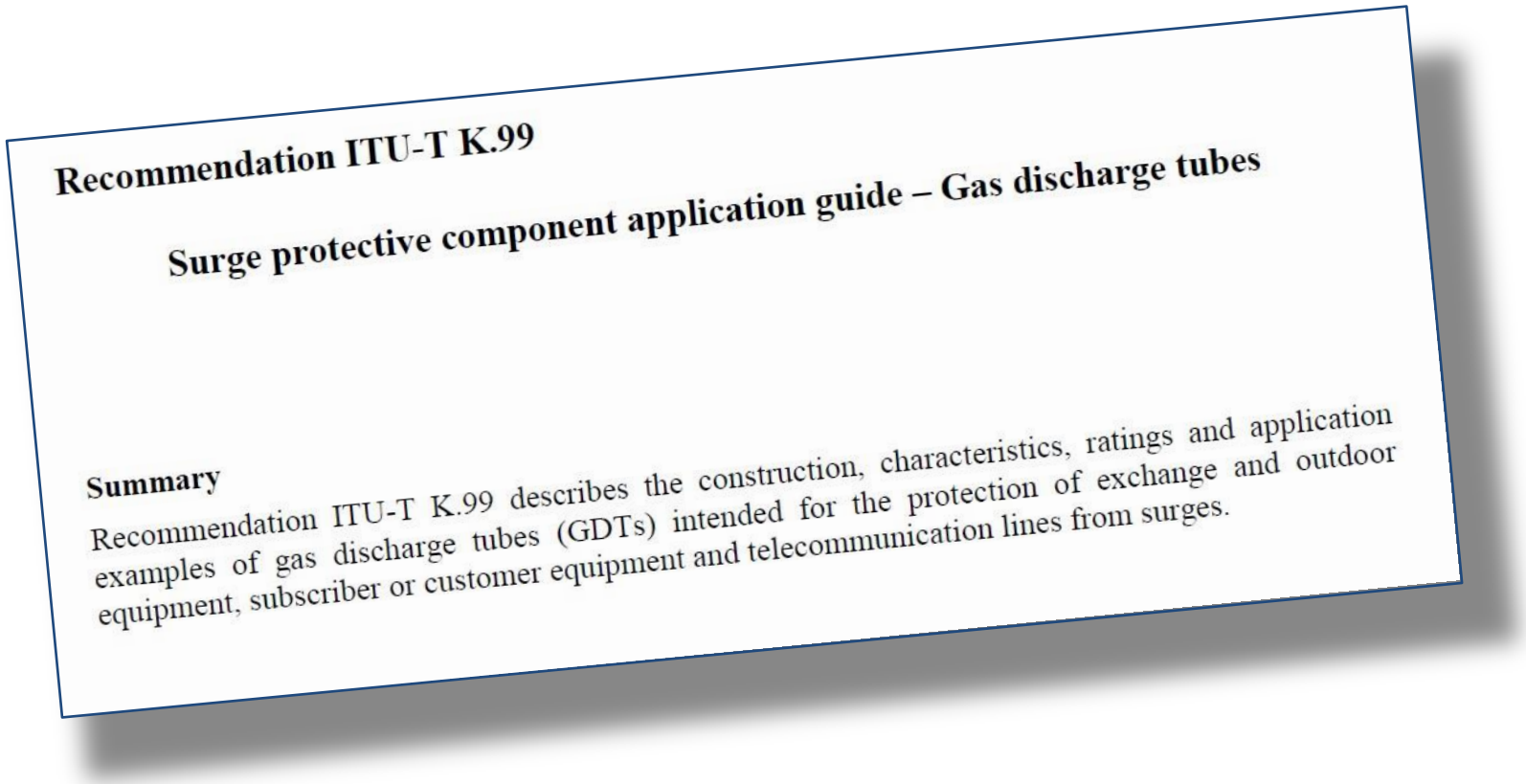
Gas Discharge Tube Packaging

Similar characteristics

GDTs in Series

- Described in ITU-T Recommendation K.99
- Recent interest from OEM customers considering additional surge withstand requirements
- Bourns Test Board
  - Circuit
  - Performance
  - Coordination with 2nd level of protection (TVS/PTVS)

ITU-T Recommendation K.99



Recommendation ITU-T K.99

Surge protective component application guide – Gas discharge tubes

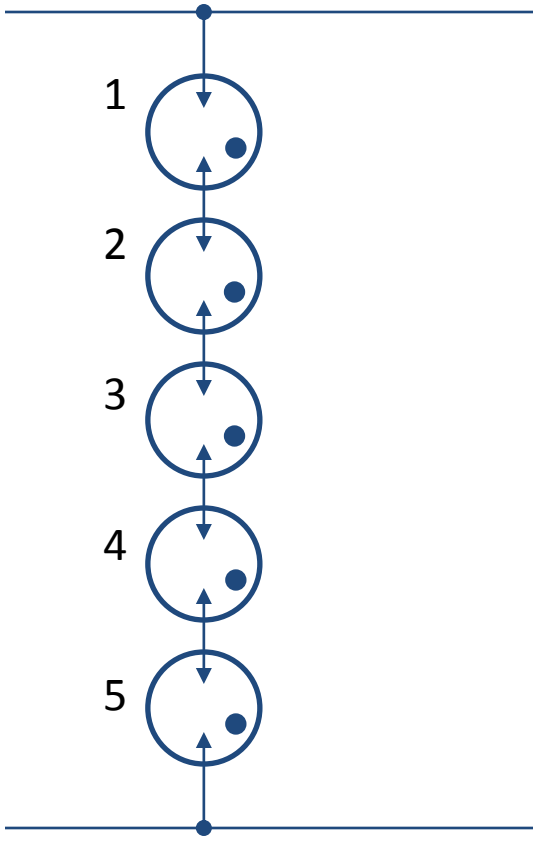
Summary

Recommendation ITU-T K.99 describes the construction, characteristics, ratings and application examples of gas discharge tubes (GDTs) intended for the protection of exchange and outdoor equipment, subscriber or customer equipment and telecommunication lines from surges.

Section 8.9 - Series connected GDTs for D.C. power applications

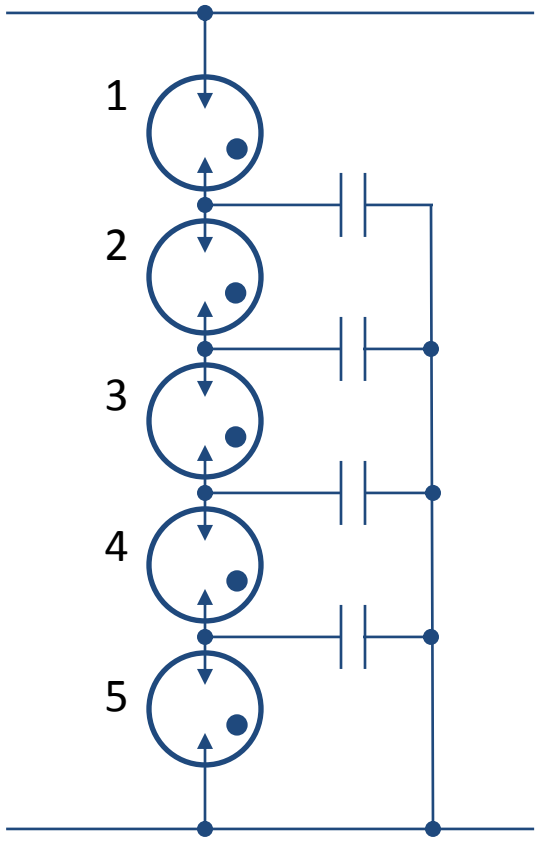
GDTs in Series

- After spark over, a single GDT approximates a short circuit
  - Placed between PWR and RTN, a GDT would short the power supply output
- A single GDT may not extinguish after a surge (VDC > Varc)
- Positive: Summation of arc voltages
  - e.g. 5 x 12 V = 60 V
- Negative: Summation of spark-over voltages
  - e.g. 5 x 150 V = 750 V

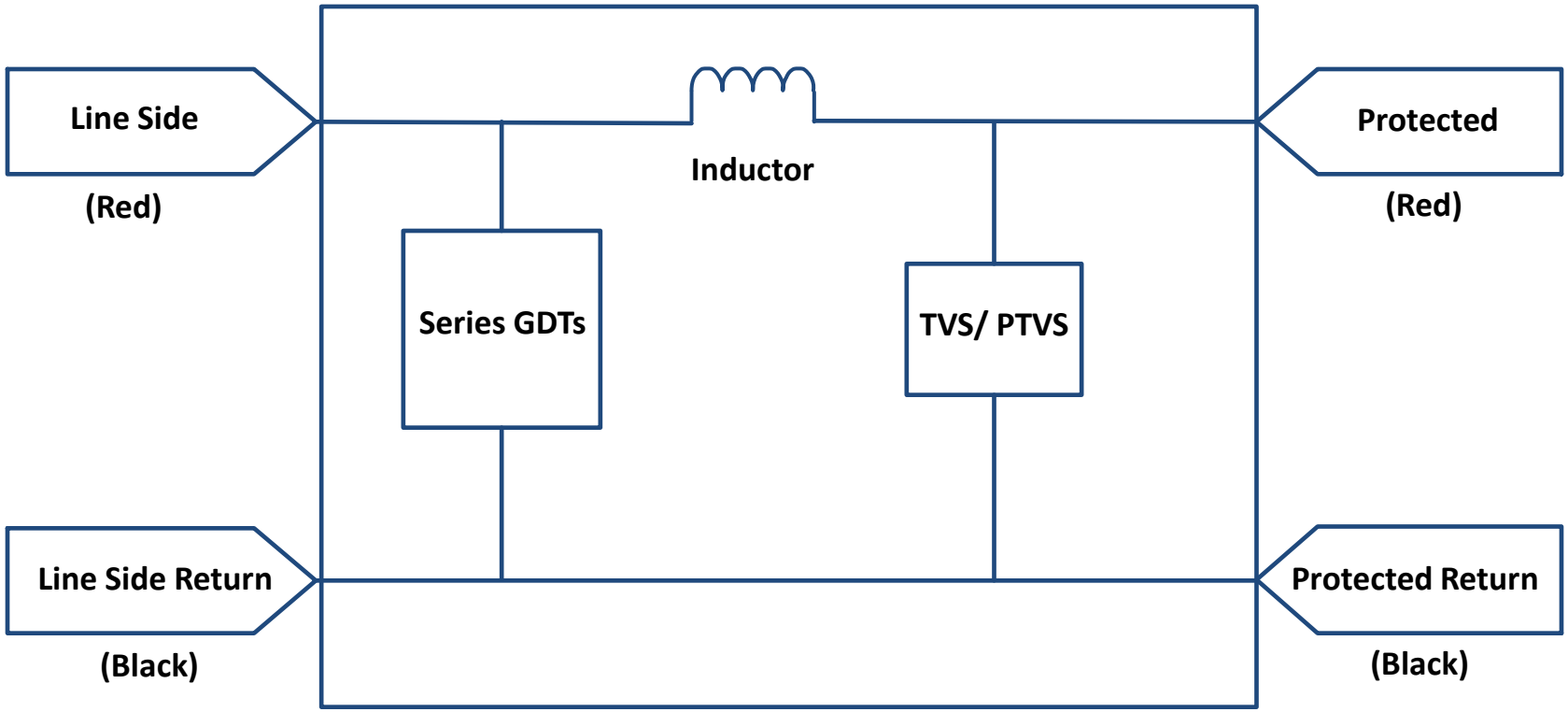


GDTs in Series with Capacitors

- GDTs spark over in rapid succession
- The spark-over voltage for the series GDTs is only slightly higher than a single GDT spark-over voltage
- Summation of arc voltages across the GDTs (e.g. 60 V)
- Still need to address let through energy due to the relatively high impulse spark over voltage (similar to a single GDT)

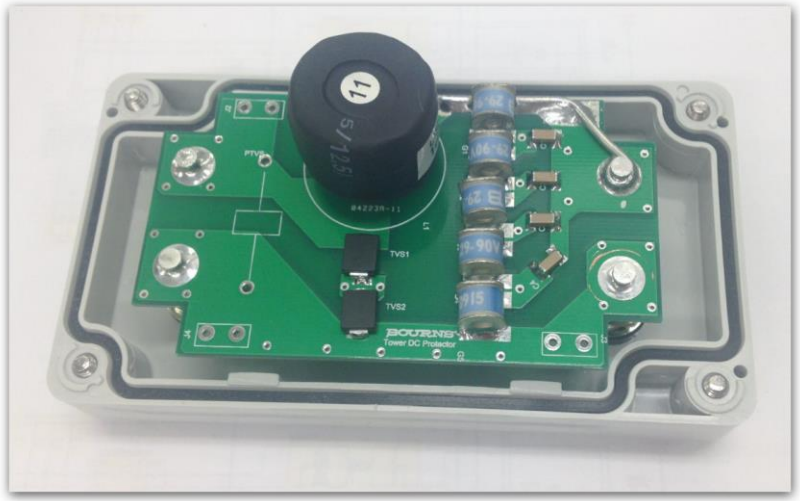


Bourns Series GDT Test Board



Two layers of protection with inductor as coordination element

Bourns Series GDT Test Board

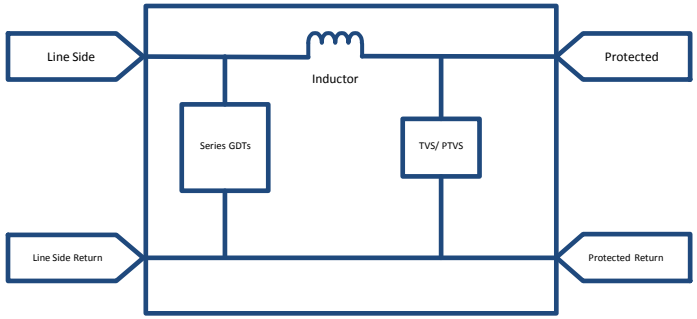


Bourns Series GDT Test Board Video

Performance to 10/350 4 kA Surge

Test Board Characterization and Performance

- Characterization
  - In-line resistance, inductance
  - Line Side to ground impedance, capacitance
  - 8/20 surge performance (1 kA to 20 kA)
  - 10/350 surge performance (1 kA to 4 kA)
  - Inductor temperature rise due to DC (15 A, 20 A)
  - Inductor temperature rise due to 10/350 4 kA surge



- Test Results
  - Withstands 8/20 20 kA, and 10/350 4 kA
  - Good clamping performance for large, fast rising surges
  - Slow rising surges increase secondary protection requirements as GDTs may not spark over

Device Comparisons

MOV

Series GDTs

Power TVS

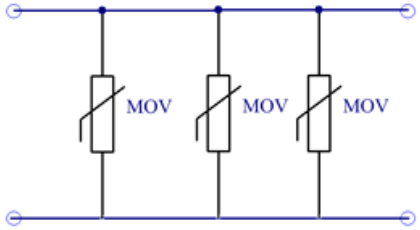
Low **Cost & Performance (8/20)** Hi

MOV

General Information

- Multiple MOV
- Positives
  - Good Clamping
  - Good Surge Current ratings
  - Lowest Cost
- Negatives
  - May require multiple 20mm MOV to attain high rating
  - MOV will age and become leaky under overstress
  - Large and expensive MOV required to meet 4 kA 10/350 rating

Key Attributes	Performance	Comment
Vdrop @20 A	0	Shunt device
8/20 Vclamp	>250 V	Better than GDT
8/20 rating	20 kA	Good Rating
Oversurge Response	Shortens Life	MOV can age over time
4 kA 10/350	No	Difficult with MOV

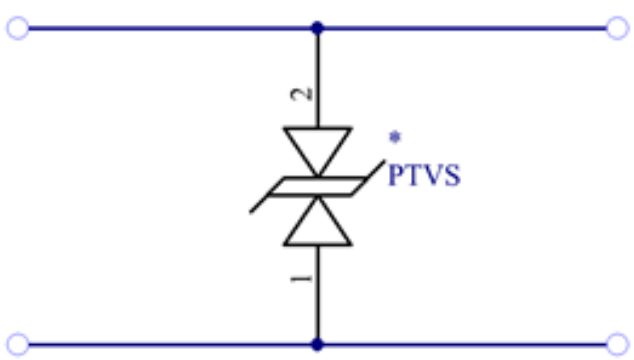


PTVS

General Information

- Power TVS
- Positives
  - Excellent clamping performance
  - Reliable if maintained within current specification
  - TVS a good second stage protector
- Negatives
  - High cost to achieve 20 kA surge current rating
  - Large chip silicon stacks required to attain Voltage/Current rating
  - Over surge will kill device

Key Attributes	Performance					Comments
	3 kA PTVS	6 kA PTVS	10 kA PTVS	15 kA PTVS	20 kA PTVS	PTVS Type
Vdrop @20 A	0	0	0	0	0	Shunt
8/20 Vclamp	~100 V	~100 V	~100 V	~100 V	~100 V	Superior
8/20 rating	3 kA	6 kA	10 kA	15 kA	20 kA	High rating-more silicon
Oversurge Response	Failure	Failure	Failure	Failure	Failure	Excess current will damage PN junctions
4 kA 10/350	No	No	No	No	No	Longer duration surge

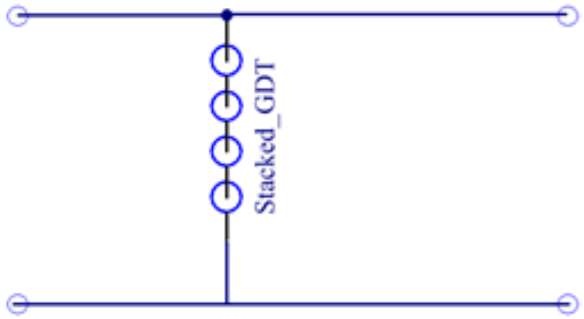


Series GDTs

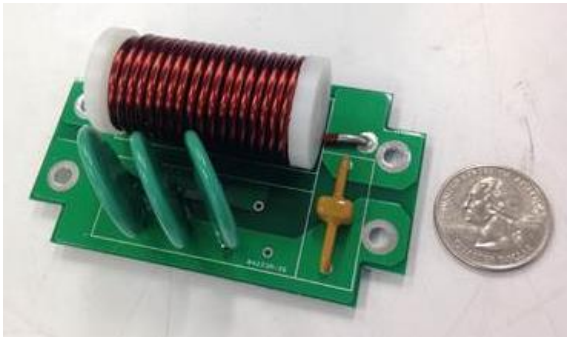
General Information

- Multi-chamber GDT
- Positives
  - High Arc voltage allows GDT to reset
  - High current ratings
  - Significant oversurge required to age device
- Negatives
  - Poor protection as a standalone OVP

Key Attributes	Performance	Comment
Vdrop @20 A	0	Shunt device
8/20 Vclamp	>1000 V	Up to 3 kA volts
8/20 rating	20 kA	Good Rating
Oversurge Response	Shortens Life	Better than MOV/TVS
4 kA 10/350	Yes	Good Rating



Hybrid Solutions



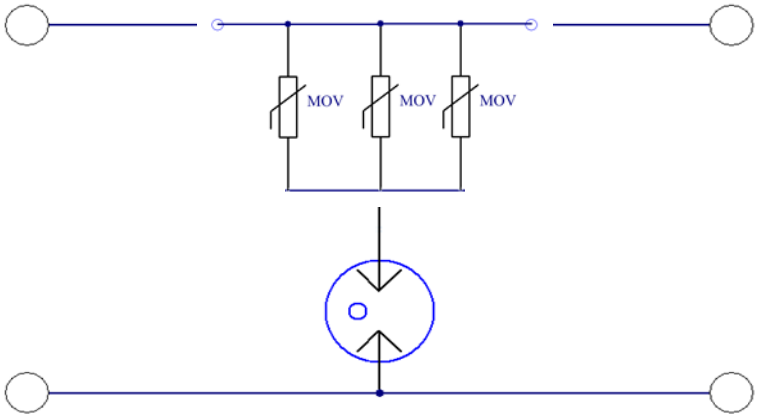
- Discrete protection technologies have positive and negative attributes
- Hybrid solutions pair multiple technologies either discrete components or in a module
- Increased level of protection and reliability at an optimal cost
- Parallel stages of protection requires attention to coordination between the stages

MOV-GDT

General Information

- Multiple MOV+ GDT
- Positives
  - Good Clamping
  - Good Surge Current ratings
  - GDT mitigates leakage issues and can extend MOV life
- Negatives
  - Requires multiple 20 mm MOV to attain high rating
  - Very large and expensive MOV required to meet 4 kA 10/350 rating

Key Attributes	Performance	Comment
Vdrop @20 A	0	Shunt device
8/20 Vclamp	~650 V	Short peak from GDT turn-on
8/20 rating	20 kA	Good Rating
Oversurge Response	Shortens Life	GDT can extend life by limting leakage
4 kA 10/350	No	Difficult with MOV

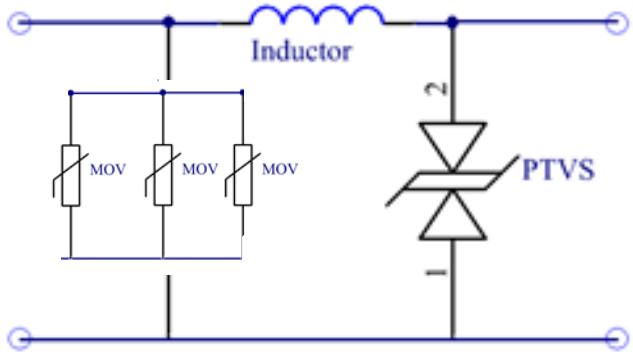


MOV-L-PTVS

General Information

- MOV-L-PTVS Hybrid
- Positives
  - Excellent Clamping of TVS
  - Lower cost solution vs. Series GDT hybrid
- Negatives
  - Larger series resistance & inductance
  - MOV still the weak link in the design

Key Attributes	Performance	Comment
Vdrop @20 A	0.3	Larger Series L needed to hold off current to PTVS until GDT operates
8/20 Vclamp	~100 V	Excellent clamping of PTVS
8/20 rating	20 kA	MOV array takes bulk of current
Oversurge Response	Will Shorten Life	MOV can leak and fail longer term
4 kA 10/350	NO	MOV fails

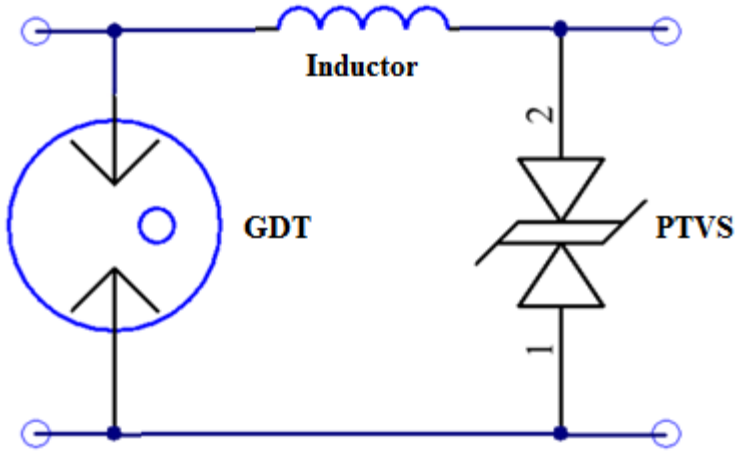


GDT-L-PTVS

General Information

- GDT-L-PTVS Hybrid
- Positives
  - Excellent Clamping of TVS
  - 50 kA performance possible
  - Most robust design
- Negatives
  - Typical GDT may not reset under 48 V powering.

Key Attributes	Performance	Comment
Vdrop @20 A	0.1	Larger Series L needed to hold off current to PTVS until GDT operates
8/20 Vclamp	~100 V	Excellent clamping of PTVS
8/20 rating	>50 kA	High Power GDT takes bulk of surge current
Oversurge Response	Can Shorten Life	Most robust solution but a direct strike could still damage
4 kA 10/350	YES	GDT handles current

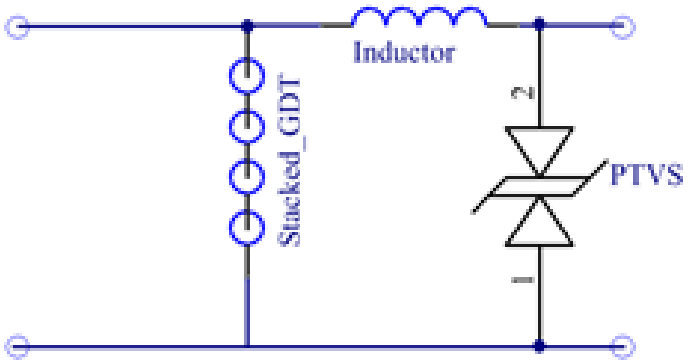


Series GDTs-L-PTVS

General Information

- GDT-L-PTVS Hybrid
- Positives
  - Excellent Clamping of TVS
  - Good surge current ratings of GDT
  - Minimal voltage drop due to series inductance
  - Robust board level solution
- Negatives
  - Series resistance & inductance
  - Large over surge can still damage the solution

Key Attributes	Performance	Comment
Vdrop @20 A	0.1	Series L needed to hold off current to PTVS until GDT operates
8/20 Vclamp	~100 V	Excellent clamping of PTVS
8/20 rating	20 kA	GDT takes bulk of current
Oversurge Response	Can Shorten Life	Large oversurge can still damage circuit
4 kA 10/350	Yes	GDT takes bulk of current



Summary

- Robust overvoltage protection is being integrated in radio equipment
- Several technologies are available to allow for cost–performance tradeoffs
- Hybrid solutions with proper component selection and coordination have promise and are under study