Snapback TVS Protection

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Agenda

Welcome to our presentation on Snapback TVS protection

Theory

Let's have some fun and review some of the common TVS protection methods.

Historical and current TVS methods – what are they good for and not good for?

Comparing alternatives

Sometimes misapplied methods

Snapback TVS – what is it good for and why?

Comparisons and applications

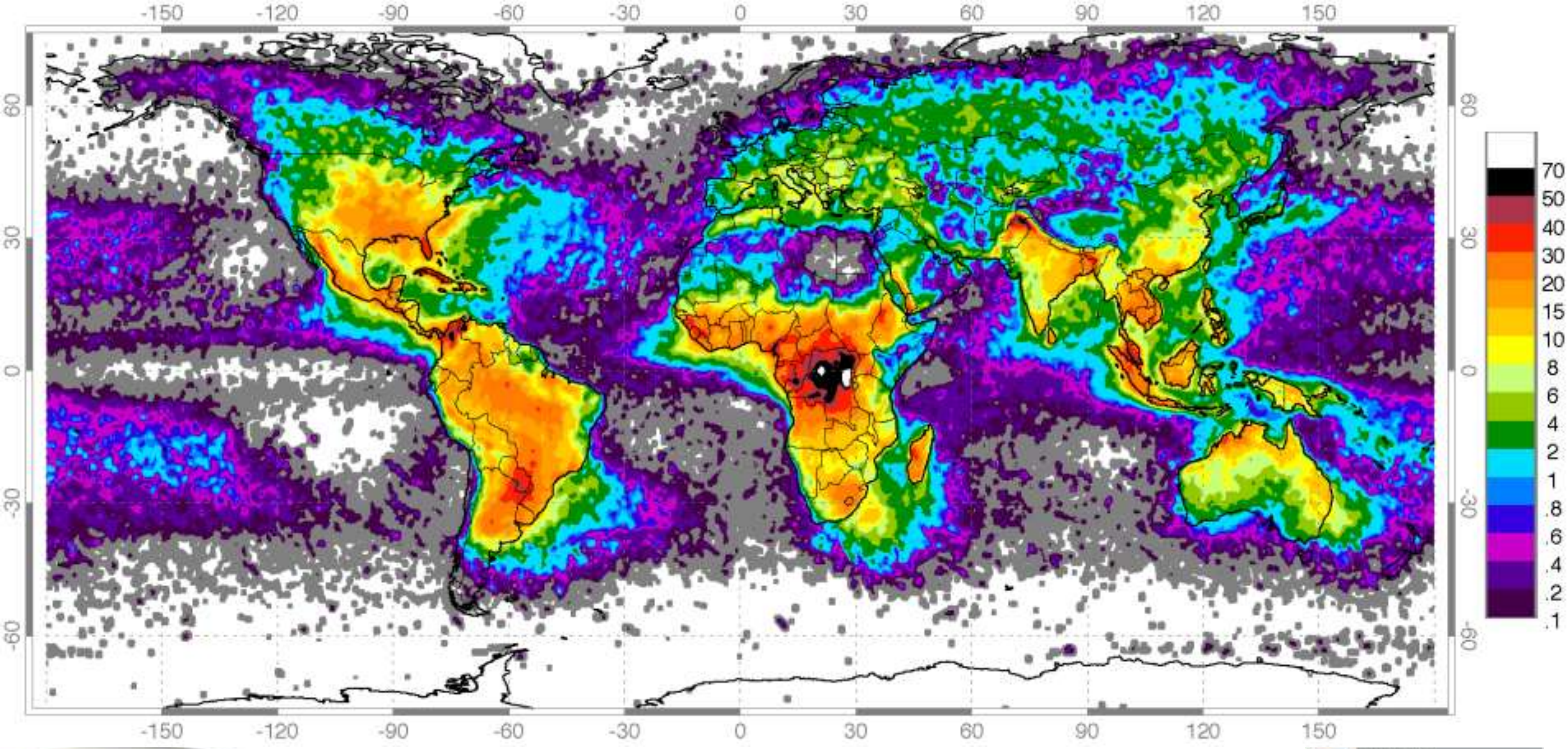
ANY TVS TECHNOLOGY

- Converts transient electrical energy into transient thermal energy and then dissipates it until transient is dissipated and – or if fuse, circuit breaker or current limiting device kicks in and interrupts the energy and its safely dissipated.

THEORY

- We will be working with n(x,t), p(x,t), Je(x,t), Jh(x,t), and E(x,t),
- Our TVS devices all have five independent equations that relate the operation:
- (1) Je(x,t) = q µe n(x,t) E(x,t) + q De ∂n(x,t) ∂x
- (2) Jh(x,t) = q µh p(x,t) E(x,t) - q Dh ∂p(x,t) ∂x
- (3) ∂n(x,t) ∂t - 1 q ∂Je(x,t) ∂x = gL(x,t) - [n(x,t) p(x,t) - ni 2] r
- (4) ∂p(x,t) ∂t + 1 q ∂Jh(x,t) ∂x = gL(x,t) - [n(x,t) p(x,t) - ni 2] r
- (5) e ∂E(x,t) ∂x = q [p(x,t) - n(x,t) + Nd(x) - Na(x)]
- We will review these as part of the discussion in that our methods essentially solve these 5 equations during operation.
- We will discuss this in detail as we review the methods

WHERE DO TRANSIENTS COME FROM? NATURE



Naturally occurring

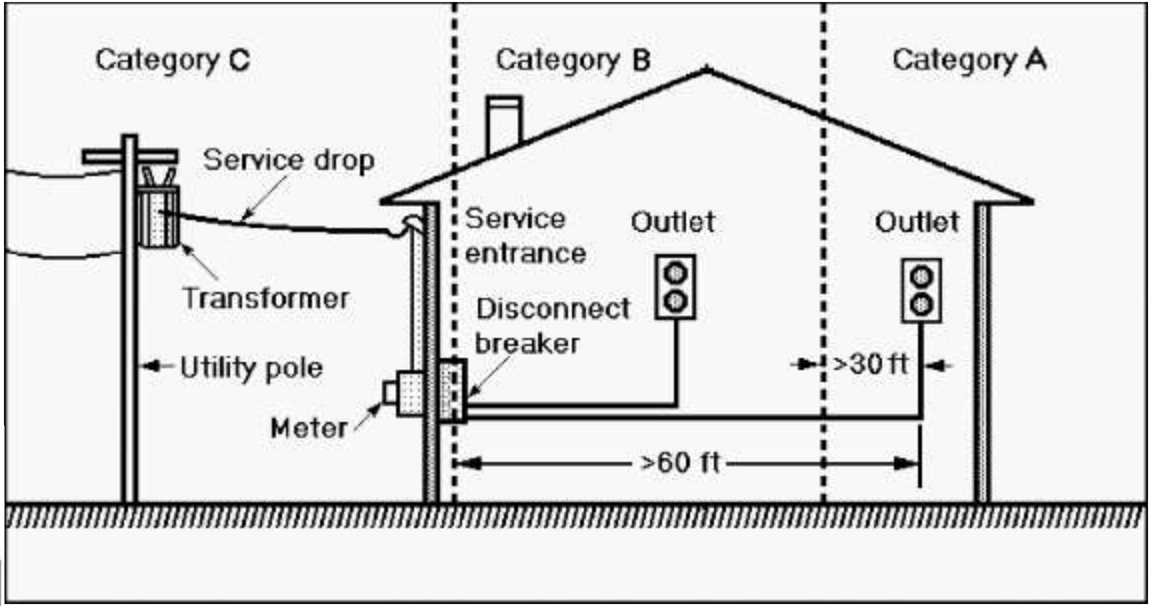
MANMADE

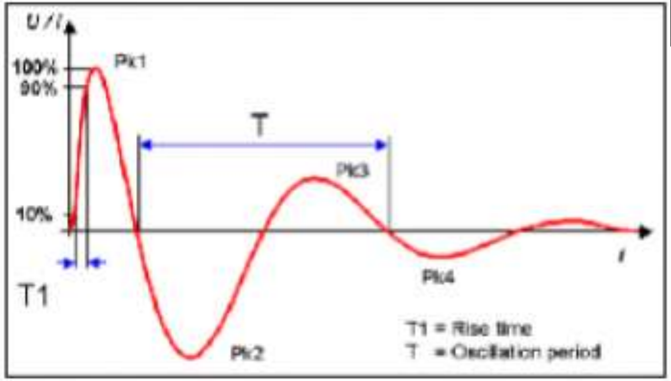
- Misuse – plug in wrong socket
- Electrical grid shut down – switching – power outages and recovery from shut off – inductive ringing, back EMF from inductive loads , capacitor discharges…+
- Electric and ICE vehicle transients – load dumps

Internal sources	External sources
• Capacitor switching • The operation of power semiconductor switches • Internal faults • Electrostatic discharge • Relay operation • Circuit breaker or switchgear operation • Load removal or addition • Arcing	• Lightning • External load removal or connection • Opening or closing of switchgears in energized systems • Switching of capacitor banks • Tap changing transformers • Loose connections at the utility end • External faults • Human errors • Short circuits caused by animals • Bad weather conditions • Neighboring circuits

NON-AUTOMOTIVE AC LINE POWER TRANSIENTS – SURGES

- IEC61000-4-2
- IEC61000-4-4
- IEC61000-4-5
- IEEE C62.41 ring waveform
- IEC61000-4-12

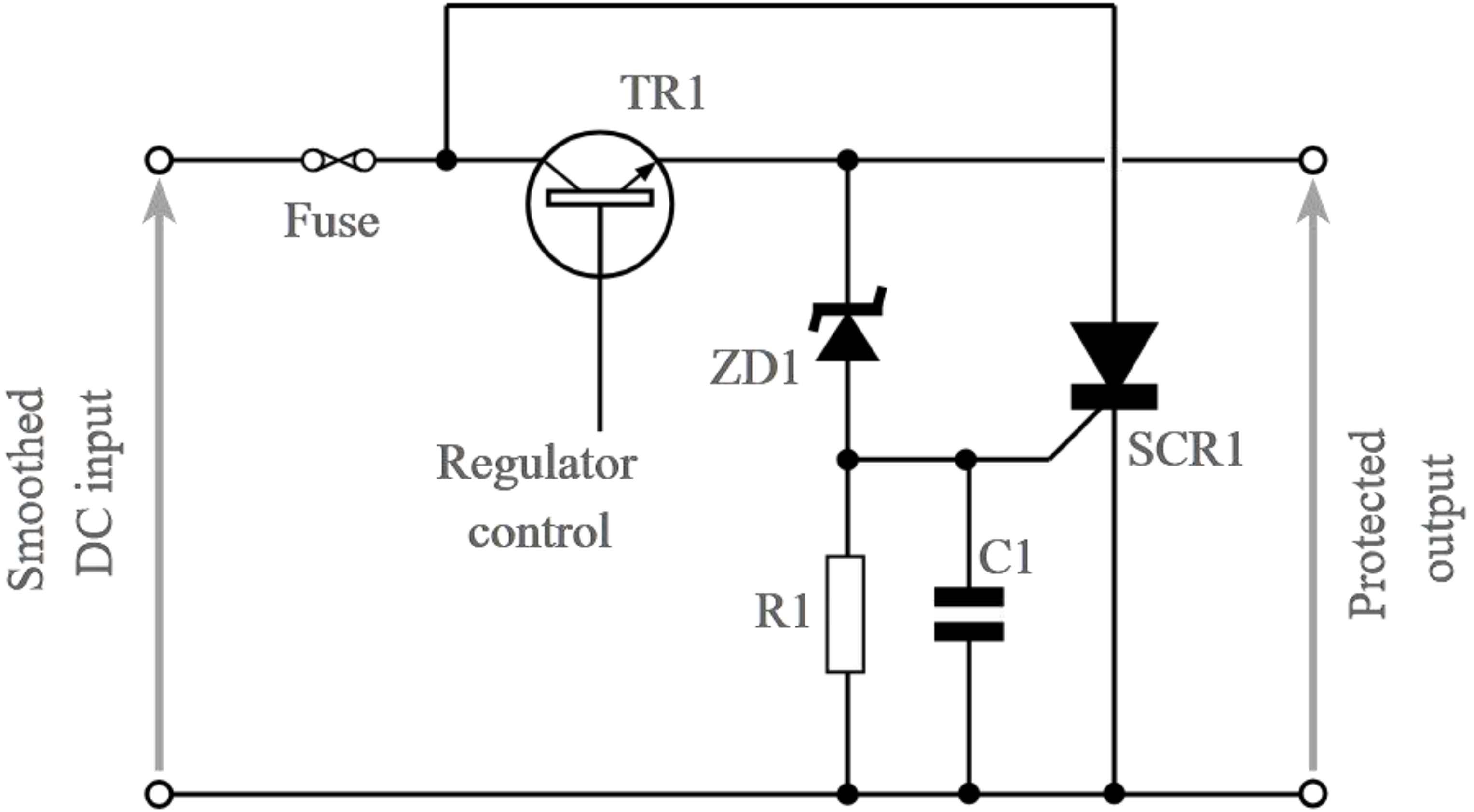




CHARACTERISTICS OF DIFFERENT TVS SOLUTIONS

Comparison of Transient Voltage Suppressor Components							
Component type	Protection time	Protection voltage	Power dissipation	Reliable performance	Expected life	Energy rating	Other considerations
Gas discharge tube	> 1 µs	60-100 V	None	No	Limited	Highest	Only 50-2500 surges. Can short power line.
MOV	10-20 ns	> 300 V	None	No	Degrades	High	Fusing required. Degrades. Voltage level too high.
Avalanche TVS	50 ps	3-400 V	Low	Yes	Long	Lowest	Low power dissipation. Bidirectional also available.
Thyristor TVS	< 3 ns	30-400 V	None	Yes	Long	High	High capacitance. Temperature sensitive.

IN THE BEGINNING – SCR CLAMP



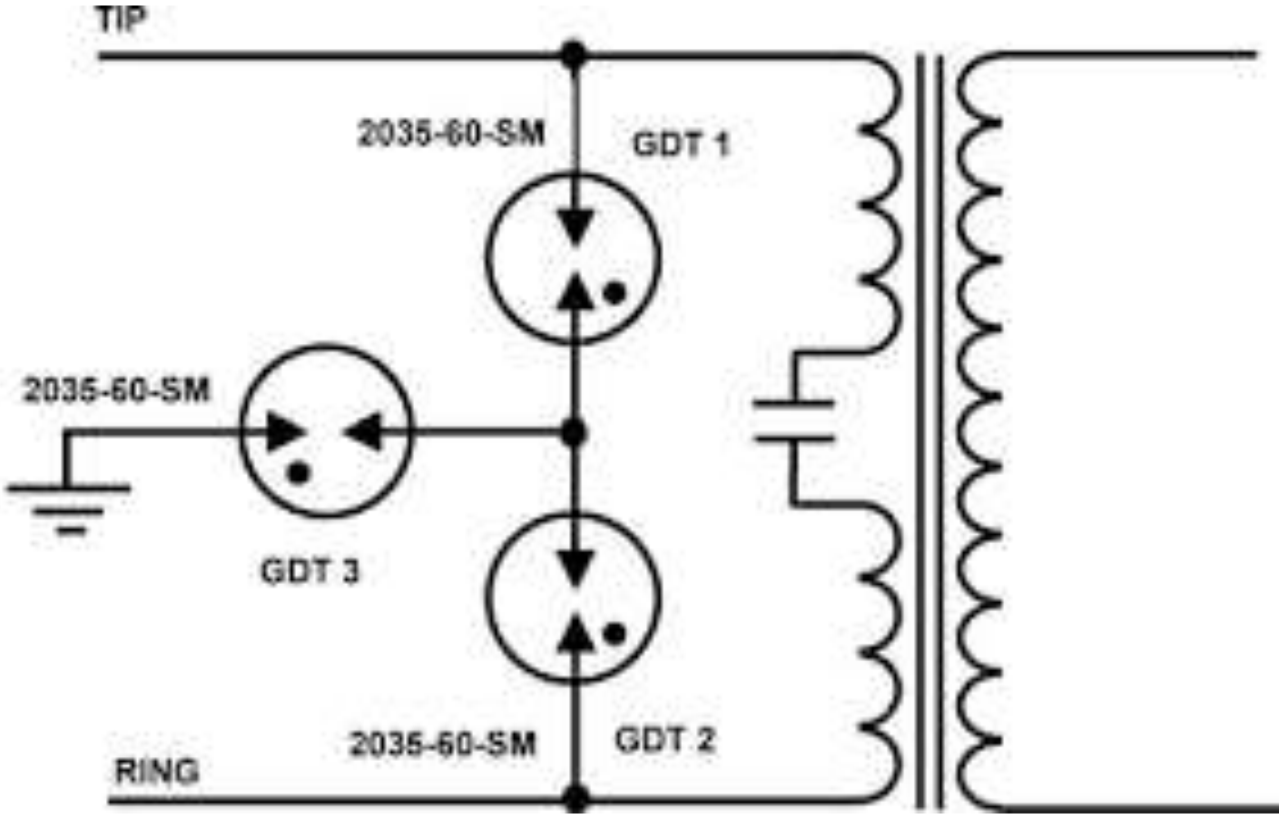
SCR CLAMP

- Benefits – it works, not very accurate but repeatable
- Downside – false noise triggering issues – RF, Motors – anything that makes noise.
- You go through a lot of fuses – it was used in SCR phase controlled, linear regulated and ferro resonant power supplies in history.
- If you use at unattended locations, you will get calls to replace fuses at remote locations guaranteed and you will learn to hate it.
- Speed – is it fast enough to protect downstream components? Probably in the 70s and maybe 80s.
- But did I mention it works and nothing else was really better at the time but MOVs were new.
- It was an early snapback protection device other than maybe a tube-based approaches
- Its not good for repetitive events – one event is what you get. SCR could be damaged recycle power supply
- Unidirectional
- Not really used anymore

GAS DISCHARGE TUBES

- Great for lightning protection
- Started with Telecom market – Bell labs
- Moderate for use with repetitive pulses depending on Pulse repetition rate and energy to be dissipated you get limited # of pulses
- Some applications provide replacement methodologies
- Sometimes combined with MOVs to make a complete solution
- Good for power line use also – see lightning protection
- Fast response
- Doesn't snap back it breaks down at a specific voltage determined by gas mixture.
- Often has to be followed up with downstream protection measures
- Not very precise or accurate but for gross events
- exothermic events when they are stressed
- Bidirectional

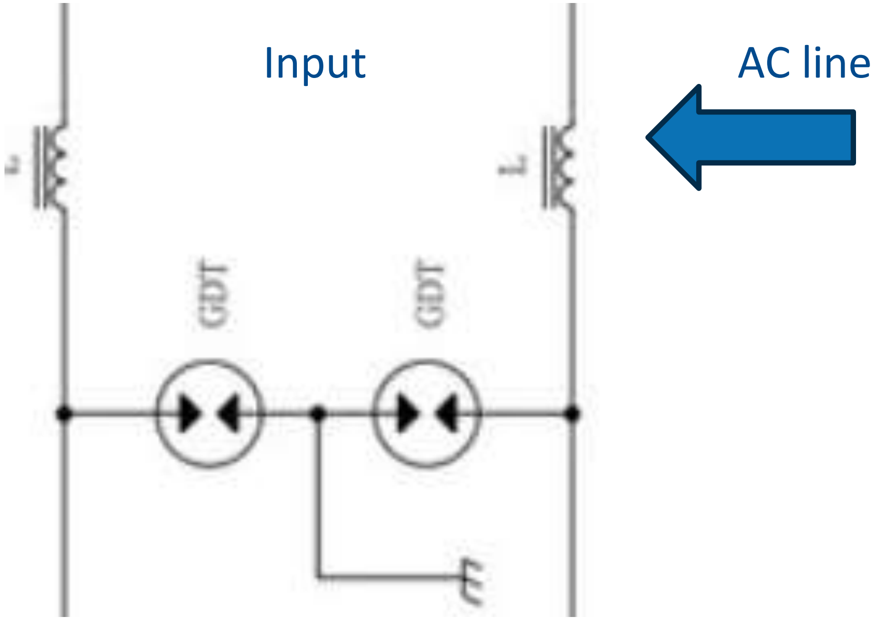
GDT – GAS DISCHARGE TUBES – FIRST USE TELECOM



AC LINE PROTECTION –SIMPLIFIED

Input

AC line filter impedance



And yes, GDTs can be used for Ethernet and other small signal lines including DC lines – differential or single ended

MOVS

- Metal oxide varistors
- Useful for non repetitive transient protection
- Once a breakover voltage is reached the device clamps
- Repetitive transients turn them into talcum power
- Used in AC Transient protection often by themselves or in combination with GDTs
- Not as fast as GDTs but usually fast enough for AC line protection
- Not used much for DC lines – but sometimes misapplied that way
- Not precision devices
- They wear out with repetitive transient applications
- No snapback to it – gross protection with something else needed downstream

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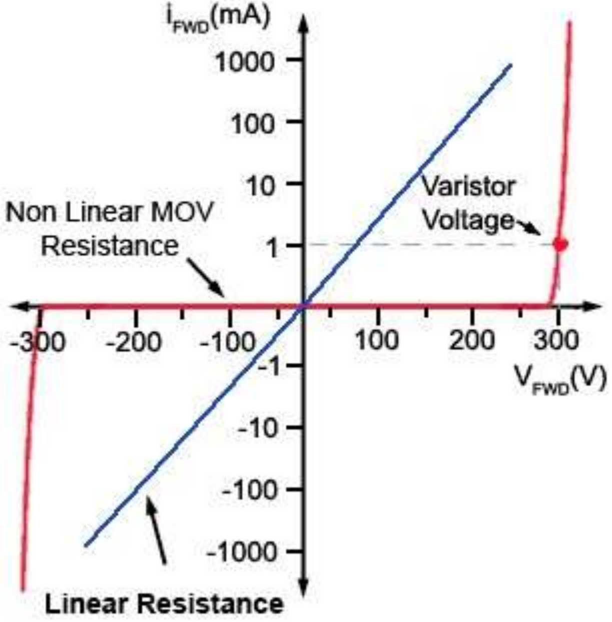
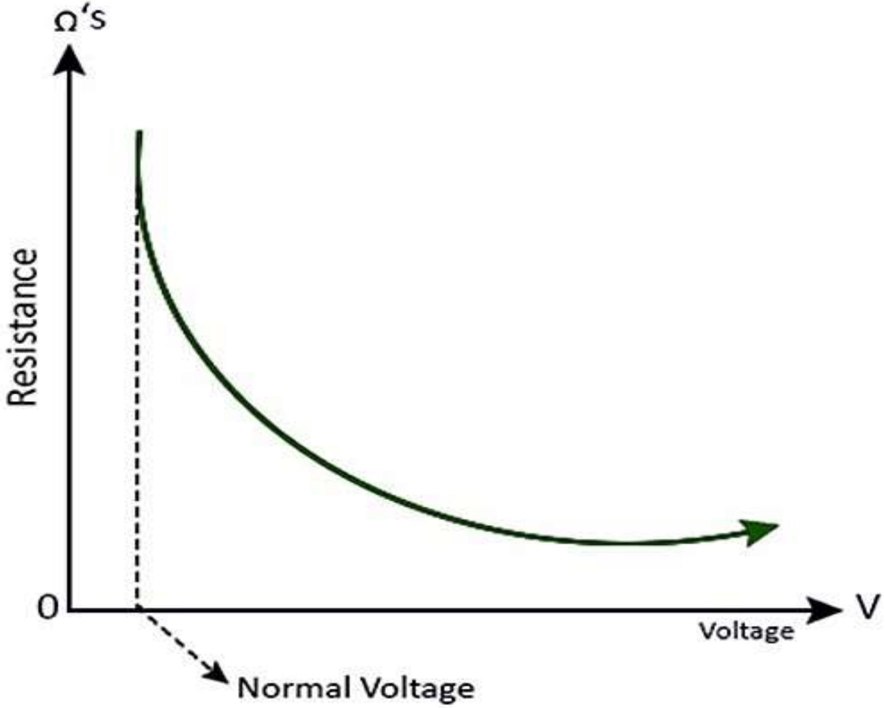
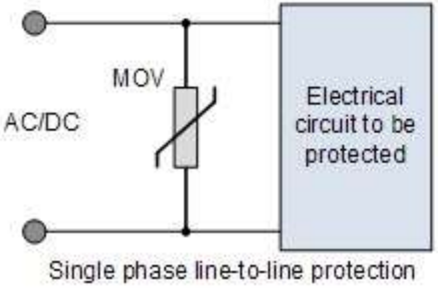
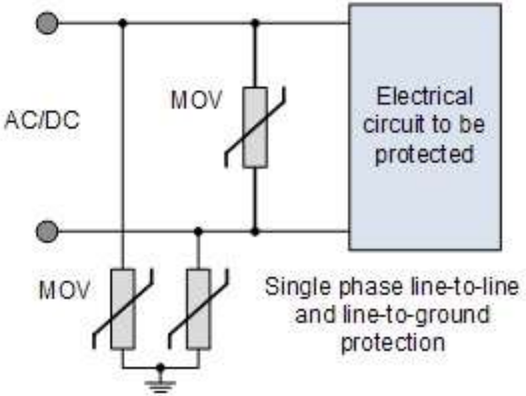
MOVS BIDIRECTIONAL –ELECTRICAL CHARACTERISTICS

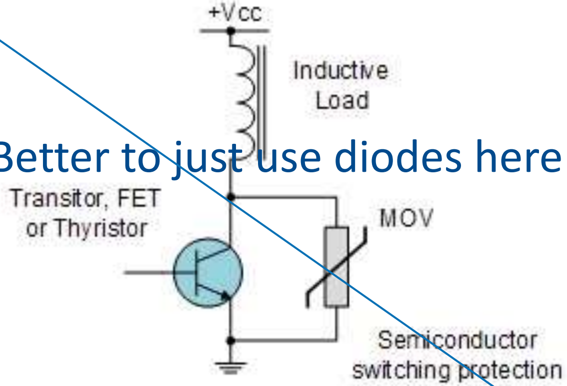




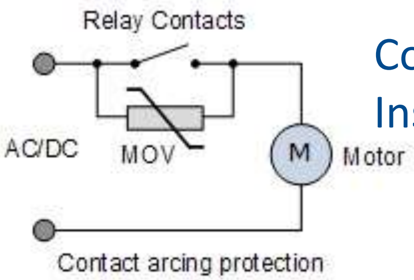
MOV APPLICATIONS –USUALLY FOR HV USED MORE FOR AC







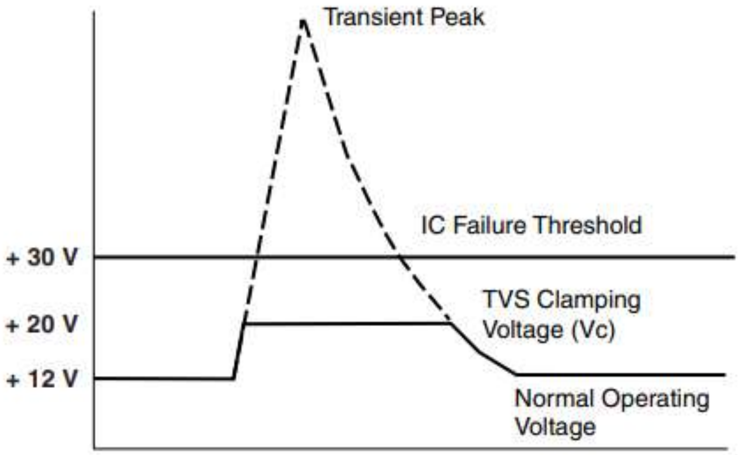
Better to just use diodes here



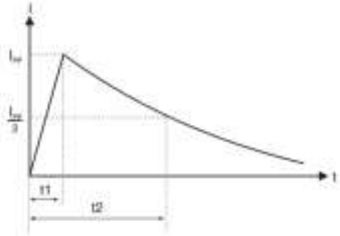
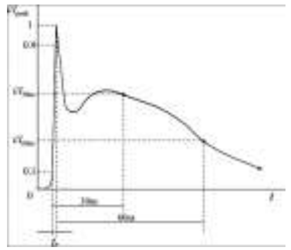
Could argue use caps
Instead, or combination

WHAT IS THE FUNCTION OF A TVS/ESD DEVICE?

- Transient Voltage Suppressors (TVS/ESD) are devices used to protect vulnerable circuits from electrical overstress such as that caused by **electrostatic discharge, inductive load switching** and **induced lightning.**



Transients of Several Thousand Volts can be “clamped” to a Safe Level by the TVS/ESD.

Circuit Protection Device	Waveform
TVS	
ESD	

TVS VS ESD

- TVS device converts transient electrical energy into transient thermal energy and then dissipates it – the goal is to clamp the circuit – protect other components and either current limit some other part of the circuit – fuse, circuit breaker, current limit circuit or source impedance until the event concludes. Higher current, lower voltages (vs ESD) rather high power 200 W to 6.6 KW peak. The voltage might exceed the protection voltage depending on repetitive transients and temperature of die.
- ESD devices clamp high voltage (static) levels at relatively low power until event is dissipated and protecting the downstream circuitry. This is why the packages can be relatively small. The voltage will not exceed maximum ratings.
- Snapback TVS is the modern equivalent of the SCR crowbar without the drawbacks. The voltage never exceeds protection voltage.

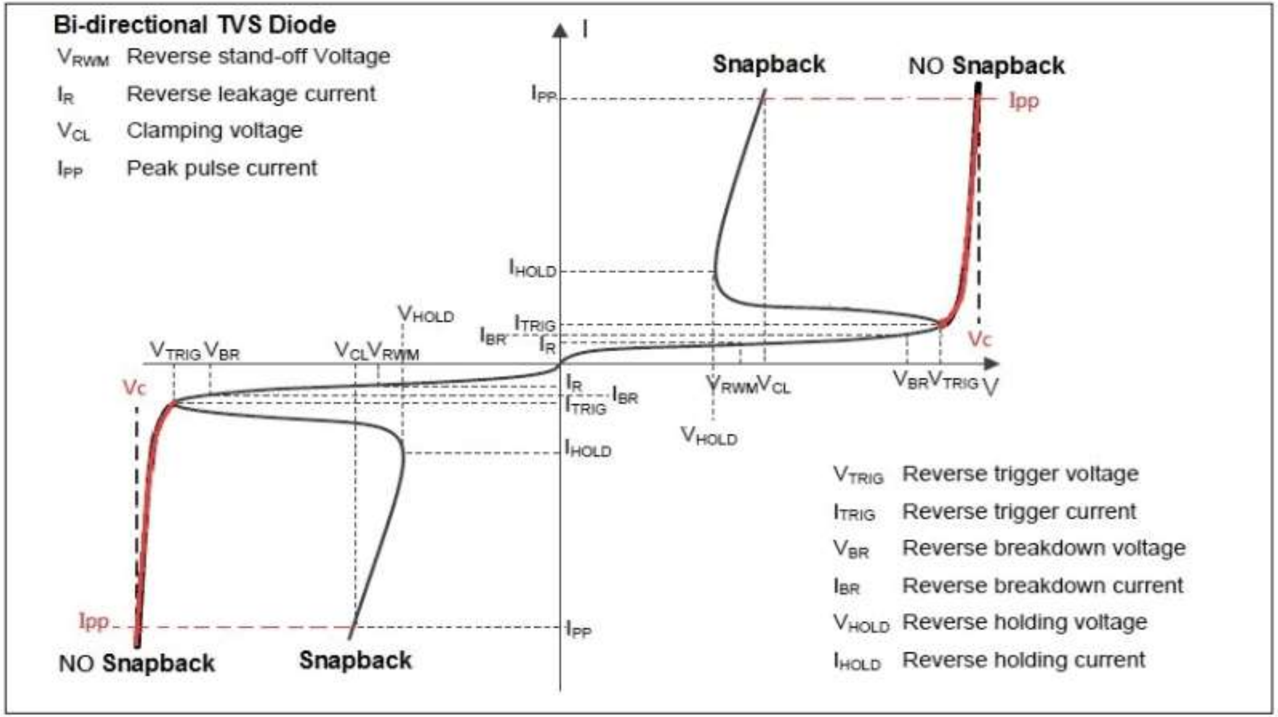
REGULAR TVS DEVICES

- Bidirectional or unidirectional available
- Fast response
- Semiconductor devices so indefinite life if specifications are not exceeded rugged if they are not over dissipated.
- Repetitive transients no problem as long as Tj is kept below 125-150-175
- More precise than other methods but they do have a tempco
- Voltage clamping moves with temperature i.e. respective transient's
- Historically no snapback characteristic
- Overdesigning sometimes needed i.e., downstream protection required to prevent damage if clamping voltage is exceeded by some amount.

SNAPBACK TVS VBR STABILITY

- Is a low clamping transient voltage suppressor (TVS) which has snapback characteristics with an extremely low clamping ratio between working voltage (VWM) and clamping voltage (VC). The low clamping ratio TVS can suppress high surge current to provide lower clamping voltage than conventional TVS and metal oxide varistor (MOV) devices.
- It allows designers to use lower working voltage components i.e. capacitors, switching MOSFETs, reverse polarity protection diodes, and regulators. No need to overdesign as the TVS device provides a "not to exceed" limit.
- Low clamp TVS devices have a breakdown voltage (VBR) difference over temperature is much lower than conventional TVS devices.
- This VBR stability vs temperature variation helps designer anticipate voltage range over temperature considerations. i.e. what could happen when….

CONVENTIONAL AND SNAPBACK TVS



TVS Diode V-I characteristics

7700W, 24V Surface Mount Transient Voltage Suppressor

FEATURES

- AEC-Q101 qualified
- Moisture sensitivity level: level 1, per J-STD-020
- RoHS Compliant
- Halogen-free

APPLICATIONS

- Transient Surge Protection

MECHANICAL DATA

- Case: DO-218AB
- Molding compound meets UL 94V-0 flammability rating
- Terminal: Matte tin plated leads, solderable per J-STD-002
- Meet JESD 201 class 2 whisker test
- Polarity: As marked
- Weight: TBDg (approximately)

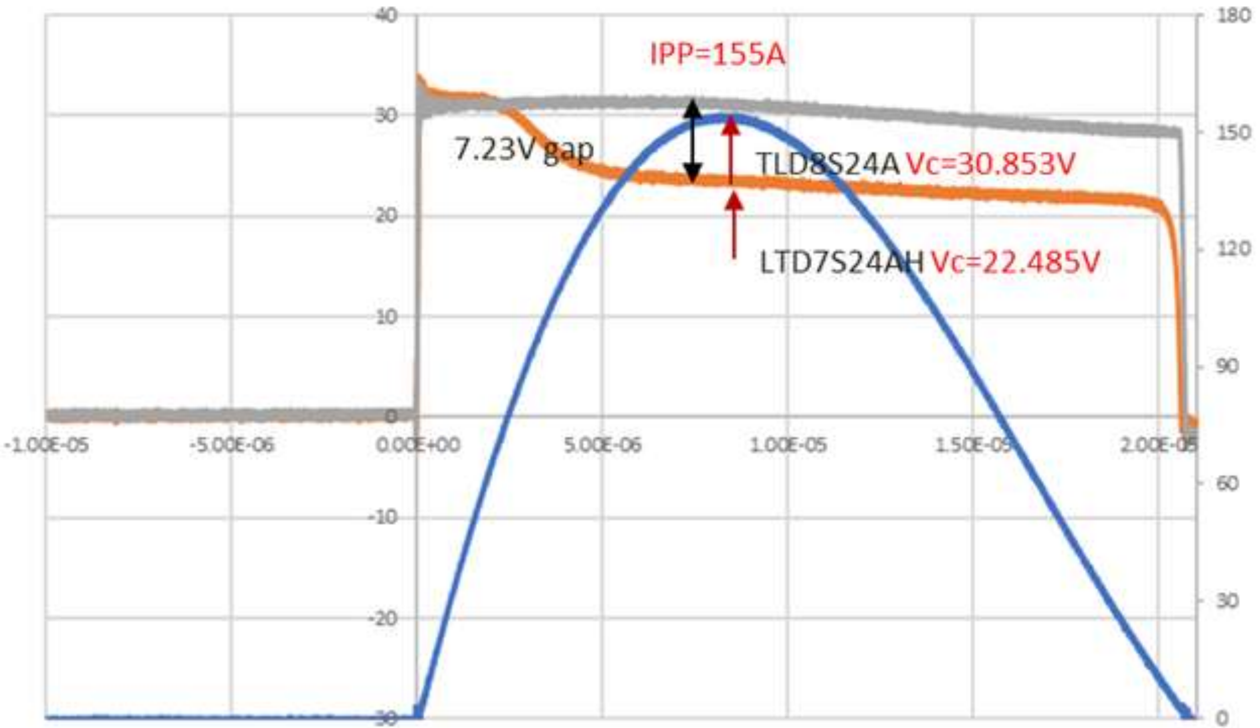
KEY PARAMETERS		
PARAMETER	VALUE	UNIT
V_{WM}	24	V
V_{BR}	29.26	V
P_{PPM} (10x1,000μs)	7700	W
$T_{J\,MAX}$	175	°C
Package	DO-218AB	

Pb Pb-Free RoHS COMPLIANT HALOGEN FREE

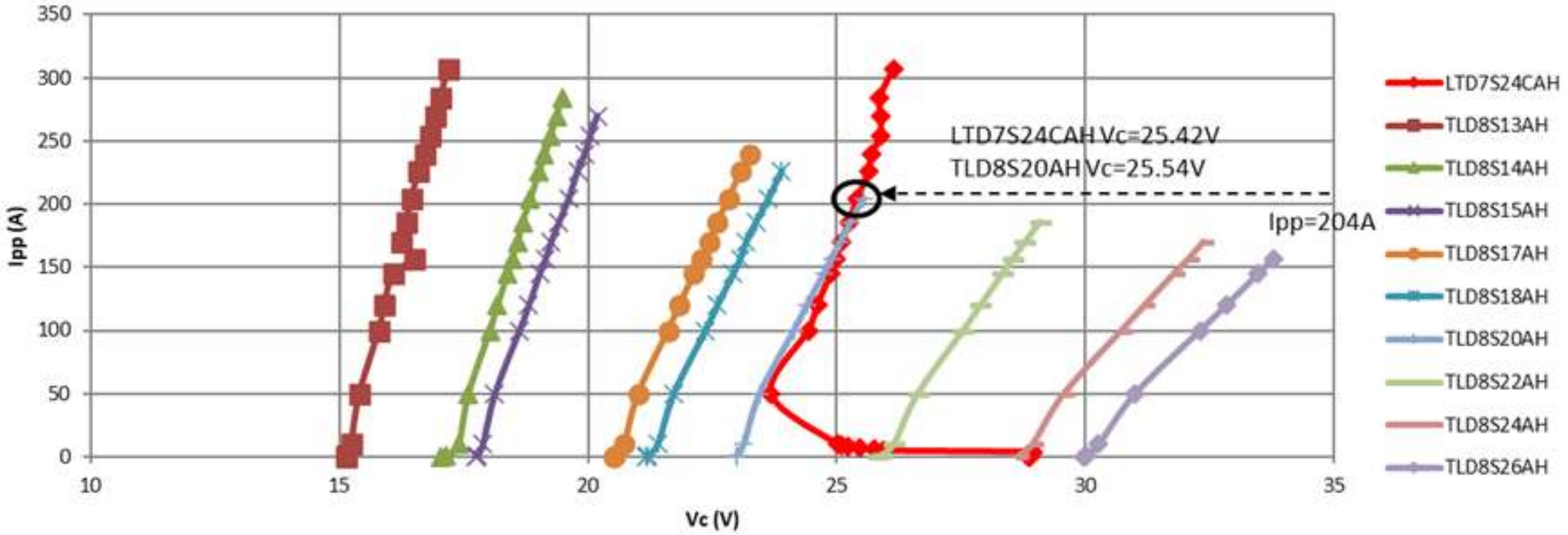
DO-218AB

BRAND NEW SNAPBACK TVS VS NON-SNAPBACK TVS 24 VOLT DEVICES

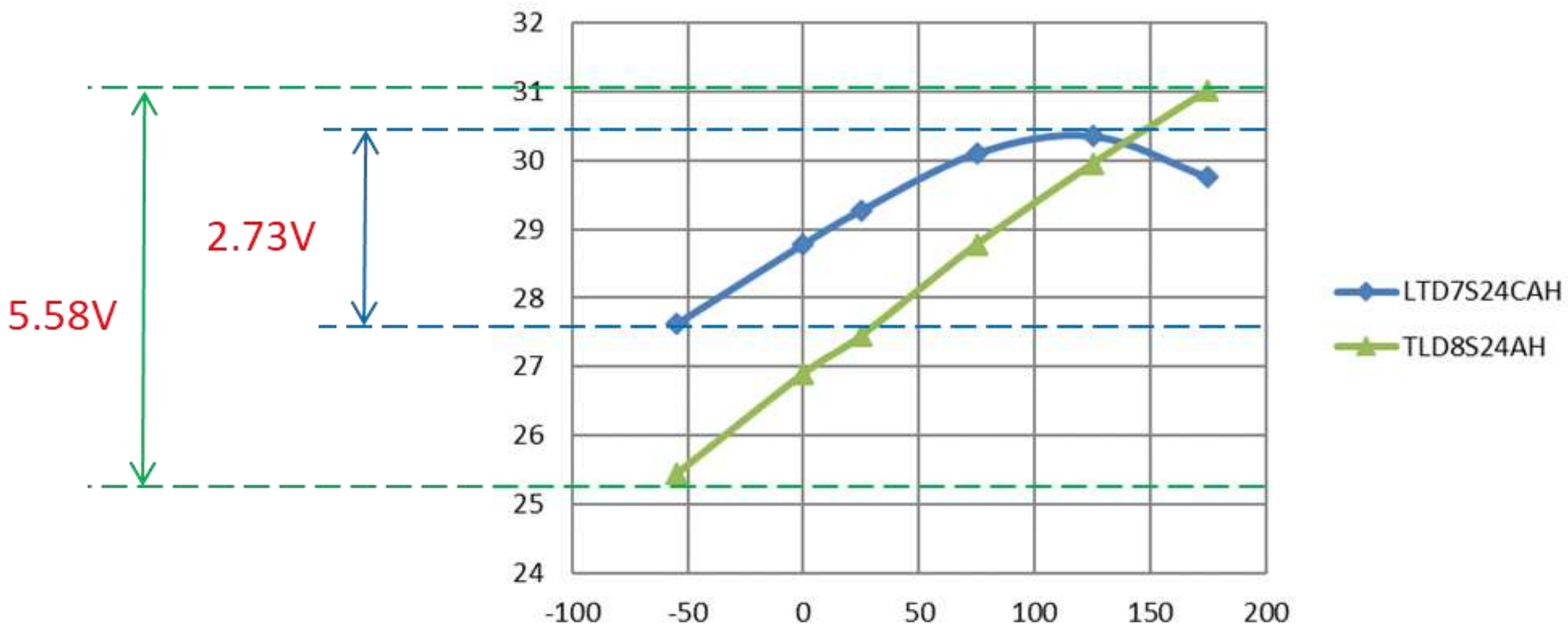
- low clamp TVS LTD7S24CAH and conventional TVS TLD8S24AH tested 8/20u IPP=155A)



HIGHER PRECISION WITH SNAPBACK –BETTER PROTECTION



BETTER OVER TEMP PERFORMANCE -55 TO +175C



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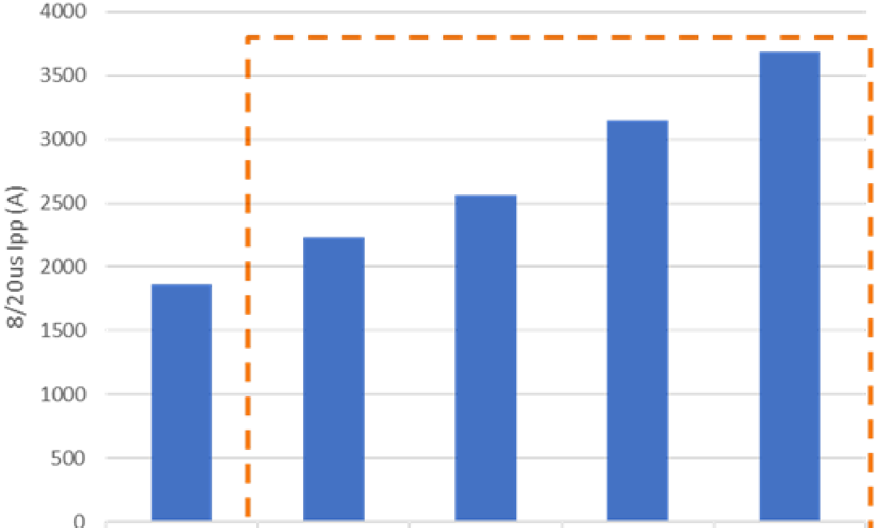
COMPARISON SNAPBACK TVS VS AUTOMOTIVE MOVS HOWEVER..

PN	V10P17AUTO	V14E17AUTO	V20P17AUTO	TLD8S24AH	LTD7S24CAH
min. VBR (V)	24.3	24.3	24.3	26.7	28
max. VBR (V)	29.7	29.7	29.7	29.5	30.8
type	10mm MOV	14mm MOV	20mm MOV	6600W TVS	7700W TVS



	V10P17AUTO	V14E17AUTO	TLD8S24AH	LTD7S24CAH	V20P17AUTO
8/20us Ipp (A)	1860	2230	2560	3150	3690

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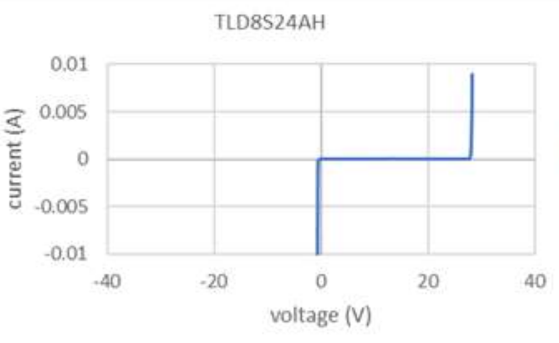
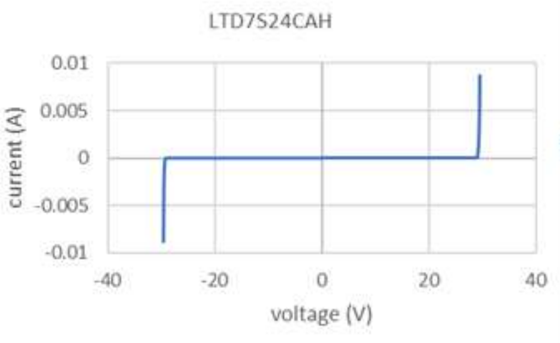
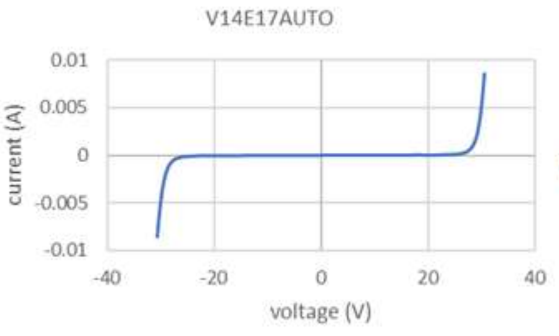
ONLY 2 MOVS CAN PASS A TEST AND THE TVS PERFORMANCE >



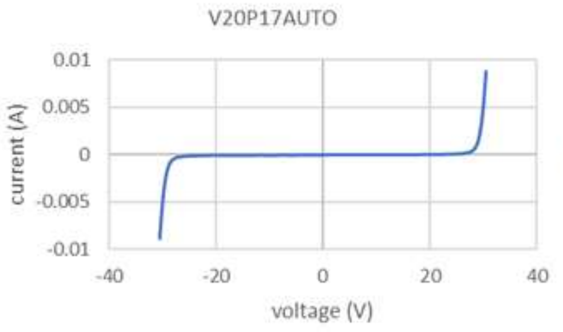
Rdny=28.46 ohm



Rdny=38.5 ohm



Rdny=305.88 ohm



Rdny=240.25 ohm

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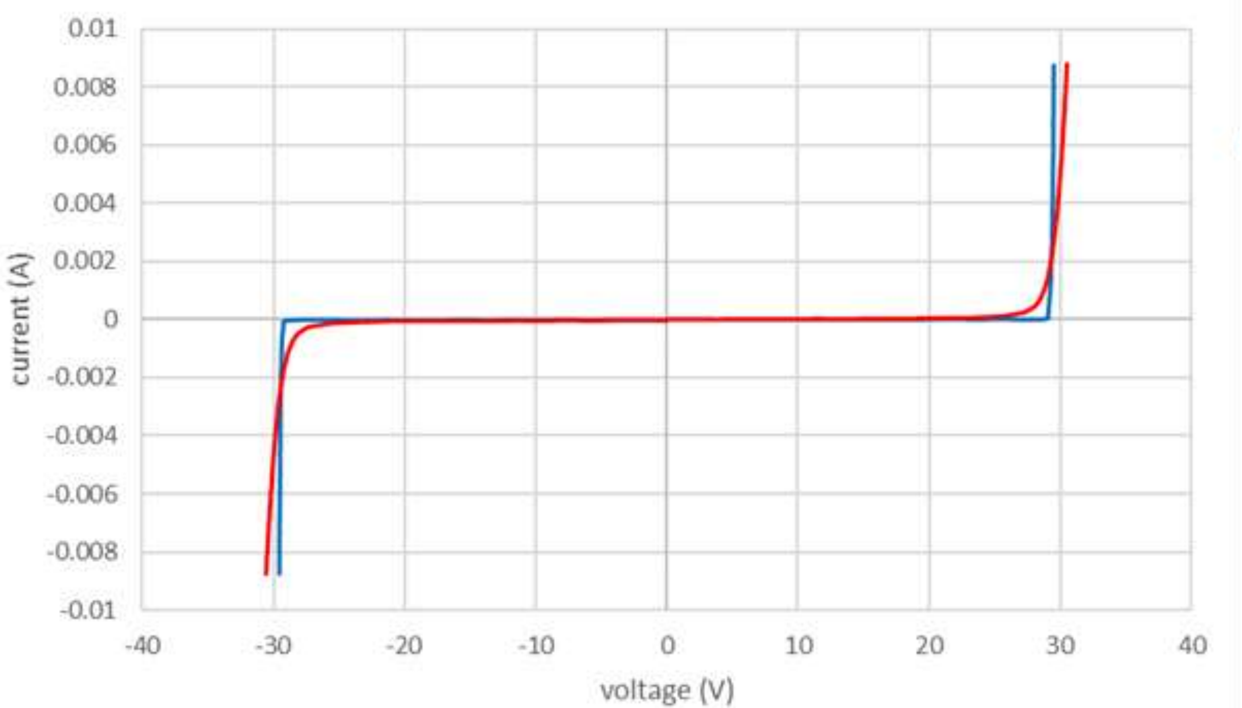
APPLIED 8/20US LIGHTING SURGE TO TEST DEVICES



SnapbackTVS LTD7S24CAH I-V - VC clamping ratio = 1.13 (VC/VWM) lower than conventional TVS TLD8S24AH VC clamping ratio = 3.25 (VC/VWM), V20P17AUTO VC clamping ratio = 4.65 (VC/VWM) and V14E17AUTO VC clamping ratio = 4.95 (VC/VWM).
Low clamp TVS VC is closer to VWM for better precision and protection. Multiple tests would destroy MOV

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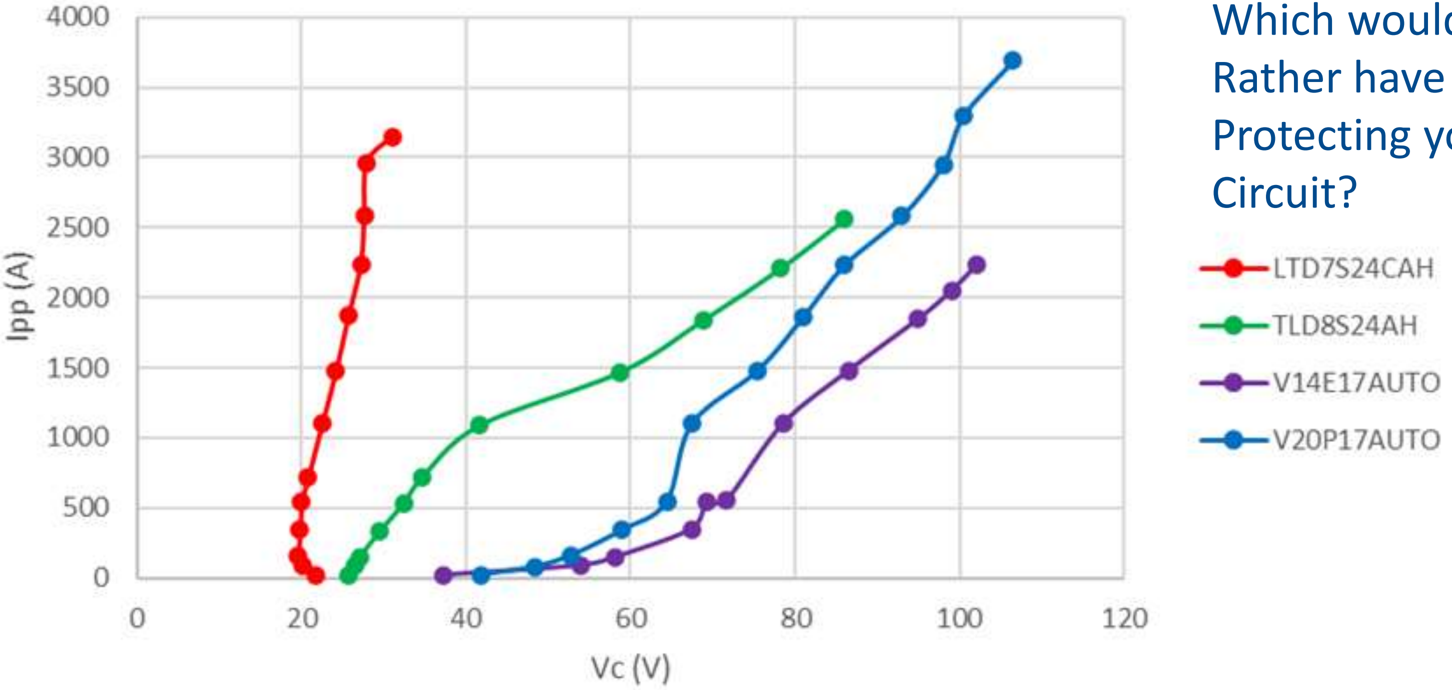
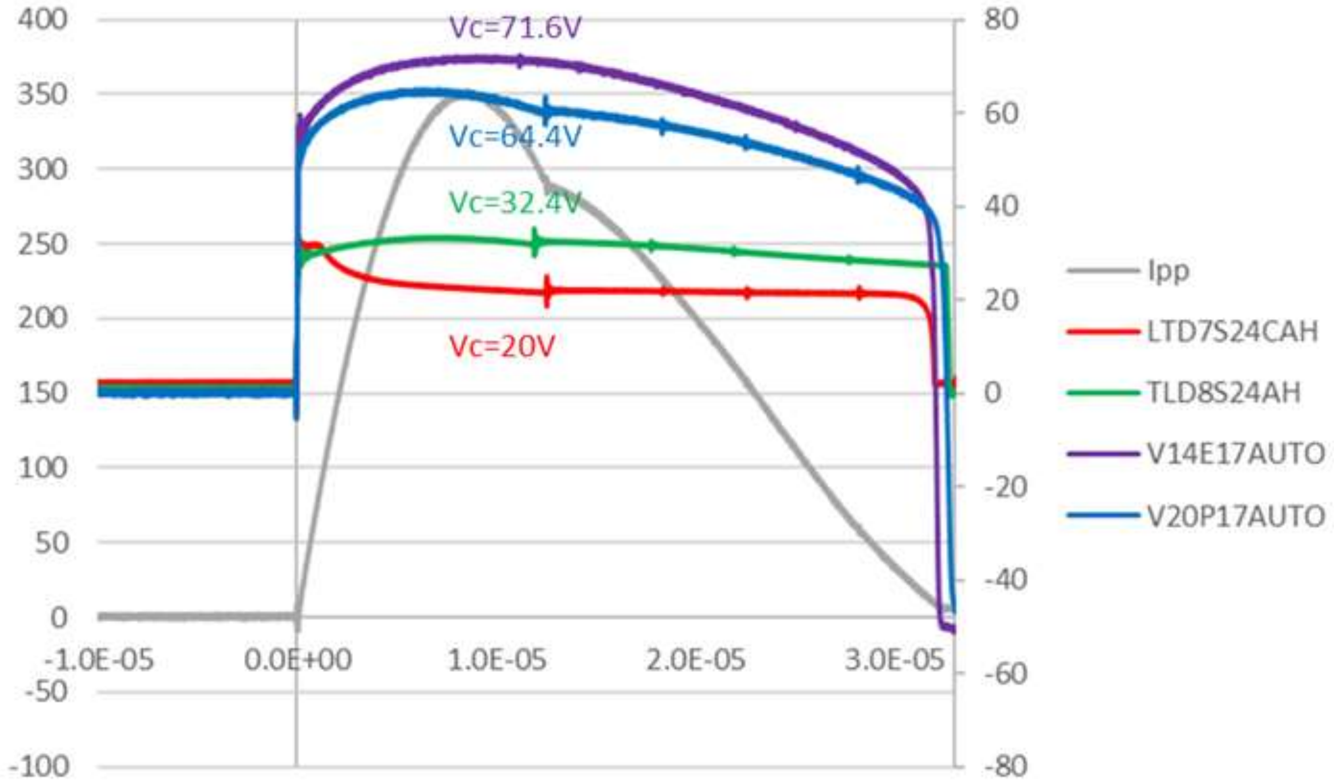
8/20US MULTIPLE PULSE I-V CURVE OF LOW CLAMP TVS, CONVENTIONAL TVS AND MOV



Which would you Rather have Protecting your 24 V Circuit?

Snapback TVS LTD7S24CAH VC=20V is lower than conventional TVS TLD8S24AH VC=32.4V, MOV V14E17AUTO VC=71.6V, MOV V20P17AUTO VC=64.4V. LTD7S24CAH Vc is only 28% of V14E17AUTO, 31% of V20P17AUTO, 61.7% of TLD8S24AH.

8/20US IPP=340A COMPARISON 1 PULSE



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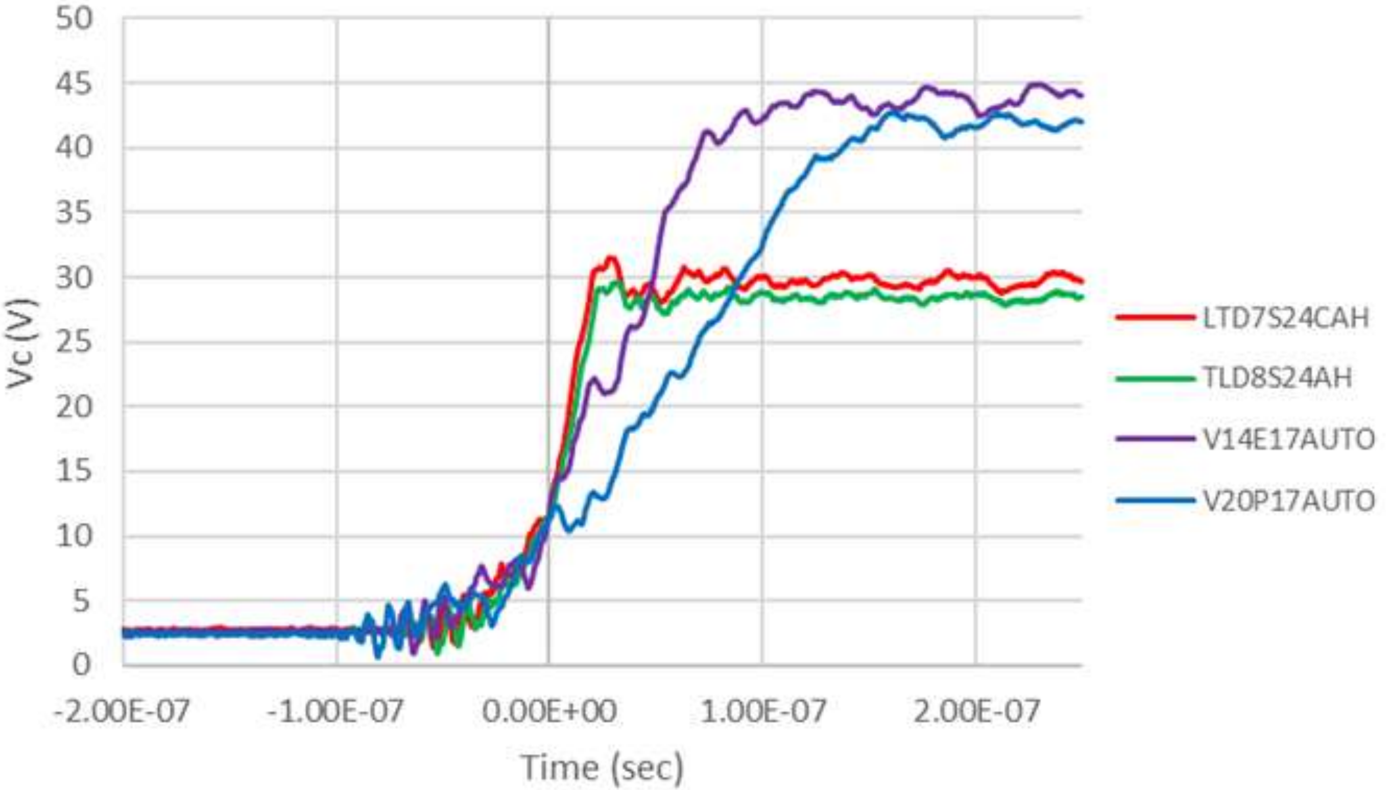
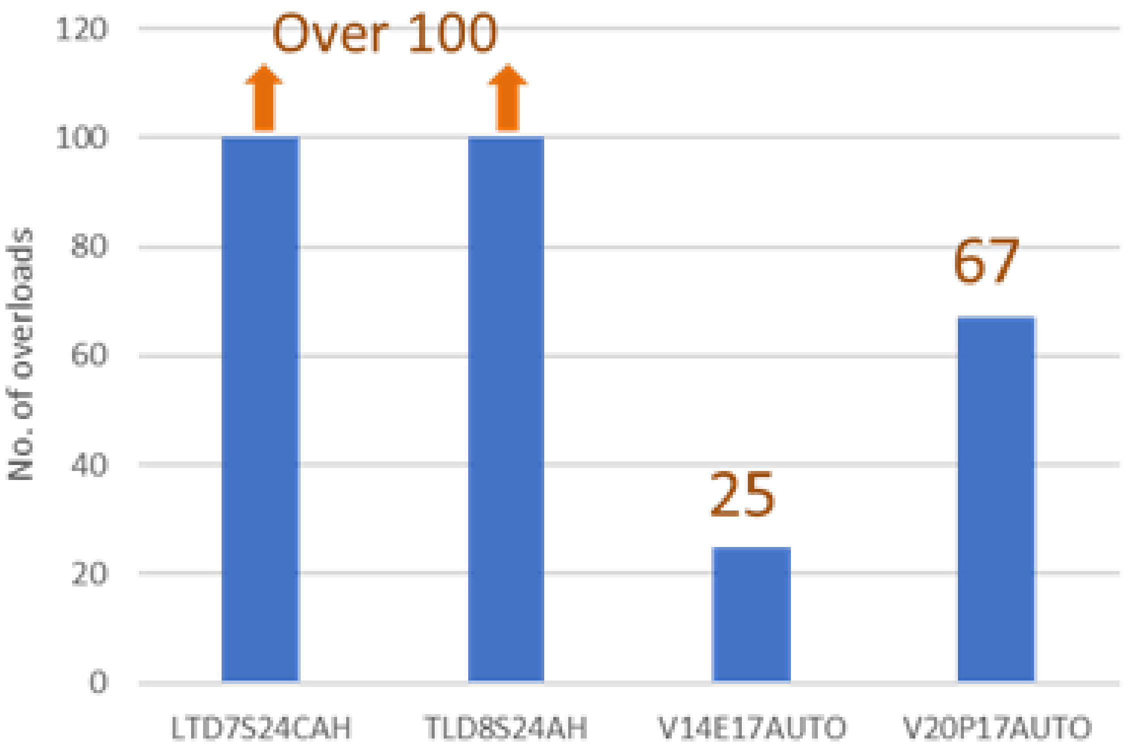
SPEED WITH 100 AMP TEST APPLIED I PULSE



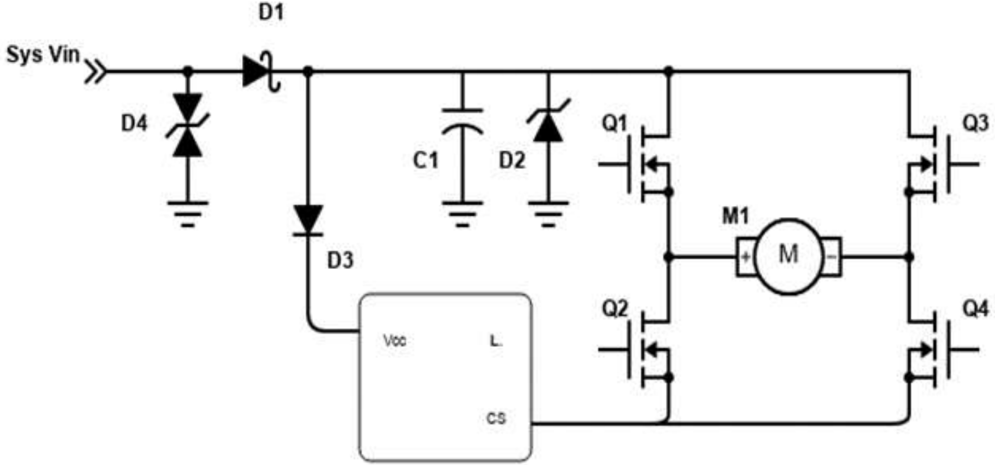
REPETITIVE 10/1000US SURGE IPP=120A SURGE ONE SECOND PRR MOV ONLY SURVIVES 25 – 67 PULSES SNAPBACK TVS SUSTAIN MORE THAN 100 TIMES



PN	numbers of overloads
LTD7S24CAH	>100
TLD8S24AH	>100
V14E17AUTO	25
V20P17AUTO	67

APPLICATION FAN SINGLE BRIDGE BLDC FAN SPEED CONTROLLER

Snapback TVS low VC helps protect discrete components with lower voltage stress compared to use conventional TVS or other alternatives > power density and less overdesign.



Supply voltage	reverse polarity diode D1	MOSFETS	TVS D4 –D2	**Back-EMF**
12V	45V	30V	18V	18 - 24V
24V	60V	60V	26V/28V	33 - 60V
48V	120V	100V	78V	80V-100V

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SUMMARY VBR TEMPCO BUT REPETITIVE PULSES = NO GO FOR MOVS

item	TVS	MOV
Surge sustain capability	Package is power density, package is smaller based on similar power dissipation	NA
Operation temperature	Wide temperature range Tj= -55 to 175C	Ta = -40 to 125C
IR temperature variation	IR is lower MOV IR is 10 – 100 times than TVS	NA
I-V curve characteristic	Vertical line of the curve after VBR, slope is tighter. Rdny = 38.5 ohm	Rdny = 240.5 ohm
Transient surge I-V curve compare	Vc clamping ratio is lower Vc clamping ratio = 1.13 - 3.25	Vc clamping ratio = 4.65 - 4.95
Vc compare	Vc is lower TVS Vc is 28% - 50% of MOV	NA
Reaction speed	Reaction speed is Faster TVS reaction speed is 2 times of MOV	NA
Numbers of overload capacity	Infiniti in theory	25 - 67 times
VBR temperature variation	Temperature coefficient = 23.05 - 24.9 mV/C	temperature variation VBR is lower Temperature coefficient = 5.7 - 6.05 mV/C
Price	NA	Cheap

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SUMMARY

- It depends on what you are trying to clamp which one works best
- Repetitive transients require something different than non-repetitive
- Energy loss is a consideration – where does it go?
- Protection needed is a primary consideration
- Snapback methods in silicon provide a new approach that doesn’t really have a parallel in the industry for performance attributes.
- Test some samples in your application under stresss

THANK YOU

Q&A

For more information kevin.parmenter@tscus.com