Protection From Lightning

- Presented by Alan Lipsky
  - Consultant
    - Grounding
    - High frequency power conversion
    - Feedback control

Organization

- Lightning:
  - Cause, Current Range, Prevalence, Damage
- Mitigation:
  - Grounding
  - Protection of AC Power and PC-board inputs with surge protection
  - Maintain Ground reference to protect communication ports
- Surge tests

Lightning

Large negative charge forms in cloud; inducing large positive charge below:

- Negative low current downward leader followed by upward high current stroke,
- Current ranges from a few hundred amps to more than 500 KA,
- 20 KA to 40 KA usually used to estimate magnitude of strike.
- Sometimes 3 to 5 distinct strokes roughly 60 milliseconds apart
  - 20 k Amps for first, ½ that for following strokes
  - Last stroke could be followed by 150 Amp current lasting 100 milliseconds

Duration and Frequency

- Typical strike duration 50 to 100 microsecond.
- Most spectral energy below **1 MHz** with < 1 microsecond rise time;
- Energy down to dc and above **1MHz**,
  - Maximum flash densities in North America in Gulf coast and Florida Peninsula

Lightning Damage

- Damage caused by large current or the heat caused by current flow
  - Electronic circuits damaged by high current or voltage caused by that current.
- If lightning occurs near an overhead electric or telephone line, large current induced or injected into the line.
- Charge can also be injected into soil. Arcing to nearby buried conductors at distances up to 100 m.

Lightning Related Failures

- Insulation breakdown
- Flashover
- Fracture
- Thermal and peak power overloads

Damage Mitigation

- Grounding
- Protection from Surges
- Testing

Grounding in Accordance with National Electrical Code

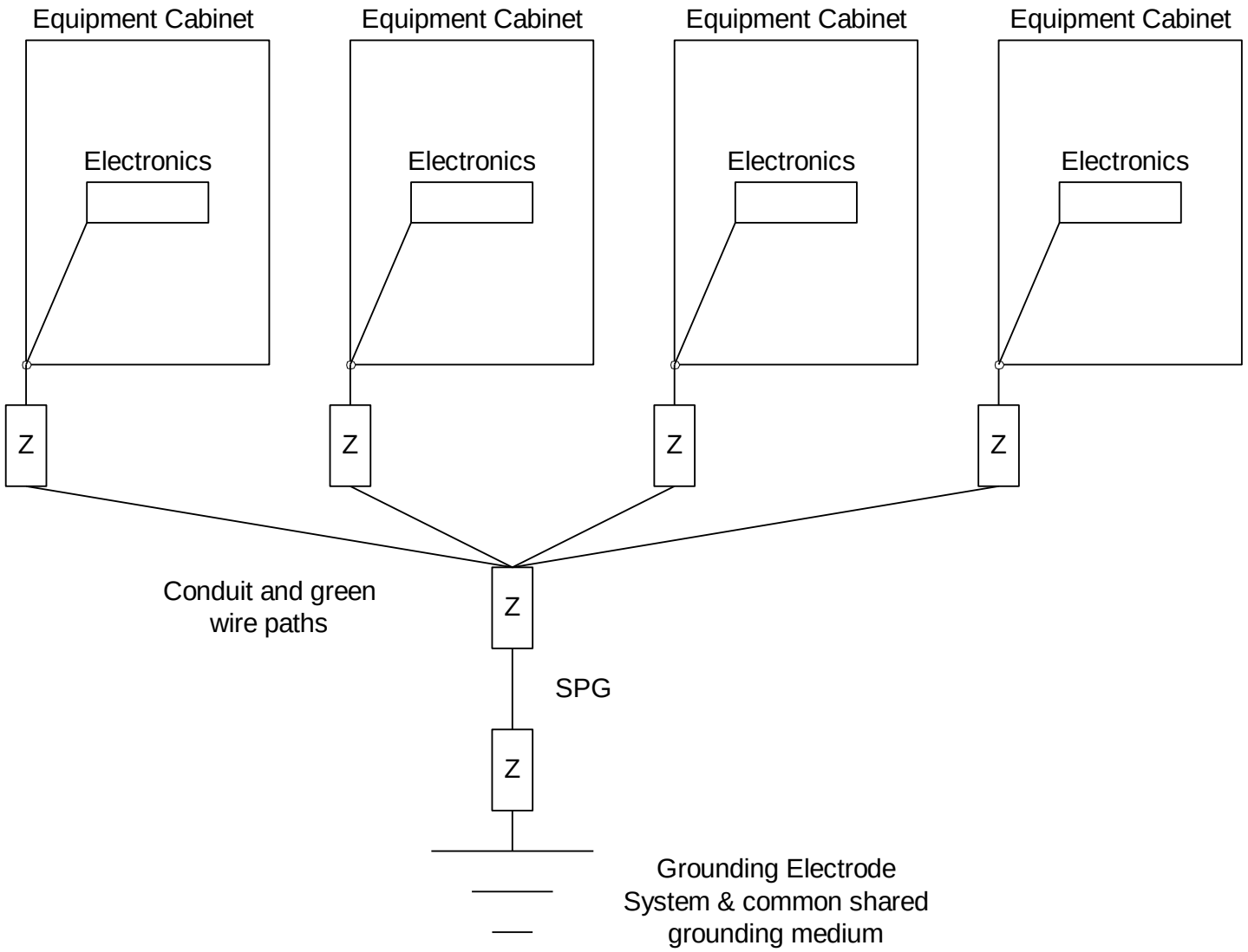
- Bond all Cabinets and other conductors such cable raceways together
- All components of grounding system must be connected together with a conductor
- Motivation is Safety and not necessarily protection from lightning
  - Purpose is to maintain conductive surfaces at or near the same potential

Grounding for Safety in Accordance with National Electric Code

Common thread:

- Grounding electrode,
- Neutral wire and bus,
- Grounding bus bonded to service entrance cabinet,
- Insulated green wire ground conductors.

Safe System in Accordance with NEC



Grounding to Mitigate Damage from Lightning

- Use Grounding suitable for high frequency
  - A Multi-Point Ground.
- Build a system reference structure, SRS.
  - High inductance grounding poses a safety and equipment hazard caused by large voltage differences between cabinets
- When circumstances permits bolt cabinets together and bond them

Grounding (Cont)

- Above 300**Khz**, and for protection from lightning, bond each cabinet at many points.
  - The single ground wire connecting each cabinet with ground has large inductance.
- Use grounding structure that resembles a plane, such as a large conducting sheet or a grid work of grounding wires bonded where they cross. Bond cabinets at all 4 corners. Wires in grid should be no more than 0.6 meters apart.

Mitigation Through Surge Protection

- Protection devices:
  - Metal Oxide Varistor
  - Gas discharge tube
  - Thyristors
  - Transient Voltage Suppressor (TVS)

- Each has different characteristics that makes their use complementary

Protect at Several Locations

- At building entrance
- At power panel
- At equipment power input
- At signal inputs
- At critical circuits

Gas Discharge Tube

- Withstand large surge current because it clamps at low voltage
- Low capacitance
- Relatively slow turn on
- Use on communication circuits and AC line
- Because of low voltage required to maintain arc, it may not extinguish after the surge is over

Metal Oxide Varistor (MOV)

- Action in PN junctions throughout bulk material
- Ratings
  - Maximum non repetitive surge current
  - Max energy
  - Clamping ratio 1.95
  - Response time – less than 20 ns
  - Clamps AC

MOV

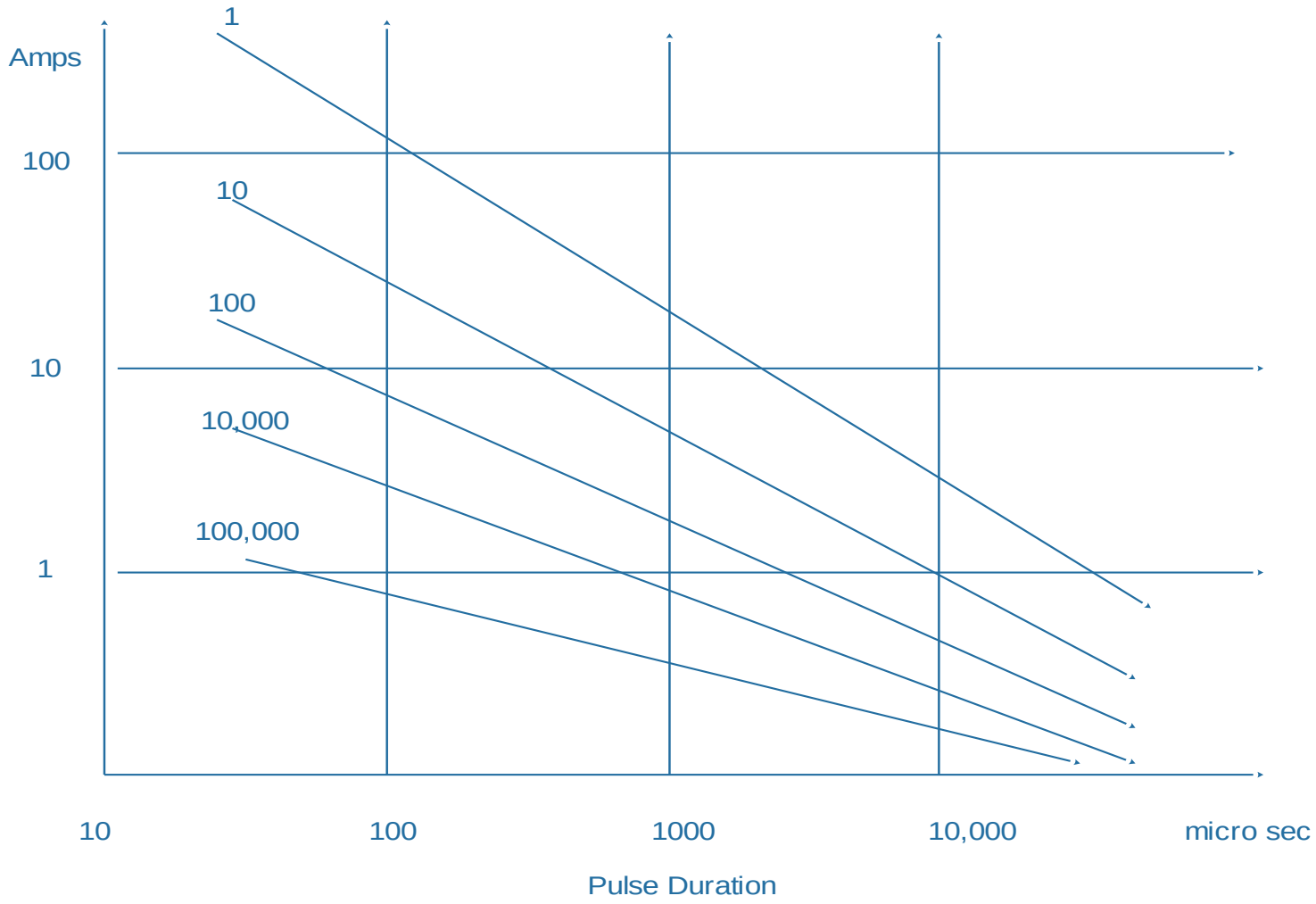
- MOV voltage definitions:

- Maximum clamping voltage _____
- Varistor voltage @ 1mA _____
- Maximum continuous voltage _____
- Ground reference _____

Use

- Use at building entrance, Power panel, Equipment power input
- Not suited for data transmission lines because of large capacitance
- Main issue:
  - Pick continuous voltage to pass normal supply voltage.
  - MOV clamping voltage should protect user equipment
  - The MOV should be protected from as many surges, swells, and spikes on the line as possible.
    - May require higher voltage ratings on equipment.

Life for Various Number of Pulses



Transient Voltage Suppressor

- Lower clamping ratio than MOV's
  - 1.6 versus 1.95
- Zener diode with a larger cross section designed for surge voltage clamping rather than voltage regulation
- Generally used at lower voltages than MOV devices
- Inserted between source of surge and circuitry being protected
- Some units manufactured for protection of data lines

TVS (CONT)

- Specified in KW of peak pulse power
  - Clamping Voltage times peak pulse current
- Clamping Voltage
- Rated Working Peak Voltage (Rated Standoff Voltage)
- Peak Pulse Power Dissipation
- Peak Impulse Current
- Some units made with low capacitance for data lines

TVS (CONT)

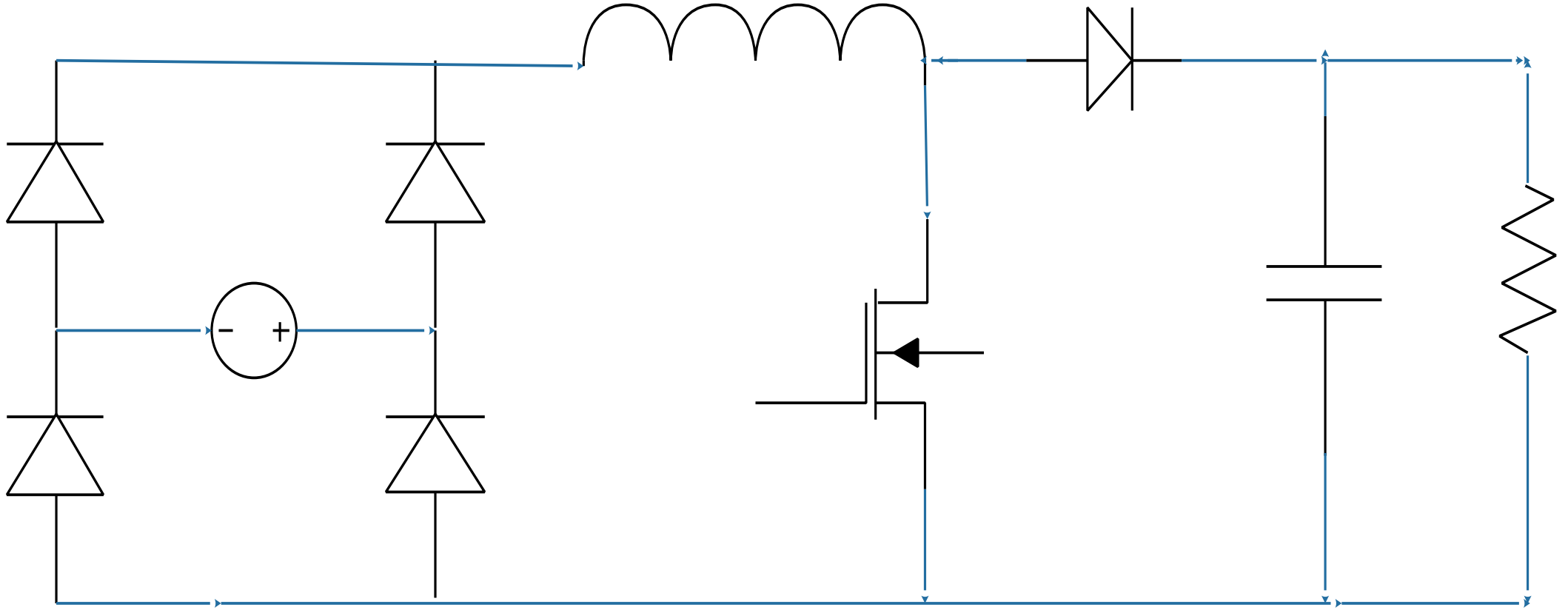
- TVS Voltage definitions:
- Vc Clamping voltage _____
- Vbr Start of avalanche _____
- Vwm Rated standoff voltage _____

- Ground Reference _____

Second Order Low Pass Filter

- Response to short voltage pulse:
  - Approximate by impulse equal to time duration times voltage amplitude
  - Amplitude of normalized impulse response depends upon damping constant
  - Amplitude = 0.38, damping = 1; Amplitude = 1, damping = 0
  - Impulse response of L-C network at end of 20 micro second pulse = 0.7% of final amplitude, ω_n = 2640 rad/s
  - Normalized amplitude times ω_n
- Used on: power rectifiers and high power factor rectifiers

High Power Factor Rectifier



High Power Factor Rectifier

- 88 Volts to 264 Volts
- Output power 270 Watt
- Inductor = 650 micro Henry; Capacitor = 220 micro Farad
- ω_n = 2640 rad/sec
- For 1000 volt 20 micro second pulse and undamped filter
  - V = 53 volts

Surge Testing

- Standard groups specify testing standards for various types of overvoltage transients

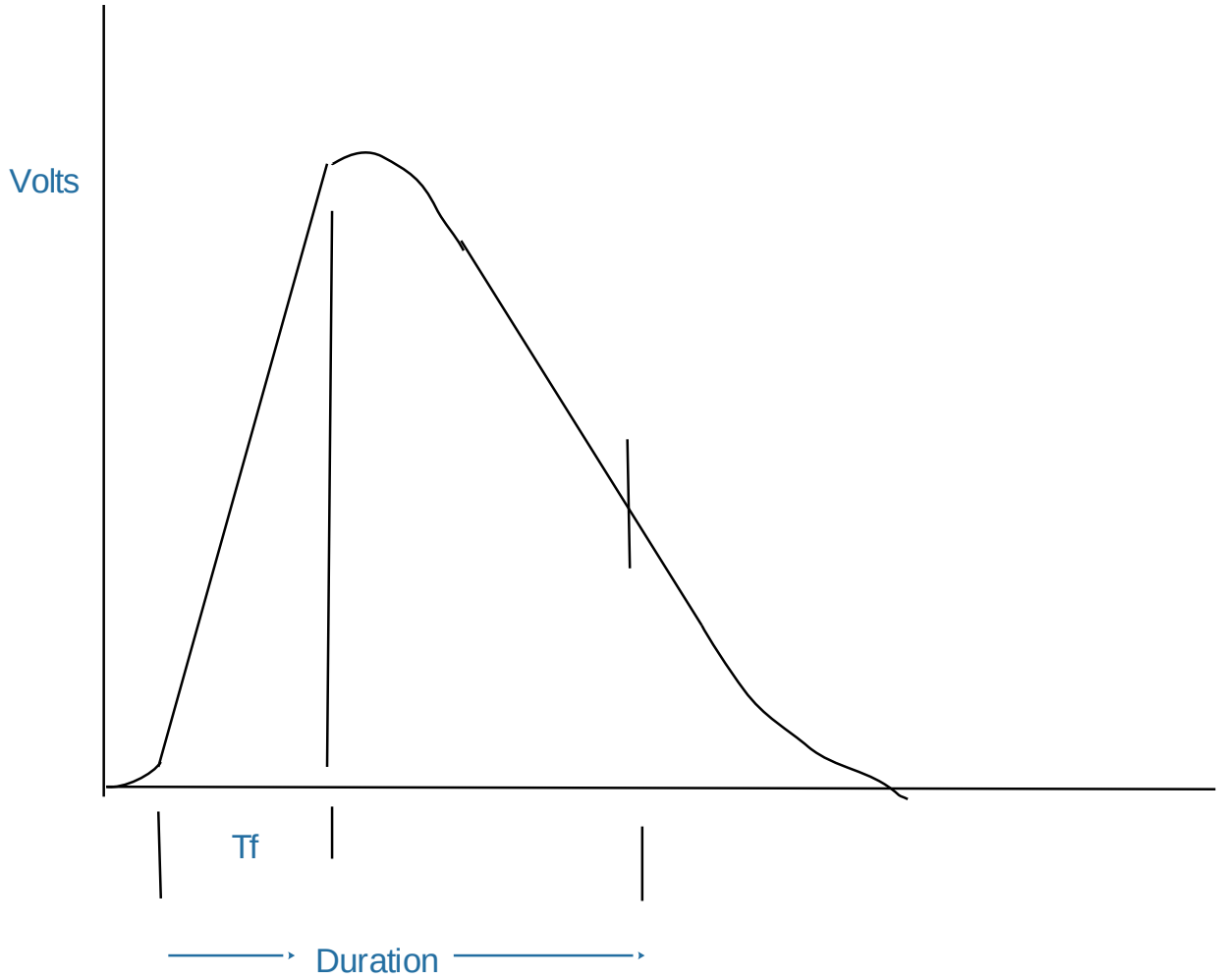
- Standards:
  - IEC 61000-4-2 Electrostatic Discharge
  - IEC 61000-4-4 Electrical Fast Transient/Burst (EFT)
  - IEC 61000 4-5 Lightning strikes & Switching Transients
  - ANSI/IEEE 62.41-1991

IEC 61000-4-5

- Contains test for both power and communication lines
- Test levels:

Level	open circuit Voltage	Short circuit Peak Current
1. Well protected	0.5 KV	0.25 KA
2. Protected	1.0 KV	0.5 KA
3. Typical Industrial	2.0 KV	1.0 KA
4. severe Industrial	4.0 KV	2.0 KA

Surge Specifications



Surge Pulse Characterization

- Front time (rise); Second time (fall time) to 50% of maximum
- Combination generator provides open circuit voltage and short circuit current
- Standard power circuit pulses:
  - 1.2 X 50 micro second open circuit voltage waveform
  - 8 micro second to 20 micro second short circuit current
- Telecommunications
  - 10 X 700 Micro second open circuit voltage waveform
  - 5 X 300 Micro second short circuit voltage waveform

References

- IEEE Recommended Practices for Powering and Grounding Electronic Equipment
- Varistor Introduction Vishay, BC Components
- Selecting Varistor clamping voltage: Lower is not better
  - F.D. Martzloff and T.F. Leedy
- Selecting a Littlfuse Varistor AN9771.1
- Micronotes 102, 104, 122, 125, 126
- TVS Diode Arrays (Low Capacitance ESD Protection)