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Service Instruments Division

Reliability Support Group

DRAFT

HIGH-VOLTAGE DESIGN GUIDELINES

INTRODUCTION

High-voltage design philosophy includes two basic goals, both of which must be met for a reliable design.

A. Design and layout the circuitry to prevent high-voltage breakdown.

B. Assume that high-voltage breakdown will occur (inside the CRT, on the CRT socket, and at the high voltage circuitry and wiring) and design and test the circuit and circuit board to safely dissipate the stored high voltage energy and to protect all components from the transient voltages and currents.

The following design practices are derived from the long and difficult experience of a few Tek engineers who have solved high-voltage reliability problems in several Tek products. Typically these problems do not show up during instrument development.

Sometimes unexplained component failures in horizontal, power supply, or vertical circuits reoccur in production instruments for years before someone discovers the cause is momentary transients in the high-voltage circuit. While the following design practices may increase manufacturing and development costs somewhat, it is usually less expensive to design and test correctly during initial design, then to detect, analyze and solve the problem in production.

RUNS ON CKT BOARDS SHOULD BE PARALLEL TO THE BOARD EDGE IF CLOSE TO SHIELD ECT...

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John F

CRT HIGH-VOLTAGE DESIGN GUIDELINES

I. Potted High-Voltage Supplies

A. Evaluate the design, construction and internal and external physical layout of the potted unit. Do not permit changes without review by instrument design team.

1. Derate caps (Don't use over 50 to 60% of rated voltage).
2. Interior layout to prevent internal breakdown and arcs to the outside.
3. Potting integrity and adhesion (hermetic seal).

B. Include complete environmental requirement in the purchase specification.

C. Evaluation by support groups

1. Environmental Test (temperature, altitude and extended humidity).
2. Transformer Engineering (review design, test prototype units).
3. Component Reliability Engineering (review design, test prototype units).

D. Consider screening by the vendor or at incoming. (Temperature cycling and turn-on while hot.) Sample reliability testing at incoming inspection is the minimum that should be specified.

II. High-Voltage Oscillator

A. Do not have maximum current and voltage at the same time.

B. Observe power and second breakdown limitations. (Steady state and when power switching.)

III. Grounding Rules

A. Make sure grounds for astigmatism, geometry, etc. go directly to same ground as the cathode capacitor. (Cathode current at fast sweep speeds is supplied from the cathode high-voltage capacitor.)

B. Analyze complete current loop-paths (including through grounds).

1. For ripple currents introducing trace modulation.

2. For stress on "innocent components" during CRT shorts and momentary high-voltage arcs and leakage.

IV. Shielding

A. Plan complete shielding for:

1. High-voltage oscillator.

2. High-voltage supply.

3. Multiplier

4. Z-axis amplifier.

B. Do not forget the bottom side of the circuit board.

C. Ideally the shields are tied to ground at only one place.

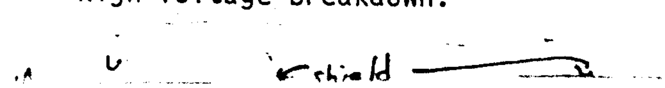
D. Watch for X-rays. Consider worst case high-voltage when regulator fails. (See UL-1244 for requirements.)

1. What:________________________

2. Why:_________________________

3. X-rays are reduced by mu-metal shield and aluminum chassis and shielding.

E. If CRT shield extends past the CRT socket, the electric field intensity is reduced, reducing the probability of high-voltage breakdown.



Higher electric field

F. Shield for the CRT helps shield anode voltage ripple out of other circuits. Post ripple is typically 15 volts.

V. Evaluation

These tests are more stringent than indicated by advertized product specifications. However, they provide the necessary margin to allow for accumulation of dirt and condensation on components and buildup of ozone.

A. Altitude Testing (most instruments are specified at 15,000 feet). 20,000 feet for 24 hours.

1. This test accumulates residual ozone from corona, causing failures.
2. Much higher altitude introduces new failure mechanisms not found in "real life".
3. 25,000 feet for 4 hours is a good preliminary test to the longer test.

B. Crowbar Testing With power turned ON, short each pin of the CRT socket to ground; short each CRT socket pin to each other-- No failure should occur any where in the instrument.

1. This test has very good correlation with observed field failures.
2. Long crowbar wire induces ringing, which induces new failure modes. Use about six inch wire, but PROTECT YOURSELF from high-voltage shocks.
3. For storage instruments, short the anode lead to the storage board outputs without failure.

4. Measure the ground and low-voltage power supply with a fast storage scope to find potential problems.

Problem points may be:
- -High-voltage leakage to ground or to other circuits
- -Leakage between grid and cathode circuits and in focus circuit.
- -Leakage at the high-voltage feedback sensing point.

C. Humidity: 5 days at 95% RH

D. To assure minimum H.V./CRT induced failure in the field, the instrument should pass these tests without failure.

This is a repeat of B??

VI. High Voltage in a Small Space

A. Get as much circuitry as possible off the board, but keep the location of components and leads fixed. (Do not depend on "proper lead dress" by assembly to maintain spacings.)

B. Use posts on potted units (even dummy posts) as circuit tie points. If using an insulator post for a tie point, make sure it is rated and has been tested for high-voltage uses.

C. Pot as much as possible of the high-voltage circuitry. (However, no more than necessary of the low-voltage circuitry.)

D. Ceramic strips are expensive and take space although they help hold things in place.

E. Use multiplier stages to minimize high-voltage AC exposure (greater than 1000 VAC).

F. Using a doubler in the cathode circuit provides better regulation in the anode supply because the doubler conducts on both peaks of the sine wave.

G. Minimize the number of multiplier stages. (Thirteen stages requires lots of parts, lots of assembly, and lots of board space--lots can go wrong.) However, too few stages requires too high of ac voltage.

H. Active focus if used can talk to high-voltage regulator and everything else. (Two separate ceramic high-voltage divider substrates may be needed.)

VII. <u>Component Selection</u>

A. Large disc caps break their leads in vibration tests (how about other large components)? Use parts with leads strong enough for the mass and leverage of the part.

B. Avoid using carbon film or metal film resistors. Use only AB carbon composition resistors wherever transient (fault) voltages may exceed resistor voltage ratings. (See Common Design Parts Catalog 5). Film (carbon or metal) resistors are spiral wound and subject to and current crowding in the conductor arc-over at laser trim points. (Assure that mix-ups cannot occur when using both types in the same kit.)

C. Use ceramic caps and high-voltage diodes at approximately 50% of rated voltage.

D. Murada caps are recommended for the following reasons:

1. Coating material doesn't break down at rated lead-to-lead voltage. Coating material does not absorb humidity. However, epoxy coating can still have voids that set up conditions for long-term degradation and eventually failure.
2. Lead spacing is better.
3. Overall process control is better.

E. Film caps are preferred for voltages over 10 kV.

F. Spark gaps: Breakdown voltage varies with ambient light. Repeated breakdowns (100 to 200 times) causes a change in breakdown voltage. (One firing per turn-on cycle is not recommended.)

G. Transformer design

1. Review spacings (interior and exterior, wire to wire, wire to core, wire to chassis). A newly available core design has a greater spacing between core and coil.
2. Metal clamps--will they compromise spacings? Ungrounded metal can generate corona.
3. Unsealed transformers are unreliable.

H. Neons are needed between the CRT grid and cathode to protect the CRT. A neon is needed between the cathode and filament if there is any circuit resistance between them.

I. CRT socket material

1. Phenolic--should be phased out.

   Description: Green

   Advantage: Common usage at Tek.

   Disadvantage: Doesn't stand up to long-term exposure to humidity.

2. Polysulfone--expect this to be the best material in the future.

   Description: Black

   Advantage: Best performance under all conditions for high voltage.

   Disadvantage: Not UL approved (yet).

3. Nylofil--recommended.

   Description: Black

   Advantage: Good short-term humidity performance UL approval.

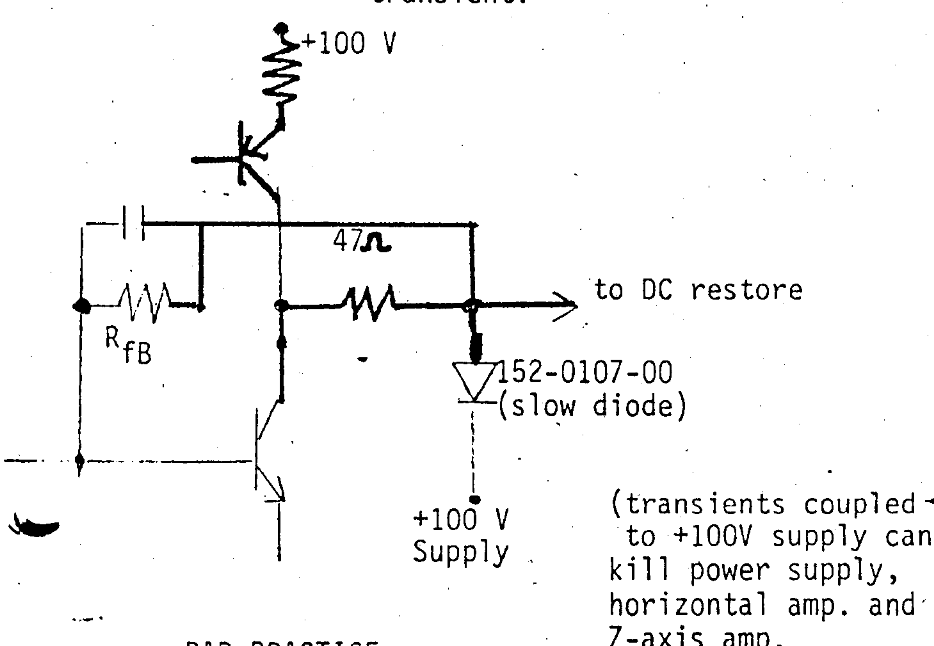
   Disadvantage:

4. Polypropolene--Do not use.

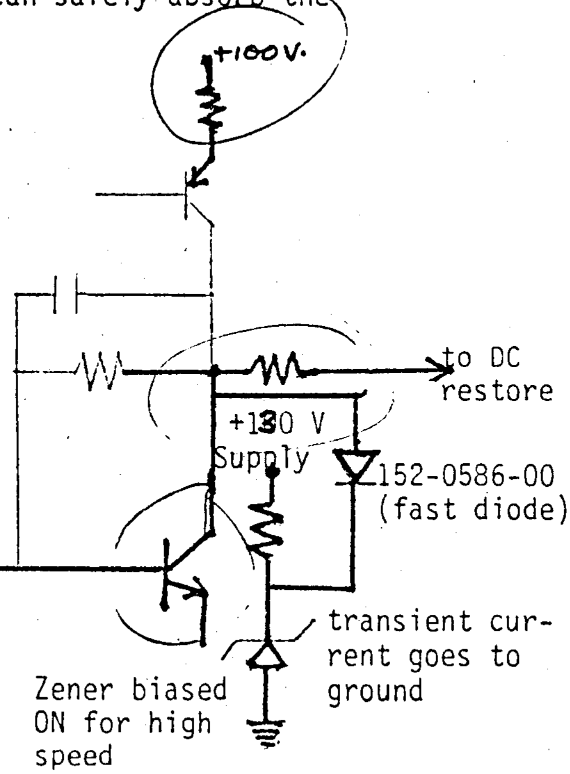
   Description: Clear or translucent white.

   Disadvantage: Deteriorates with age, humidity and high voltage.

J. High-votage protection diodes must be fast, and they must route the transient to places which can safely absorb the transient.



BAD PRACTICE



VIII. Circuit Board Layout

A. Maximum steady state stresses to allow:

1. On circuit boards: 5 volts/mil. of spacing.

2. Condutors in free air: 12 volts/mil. if ventilation prevents ozone build-up.

(In tight locations the spacings may be reduced by 40% where the voltage is normally low, high only during fault.) Remember the fault condition: The normally low-voltage circuit may become a high-voltage circuit, requiring greater spacing. Series resistors to limit fault currents might be bypassed during a fault if adjacent run spacing is too close.

B. Use a larger spacing if circuit board runs are near a board edge or if surfaces of large components contact the board allowing moisture entrapment.

C. Outside coatings on many parts are not adequate high-voltage insulators. Ensure that adjacent sides of parts are near the same potential, or provide adequate spacing. For example adjacent disc caps.

D. Potted units (high-voltage multipliers, etc.) can break down through the case to adjacent parts, depending on location of parts and leads inside the unit.

IX. Other Design Considerations

A. Do not depend on production people to "properly" dress wires and components to prevent arcs. Murphy's Law will get you! Proper dress should be controlled by placement of mounting lead holes and fasteners.

B. DC restorer diodes are common field failures.

   1. Select proper diode--can handle peak transient currents.
   2. Limit transient currents with series resistor (AB only).
   3. Diode capacitance can be a problem.

C. Using a regulated primary supply allows a simpler oscillator with higher efficiency.

D. Minimize energy available to cause damage during the fault condition by minimizing capacitor values. For example: the 3 capacitor (.001 uf) DC restore scheme stores less energy than the 2 capacitor (.0068 uf) scheme.

E. Do not have any exposed AC (greater than 1 kV)

   1. Coat exposed metal with corona dope.
   2. Keep as much of the high voltage AC circuit as possible inside potted or sealed units.

F. Mesh CRTs--a clamp is needed on the mesh voltage supply to protect against shorts from post accelerator anode to mesh.

G. Add 47Ω resistors in series with the capacitors in the cathode supply pi filter to absorb energy during high-voltage shorts.

H. Transients seen by components can be either polarity due to ringing after the fault.

I. IC op amps cannot stand high momentary voltages. 100 volt transients have been observed on ±15 volt supplies. Use a capacitor between supply pins within one inch of the IC.

I. Use high-voltage wire with adequate insulation.