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Solving EMI for Low Wattage Universal Input Power Supplies

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Purpose of the paper

- Cookbook to help design universal input flyback switching power supplies.
- Help understand the various techniques used on their effects of reducing EMI.
- Help reduce the engineering cycle time and improve the time to market of products.
- Educational tool to help novice switching power supplies engineers solve a sometimes black magic item

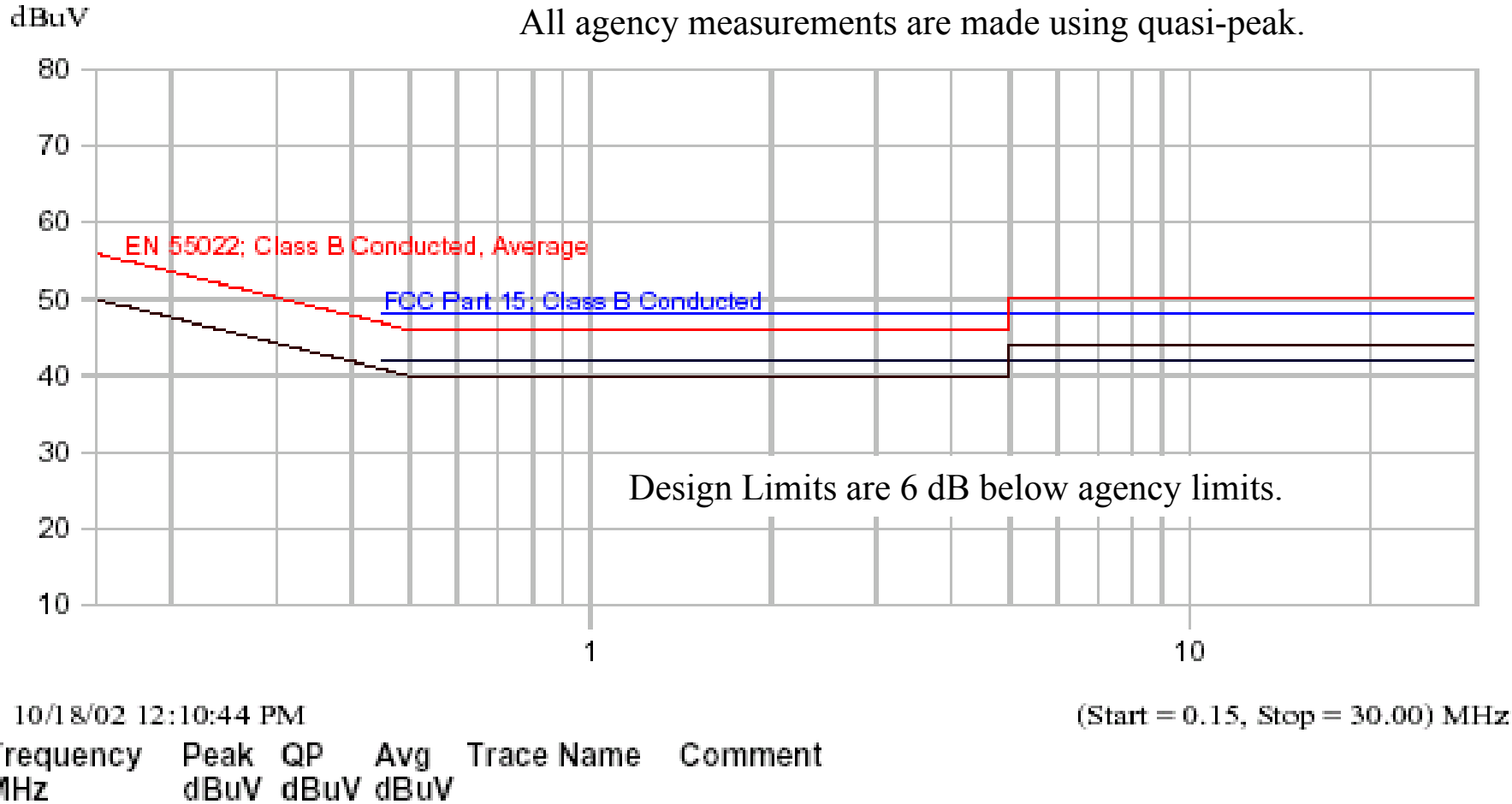
Example: TV Set-Top Box

- Universal input (85-270 Vac 47-63 Hz).
- 2-wire AC input (no earth ground plug).
- Multiple outputs all referenced to a common ground.
- 20 Watts.
  - Vout = 3.3, 5.0, 12.0, and (32 or 38 LNB)
  - Flyback topology used for tracking and cross regulation.
- 2 options: Fixed Frequency (NCP1000) and the Critical Conduction Mode (MC33364)

FCC limits

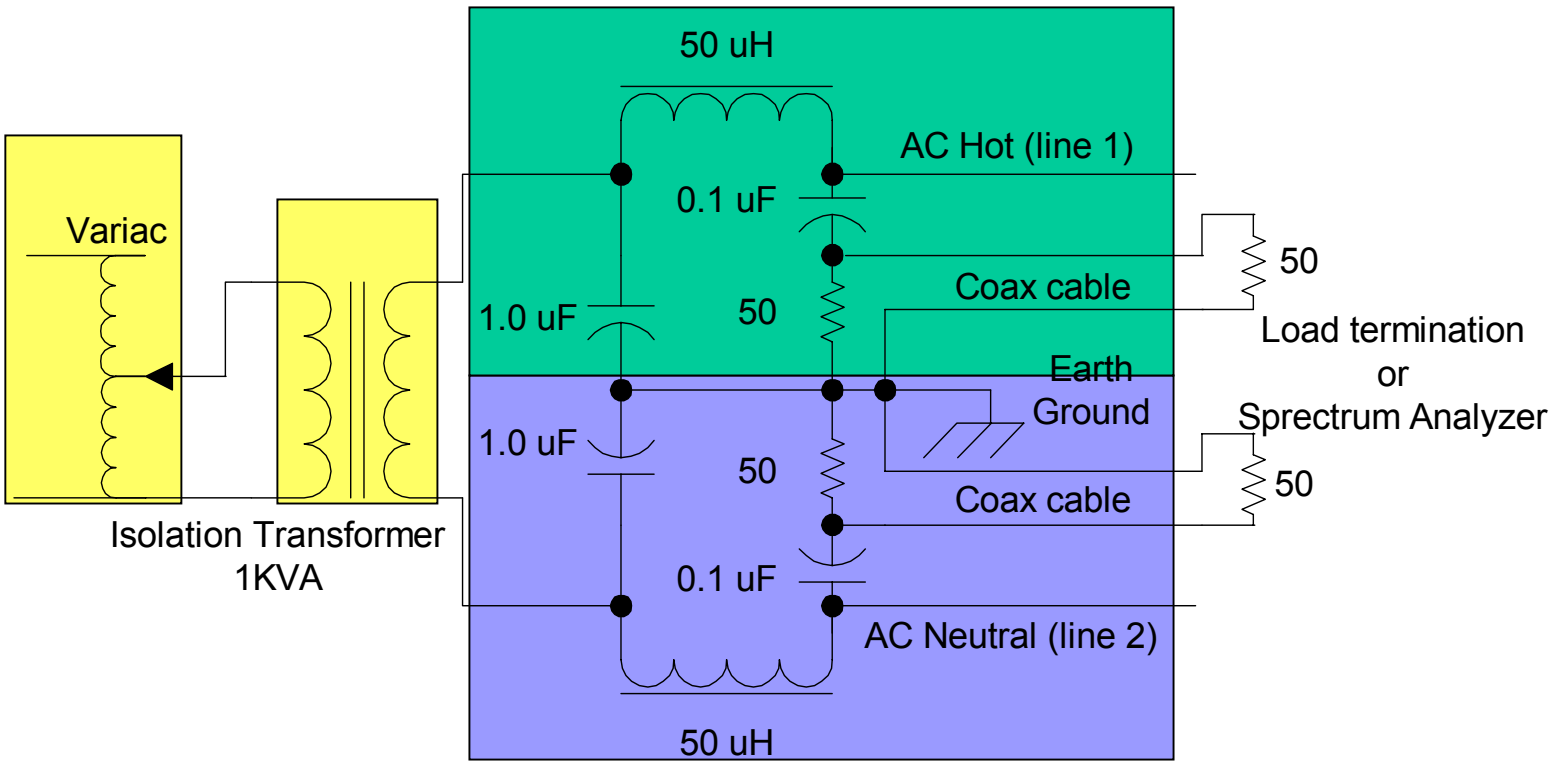
- FCC
  - Class B (Consumer Limits)
  - Part 15, sub-part J
- Spectrum Analyzer
  - HP 8562A peak detector
  - HP E7401A EMI Analyzer
- Line Impedance Stabilization Network (LISN)
  - EMCO #3810/2 (modified 0.1 uF for FCC)
  - Discrete Dual per FCC specification (Dave Pacholok)

Line Conducted Limits



FCC style LISN

(Line Impedance Stabilization Network)



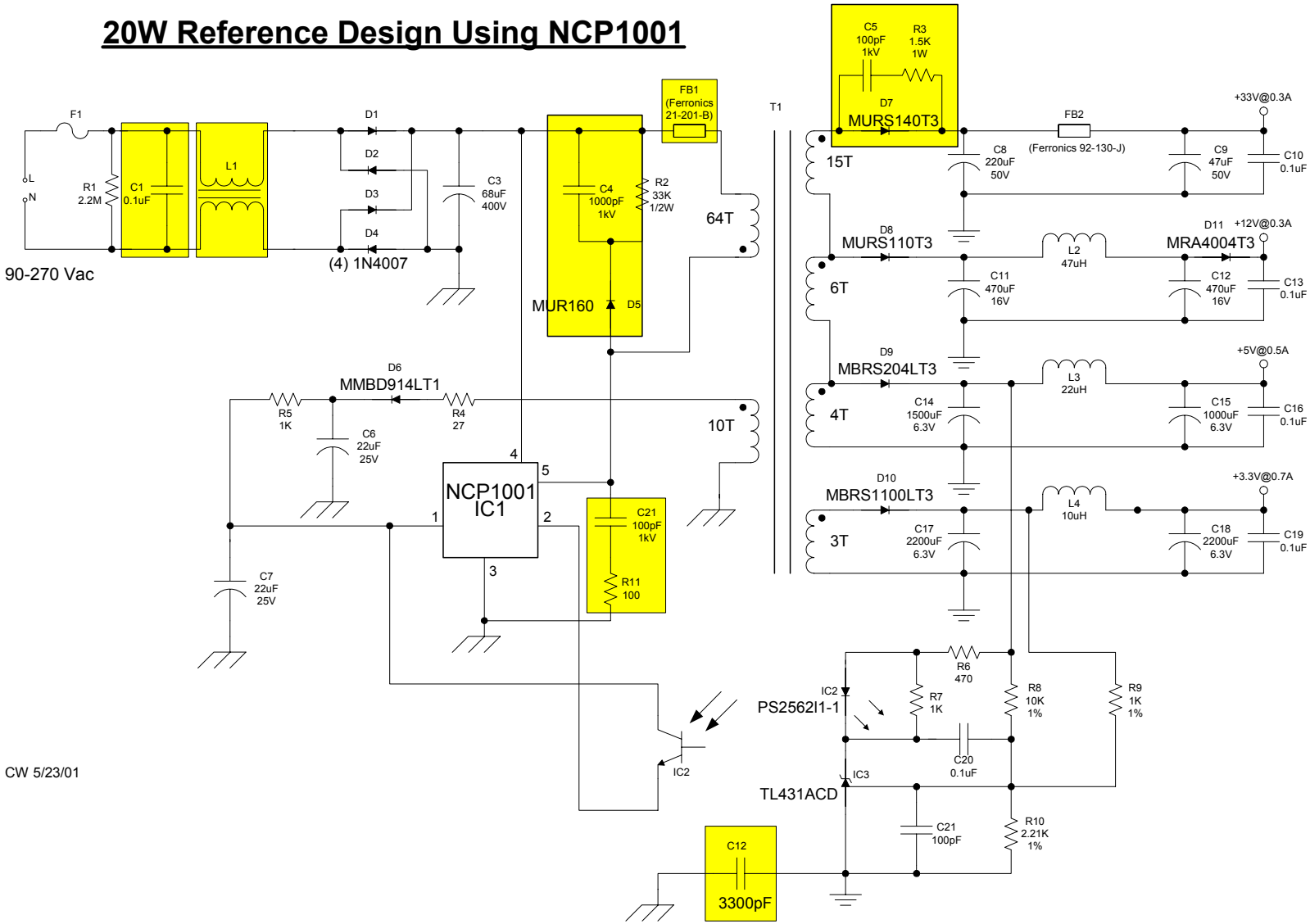
CISPR 0.47 uF Coupling Capacitor

Circuit Tools Available for Engineers

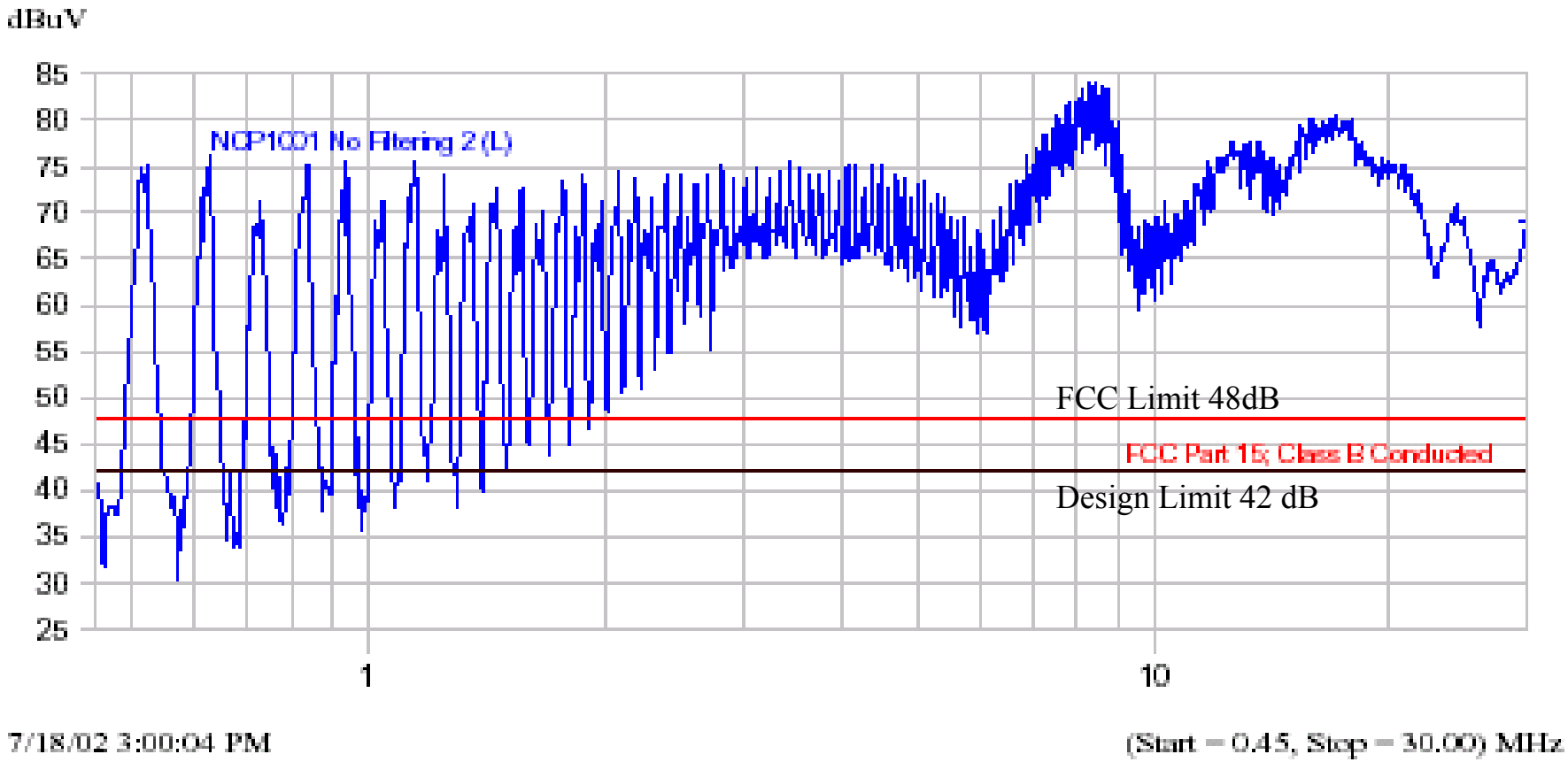
- Hot-Cold Ground Capacitor (Y-Capacitor)
- Common-Mode Choke
- Line-Line Capacitor (X-Capacitor)
- Transformer Snubber (DRC)
- Ferrite Beads (EMI suppression type)
- Switch RC Snubbber
- Output Diode Snubber (RC)
- Schottky Rectifier vs Ultra-Fast Rectifier

EMI Circuit Parts

20W Reference Design Using NCP1001



NCP1001 with no filtering

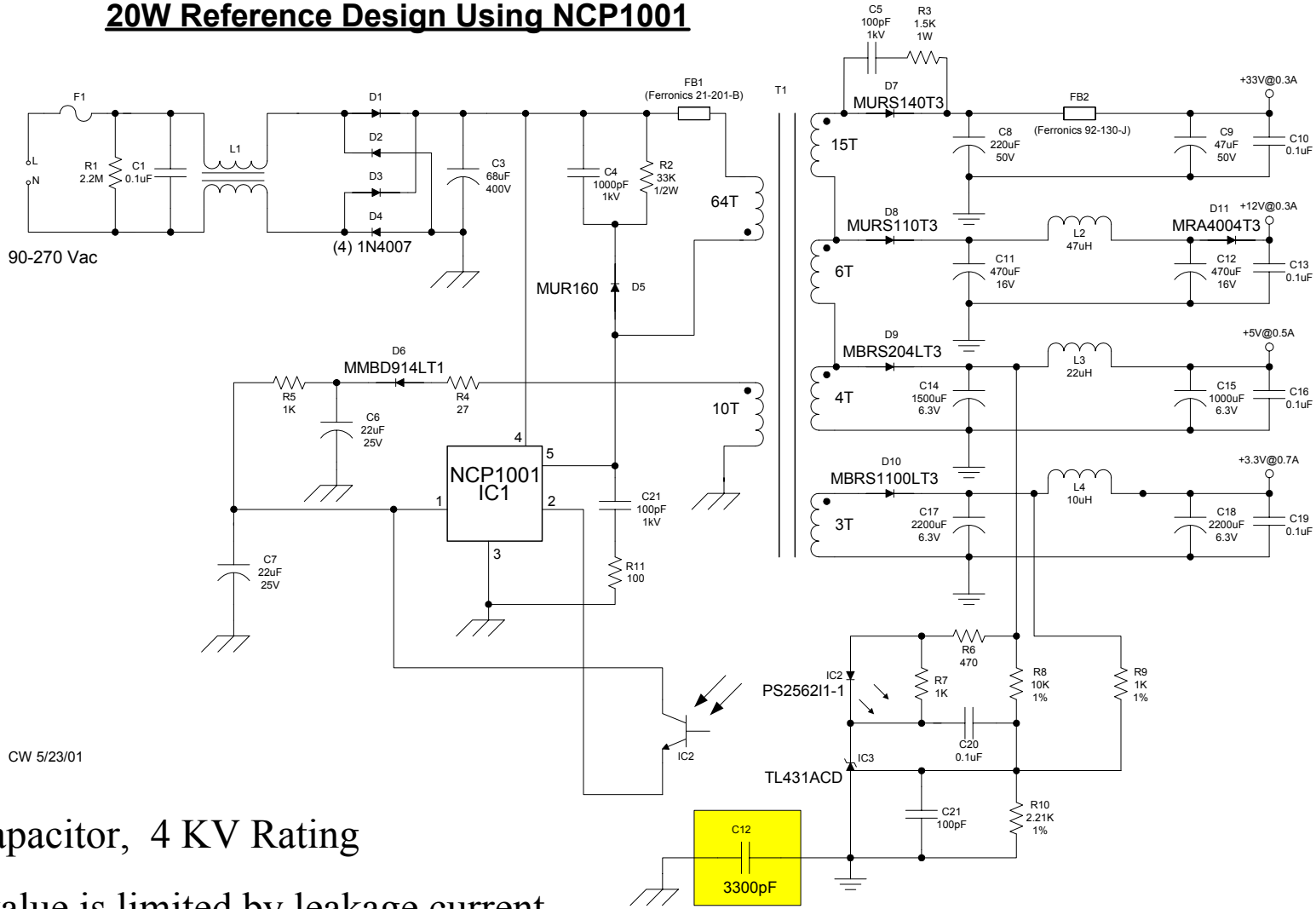


Frequency MHz	Peak dBuV	Delta Pk-Limit dB	QP dBuV	Delta QP-Limit dB	Avg dBuV	Trace Name	Comment

FCC indicates using highest Line or Neutral, only Line is shown here.

Hot to Cold Ground Cap. Schematic

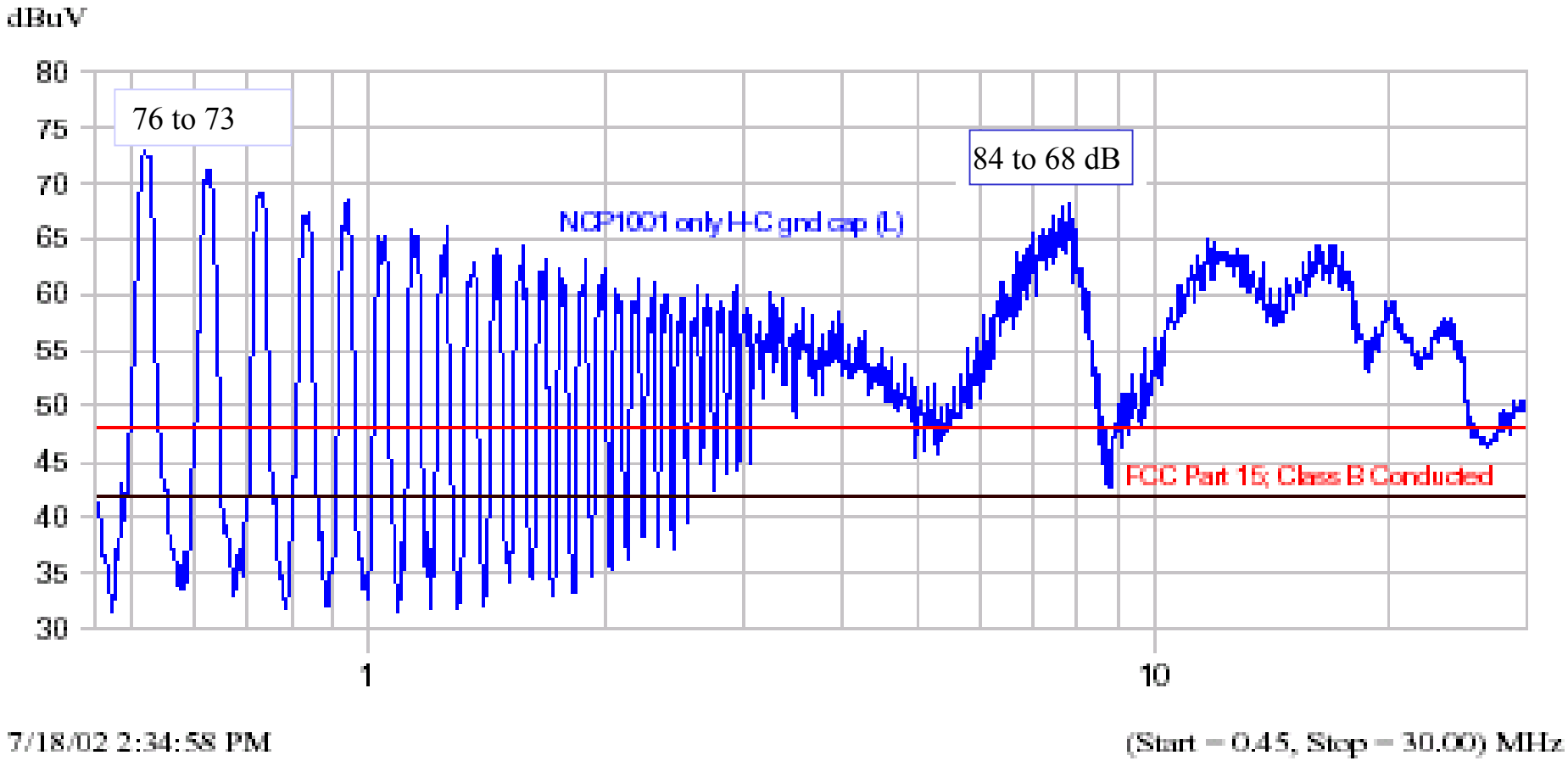
20W Reference Design Using NCP1001



"Y" Capacitor, 4 KV Rating

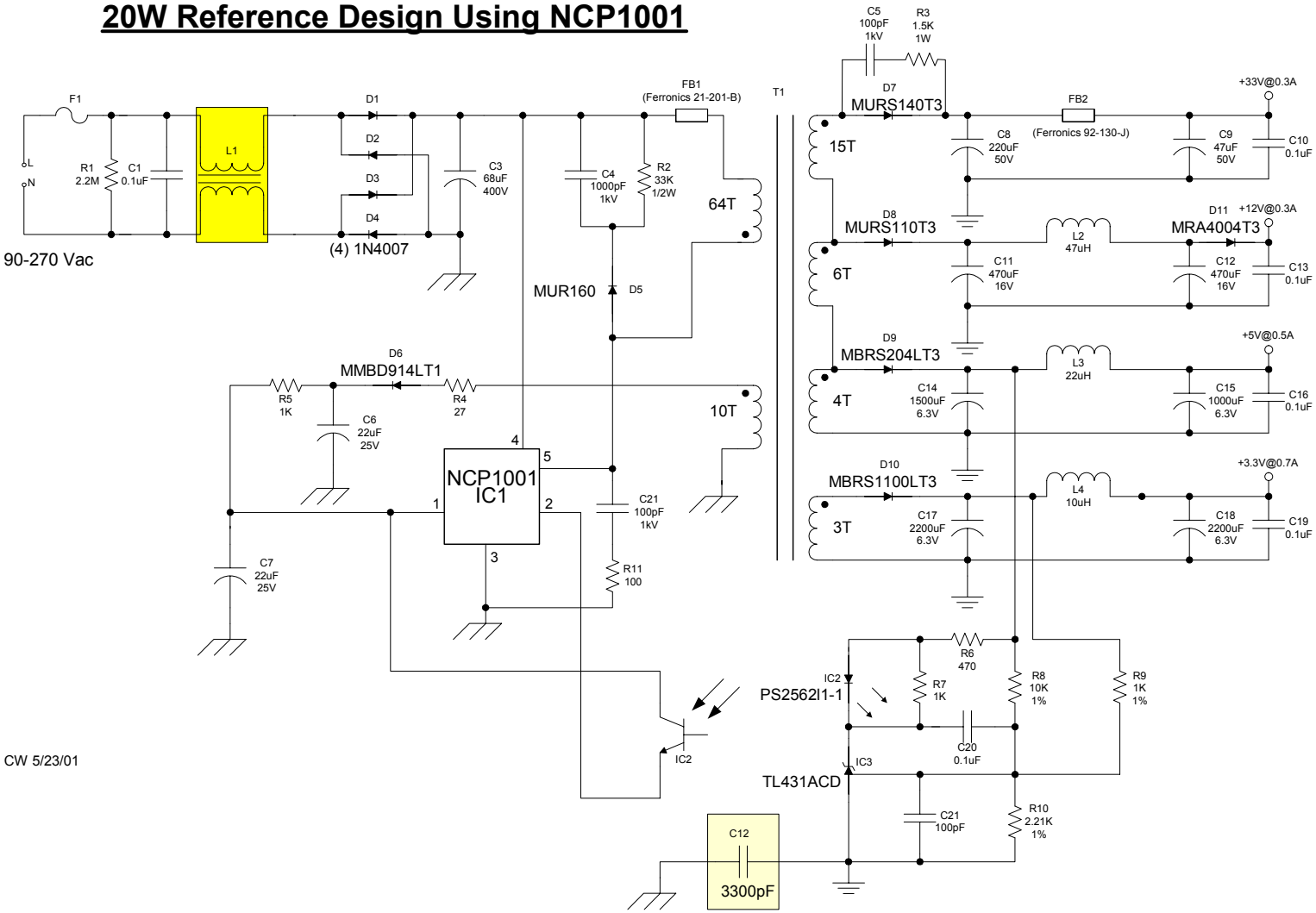
Max. value is limited by leakage current.

NCP1001 Hot-Cold Ground Cap (3300pF 4KV)



Frequency MHz	Peak dBuV	Delta Pk-Limit dB	QP dBuV	Delta QP-Limit dB	Avg dBuV	Trace Name	Comment

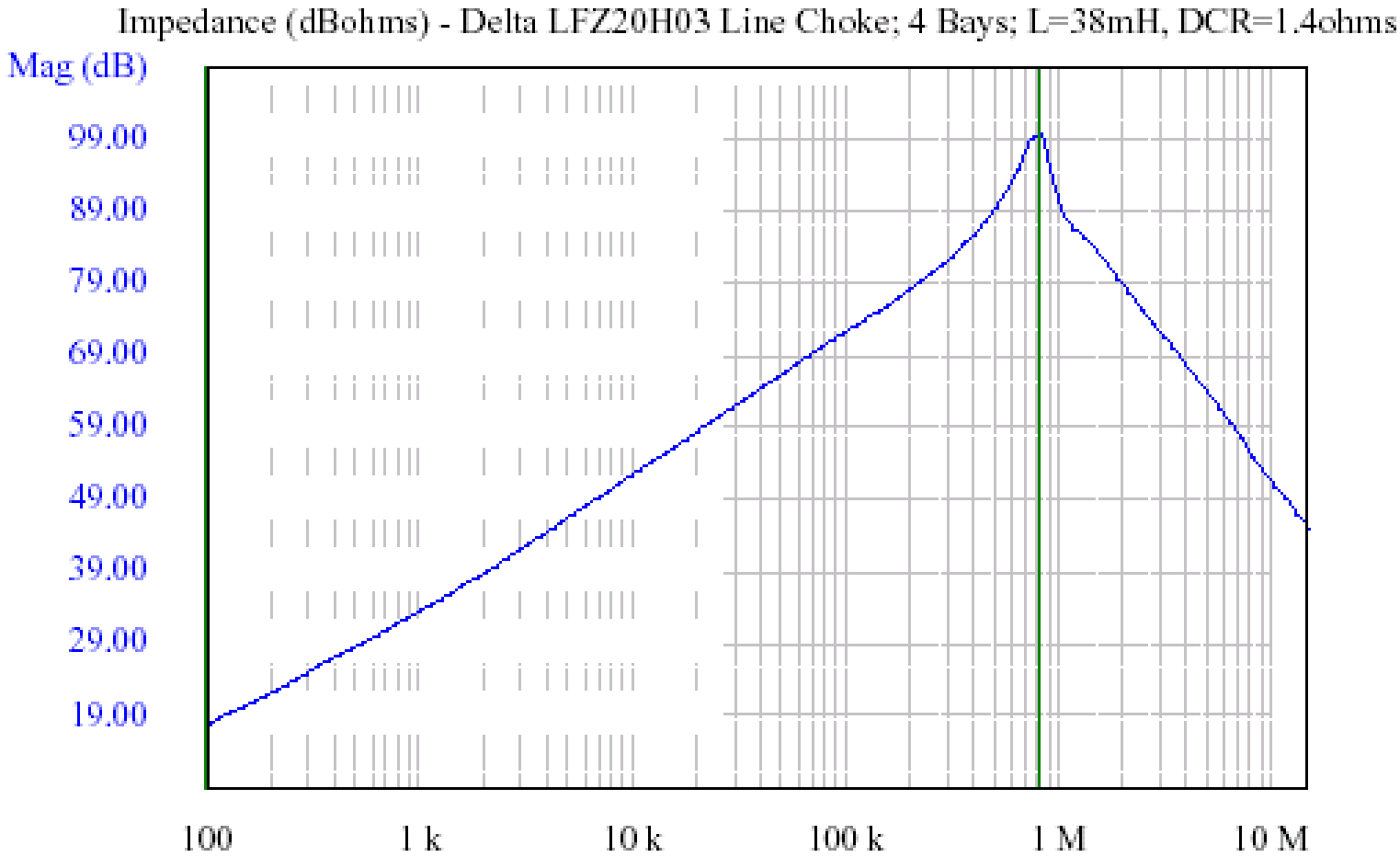
Common Mode Choke Schematic



Common Mode Choke

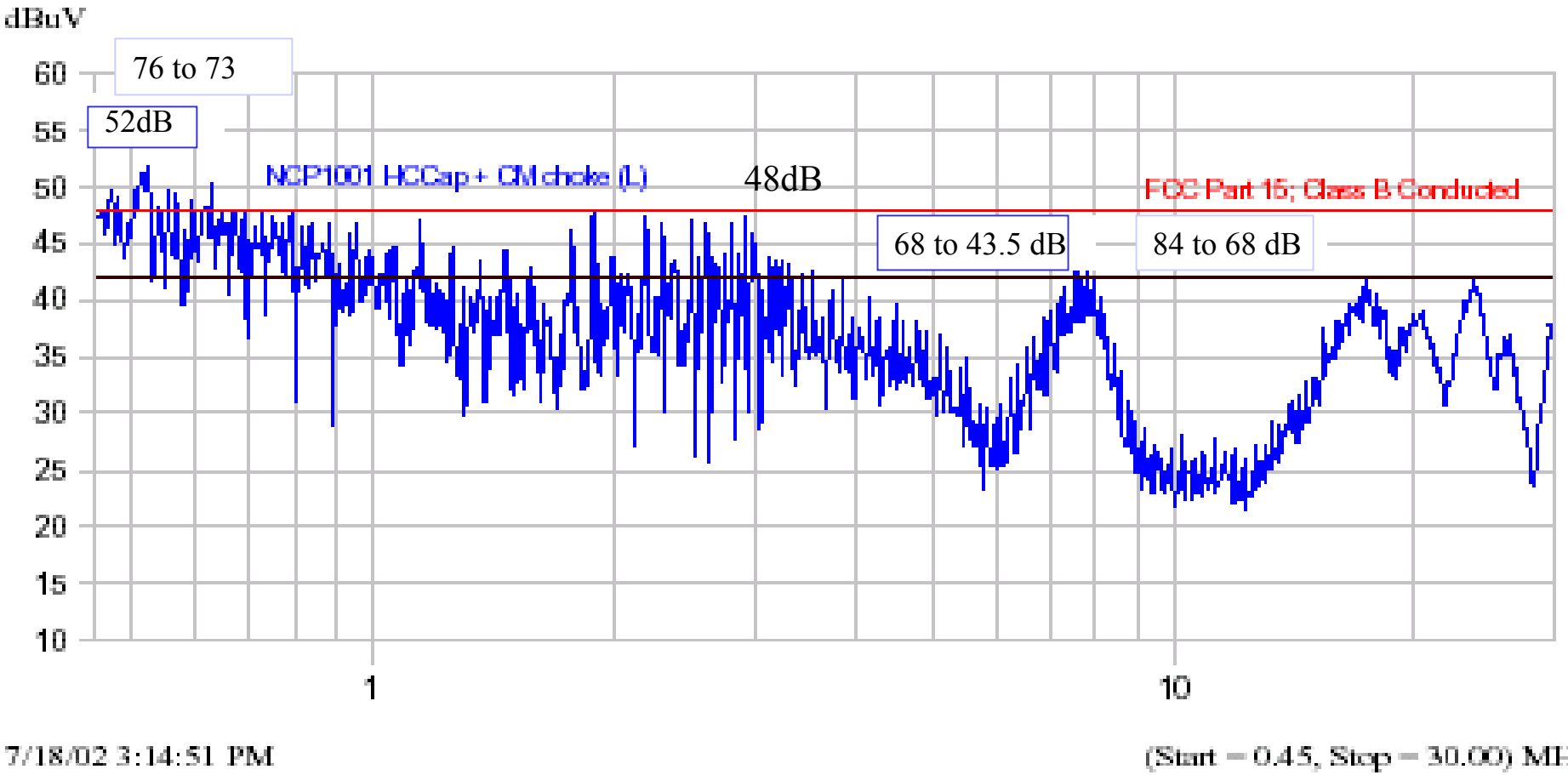
- Line Inductance Leg 39.4 mH
- Neutral Inductance Leg 39.4 mH
- Resistance per Leg 1.3 ohms
- Mutual Inductance 39.35 mH
- Coupling Coefficient 0.9975
- Capacitance between Sections 3.0 pF

Common Mode Choke Impedance Plot



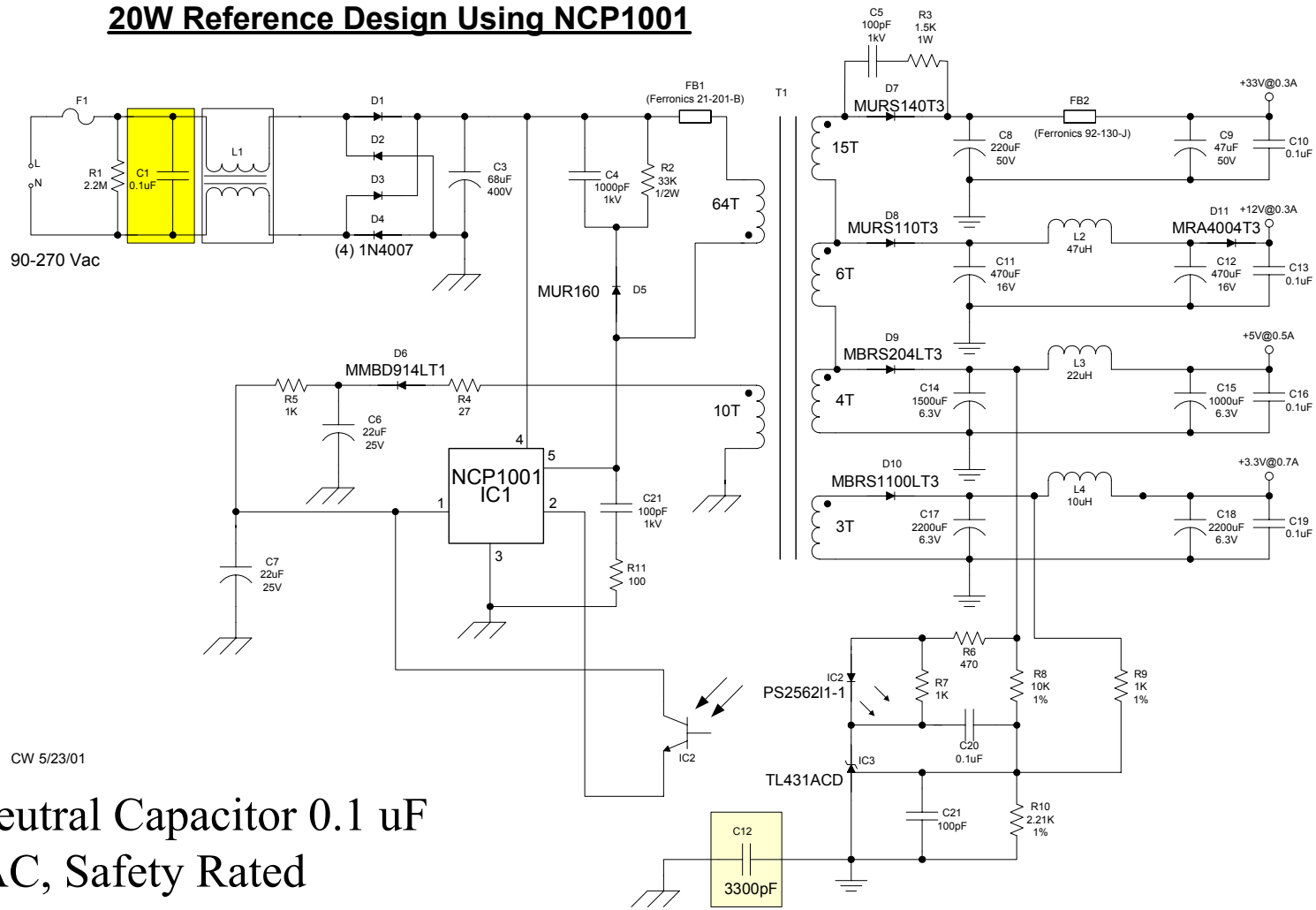
AP102B Frequency Response Analyzer

Common Mode Choke with **Hot-Cold Ground Capacitor**



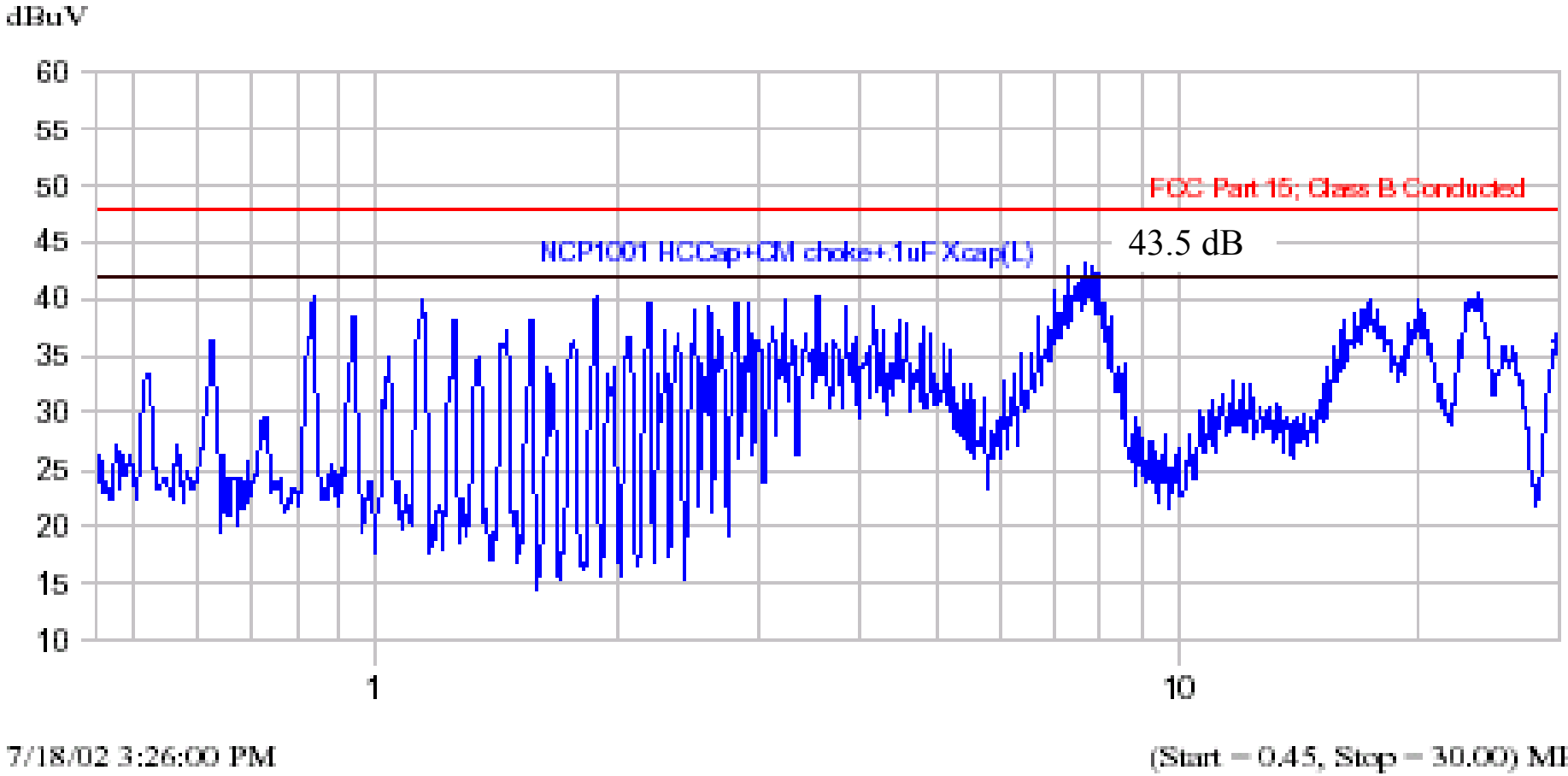
Frequency MHz	Peak dBuV	Delta Pk-Limit dB	QP dBuV	Delta QP-Limit dB	Avg dBuV	Trace Name	Comment

Line-Line Capacitor Schematic



Line-Neutral Capacitor 0.1 uF
250 VAC, Safety Rated

Common Mode Choke with X Capacitor and H-C Cap

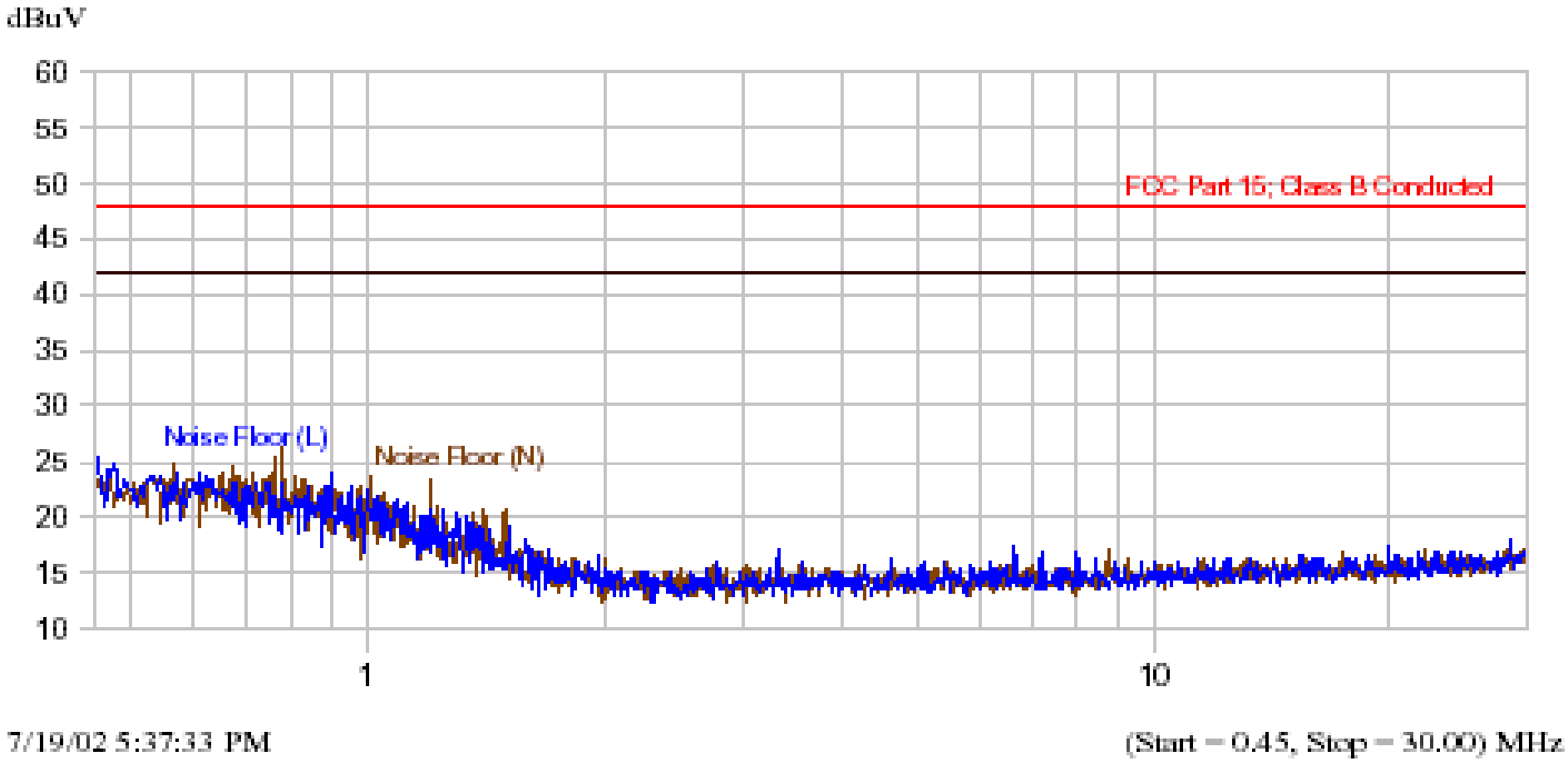


Frequency MHz	Peak dBuV	Delta Pk-Limit dB	QP dBuV	Delta QP-Limit dB	Avg dBuV	Trace Name	Comment

Met the FCC Class B limit

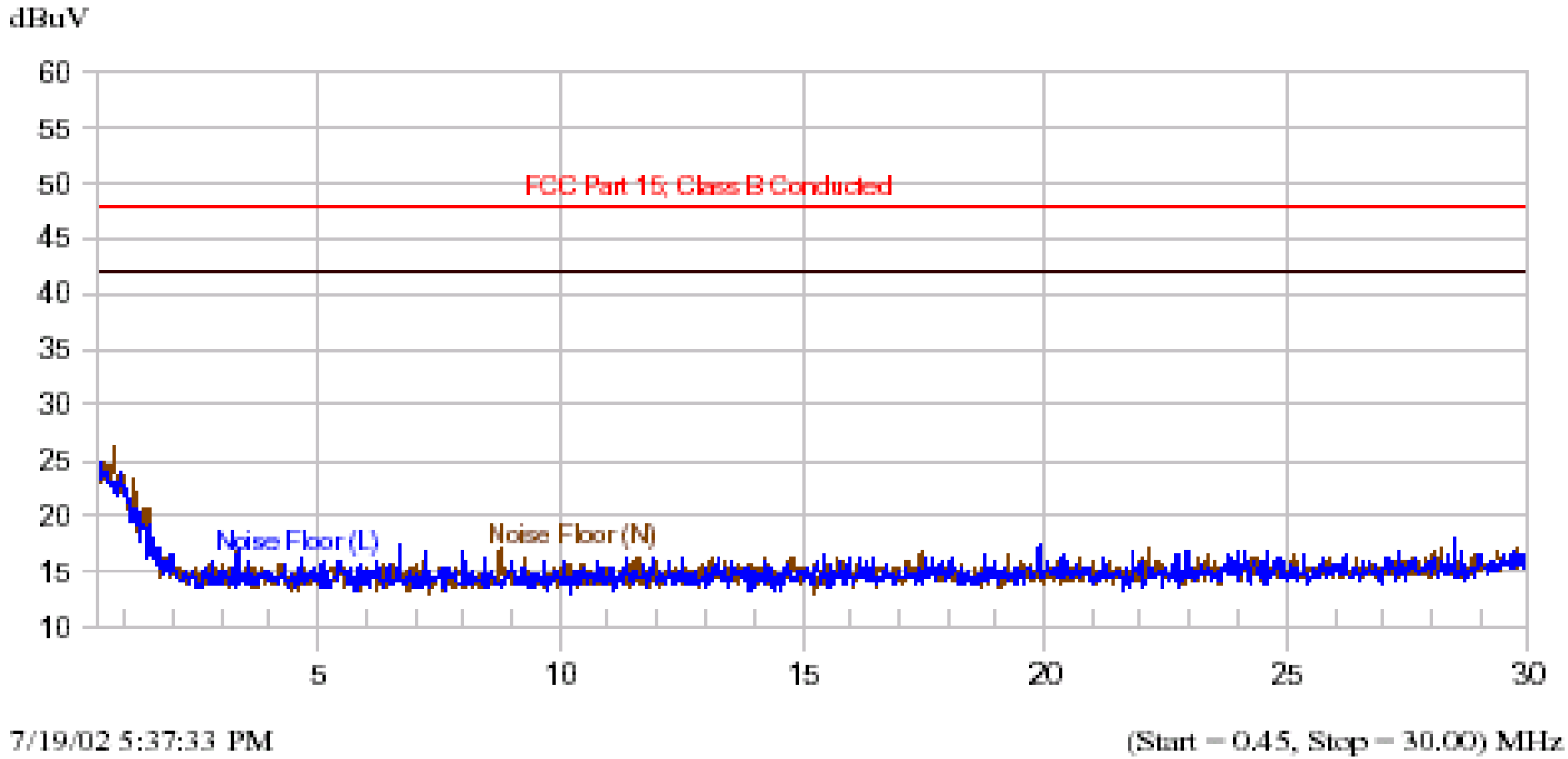
- Just above the 42 dB spec. design limit.
  - Quasi peak vs Peak detect can add up to 2 dB of additional margin.
- Below the 48 dB FCC limits (Quasi Peak).
- 2-Wire system with NO Ground Plane
- Easily meets the Class A limits.
- What is the ground noise floor limit?

Ground Floor (log scale)



Frequency MHz	Peak dBuV	Delta Pk-Limit dB	QP dBuV	Delta QP-Limit dB	Avg dBuV	Trace Name	Comment

Ground Floor (Linear scale)



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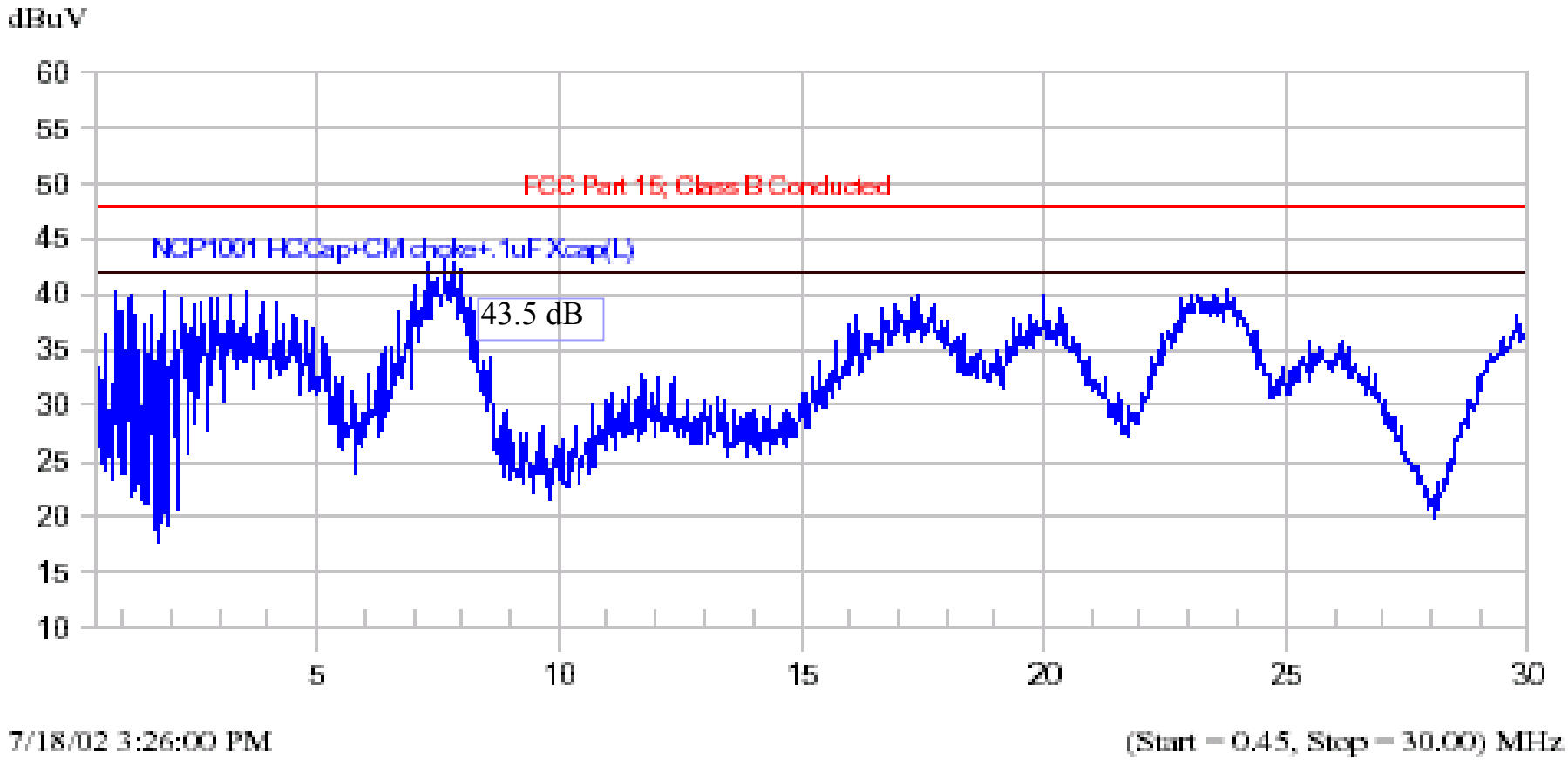
(Start = 0.45, Stop = 30.00) MHz

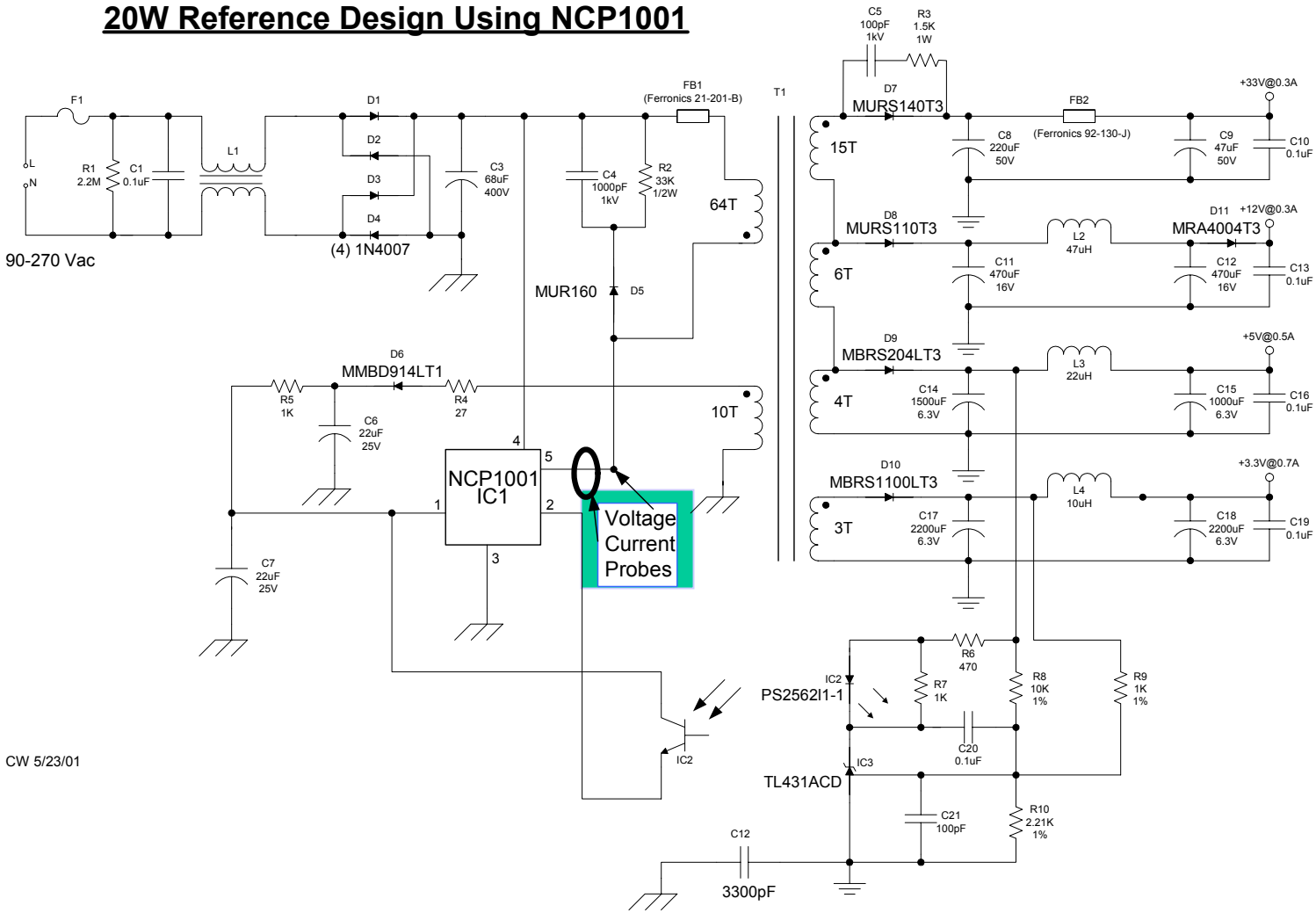
Frequency MHz	Peak dBuV	Delta Pk-Limit dB	QP dBuV	Delta QP-Limit dB	Avg dBuV	Trace Name	Comment

Additional Reductions

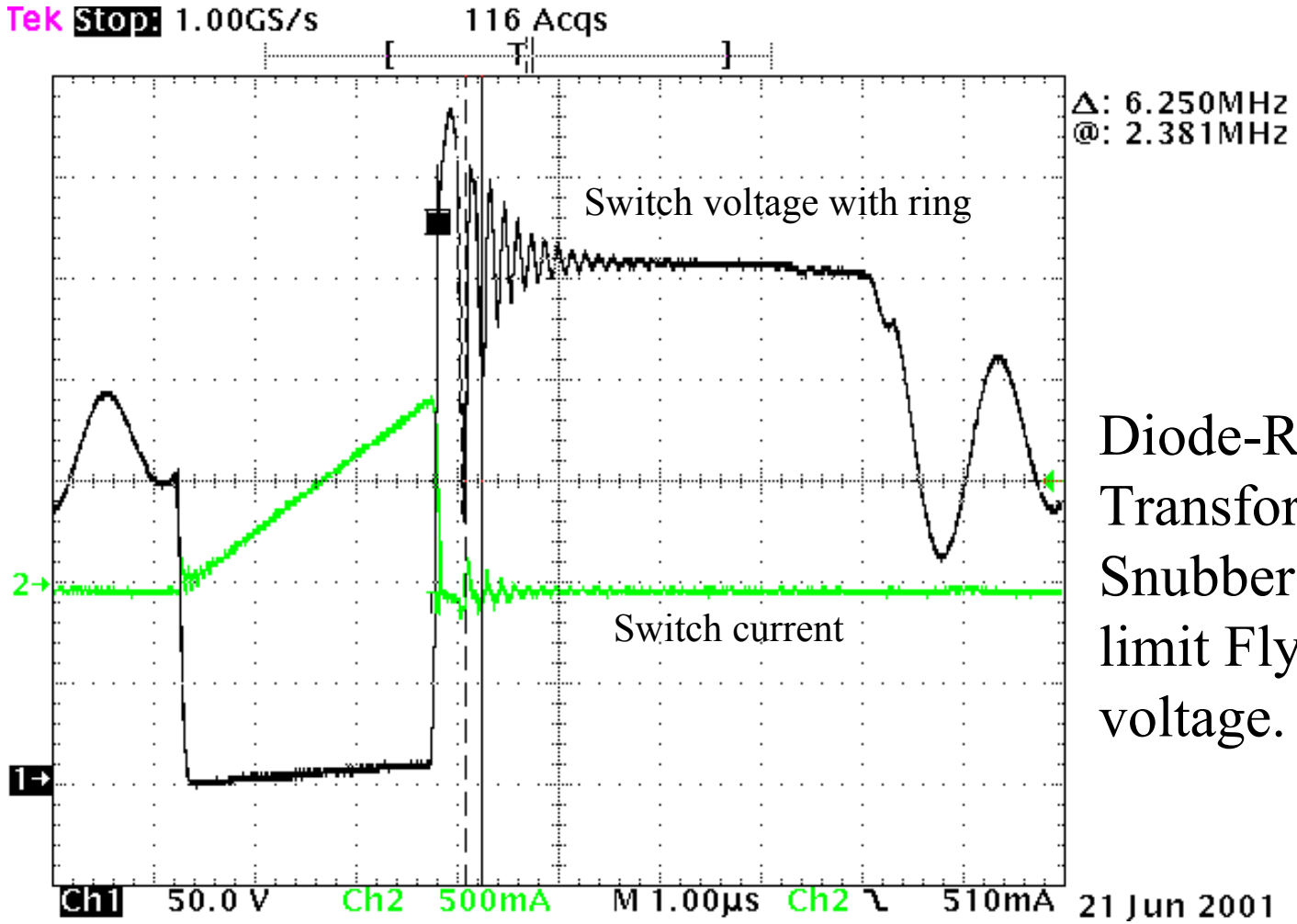


Frequency MHz	Peak dBuV	Delta Pk-Limit dB	QP dBuV	Delta QP-Limit dB	Avg dBuV	Trace Name	Comment

Switch Voltage and Current

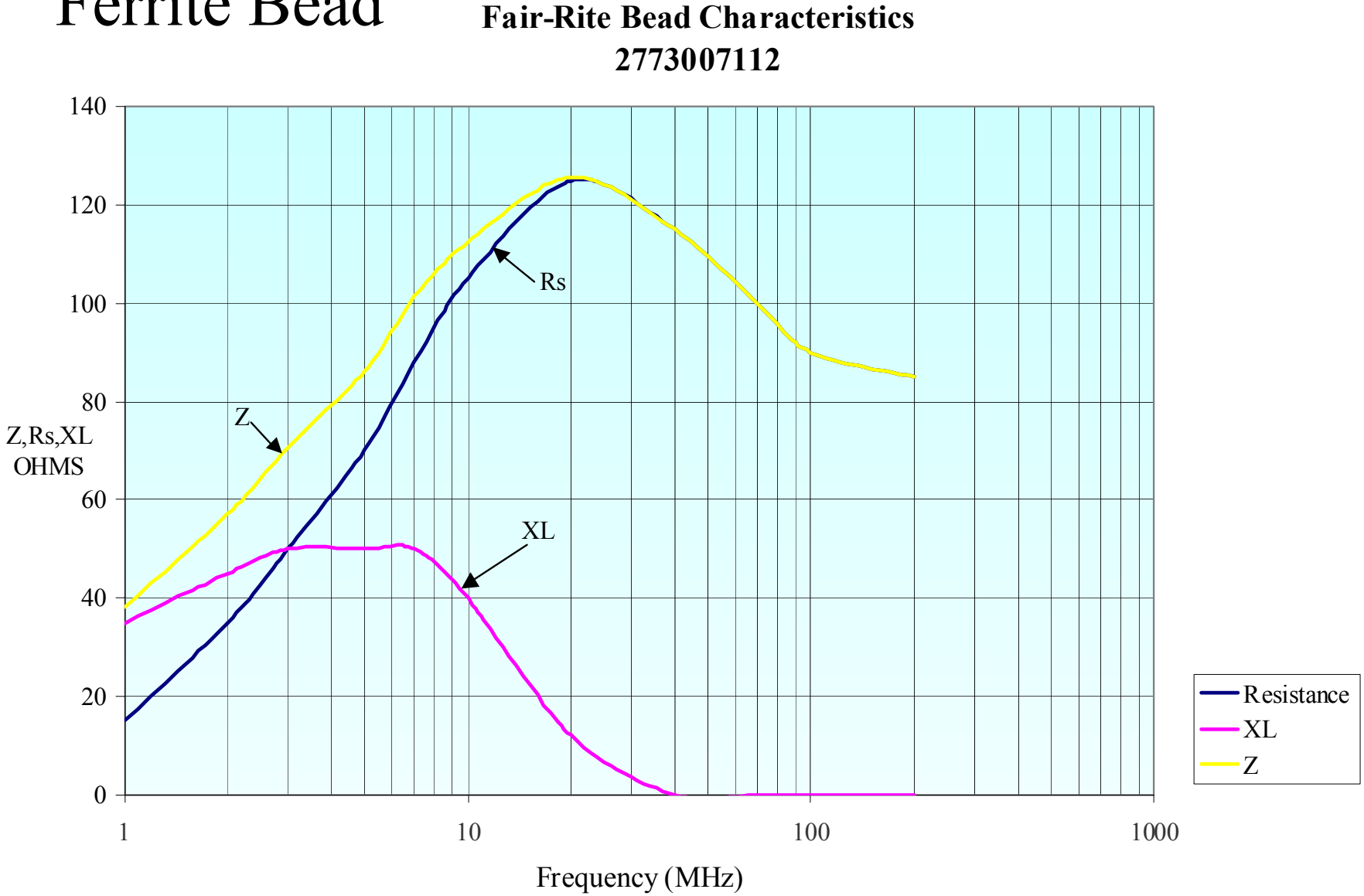


Transformer EMI Ringing

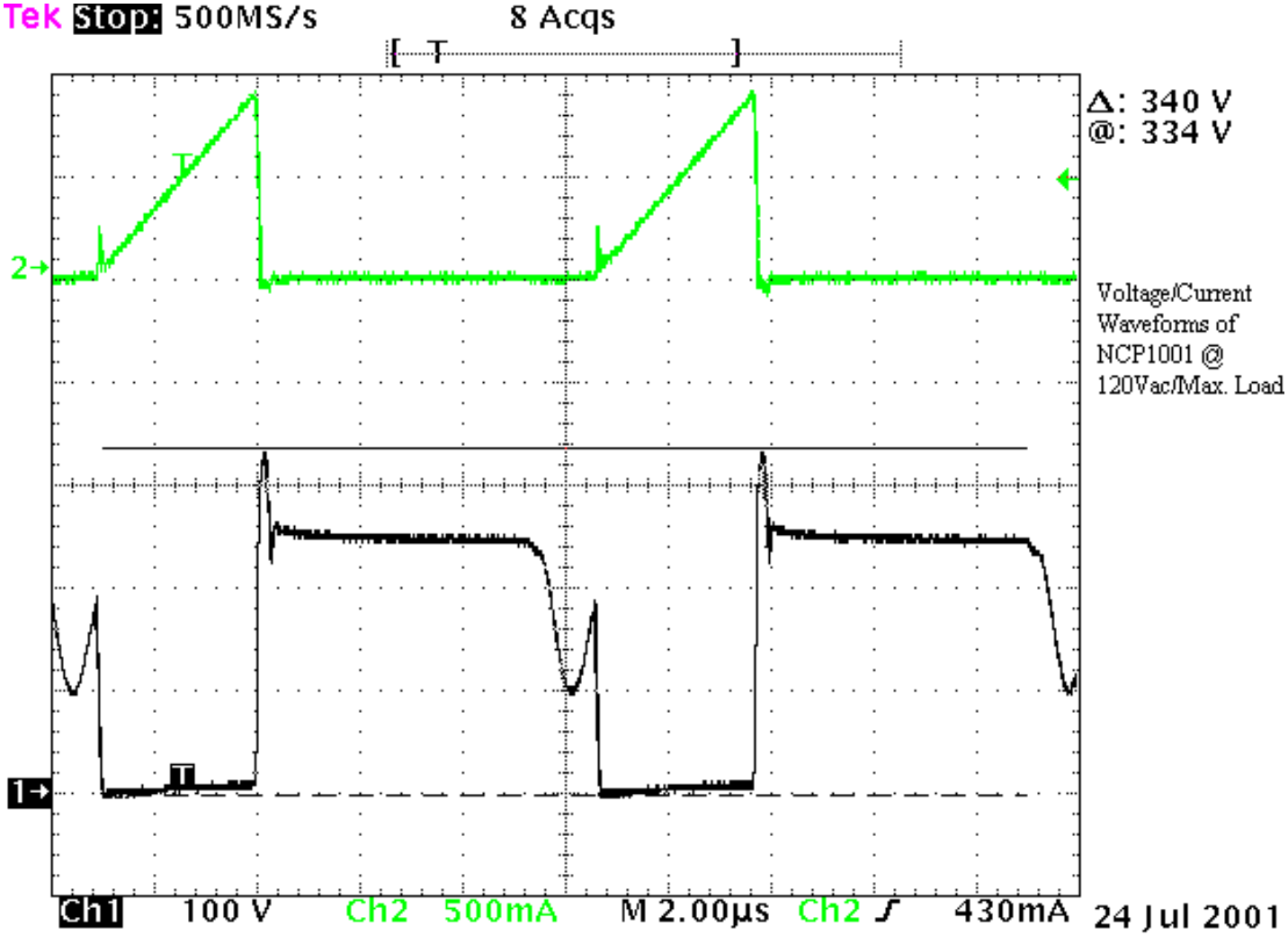


Diode-RC Transformer Snubber to limit Flyback voltage.

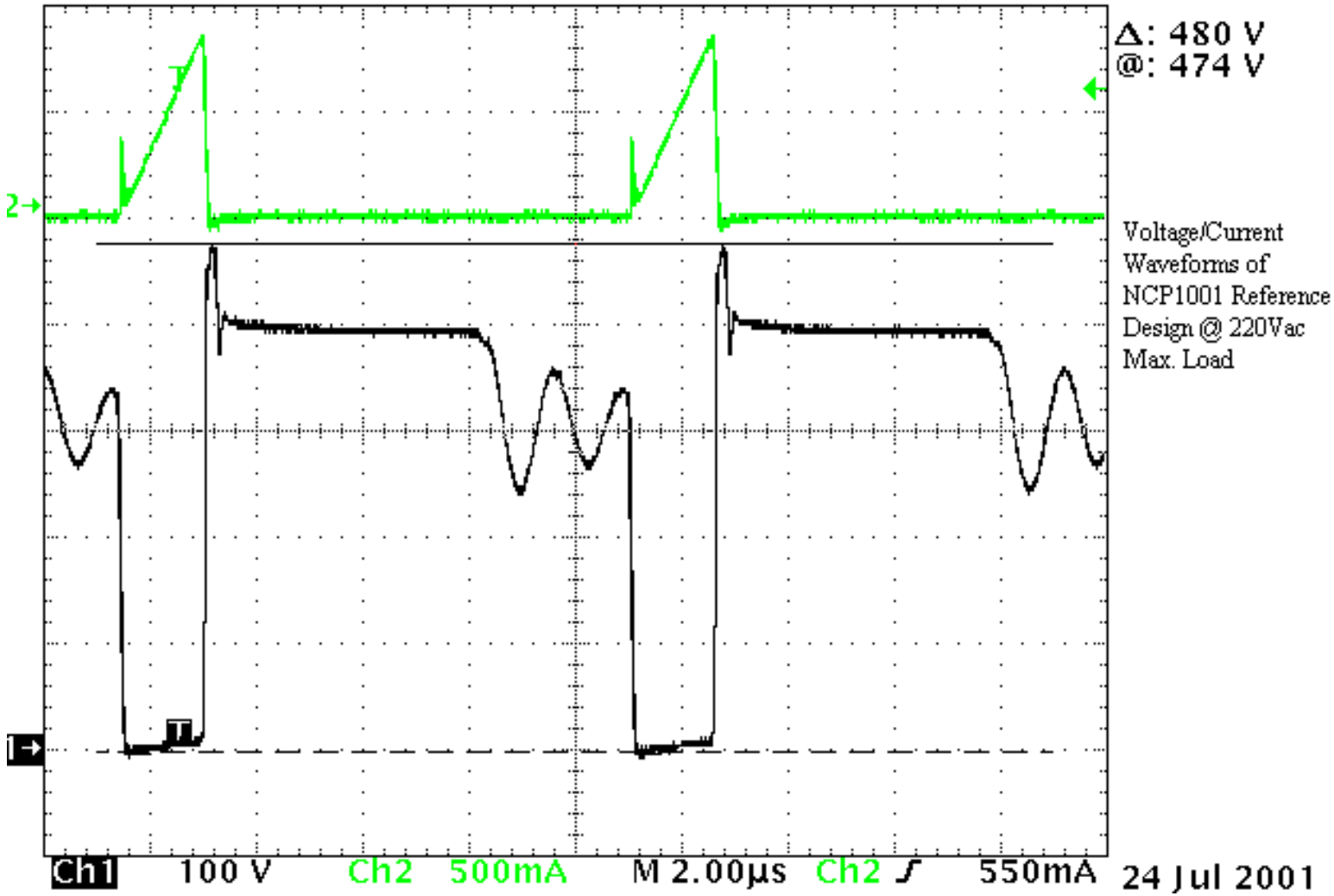
Ferrite Bead



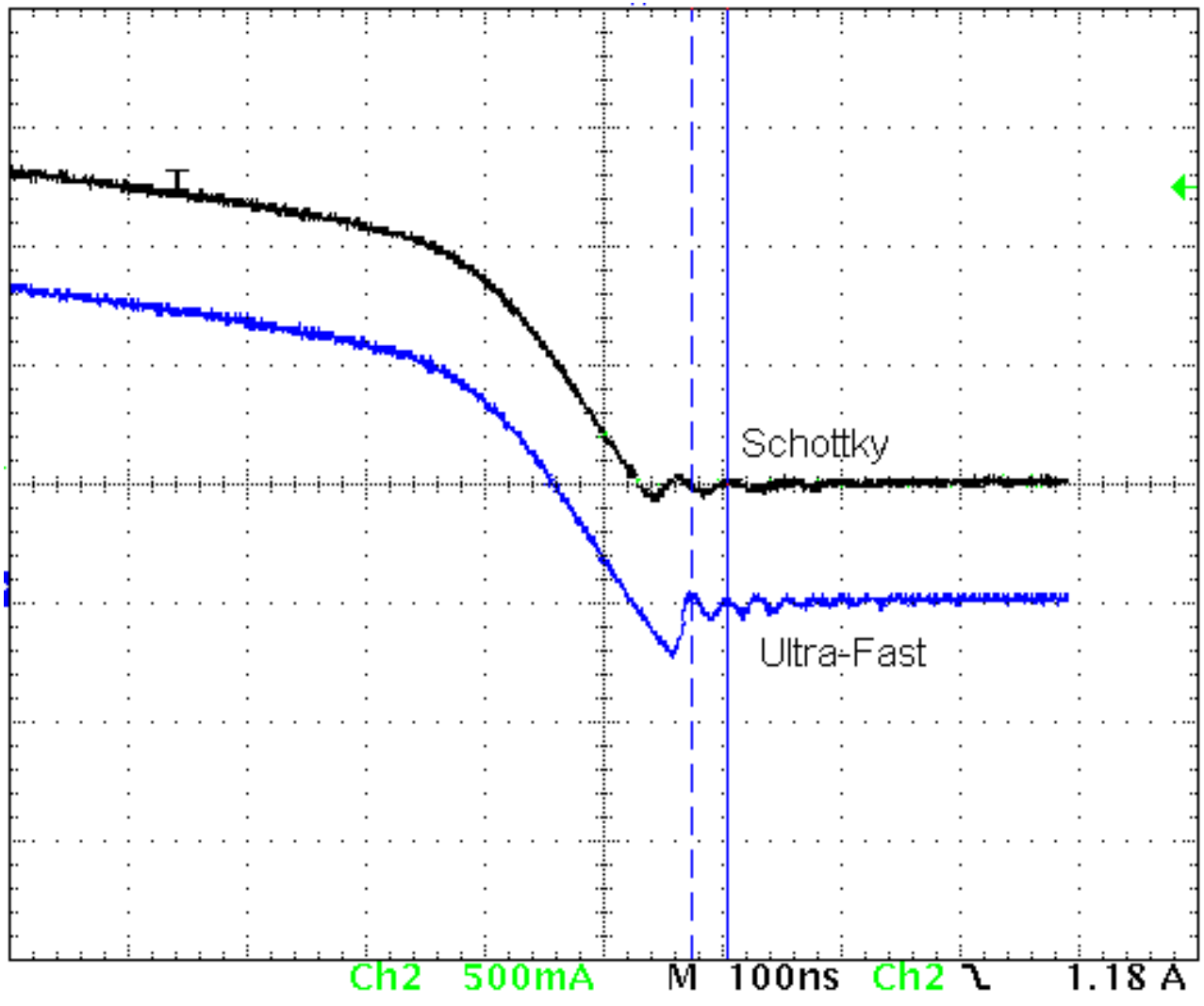
Ferrite Bead 120 Vac



Ferrite Bead 220 Vac

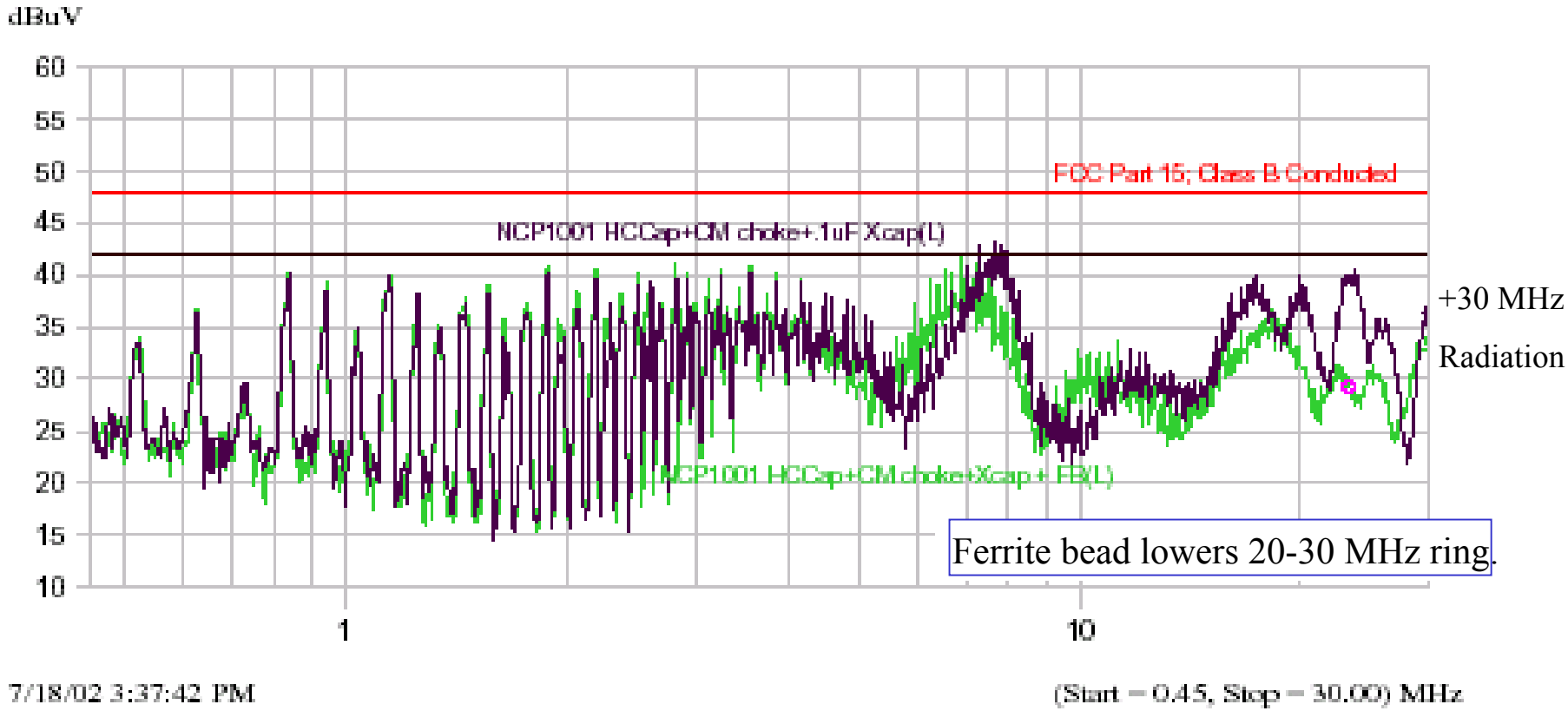


Reverse Recovery Diode (t_{rr} issues)



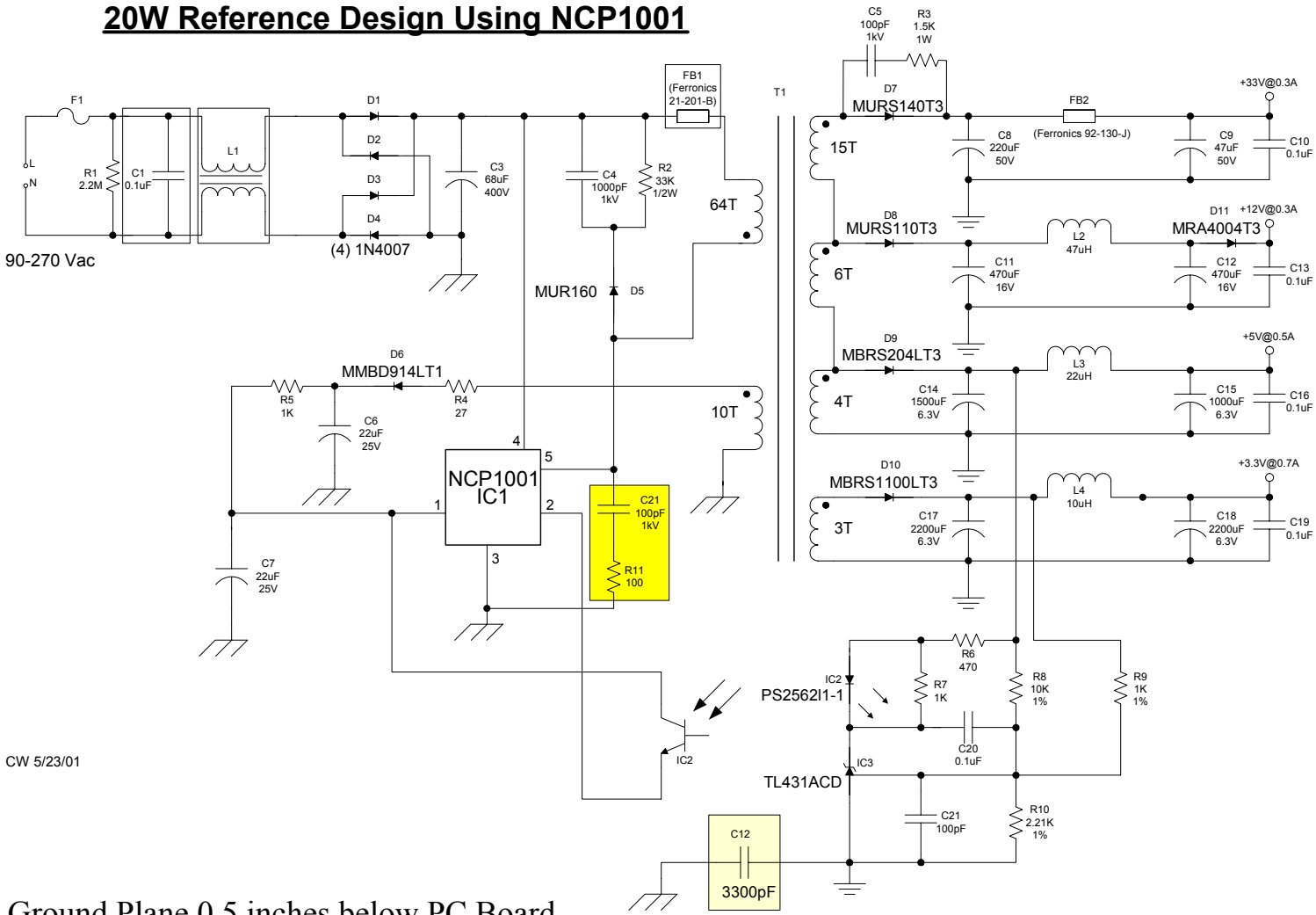
Frequency beyond the Line conducted limits. Problems with FCC radiation start to appear.

Ferrite Bead



Frequency MHz	Peak dBuV	Delta Pk-Limit dB	QP dBuV	Delta QP-Limit dB	Avg dBuV	Trace Name	Comment
23.218	29.2	-18.8				NCP1001 HCCap+CM choke+Xcap + FB(L)	

Ground Plane added beneath PC Board

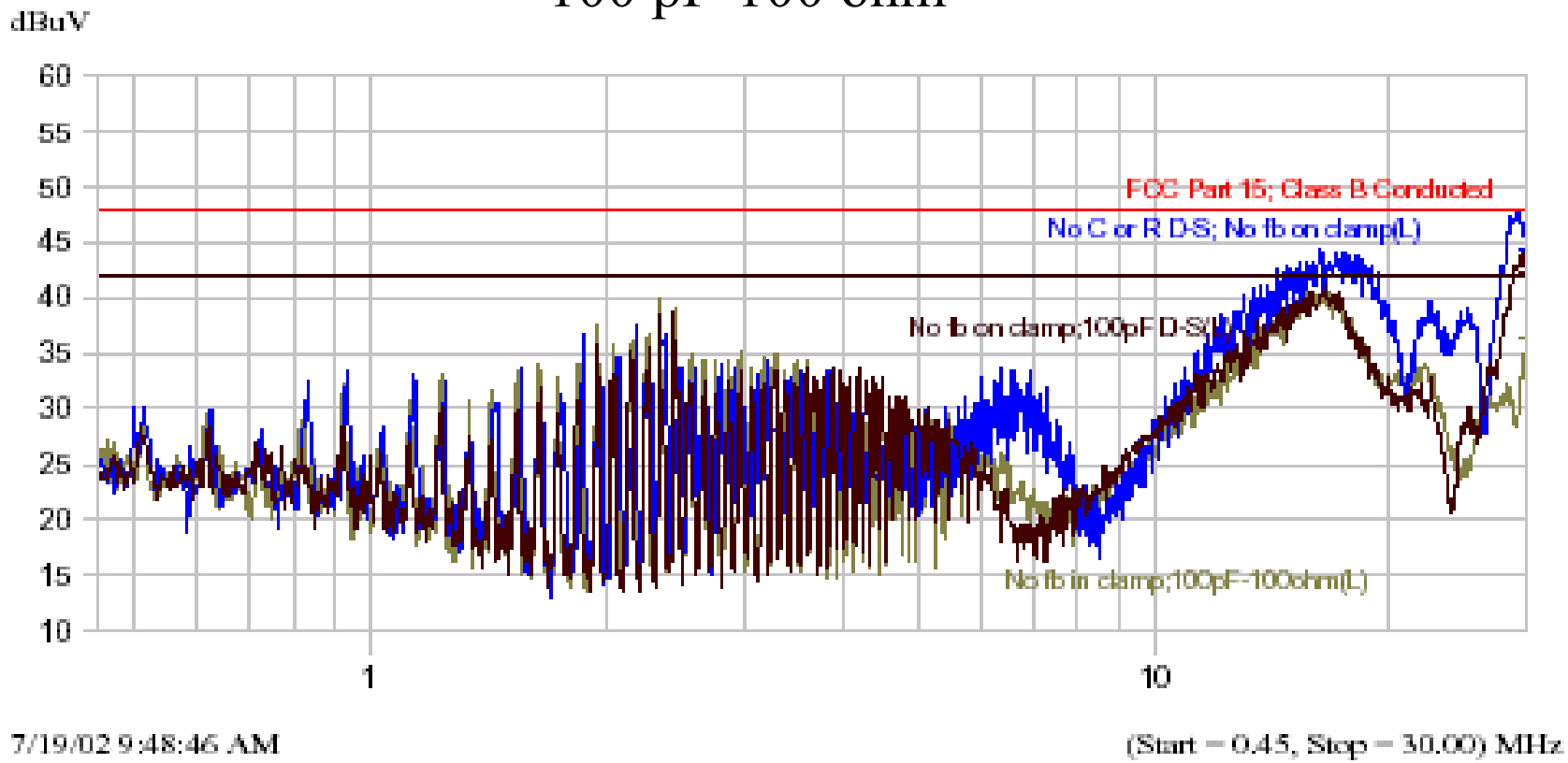


Ground Plane 0.5 inches below PC Board

Ground Plane

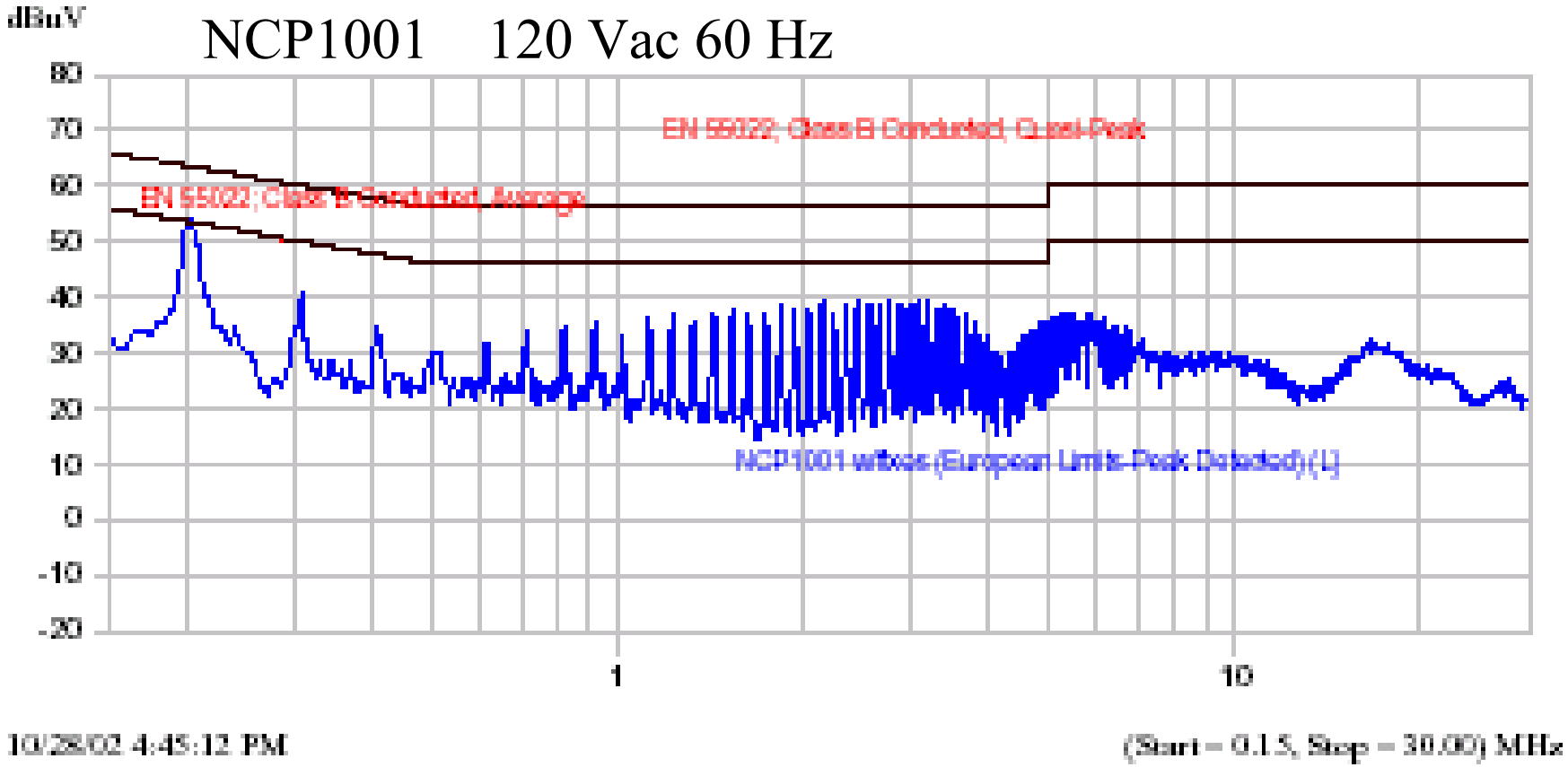
Switch Snubber

100 pF-100 ohm



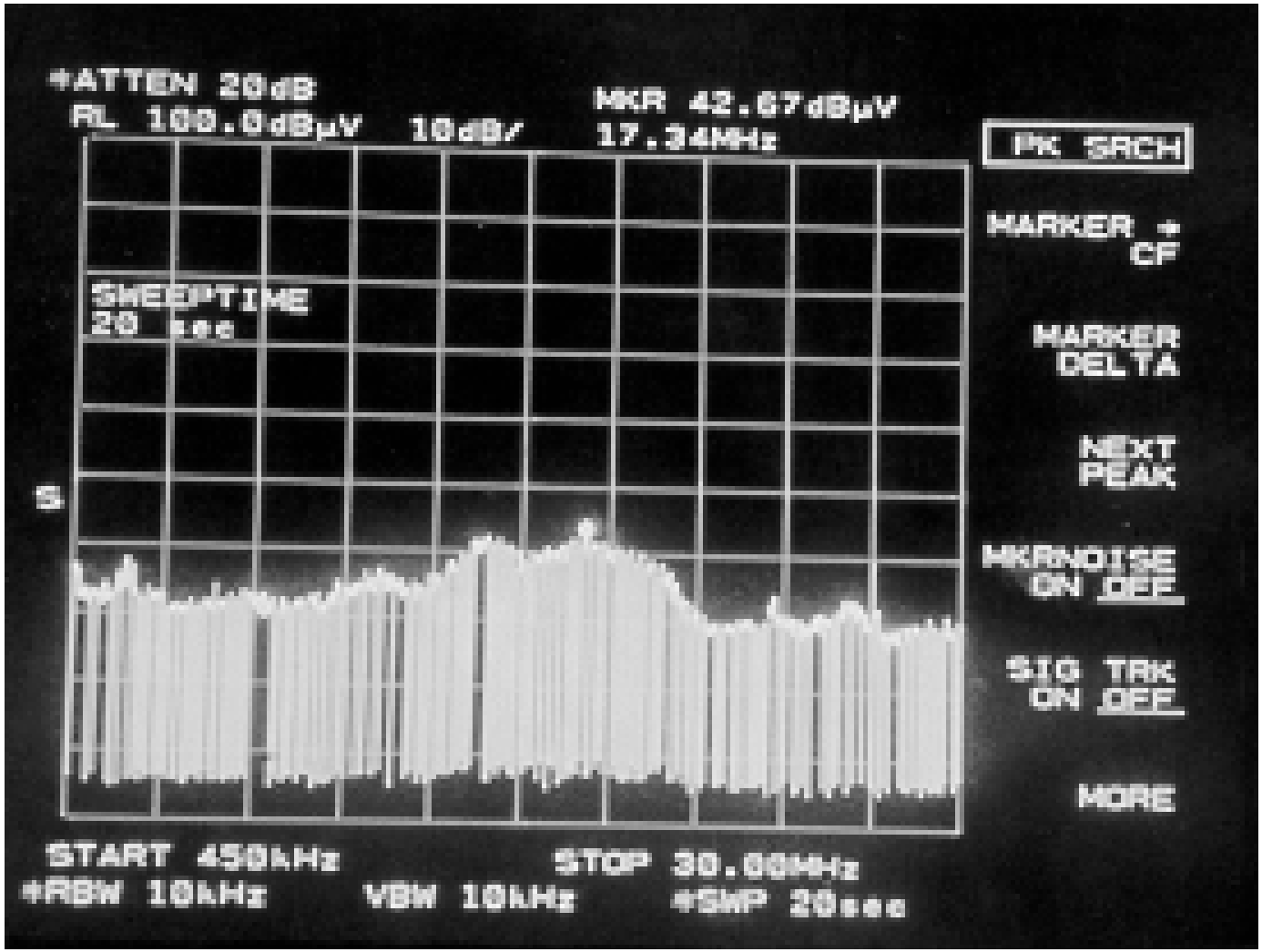
Frequency MHz	Peak dBuV	Delta Pk-Limit dB	QP dBuV	Delta QP-Limit dB	Avg dBuV	Trace Name	Comment

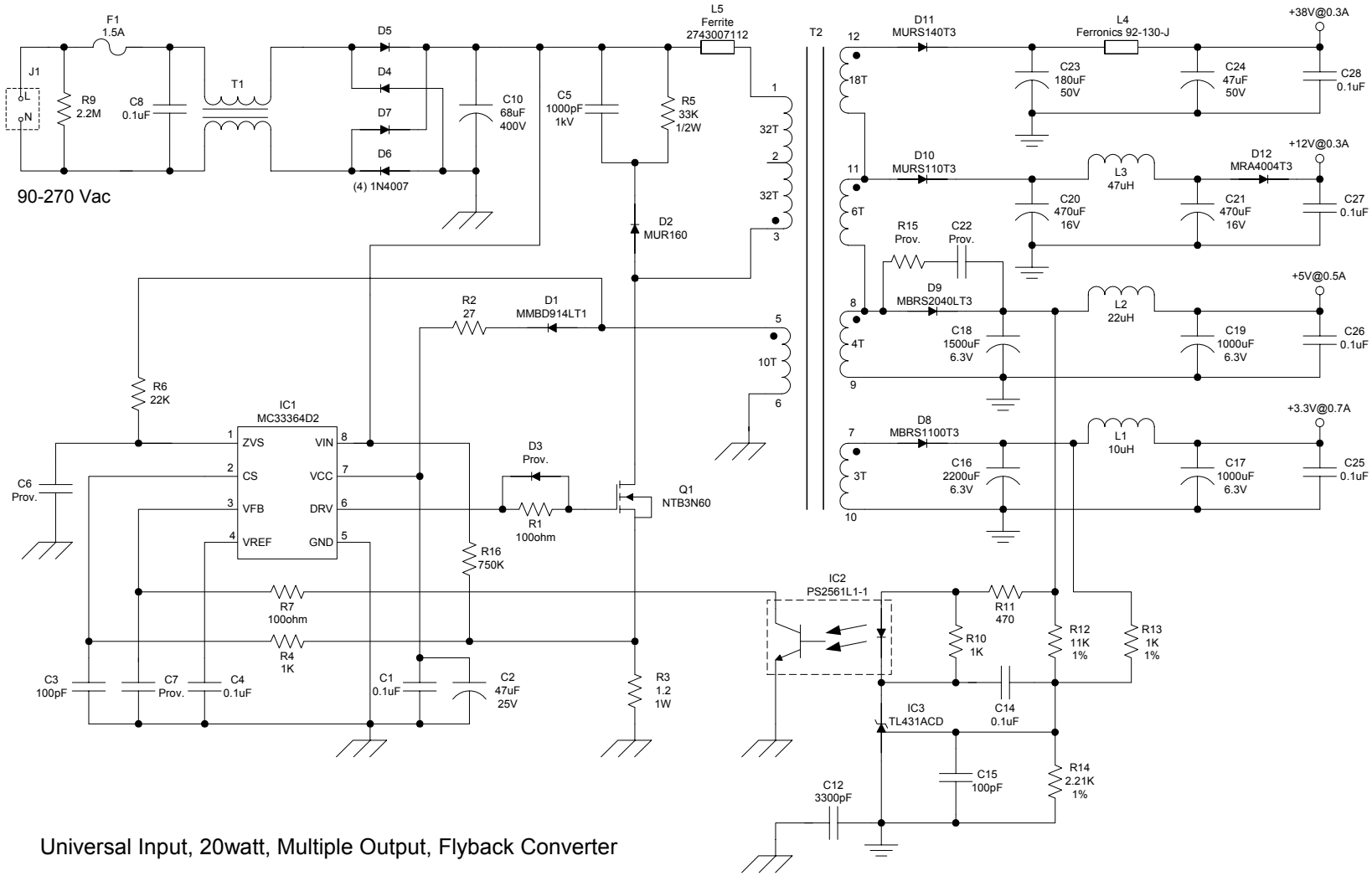
EMI using European Standards



No Ground Plane

Ground Plane added





Universal Input, 20watt, Multiple Output, Flyback Converter

Other Sources of Information

- Ott, Henry, Noise Reduction Techniques in Electronic Systems, 1988 John Wiley
- Mills, Jeffrey, Electro-Magnetic Interference Reduction in Electronic Systems, 1993 Prentice Hall
- Ott, Henry, 'Understanding and Controlling Common-Mode Emissions In High-Power Electronics', Professional Education Seminars IEEE, APEC Mar. 2002
- Schutten, Michael, 'EMI: Theory, Issues, and Solutions', Professional Education Seminars IEEE, APEC Mar. 2002
- Class Notes ECE-522, Electro-Magnetic Compatibility, Dr. Jeff Mills, Illinois Institute of Technology.
- Dr. Ridley, Power 4-5-6. Ver 8.0, Snubber design

Thank You,

Comments,

? Questions ?

For copy of the presentation in pdf format, please give Carl, Dennis, or my self a business card.