AC Ripple Considerations on DC Battery Systems

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There are numerous issues to consider regarding ripple on DC battery systems. These issues differ depending on application. I will review ripple concerns for each of the major applications.

Communications – The Telephone industry developed the original ripple specifications to decrease noise or hum on talking circuits. The original specifications allowed a maximum of 30 millivolts peak-to-peak ripple at the battery terminals. This was usually measured with an oscilloscope. A further definition stated the battery 8-hour ampere-hour capacity must be at least 4 times the maximum ampere rating of the total charger capacity. By insuring the battery was relatively large in relationship to the chargers the filtering effect of the battery is very effective in reducing the system ripple. Charger (rectifier) manufacturers incorporated chokes and large filter capacitors in the charger to comply with this specification.

This requirement also led to the slip-bus power plant. This meant the rectifiers were connected directly to the battery terminals and the load was connected directly to the battery terminals rather than to a common bus in the power board. This connection method fully utilized the very large capacitance of the battery as additional filtering. A battery has approximately 1.5 Farads of capacitance per 100 ampere hours, thus a typical 1680 ampere hour telephone battery is approximately 25 Farads of capacitance. The actual ripple current into the battery in these systems was relatively low (less than 1 amp RMS per 100-ampere hours of battery capacity) because the battery was so large in relationship to charger capacity.

With the advent of electronic switching equipment, the DC noise spec was made more stringent to avoid damage to the electronics. Most manufacturers now make switch mode rectifiers which have infrequently little ripple and are very easy to filter to meet the current spec. Since the ripple on Telephone systems is so low it never has any detrimental effect on the battery.

Power Company – switch gear applications – typically the power company industry did not buy filtered chargers for generating and substations since the connected equipment could withstand the ripple of a normal charger while connected to a battery.

IEEE 637.90, 1989 specifies an allowed ripple of 5% peak. For a 130 volt system this allows 6.5 volts ripple. (See graph 1) Now, looking at various scenarios of substation operation. An unfiltered SCR charger running at 50% load has higher ripple than the same charger running at 100% load. I used the worst case situation in these comparisons.

Graph #	Charger Condition	Peak-to-peak ripple
2	SCR-130-1-25 Unfiltered 50% load with battery	856 millivolts
3	SCR-130-1-25 Unfiltered 50% load without battery	135 volts
4	SCRF-130-1-25 Filtered 50% load with battery	27 millivolts
5	SCRF-130-1-25 Filtered 50% load without battery	570 millivolts

The above chargers are all 130 Volt, single phase, and 25-amp output. Notice that any ripple condition is well within the IEEE standard of 6.5 volts ripple except the unfiltered charger running without a battery. In this case, the 135 volts peak-to-peak voltage would damage ripple sensitive equipment. The battery could accidentally go open circuit if an inter cell connector had a loose or badly corroded connection of if someone purposely opens the battery circuit to do battery maintenance work. To avoid any damage to connected equipment is a utility application we recommend a filtered charger be used on any system that has ripple sensitive equipment.

There is another charger available sometimes called a battery eliminator. This charger has additional filtering maintaining the ripple under a maximum of 30 millivolts even when operated without a battery. All ripple references are to voltage ripple at the battery terminals when the battery has an ampere hour capacity equal to 4 times the maximum charger output current. Since the battery is relatively large compared to charger rating the ripple current in the battery never has a detrimental effect on the battery.

UPS Systems - Put a high ripple current into the battery because the UPS is taking power from the DC system in a very high current short duration pulses. This usually means an inverter can not be powered from a DC system that has other ripple sensitive equipment (like communication) on it since the inverter would put well in excess of allowed ripple voltage onto the DC system. (See attached graph #6.) Notice this is approximately 20 volts peak-to-peak ripple on this system.

The negative pulses take power out of the battery while the positive pulses put power back into the battery. Graph 7 shows battery ripple on a UPS system. The positive power is coming from the rectifier while the negative power is going to the inverter. Aging DC capacitors in the UPS system will contribute to higher ripple current since the battery will act like a filter capacitor.

Battery ripple current maximums are expressed in various ways. There is a general consensus among battery manufacturers that ripple current causes IR drop (thus heat) in the internal conductors. Thus the conclusion was if ripple doesn't cause a battery temperature rise it is not detrimental to battery life. IEEE 1188 "VRLA Maintenance" recommends battery ripple current and voltage be measured annually and assure that the ripple does not raise battery temperature above ambient. There is some feeling among battery manufacturers that ripple below the 6amps per 100-ampere hours, while not causing heating, is causing deterioration of the grid and active material.

With ripple – less is batter. If your periodic battery ripple checks on a UPS battery show increase in ripple current this may indicate need for UPS system maintenance. Ripple in excess of the stated maximum can contribute to thermal runaway since ripple current tends to add to the heat created by recharge current. Also, keep in mind the reaction at the negative plate of a VRLA battery is exothermic, thus going further toward thermal runaway. I suggest battery manufacturer's and consultants further examine the ripple standard and determine whether a decrease from the current 6 amps per 100 ampere hours is justified as a way to extend life and improve reliability in both flooded and VRLA, UPS batteries.

Graph #1

IEEE - C37.90, 1989

6.5 Allowable AC Component in DC Control Voltage Supply

An alternating component (ripple) of 5% peak or less in the dc control voltage supply to protective or auxiliary relays shall be permitted, provided the minimum instantaneous voltage is not less than 80% of rated voltage. The ripple content of a dc supply expressed as a percentage is defined as follows:

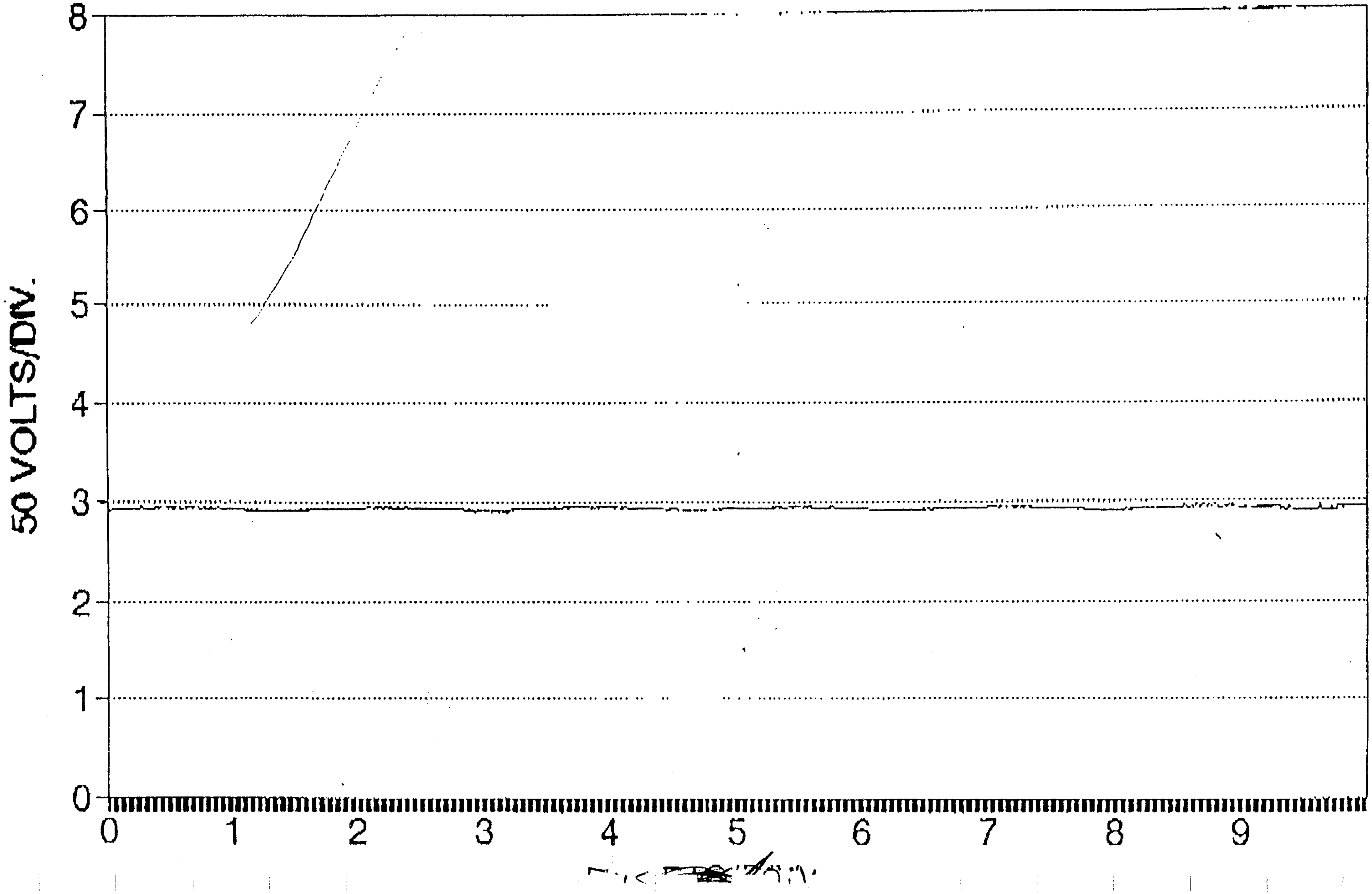
$$\frac{(\text{peak value - dc component})}{(\text{dc component})} \times 100$$

NOTE: The above refers to low frequency ripple as might typically be introduced on the dc control power bus by a battery charger. Higher frequency effects, such as might be introduced by a dc/dc converter within the relay itself, are not sufficiently defined at this time to be included to this standard.

Graph 2

856 MV Peak- Peak

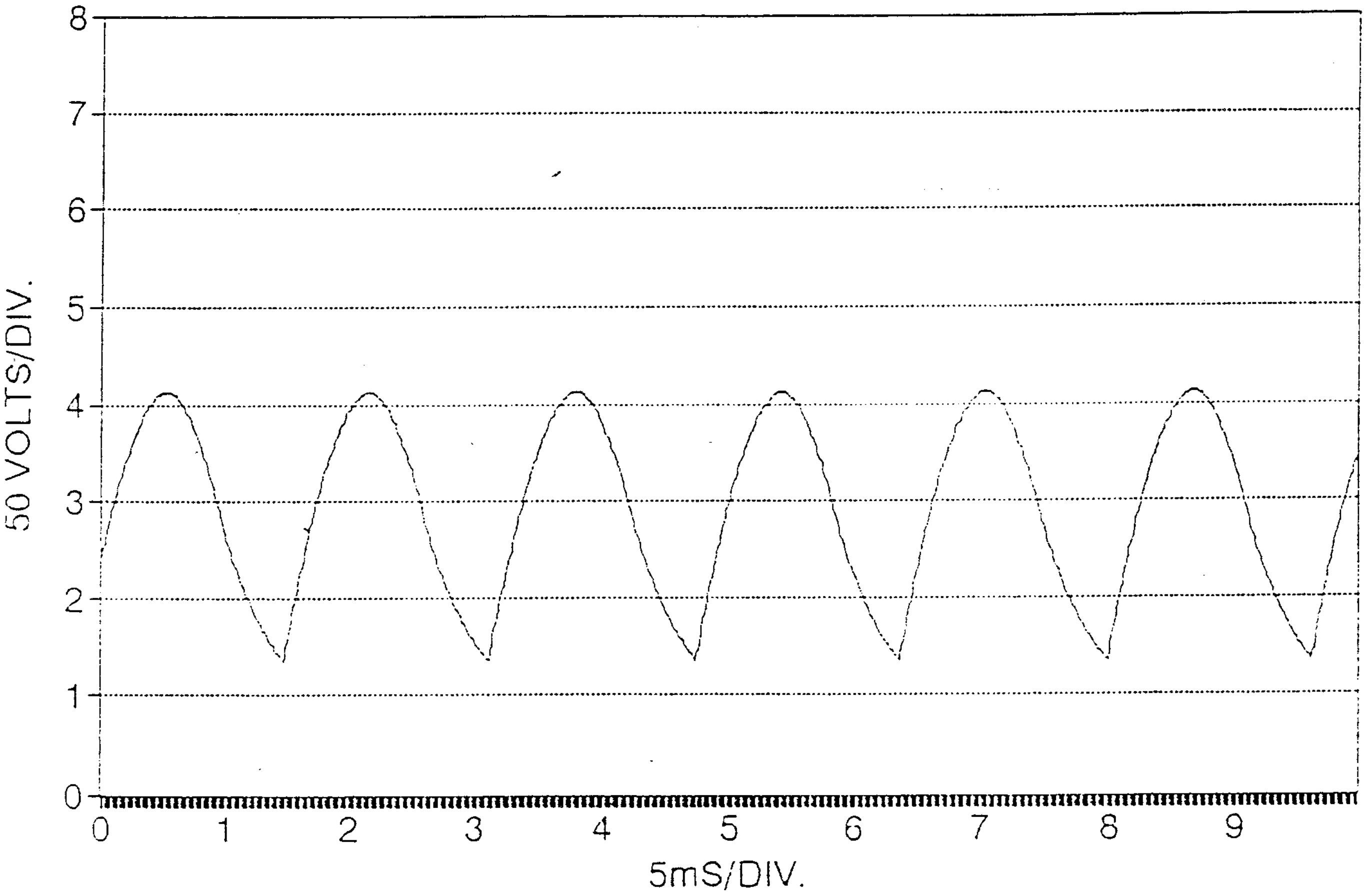
SCR130-1-25 50% LOAD
WITH BATTERIES



Graph #3

67.5V
Peak
V P-P
135 V

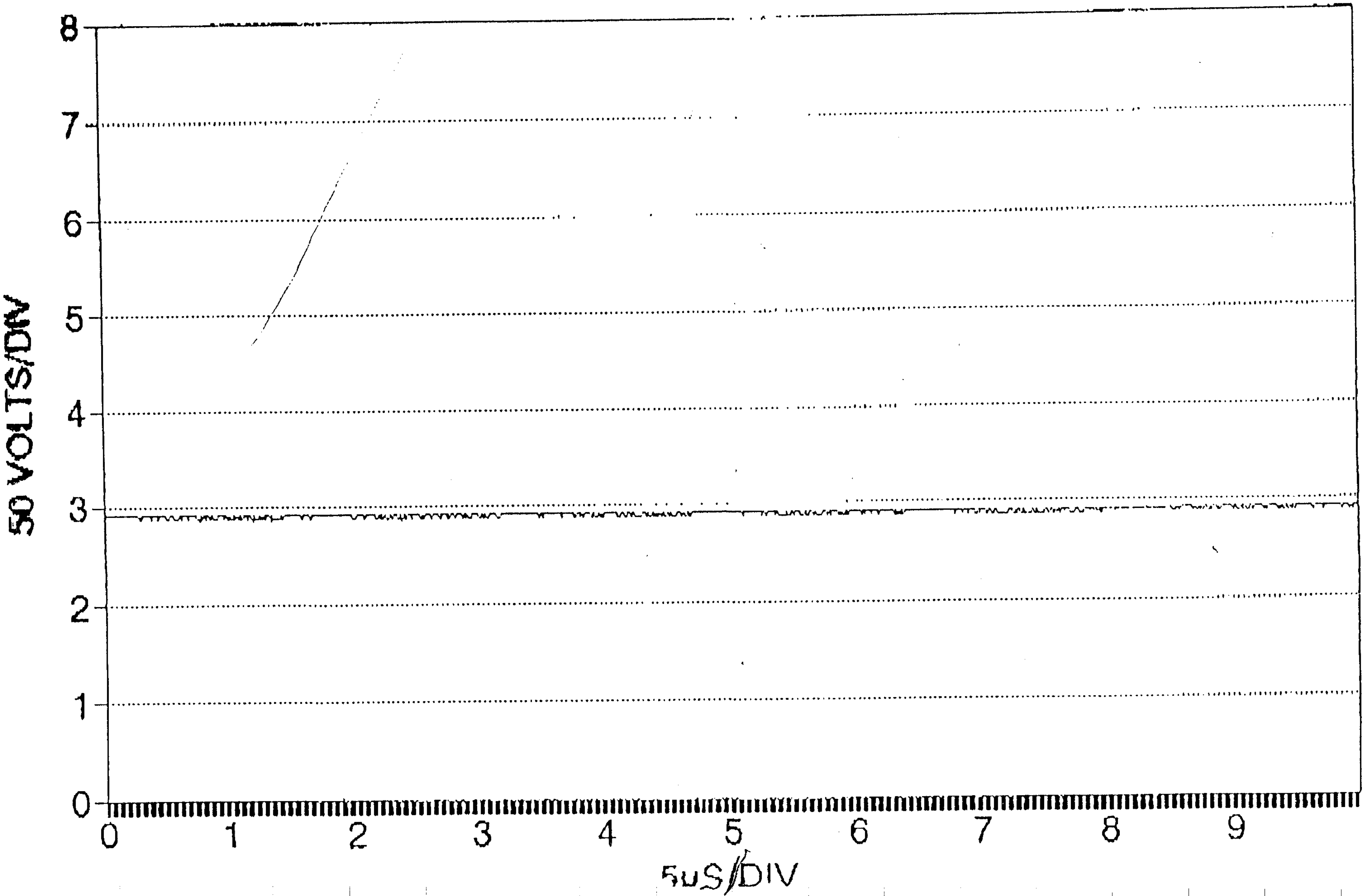
SCR130-1-25 50% LOAD
WITHOUT BATTERIES



Graph 4

Peak-Peak 27 MV

SCRF130-1-25 50% LOAD
WITH BATTERIES

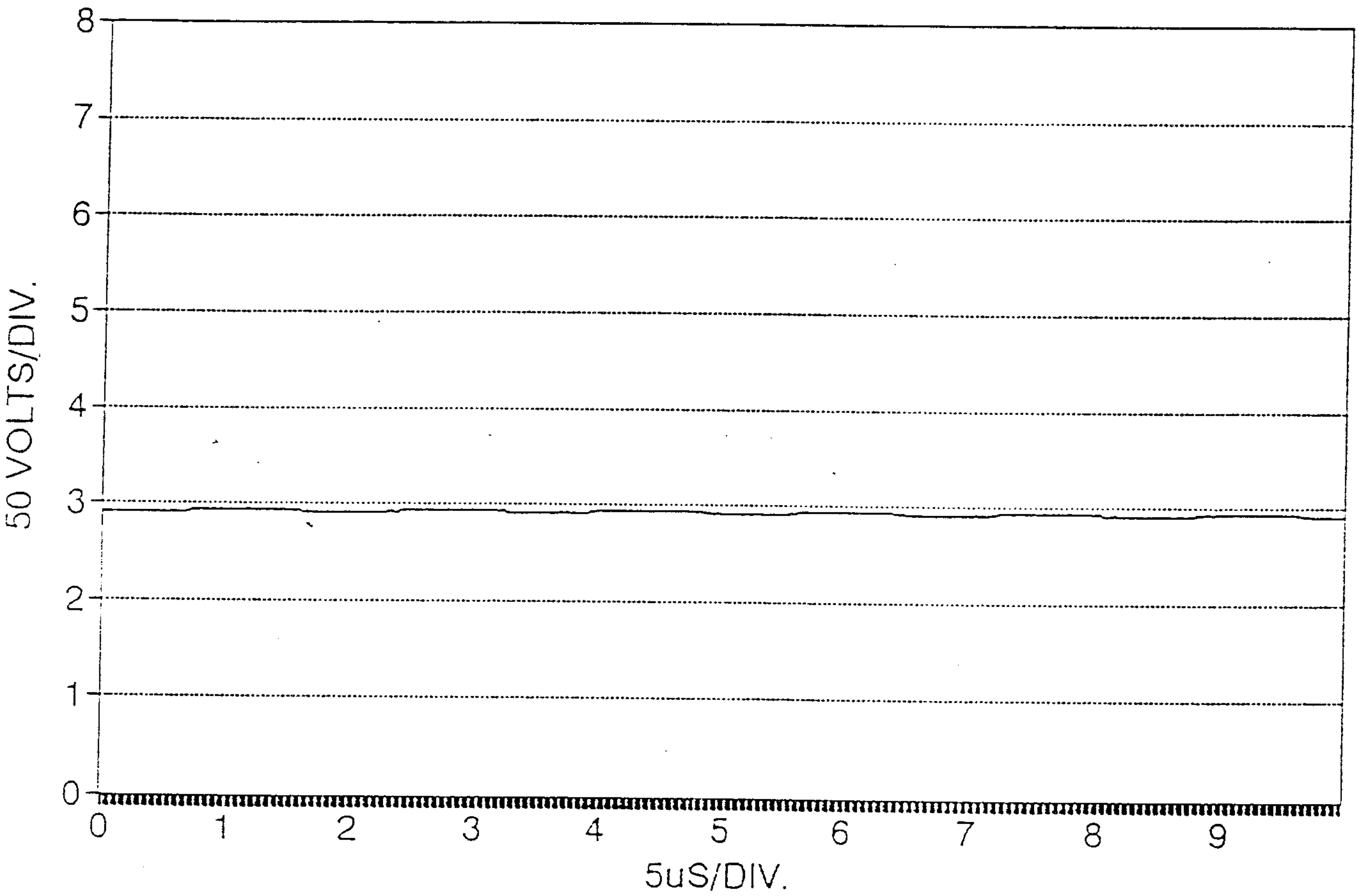


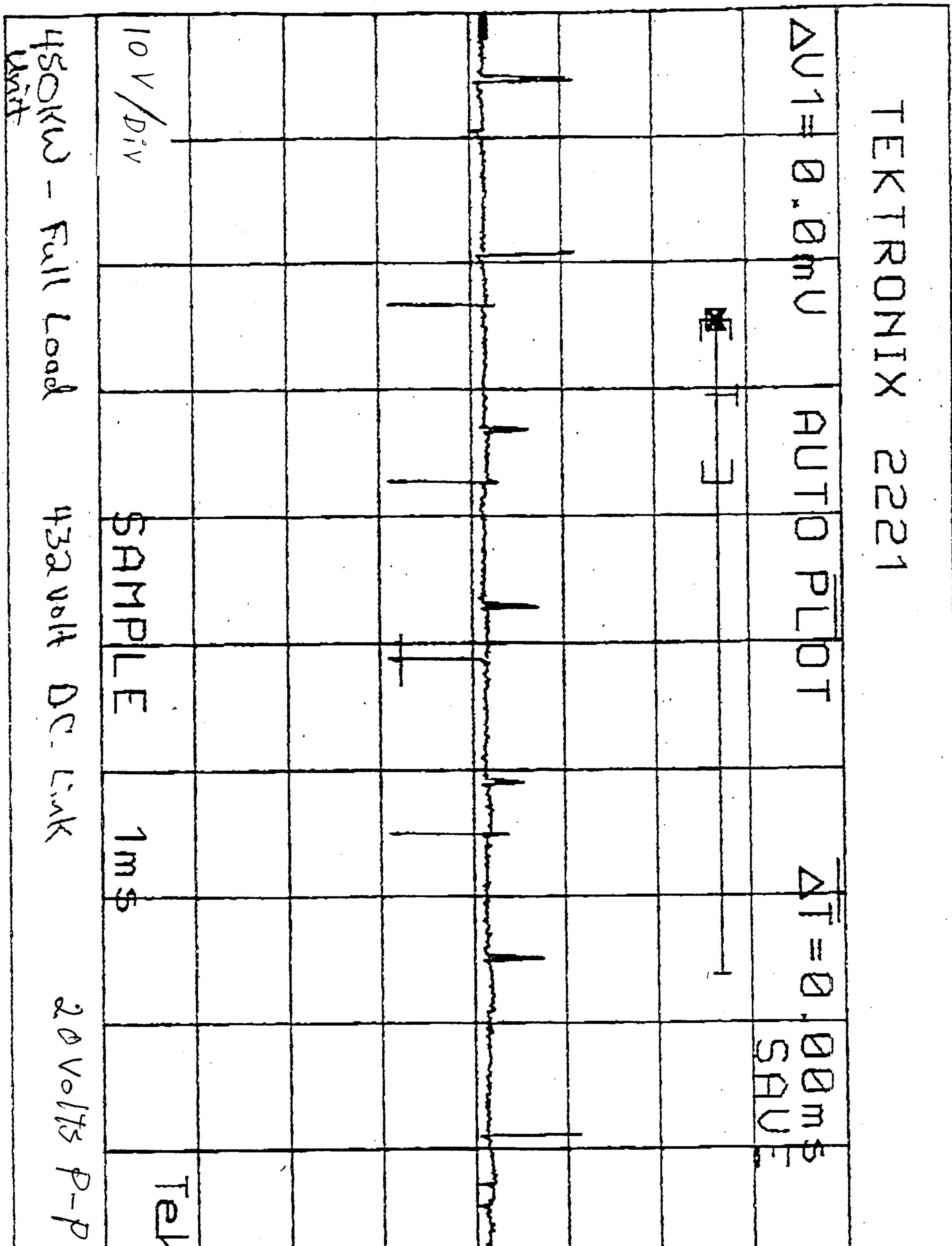
Graph #5

570 MV
Peak - Peak

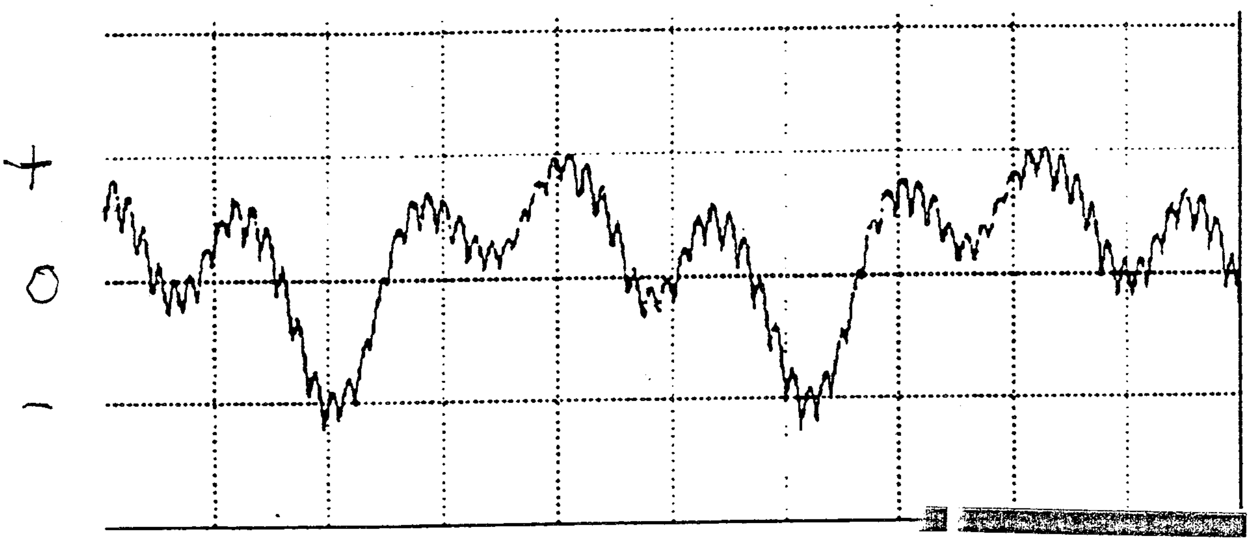
SCRF130-1-25 50% LOAD

NO BATTERIES




TEKTRONIX 2221
ΔV1=0.0mV
AUTO PLOT
ΔT=0.00ms
SAVE
SAMPLE
1ms
Tek
10V/Div
450KW - Full Load Unit
432 volt DC Link
20 Volts P-P

Graph "6"



Graph 7 - Battery ripple current caused by UPS.

Fig. 2 UPS Discharge current (PWM type)