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TEST RESULTS OF HIGH-VOLTAGE, HIGH-POWER, SOLID-STATE REMOTE POWER CONTROLLERS

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Science and Engineering Directorate

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George C. Marshall Space Flight Center

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TECHNICAL MEMORANDUM

TEST RESULTS OF HIGH-VOLTAGE, HIGH-POWER, SOLID-STATE REMOTE POWER CONTROLLERS

INTRODUCTION

The use of high-voltage, high-power, solid-state remote power controllers is applicable in many scenarios. This report deals with remote power controllers (RPC) for use in direct-current (dc) aerospace systems. In particular, the RPCs in this report were evaluated in a 24 kW, 200 Vdc, Autonomously Managed Power System (AMPS) breadboard/test facility. Included in this report are the test results of two type E-F, 200 Vdc, 30 A remote power controllers.

These RPCs were designed and built by John C. Sturman at the Lewis Research Center, Cleveland, Ohio. The tests discussed in this report parallels Sturman's report [1], but with changes in test set-up. Results of testing with these test set-up changes are presented herein.

BACKGROUND

The two RPCs shipped to Marshall Space Flight Center (MSFC) were two of seven types of units that Sturman constructed and tested. The type E-F MOSFET RPC tested at MSFC uses MTM15N40 MOSFETs. They are one of four different types of MOSFET RPCs developed by LeRc. A table of the type E-F MOSFET RPC characteristics are shown in Table 1. The 200 V, 300 A RPC has six MTM15N40 MOSFETs in parallel.

Potential uses of the RPCs would be to replace electromechanical relays in the existing breadboard and in high Vdc space power. The AMPS breadboard has 20 electromechanical relays that act as RPC simulators. Putting actual RPCs in the breadboard would provide a more realistic high-voltage breadboard and provide long term data on the RPC operations.

DESCRIPTION

Figures 1 through 3 show the RPC circuit layout. Figure 1 shows the RPC interface control wiring. The actual interface is a separate unit from the RPC. The interface control wiring consists of separate on, off, and place short switches. There are LED's which indicate "on" and "tripped" status. Included is a short circuit, enabling a short to be placed manually. The function of the interface control cabling is listed in Table 2 [1].

Figure 2 is the RPC control and power supply. This section consists of the turn-on circuit, RPC turn-on section, turn-off circuitry, and power supply to supply regulated power inputs for the control circuitry [1].

The turn-on circuit is continuously energized in order to accept the on command from the RPC interface control wiring and activate the RPC turn-on section. The turn-off circuit turns off the RPC in case of low line voltage (below 21 V) and also prevents it from getting into a high power dissipation state [1].

Figure 3 is the MOSFET power switching circuit. It consists of the MOSFET driver board and the six MTM15N40 MOSFET power switches. The opto-isolators OP1 and OP3 couple the turn-on and turn-off signals from the power supply and control circuits to the power switching circuit [1].

RPC CIRCUIT CHANGES

The circuit shown in Figure 1 is a different RPC control circuit from the one that Sturman used. Figure 3 was slightly modified when tested at MSFC. The highlighted sections show these changes. For testing purposes, the RPC was secured to a heat sink. To absorb transient voltages, ten zener diodes (1N5624A) were placed in series across the power switches. These diodes were 24 V zener diodes which combined to make 240 V of zener diodes.

Diodes and a 0.1 μF capacitor were also added to +5 and ground from OP3 of the MOSFET driver board due to a continuous "on" indicator (see 28V RPC Testing and Evaluation).

28 V RPC TESTING AND EVALUATION

The initial test set-up and RPC verification used a 28 V power supply and a 9 Ohm slide-wire load. Power and control used the same 28 V source. Glitch shorting the slide-wire (load) caused the "tripped" indication to come on, but the "on" indication would stay on due to a failure of the opto-coupler (OP3) in the RPC. Voltage surge protection consisting of two diodes (1N4148) and a 0.1 μF capacitor were added to +5 to ground from the opto-copuler output which remedied the problem.

Figure shows an oscilloscope photo of the voltage across the switch when a short circuit was applied. There was a 225 V peak and 45 μsec start of peak.

Figure 5 shows the current through the switch when shorted. The current probe was on the positive output of the RPC. As expected, there was a 90 A peak. Figure 6 also shows the current at the positive input of the RPC when shorted. The difference in the turn-off slope of these two traces was due to an RC network discharge on the output.

Figure 7 shows the voltage from gate to common of the power MOSFET when shorted and Figure 8 the voltage from drain to source of the RPC when shorted.

During the next phase of the 28 V testing, 10 μH were added at the input of the switch to monitor operation into an inductive load. Figures 9 through 11 show traces with the additional 10 μH. The additional 10 μH seemed not to effect the RPC in any adverse way.

In order to obtain traces of a normal turn on and a normal turn off, the input voltage was increased to 45 V. Figures 12 and 13 show these traces. On the turn-on trace, the trace was triggered with the "on" indication of the positive-going slope. The turn-off trace was triggered with the "on" indication of the negative-going slope [1].

200 V RPC TESTING AND EVALUATION

To test the RPCs at 200 V, an EMHP 200 Vdc, 150 A power supply was utilized. The load center associated with the AMPS was used for the load. The power circuit for the 200 V RPC evaluation is shown in Figure 14. The actual line lengths are also shown. Figures 15 through 26 show the overcurrent trip times, switch current and voltage transients, and switch response to sudden overloads. No problems were encountered during the 200 V testing of the RPCs. Table 3 shows the slow over-current trip times. These trip times were comparable to expected operation of the RPC. The slow turn-off feature operated until three times the rated current of the RPC. Currents above this enabled the fast trip circuit. As the load values increased, the time for the RPC to trip decreased [1].

CONCLUSIONS

The testing of the type E-F 200 V, 30 A Remote Power Controllers provided favorable results for space applications. They performed well under every test situation. When installed in the AMPS breadboard, the RPCs should improve the performance of the AMPS breadboard by providing additional flight type protection. The AMPS breadboard should also give even more data concerning the type E-F RPC for future applications. It is not yet known how the actual interface of the RPCs and AMPS breadboard will be done. To replace the 20 electromechanical relays mentioned earlier, 18 additional RPCs would be needed. Software and hardware changes in AMPS will be necessary to make this exchange. Since the relays are much smaller than the RPCs, additional space for the RPC will also be needed [2]. A partial replacement with two or more of the RPCs could be an initial step.

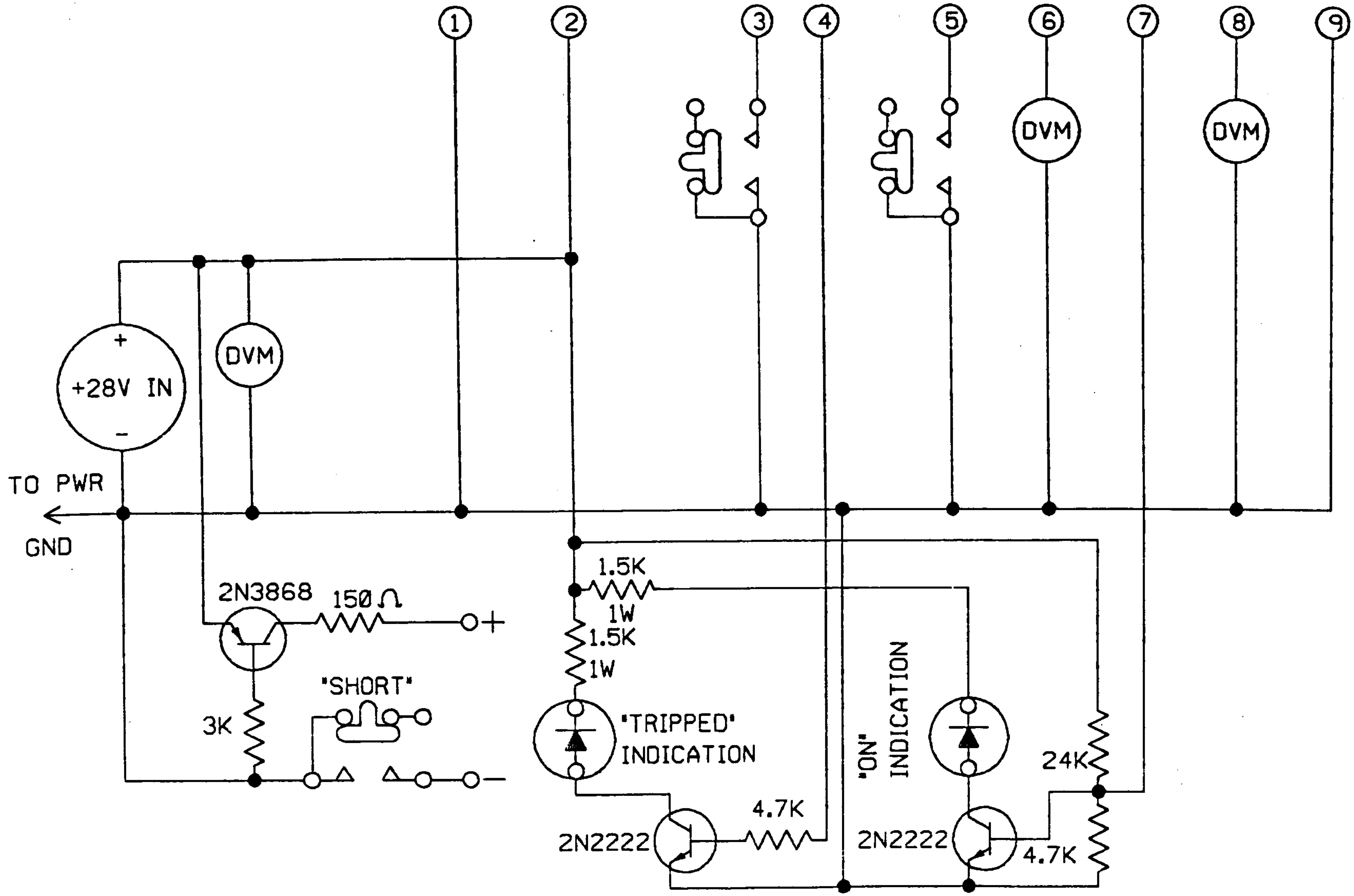


Figure 1. RPC control wiring.

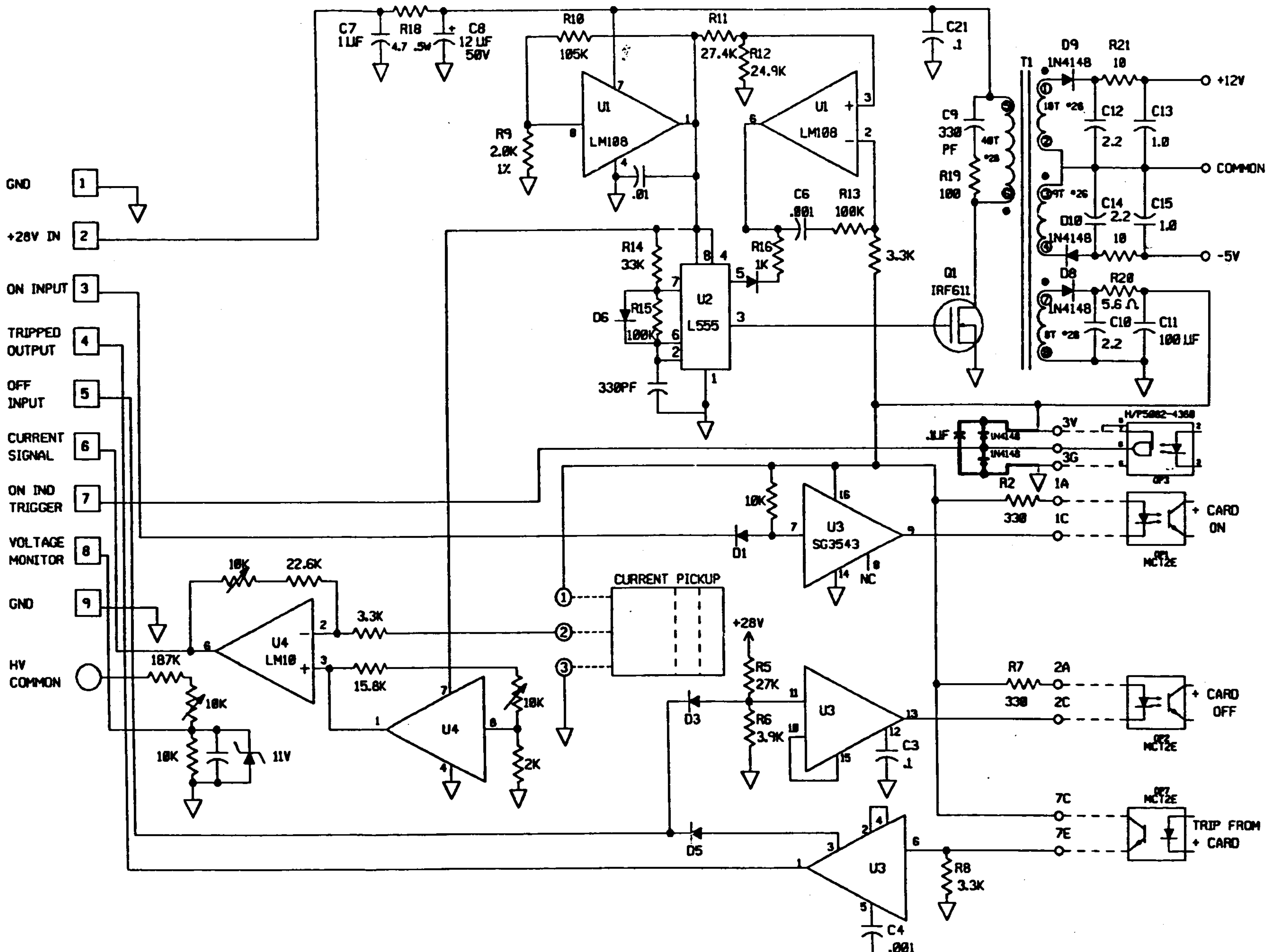

GND
+28V IN
ON INPUT
TRIPPED OUTPUT
OFF INPUT
CURRENT SIGNAL
ON IND TRIGGER
VOLTAGE MONITOR
GND
HV COMMON
C7 1UF
R18 4.7 .5W
C8 12UF 50V
R10 105K
R11 27.4K
R12 24.9K
R9 2.0K 1%
U1 LM108
.01
C21 .1
C9 330 PF
R19 100
T1
D9 1N4148
R21 10
C12 2.2
C13 1.0
C14 2.2
C15 1.0
D10 1N4148
D8 1N4148
R20 5.6 Ω
C10 2.2
C11 100UF
+12V
COMMON
-5V
R14 33K
R15 100K
D6
330PF
U2 L555
R16 1K
C6 .001
R13 100K
3.3K
Q1 IRF611
H/P5082-4360
.1UF
1N4148
3V
3G
1A
R2 330
1C
+ CARD ON
OP1 MCT2E
10K
D1
U3 SG3543
NC
CURRENT PICKUP
+28V
R5 27K
R6 3.9K
D3
U3
C3 .1
R7 330
2A
2C
+ CARD OFF
OP2 MCT2E
7C
7E
TRIP FROM + CARD
OP7 MCT2E
D5
R8 3.3K
C4 .001
U4 LM10
22.6K
15.8K
187K
11V
2K

Figure 2

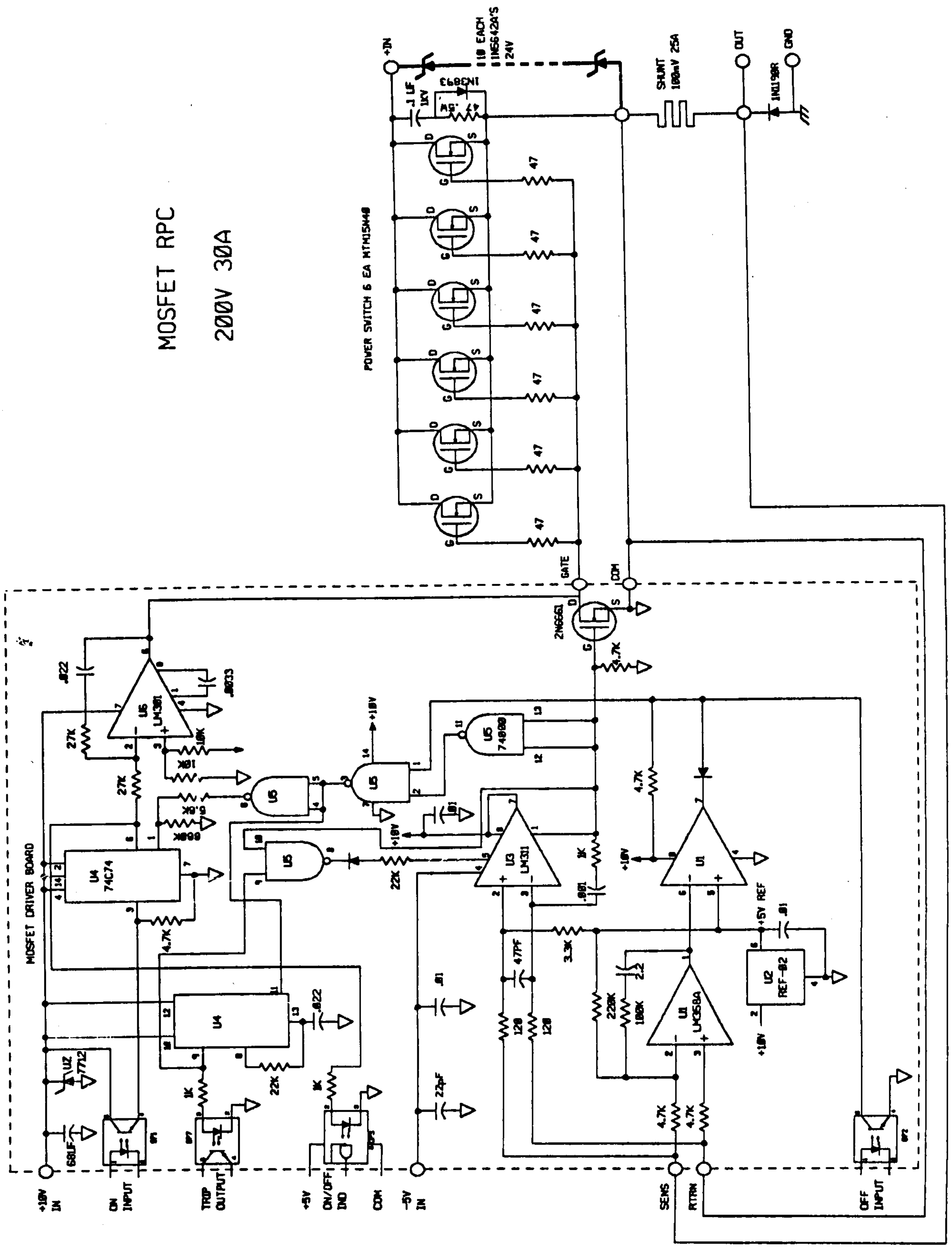
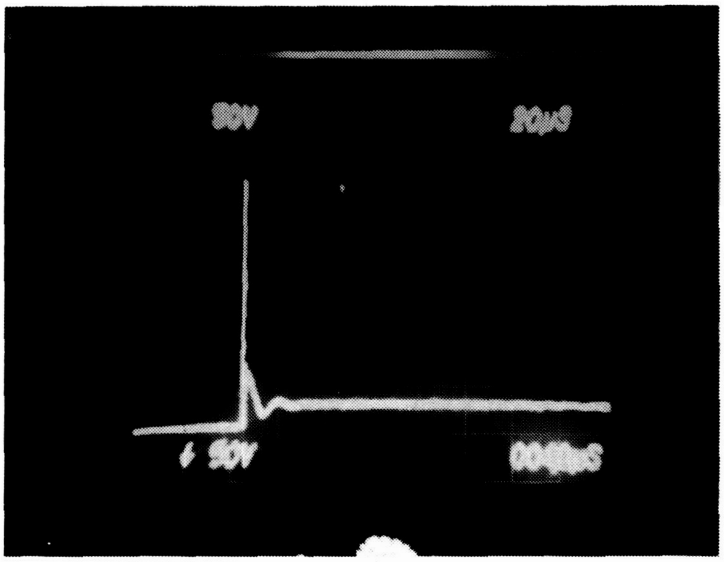
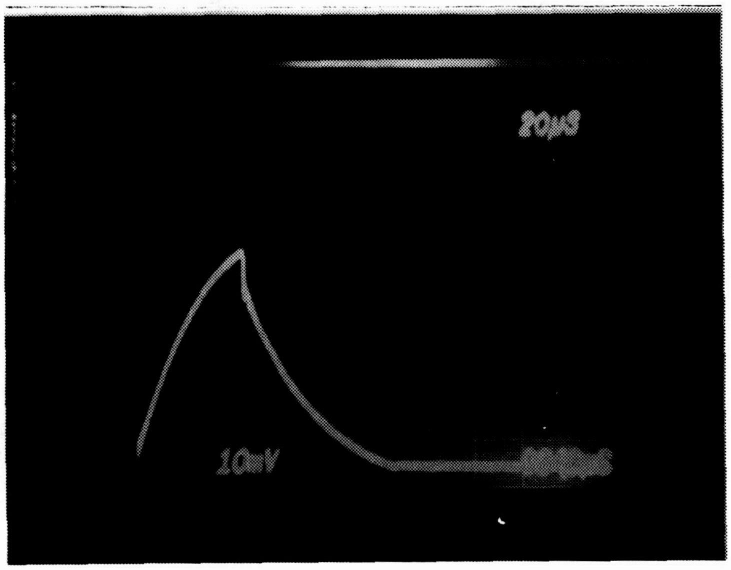

MOSFET RPC
200V 30A
POWER SWITCH 6 EA MTM15N40
+IN
.1 UF 1KV
1N3893
10 EACH 1N5642A'S 24V
SHUNT 100mV 25A
OUT
GND
1N1190R
GATE
COM
2N6661
MOSFET DRIVER BOARD
U4 74C74
U6 LM301
U5 74C00
U3 LM311
U1 LM358A
U2 REF-02
+5V REF
+10V IN
ON INPUT
TRIP OUTPUT
+5V
ON/OFF IND
COM
-5V IN
SENS
RTRN
OFF INPUT

Figure 3



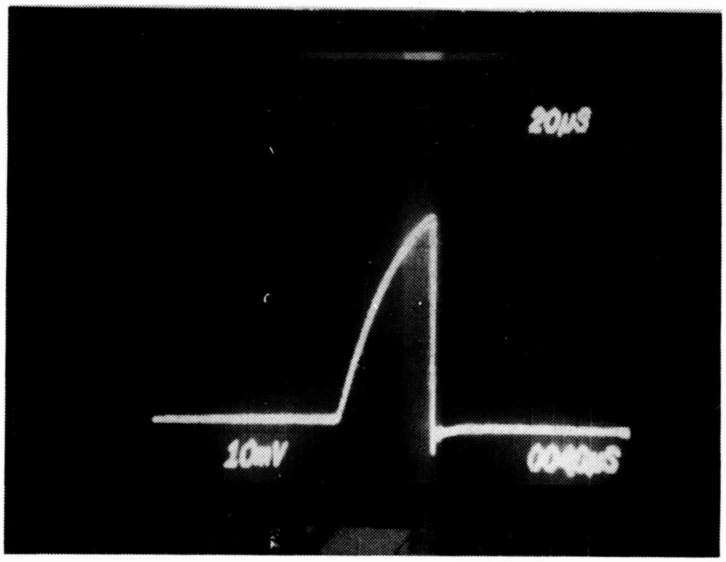
50 V/DIV

Figure 4. Voltage across switch when shorted.



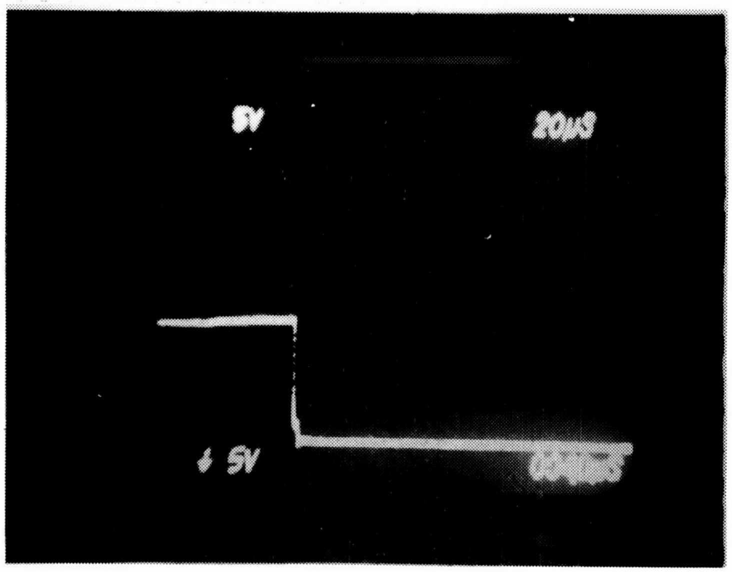
20 A/DIV

Figure 5. Current through the switch when shorted.



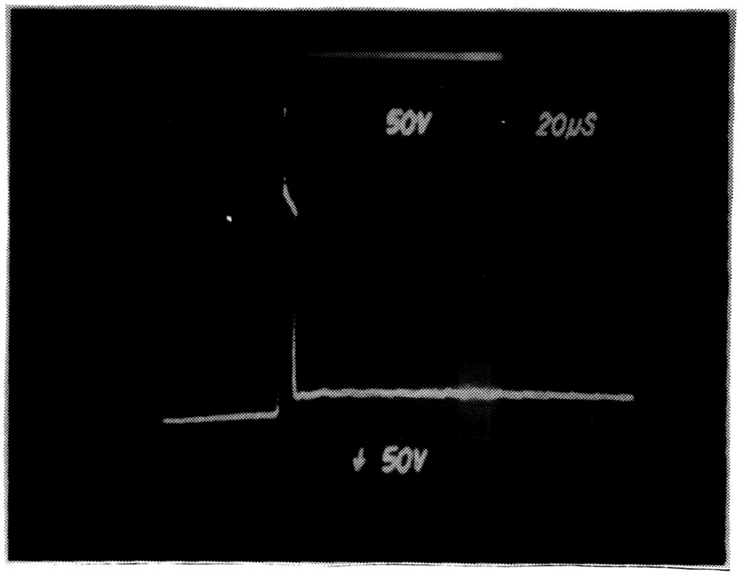
20 A/DIV

Figure 6. Current through the switch when shorted (current probe on positive input).



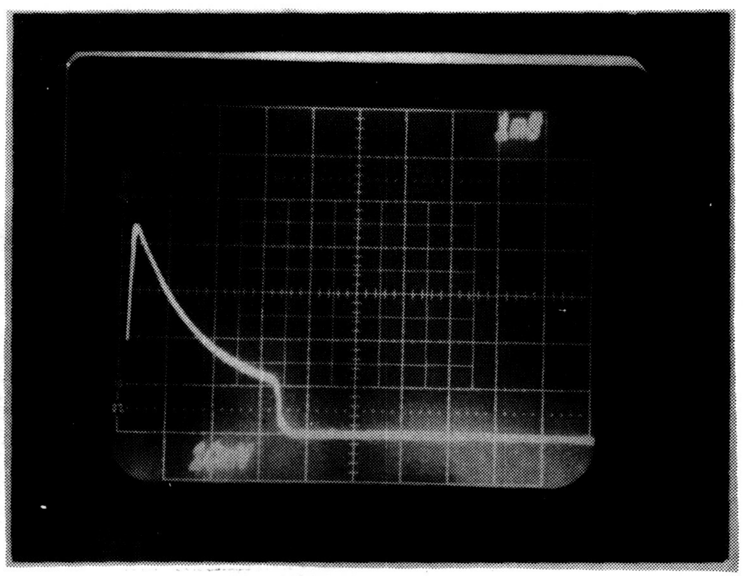
5 V/DIV

Figure 7. Voltage from gate to common when shorted.



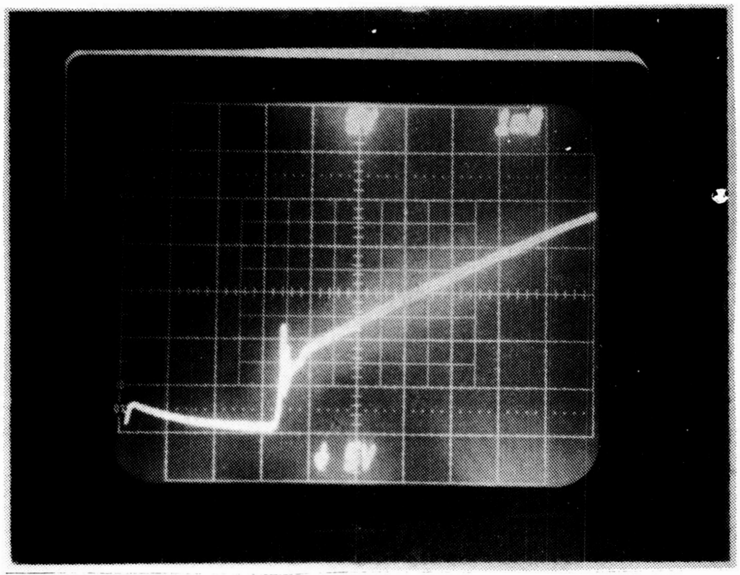
50 V/DIV

Figure 8. Voltage from drain to source when shorted.



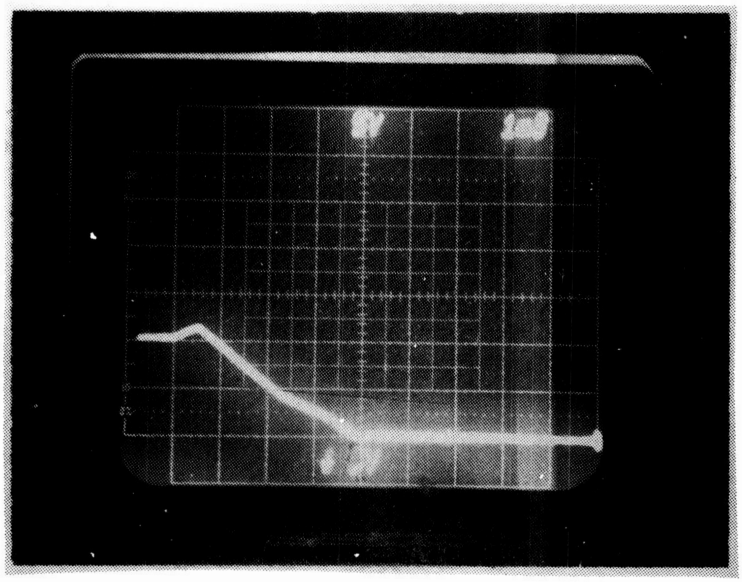
20 A/DIV

Figure 9. Current through the switch with additional 10 μH.



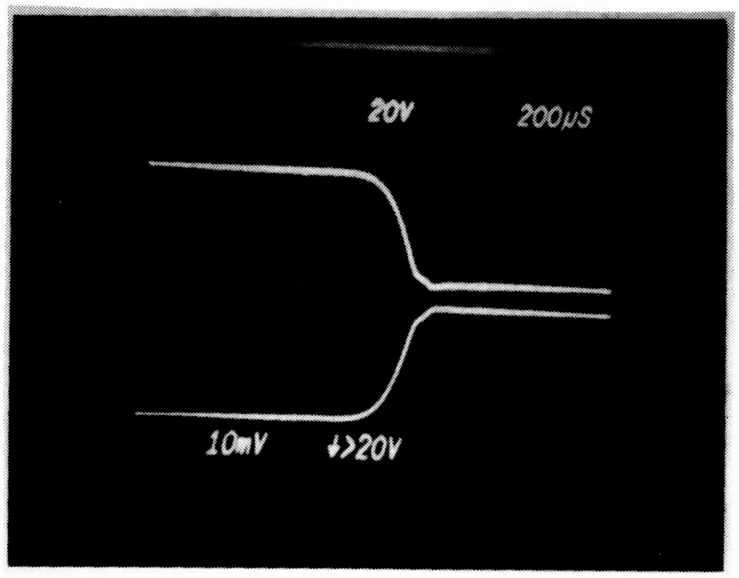
5 V/DIV

Figure 10. Voltage across the switch with additional 10 μH.



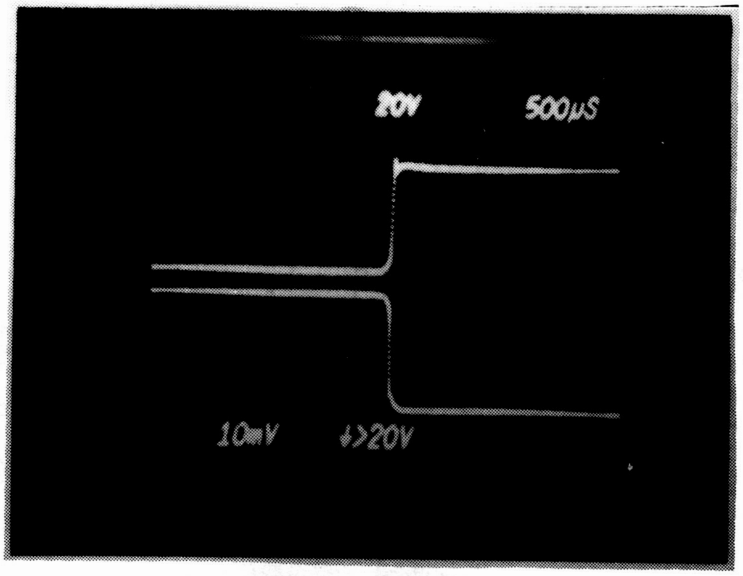
5 V/DIV

Figure 11. Voltage from gate to common with additional 10 μH.



20V/DIV, 2A/DIV

Figure 12. Normal turn on using 45 V source onto 9 Ohm load, triggered with "on" indication signal on positive-going slope.



20V/DIV, 2 A/DIV

Figure 13. Normal turn off using 45 V source onto 9 Ohm load, triggered with "on" indication signal on negative-going slope.

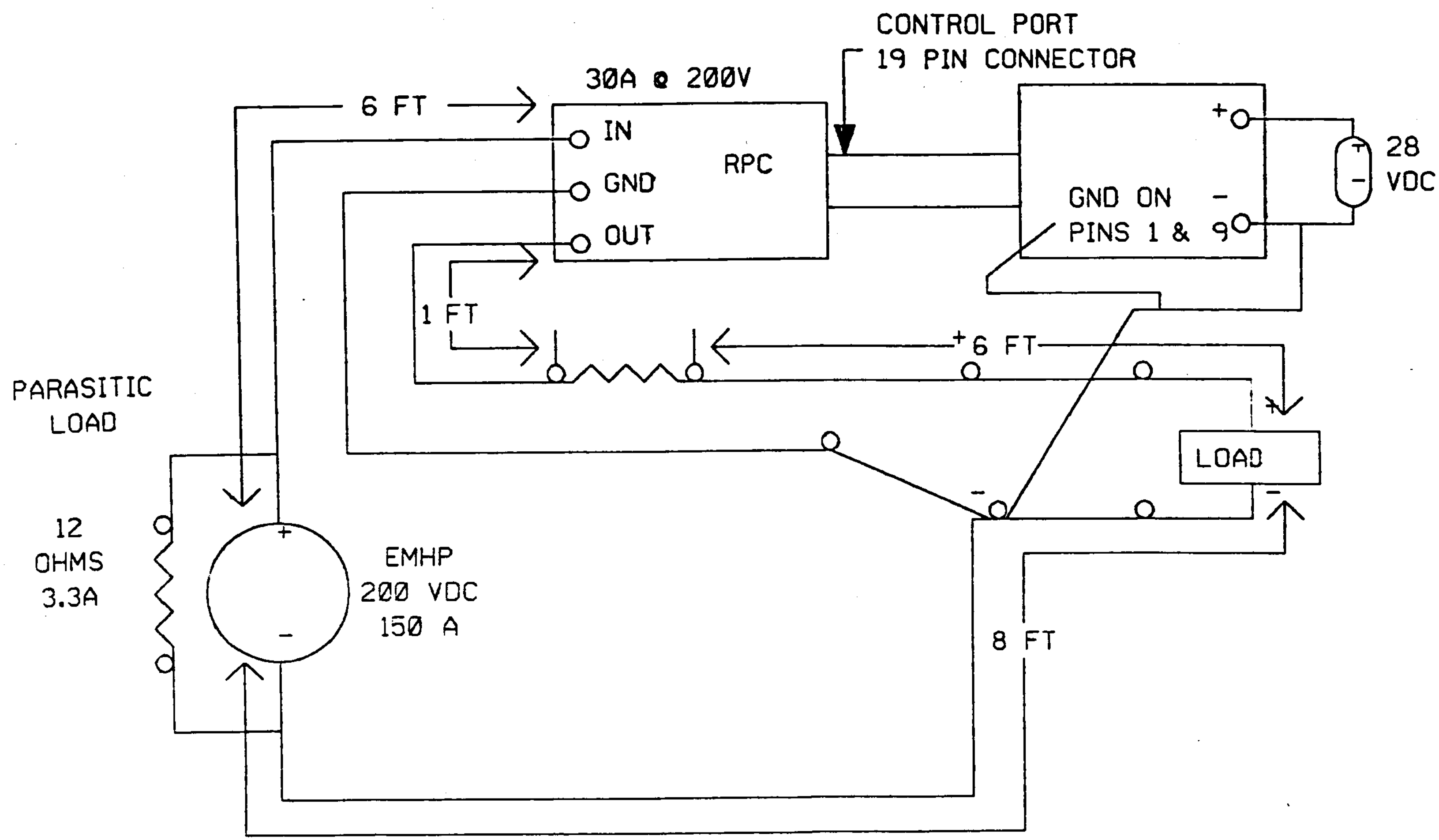
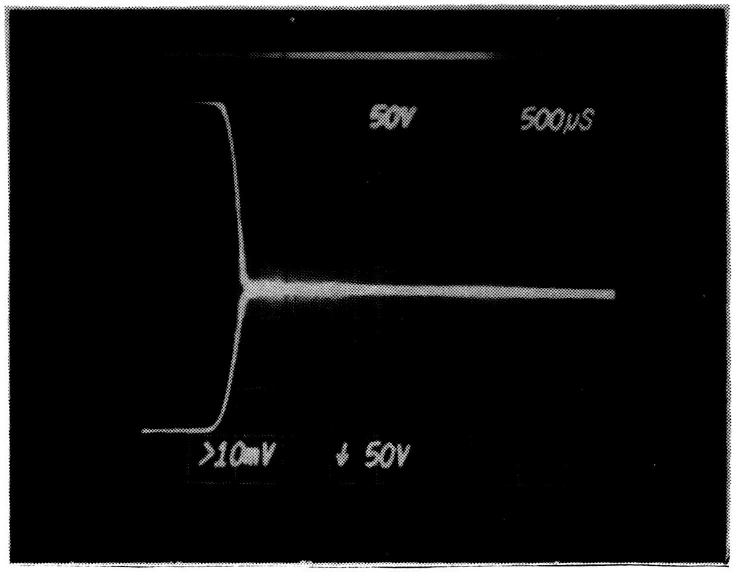
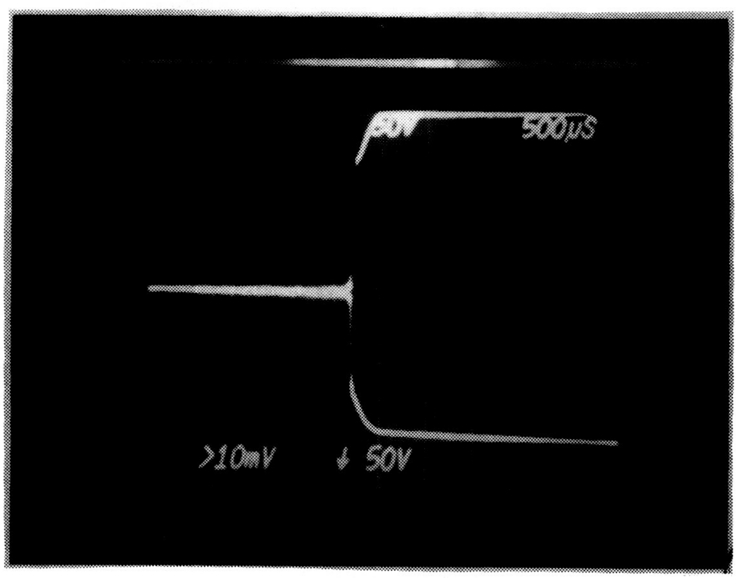


Figure 14. Power circuit for RPC evaluation.



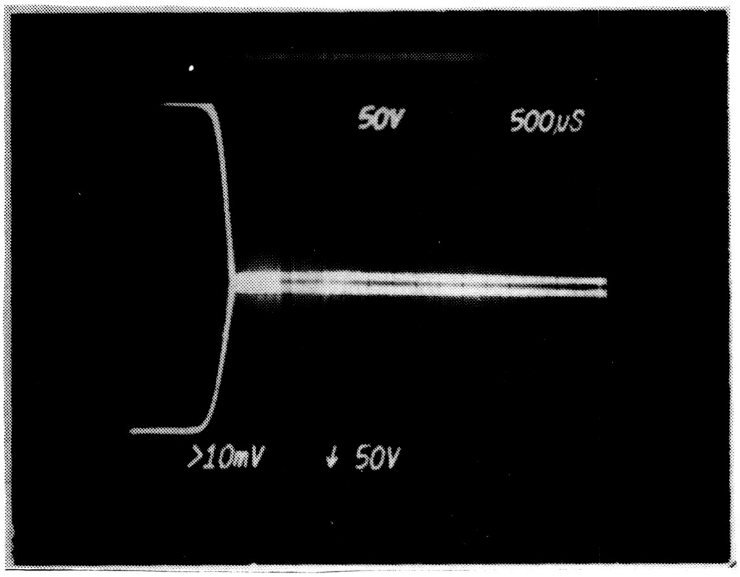
50 V/DIV, 10 A/DIV

Figure 15. Normal turn on at 200 V 30 A load.



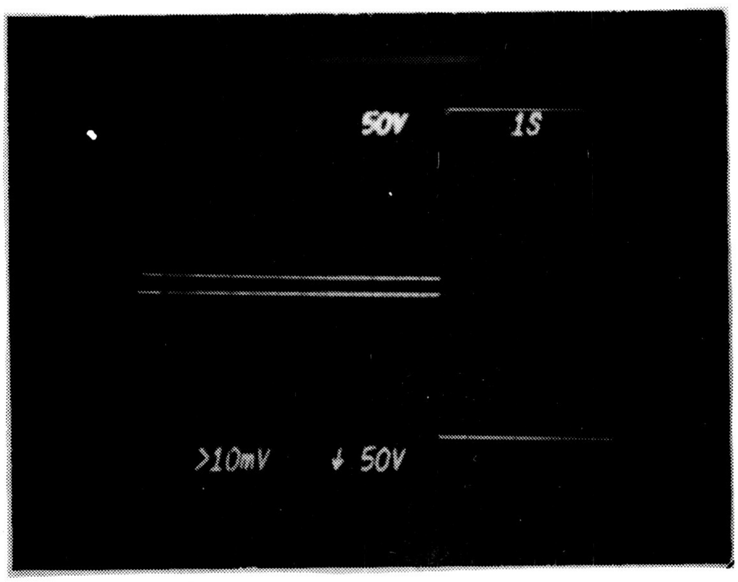
50 V/DIV, 10 A/DIV

Figure 16. Normal turn off at 200 V 30 A load.



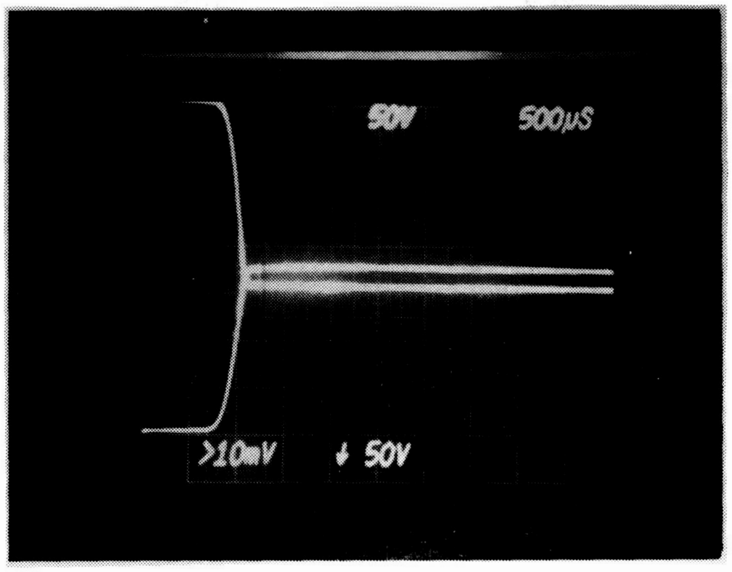
50 V/DIV, 10 A/DIV

Figure 17. Normal turn on at 200 V 33.2 A load.



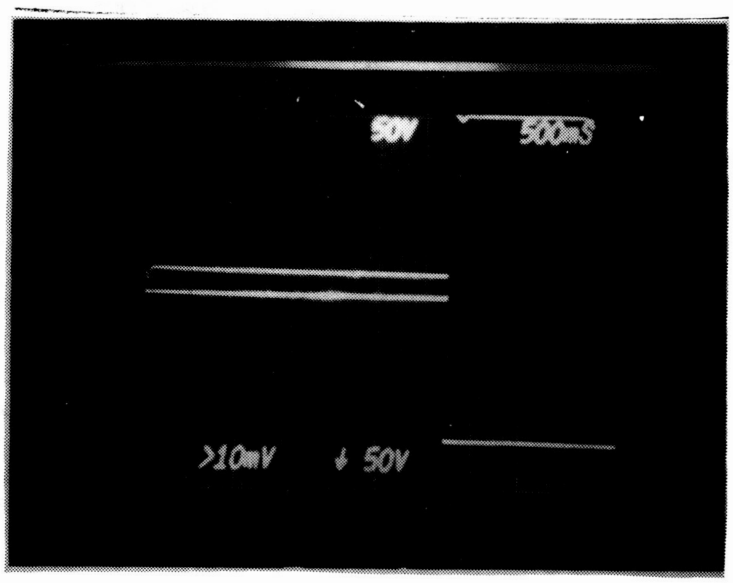
50 V/DIV, 10 A/DIV

Figure 18. Normal turn off at 200 V 33.2 A load.



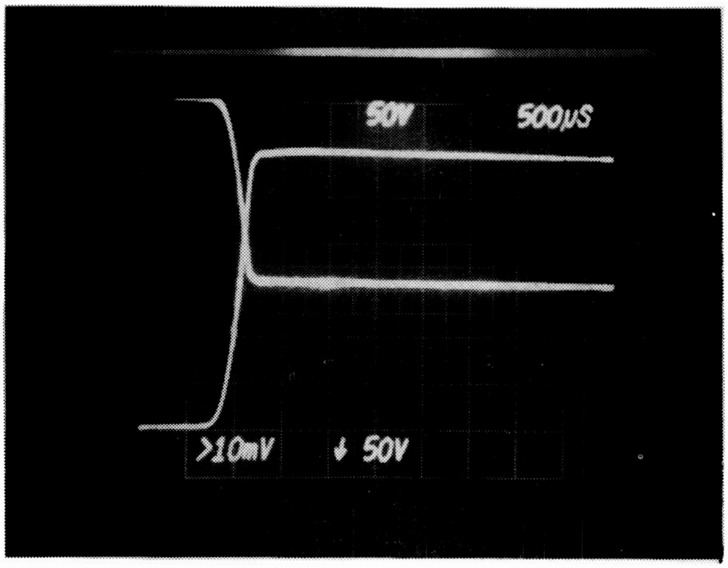
50 V/DIV, 10 A/DIV

Figure 19. Normal turn on at 200 V 34.8 A load.



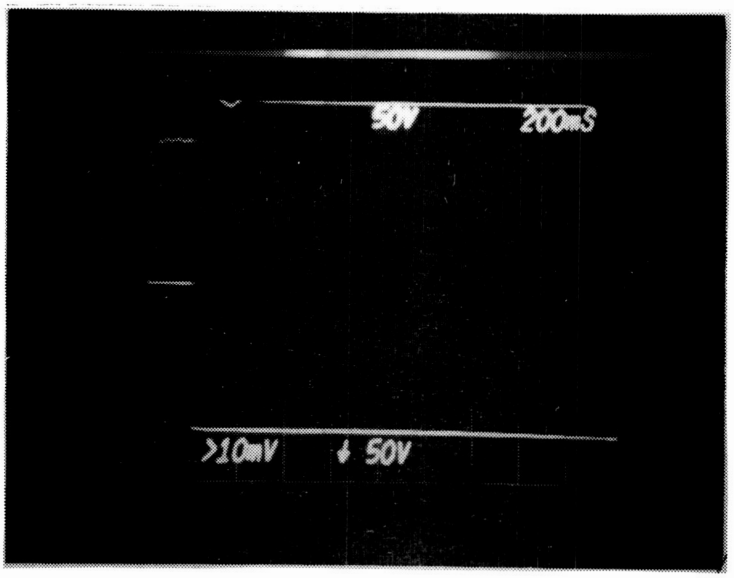
50 V/DIV, 10 A/DIV

Figure 20. Normal turn off at 200 V 34.8 A load.



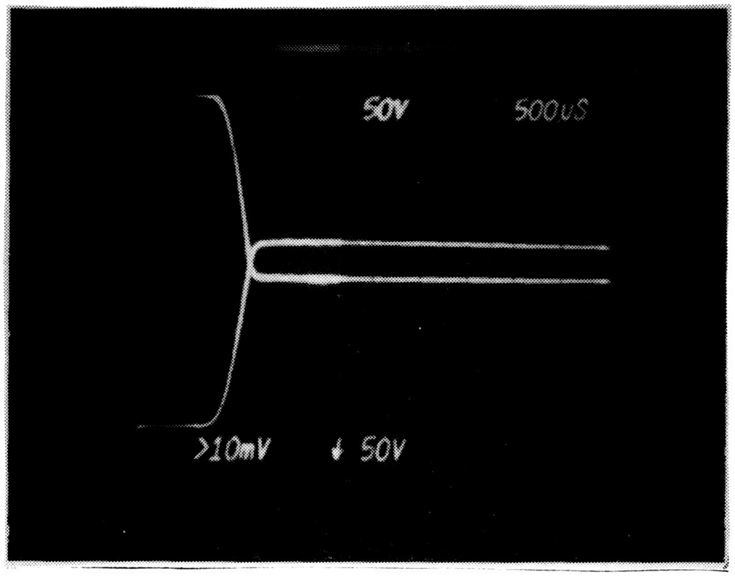
50 V/DIV, 10 A/DIV

Figure 21. Normal turn on at 200 V 60 A load.



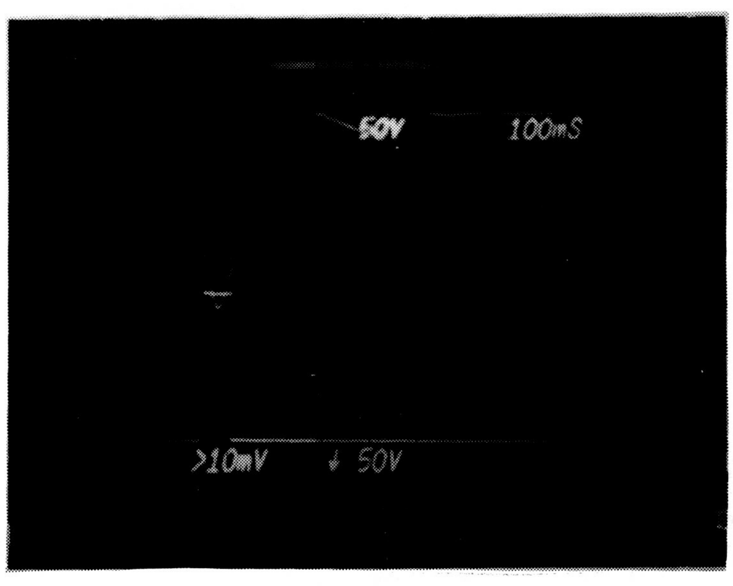
50 V/DIV, 10 A/DIV

Figure 22. Trip turn off at 200 V 60 A load.



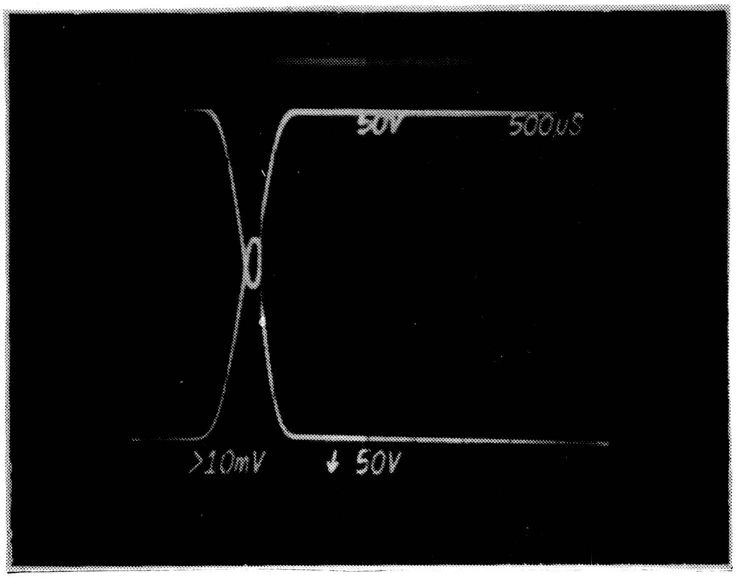
50 V/DIV, 20 A/DIV

Figure 23. Normal turn on at 200 V 80 A load.



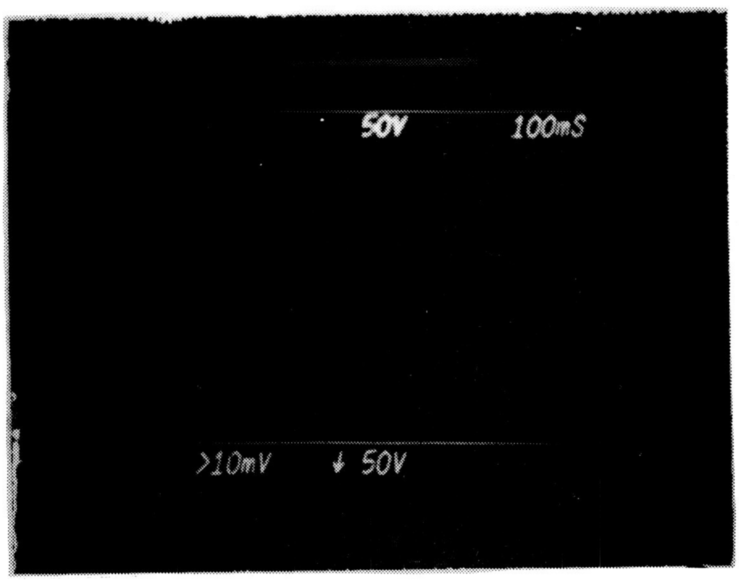
50 V/DIV, 20 A/DJV

Figure 24. Trip turn off at 200 V 80 A load.



50 V/DIV, 10 A/DIV

Figure 25. Normal turn on at 200 V 90 A load.



50 V/DIV, 10 A/DIV

Figure 26. Trip turn off at 200 V 90 A load.

TABLE 1. TYPE E-F RPC CHARACTERISTICS

Operating Voltage	200 V
Full Load Current	30 A
Control Power Source	28 V
Fault Turnoff Time	4 μsec
Device	MTM15N40

TABLE 2. CONTROL CABLE CONFIGURATION

Conductor No.	Function
1	Provide ground. This ground is both the low potential of the control voltage and the main supply voltage for energizing the load.
2	+28 Vdc. Externally provided dc voltage for operation of control circuits in RPC.
3	"Command on." Momentary ground commands the RPC to turn the switch on and apply main supply voltage to load.
4	"Tripped off." Low voltage feedback from the RPC indicates that the RPC interrupted power to the main load due to overcurrent or fault identification.
5	"Command off." Momentary ground commands the RPC to turn the switch off and de-energize the load.
6	Feedback from RPC to indicate load current or current through the switch. (Analog voltage).
7	"On." Low voltage feedback from the RPC indicates that the RPC is on and current is being conducted through the load.
8	Feedback from RPC to indicate voltage applied to load. (Meaning voltage is extended through the switch toward load). Analog voltage proportional to actual voltage.
9	Common ground. (Redundant connection)

TABLE 3. SLOW OVERCURRENT TRIP TIMES

Current (A)	Time (sec)
32.6	7
33	7
34	3.4
36	2.4
40	1.3
50	0.5
60	0.25
70	0.13
80	0.17

REFERENCES

1. Sturman, J. C.: High-Voltage, High-Power, Solid-State Remote Power Controllers for Aerospace Applications. NASA Technical Paper 2437, March 1985.

2. Callis, C. P.: Evaluation of High-Voltage, High-Power, Solid-State Remote Power Controllers for AMPS. NASA Contractor Report (Research Reports-1987 NASA/ASEE Summer Faculty Fellowship Program). Contract No. NASA-NGT-01-008-021.

APPROVAL

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By Yvette Binford Johnson and Robert E. Kapustka

The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

W. C. BRADFORD
Director, Information and Electronic
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16. ABSTRACT

This report discusses the results of testing high-voltage, high-power, solid-state remote power controllers (RPC) using RPC's designed and built by John C. Sturman at the Lewis Research Center, Cleveland, Ohio, and utilizing the Autonomously Managed Power Systems (AMPS) breadboard/test facility. These test results are used to determine usefulness of the RPC's for future applications in high voltage Direct-Current space power.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
Remote Power Controller (RPC) Autonomously Managed Power System (AMPS) Power Switching Circuit, Direct Current, High Voltage, High Power, Solid State	Unclassified – Unlimited

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