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HIGH VOLTAGE PROTECTION CHASSIS FOR PROPORTIONAL WIRE CHAMBERS

Introduction

The High Voltage Protection Chassis (SLAC-135-231) is designed for use with multiple arrays of proportional wire chambers, in conjunction with a 12-Channel High Voltage Distribution Chassis (SLAC-900-851) capable of operating up to 6 kV.

The Protection Chassis is designed to disconnect the High Voltage Supply instantly the moment leakage current (i_{lkg}) starts to flow through the chamber over a preset threshold point (i_{th}), thus automatically protecting the chamber.

General Description

Each Protection Chassis has 12 channels and is to be used in series with 12-Channel High Voltage Distribution Chassis already existing at SLAC. The system is shown in the block diagram of Fig. 1. The basic circuit diagram is shown in Fig. 2. The chassis has a DC 0-50 μA ammeter connected in series with each channel, which in turn consists of a series of protection resistors of 10 MΩ total resistance. The current is sensed through an optical isolator rated at 10 kV. The isolator output current which is proportional to the leakage current, is sensed relative to an adjustable reference voltage on the low-voltage side of the circuit.

When the voltage output directly proportional to i_{lkg} exceeds the reference voltage (v_{ref}) at the comparator, the D-type flip-flop latches, the high voltage vacuum relay opens, and a NIM level signal is generated at a BNC output. An audio (Sonalert) alarm is also activated.

For economic reasons, high voltage relays were not used for each channel; instead the entire chassis is shut off and the tripped channel identified by a front-panel LED. An OVERRIDE circuit is necessary to prevent tripping during turn-on. A RESET enables the circuit to be re-energized. The circuits operate on a 24 V dc power supply; 10 kV rated connectors are used throughout. The layout of printed circuits is carefully designed to eliminate possible arcing.

Circuit Details

Refer to Fig. 2. Ten 1 MΩ, 2W, 5% carbon resistors are located in series with the power supply and the chamber in each channel. Since a 6 kV power supply is used, the maximum i_{1kg} that may flow in the chamber is limited to 600 μA. This would be the case if a chamber wire were completely shorted to ground.

Each resistor breakdown voltage is 600 V such that even in the case of a short circuit, the resistors could hold off 6 kV, and the peak current would be limited to 600 μA.

At the instant a spark occurs in the chamber, i_{1kg} starts to flow through the 50 μA ammeter, resulting in a coupled positive current signal (i_c) through the MCT5-10 10 kV isolator. The DC collector current transfer ratio (I_F/I_C) of the MCT5-10 is typically 15 for V_{CE} = 10V. The lower portion of I_C/I_F characteristic curve was measured to be very nonlinear and less sensitive for I_F less than 50 μA (see Fig. 3). Between 30 and 50 μA and V_{CE} = 12 V, I_C/I_F = .015.

Thus at I_F = 50 μA, $I_C \cong$ .4 μA = 400 nA. This compares with the dark current (I_{CEO}) of 5 nA typical, 100 nA maximum at 25°C. Because the μA710 comparator requires an input bias current of 13 μA typical, which could completely swamp the isolator signal current at $I_F \leq$ 50 μA, a buffer is required. The ZA801 operational amplifier connected as a voltage follower is therefore inserted between the MCT5-10 and the μA710, thus limiting the bias current requirement to only 25 pA. Thus the dc stability depends completely upon changes in i_{1kg} of the optical isolator. A 1 K trimpot is used for the zero OFFSET adjustment at the output of the ZA801. The voltage at the ZA801 output (V_o) versus the forward current (I_F) is plotted in Fig. 4 for different values of initial V_o.

The OVERRIDE switch is provided to minimize the possibility of an instant HV relay shut-off by a transient current immediately following the HV supply power switch turn-on. Since the typical input bias current of the μA710 is 13 μA, the 100K trimpot can set V_{ref} between (39-13) μA x 786Ω = 36 mV and (6200-13) μA x 786Ω = 4.9 V. The OFFSET adjustment to the μA710 by the 1 K trimpot should cover a range of 100Ω x 13 μA = 1.3 mV. Actually the 1 K trimpot of the ZA801 can give an OFFSET adjustment of ~ ± 40 mV.

By a relative adjustment of 1 K and 100 K trimpots, about 500 nA i_{lkg} lower sensitivity was obtained.

Once the signal proportional to i_{lkg} exceeds i_{th} set by the μA710, the SN7474 flip-flop latches the output, opening the HV relay switch and keeping it latched until the RESET button is pressed. If $i_{lkg} > i_{th}$ is continuously flowing at the time the RESET is pressed, the relay switch would open immediately at the moment the RESET is released. Figure 5 shows the timing relationships. During the time the RESET button is pressed, a green LED is ON. a red FAULT LED is OFF, and HV relay is ON even if i_{lkg} exceeds i_{th}. The reason is that the logic circuit is triggered by the pulse edge, not by the pulse level. Therefore, when a FAULT is showing, the main HV switch should be first turned OFF and the cause of the fault should be detected. When the green LED is ON, then the current in the chamber is "NORMAL". Once i_{lkg} exceeds i_{th} , one of the twelve SN7401 OR gates draws current through a low voltage mercury relay and the red LED lights, indicating that the HV relay is disconnected (OFF).

The 50 μA DC ammeter internal resistance is 4 KΩ. A 300Ω resistor and an HPA2900 diode in parallel protect the meter over the range of input currents. The meter reading error up to 50 μA i_{th} has been measured to be about 14% maximum. Since the constant low current in the chamber is perhaps 10 μA, the meter reading error is negligible. In the case of a maximum (short circuit) current of 600 μA, the meter current would be about 70 μA and the remainder would be bypassed through the HPA2900. A current of 70 μA will not damage the meter.

A differential current switch stage is provided to generate a NIM signal into 50Ω to use to set a flag in the system computer.

<u>Summary</u>

The unit described in this report protects proportional wire chambers operating up to 6 kV with protective circuitry which operates at low voltage through an optical isolator. A trigger threshold equivalent to 50 μA of chamber current is typically used. Threshold setting is stable over a wide temperature range. The response of the unit to transient noise can be dampened by increasing the time constant in the follower stage.

The sensitivity of the unit ranges from 1 μA to 170 μA i_{1kg}, limited only by the range of the meter. The unit has been thoroughly tested and proven to be very stable over normal operating temperatures.

The actual speed of response to any chamber spark pulse is primarily limited by the mechanical response time of the mercury and HV vacuum relays, which is in the region of milliseconds.

Acknowledgement

The author is particularly indebted to R. S. Larsen for his suggestions and supervision throughout the course of this design. It is a pleasure to thank F. Rosche and E. Cisneros for their interest and help during lab tests. The contribution of Ting Pun in defining the requirement is gratefully acknowledged. Appreciation is extented to T. Heaslett for his meticulous work in the mechanical design of the chassis.

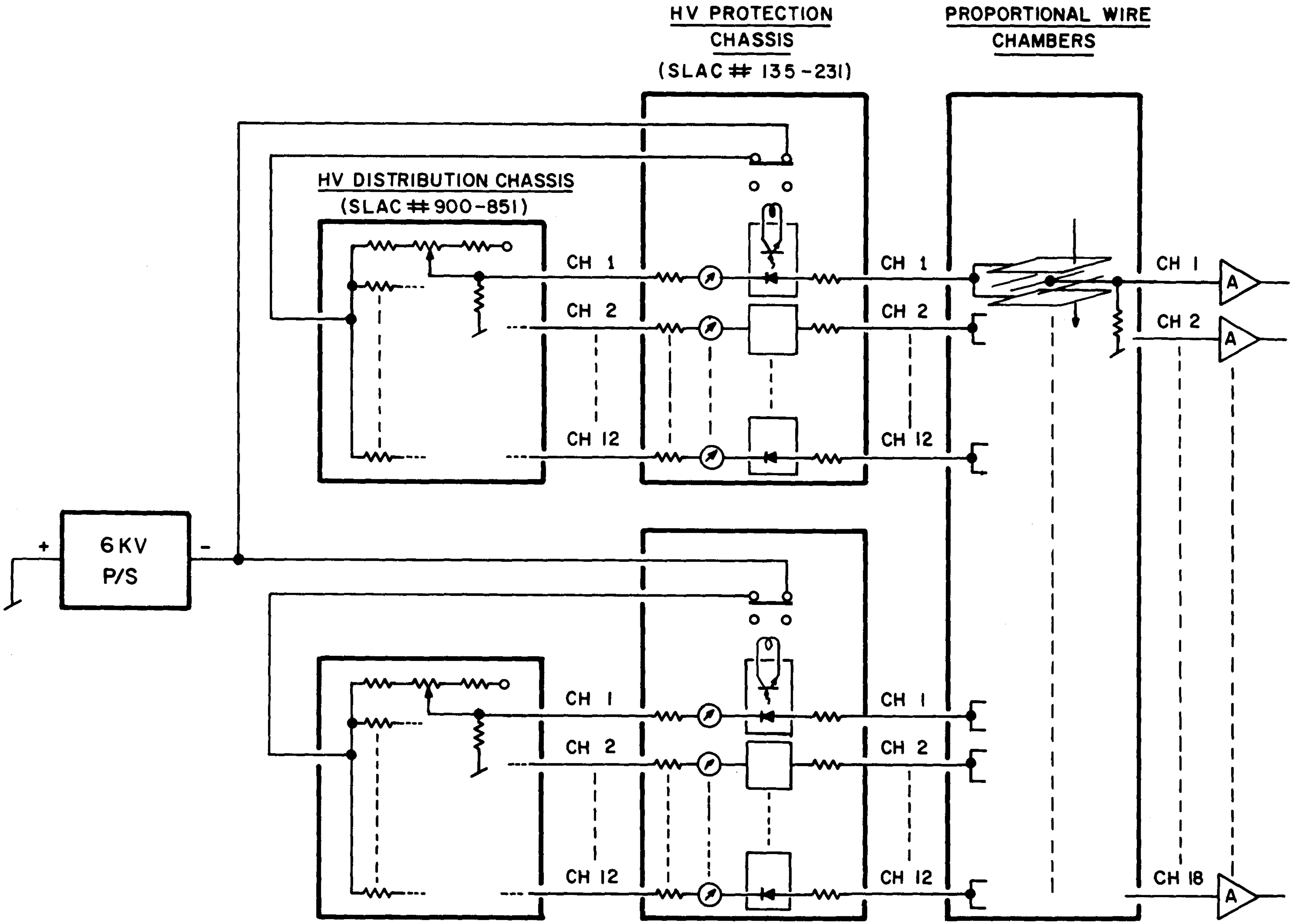

FIG. 1 - SYSTEM SCHEMATIC DIAGRAM

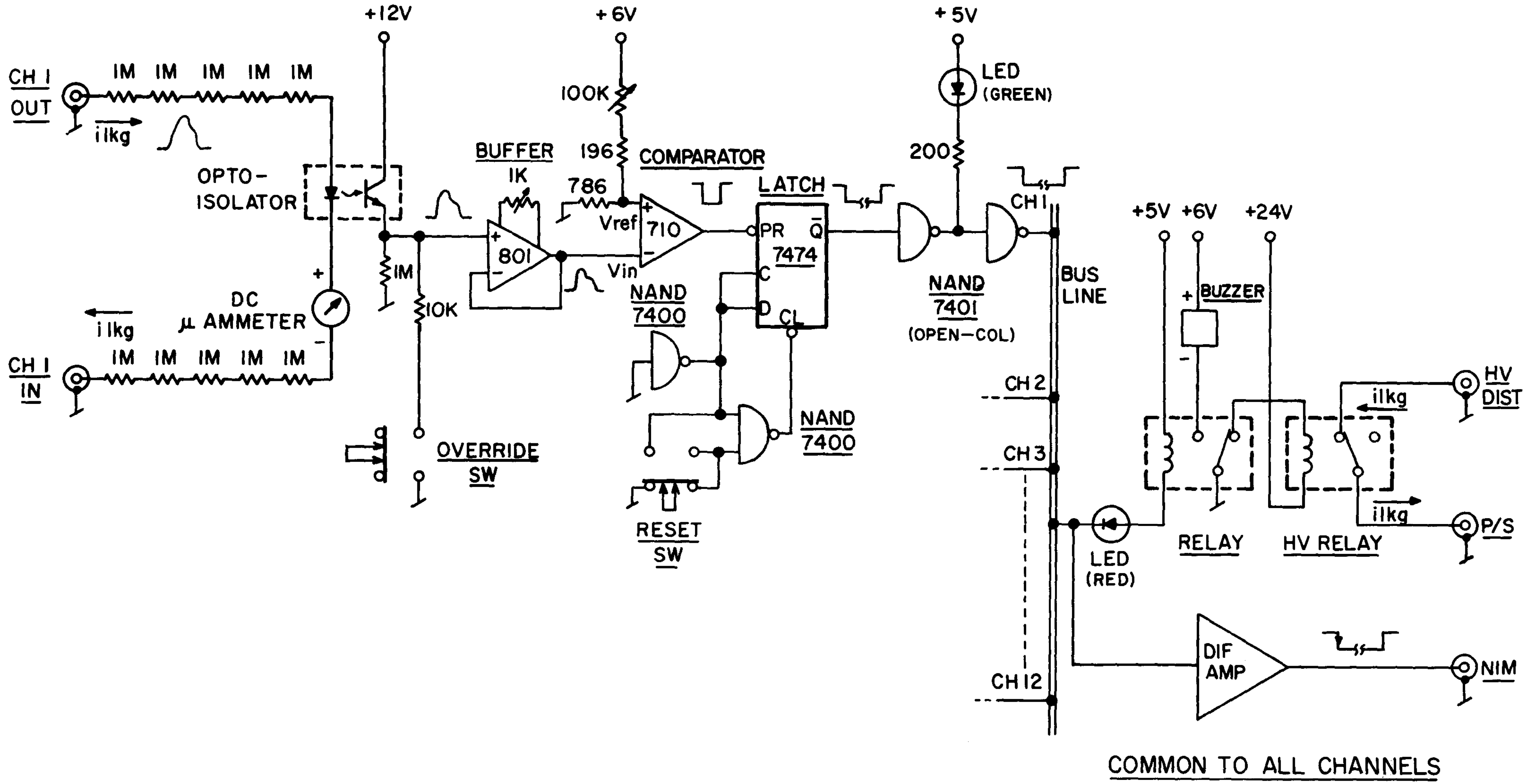

FIG. 2 – BASIC CIRCUIT DIAGRAM

(1 CHANNEL)

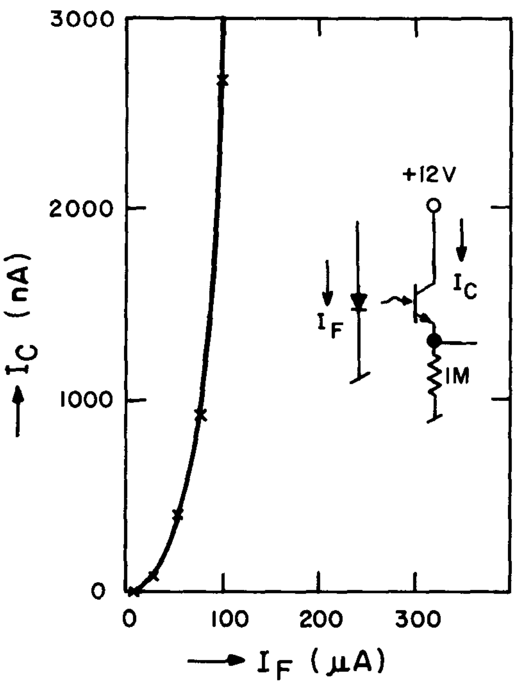

FIG. 3 - MCT5-10 DC CURRENT TRANSFER CURVE

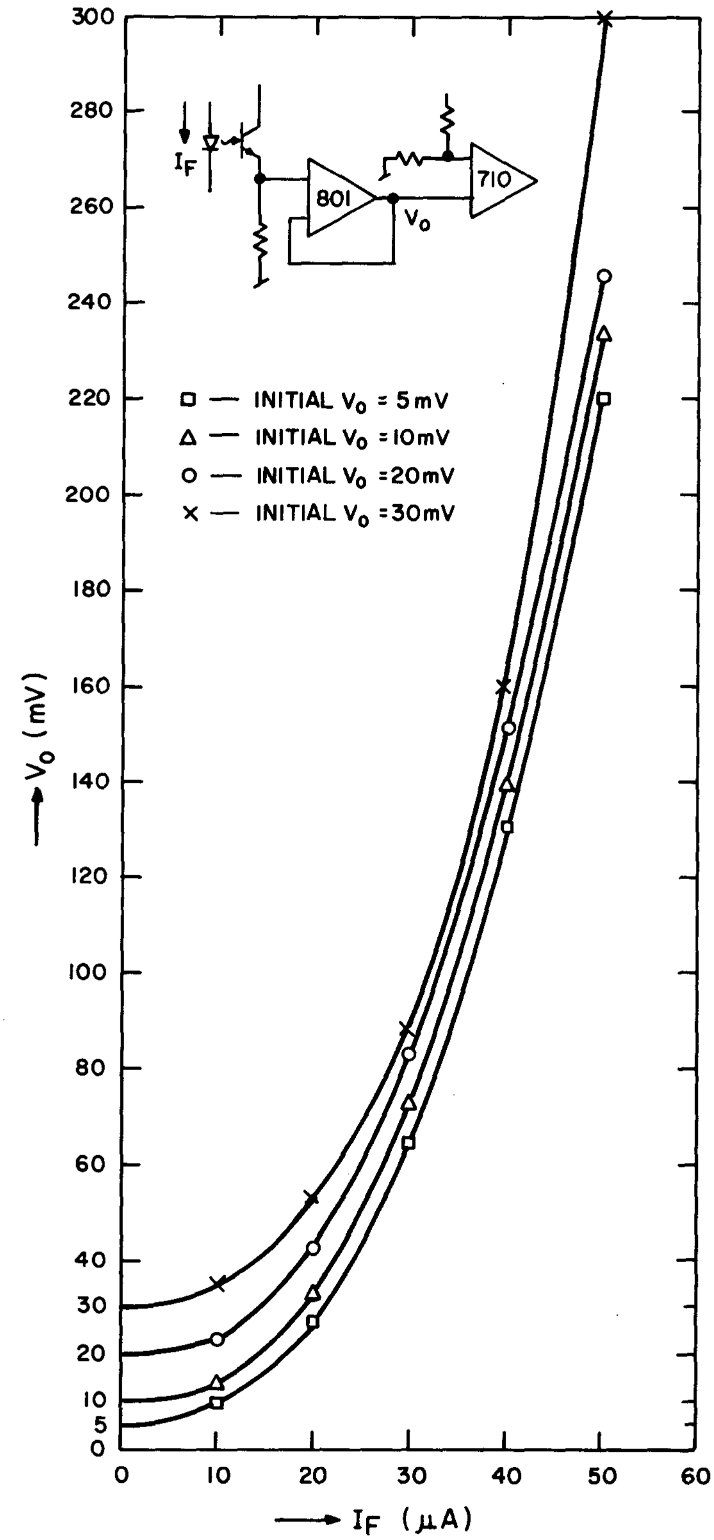

FIG. 4 - FOLLOWER OUTPUT (V_o) vs I_F SENSITIVITY CURVE

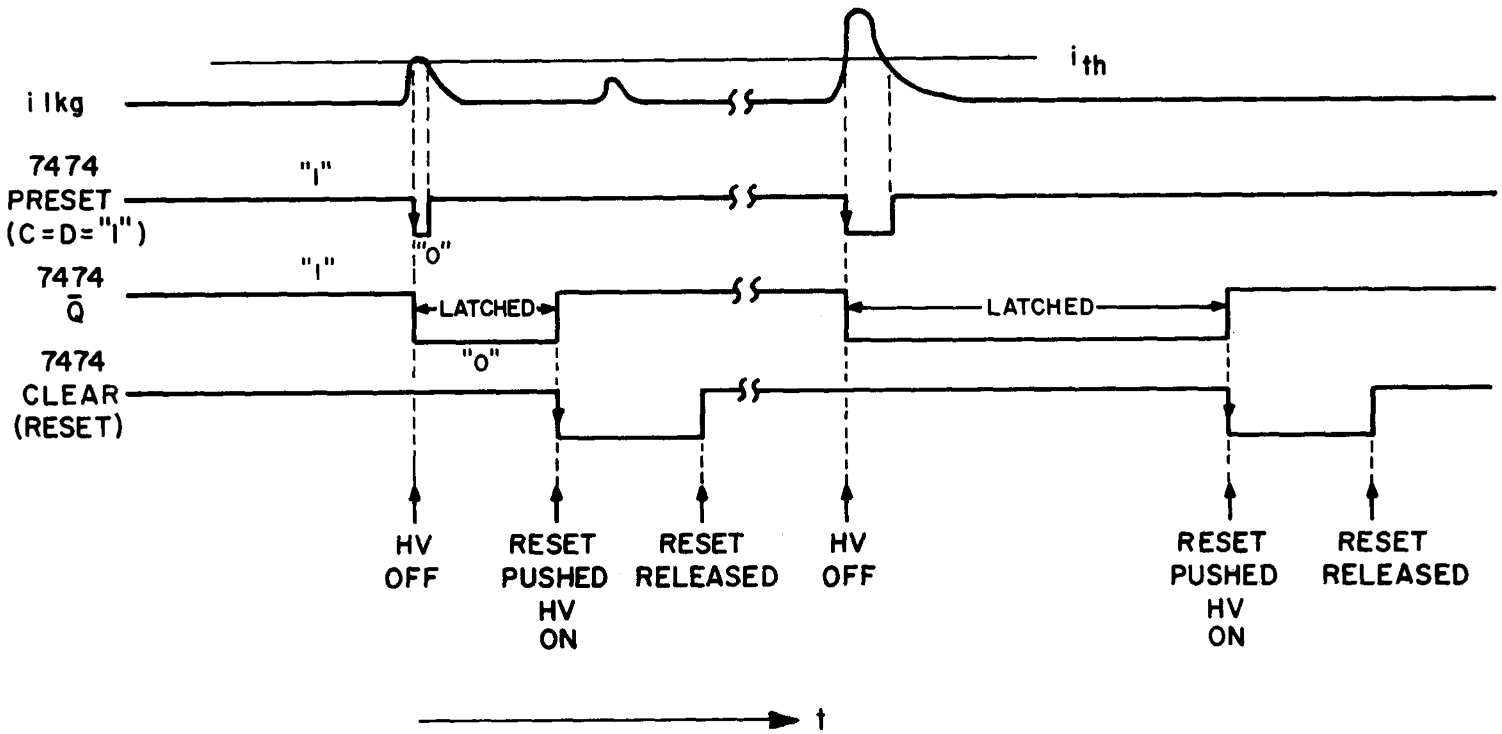

FIG. 5 – 7474 LATCH TIMING DIAGRAM

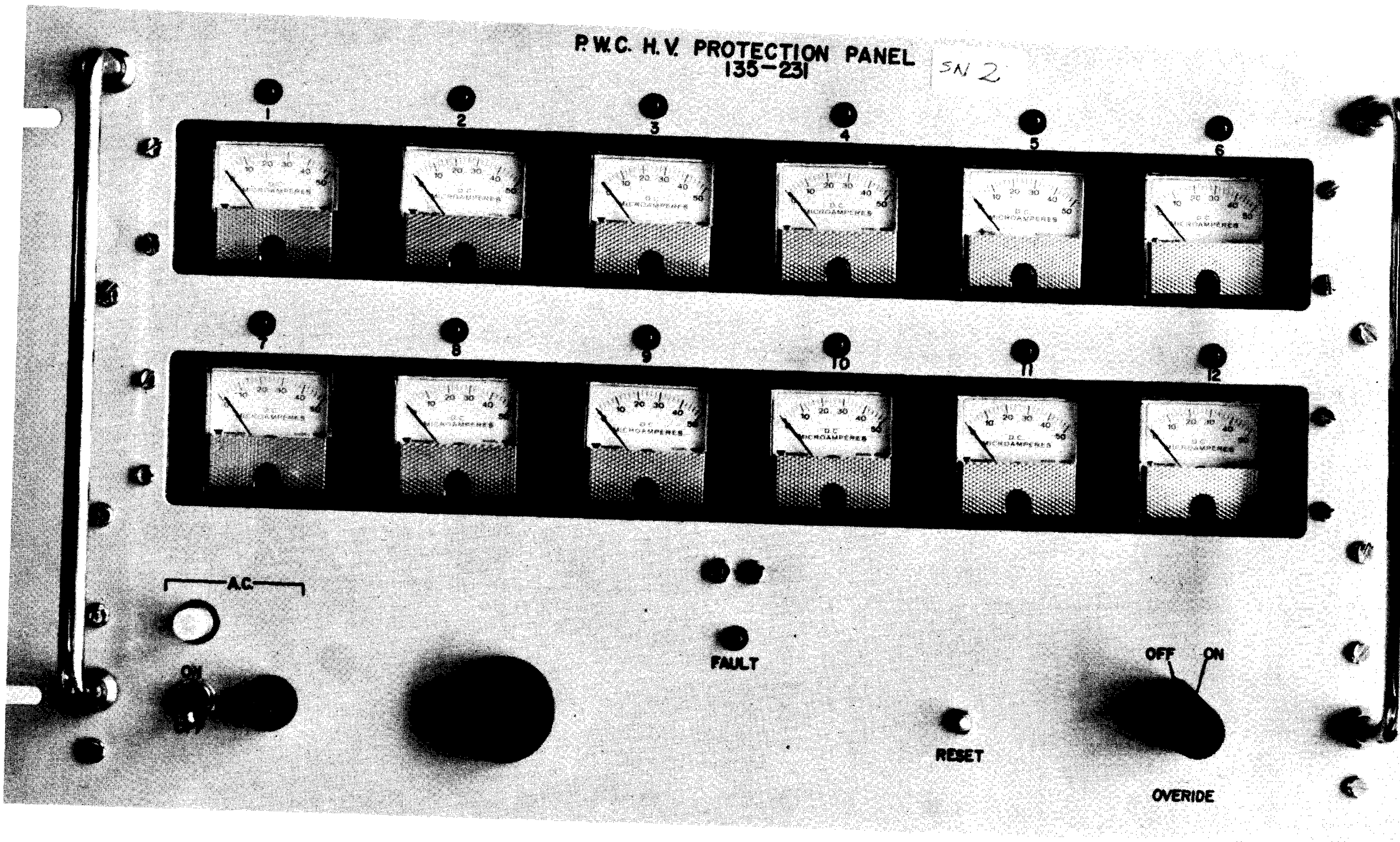
P.W.C. H.V. PROTECTION PANEL
135-231
SN 2
1
2
3
4
5
6
7
8
9
10
11
12
D.C.
MICROAMPERES
A.C.
ON
FAULT
RESET
OFF
ON
OVERIDE

Fig. 6A

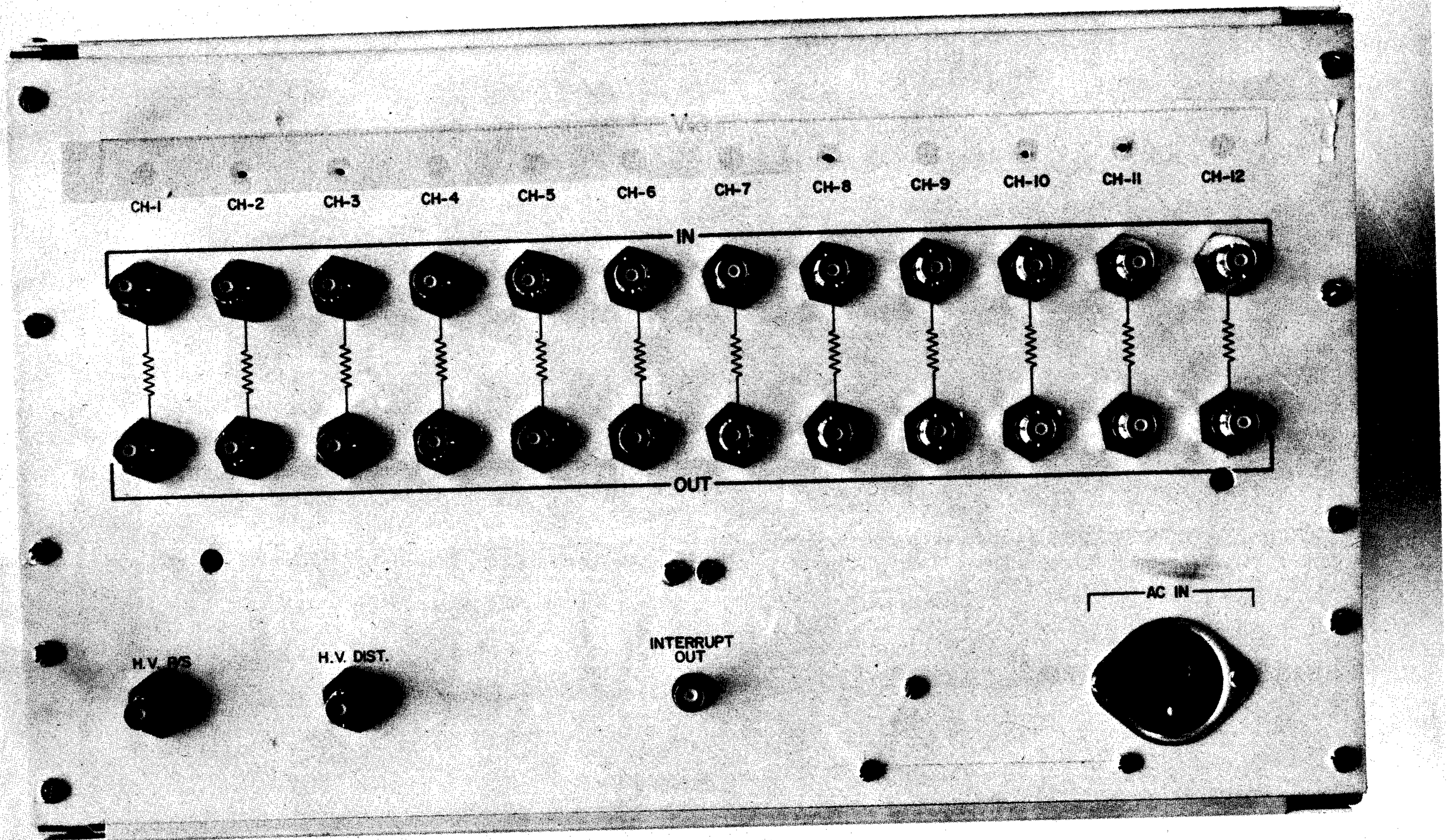
CH-1
CH-2
CH-3
CH-4
CH-5
CH-6
CH-7
CH-8
CH-9
CH-10
CH-11
CH-12
IN
OUT
H.V. P/S
H.V. DIST.
INTERRUPT OUT
AC IN

Fig. 6P